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DOE/SF/11432-1
(DE82001847)

CONCEPTUAL DESIGN OF A SOLAR COGENERATION FACILITY AT PIONEER MILL CO., LTD.

Final Report

August 1981

Work Performed Under Contract No. AC03-80SF11432

Bechtel Group, Inc.
San Francisco, California

U.S. Department of Energy

Solar Energy

34.0107

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A25
Microfiche A01

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Distribution Category UC-62c

CONCEPTUAL DESIGN OF A SOLAR COGENERATION FACILITY AT PIONEER MILL CO., LTD.

FINAL REPORT

BECHTEL GROUP,INC.
SAN FRANCISCO,CA
JOB NO. 14481

SUBCONTRACTORS:
AMFAC SUGAR COMPANY
FOSTER WHEELER DEVELOPMENT CORP.
NORTHRUP, INC.

UNITED STATES DEPARTMENT OF ENERGY
SAN FRANCISCO OPERATIONS OFFICE
Contract No. DE-AC03-80SF11432

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Section 1

EXECUTIVE SUMMARY

1.1 PROJECT SUMMARY

A conceptual design for a solar cogeneration facility has been prepared by a team led by Bechtel Group, Inc. with funding from the U.S. Department of Energy (DOE). The design involves the addition of a solar central receiver steam supply system to the Pioneer Mill Co., Ltd. sugar factory. Implementation of this project would demonstrate a typical industrial application of solar energy to reduce the consumption of imported oil.

Amfac Sugar Company, the owner and operator of Pioneer Mill, has been heavily involved in the design effort. Their requirements of simplicity and reliability were important criteria in the selection of water/steam for the system working fluid. As a typical industrial energy consumer, they have also been thoroughly introduced to this technology through this involvement.

This project provides an excellent opportunity for a joint effort by the government and the industrial sector to demonstrate that such a system can achieve wide commercial success under certain conditions in those areas of the U.S. posessing a significant solar resource.

1.2 INTRODUCTION

This report presents the results of a conceptual design study of the retrofit of a solar central receiver system to an existing cogeneration facility. The facility in question is Pioneer Mill Co., Ltd., a raw sugar factory near Lahaina, Maui, Hawaii. An artist's rendering of the solar cogeneration facility is shown in Figure 1-1.

This site-specific study was conducted as part of the DOE Solar Cogeneration Program. The general objectives of this program were to demonstrate that (1) solar central receiver systems and cogeneration facilities can be integrated in such a way as to save oil and gas in a cost-effective manner, and that (2) an integrated facility of this sort has the potential for widespread commercial application.

The Pioneer Mill facility was selected because it would provide an excellent demonstration of solar cogeneration. It is currently operating as a cogeneration facility, and the solar equipment could be added with

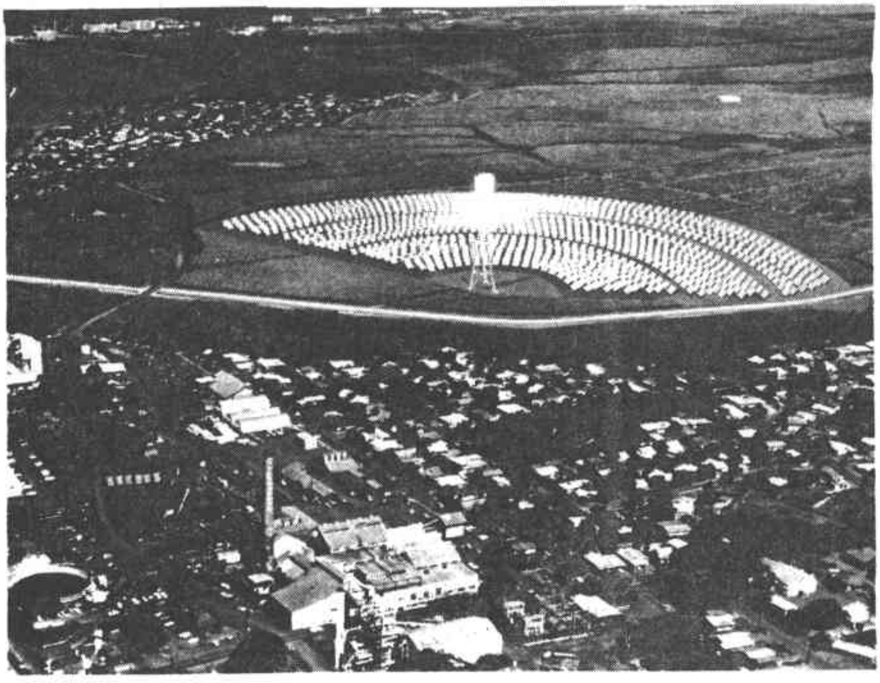

Figure 1-1 ARTIST'S CONCEPT OF SOLAR COGENERATION FACILITY

minimal cost of modification to the existing plant. There is a long history of cooperation between the sugar plantations and the Hawaiian utilities, and the various plantations on Maui currently provide approximately 31 percent of the island's annual electrical generation. The plant is also relatively small, with a total turbine-generator capacity of 13.5 MWe, which would allow for an economic yet credible demonstration of the technology.

The State of Hawaii depends on imported oil for over 90 percent of its electric power, and renewable energy resources may be the only available options for the future. The area around Pioneer Mill receives high annual solar insolation because of the 21° latitude and the shelter provided by the mountains of west Maui from the weather patterns of the trade winds.

The proposed cogeneration system is very adaptable to many industrial processes within the range of electrical-to-heat power ratios from 0.1 to 0.6. The pressure and flow of controlled turbine extractions or backpressure turbine exhaust can be matched to most processes that require relatively large amounts of low or intermediate pressure steam.

Solar energy applied to cogeneration systems will yield more efficient utilization than power plant applications. Thus, the combination of solar and cogeneration offers a high potential for displacement of fossil fuels.

The proposed facility can be operational by 1985, and it will demonstrate that similar solar cogeneration systems can achieve a wide commercial application and result in a significant savings in critical oil and gas fuels.

The study was organized into six technical tasks and one management task. Task 1 was the preparation of a system specification. Task 2 covered the selection among major choices of system configuration and size. Task 3 was the conceptual design of the facility. Task 4 was the performance estimate of the conceptual design. Task 5 included capital and O&M cost estimates, as well as economic analysis. A development plan and schedule were developed under Task 6. Task 7 included project management and reporting.

Bechtel Group, Inc. was the prime contractor to DOE for the study. Sandia National Laboratories acted as DOE's Technical Manager. Amfac Sugar Company, the site owner/operator, was a major subcontractor. Foster Wheeler Development Corp. designed the solar receiver and Northrup, Inc. was responsible for the design of the collector system. An organization chart, showing the key people involved, is given in Figure 1-2.

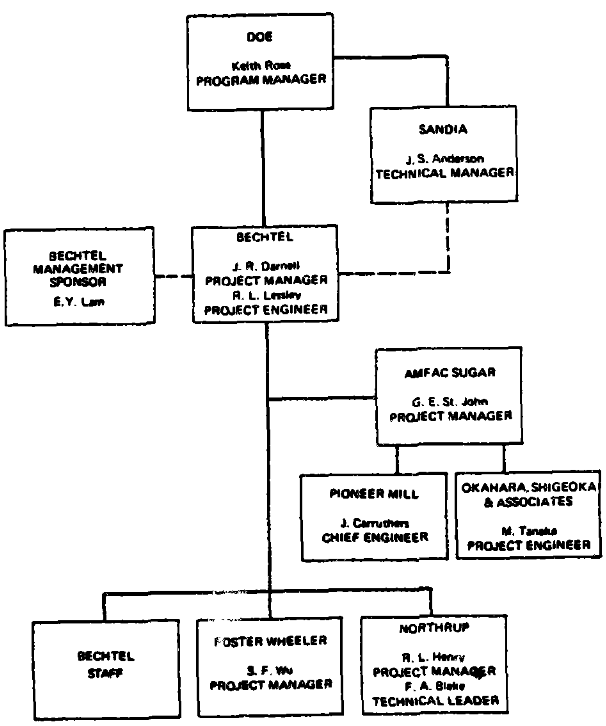

Figure 1-2 PROJECT ORGANIZATION CHART

1.3 EXISTING FACILITY DESCRIPTION

Pioneer Mill is an existing cogeneration facility. Steam generated in the boilers is supplied to the main turbine generator (which produces electric power), to mechanical drive turbines (which supply shaft power for mill equipment), and to the evaporators as process heat. The normal steam production capacity is 81 650 kg/hr (180,000 lb/hr).

The operations at Pioneer Mill produce a by-product biomass fuel called bagasse, which is the cellulose residue of sugar cane. Bagasse currently provides about 76 percent of the annual energy input to the steam produced. The remainder of the energy is supplied by No. 6 oil. Bagasse can be stored for a few days, and can therefore be used in place of thermal storage for the solar facility, which was designed to displace the maximum posible oil consumption at Pioneer Mill.

1.3.1 Site Location

Pioneer Mill is located on the west coast of Maui in the Hawaiian Islands, adjacent to the town of Lahaina, at coordinates 20.8° north and 156.7° west, as shown in Figure 1-3.

1.3.2 Site Geography

The plantation at Pioneer Mill, which is owned by Amfac, occupies 35.5 km^2 (8,776 acres) of land. The area has a general west-facing slope, which extends from a populated resort area along the beach to the steep foothill slopes of the West Maui Mountains. The plantation altitude varies between 3 m (10 ft) and 590 m (1,925 ft) above sea level. The soil in the vicinity of the mill is silty clay loam.

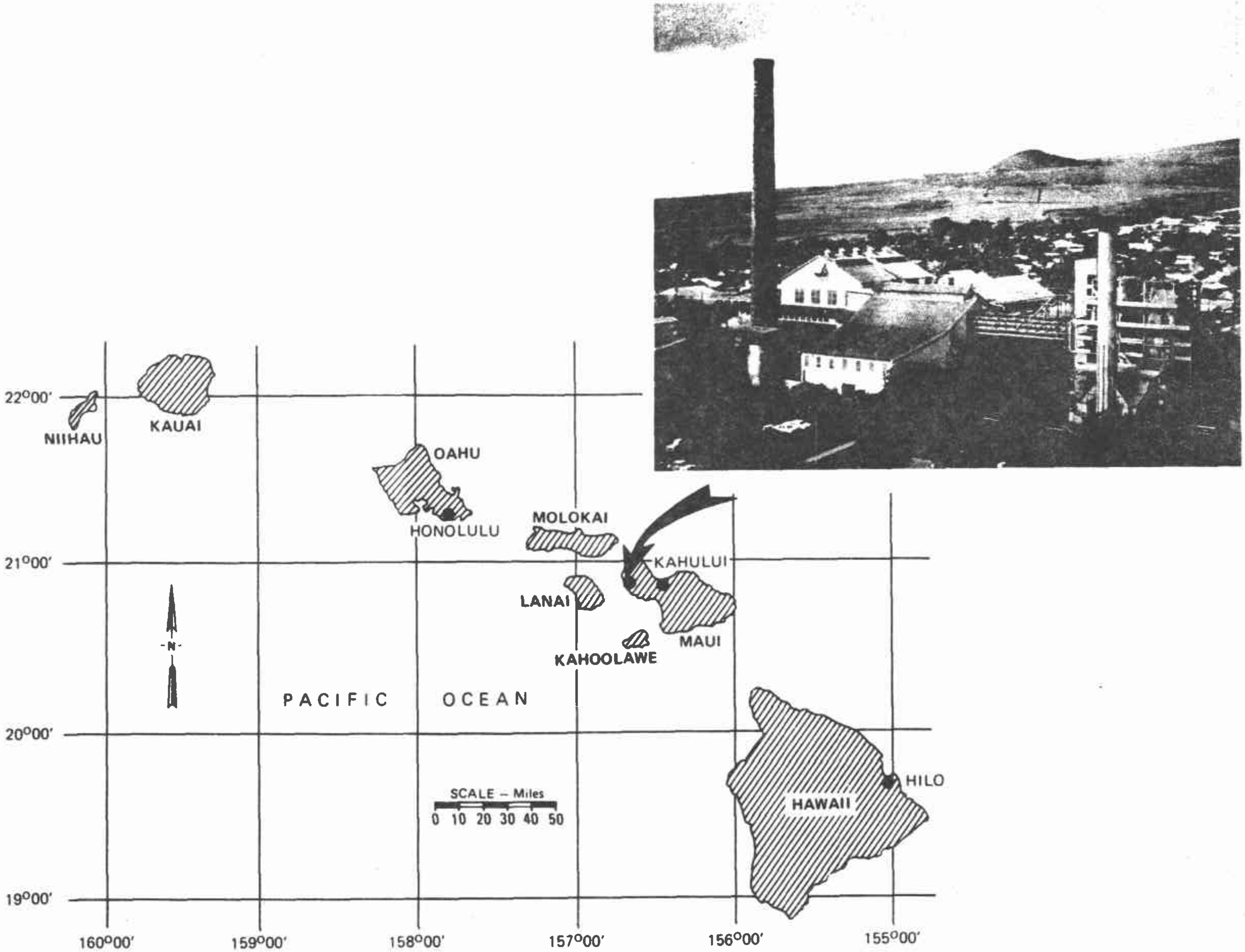

Figure 1-3 LOCATION OF PIONEER MILL

The water supply to the mill comes from wells. The large amount of rainfall on the upper slopes of the mountains is absorbed in the porous soil and flows underground. A series of pumps and tunnels conveys water to the mill and supply the irrigation pumps.

1.3.3 Site Climate

The general climatic pattern at the site is dominated by the trade winds that blow consistently from the northeast. Because of its location relative to the West Maui Mountains, the Lahaina area is classified as a leeward lowland. These areas are typically sunny and dry and have relatively light winds. The only exception to this pattern is caused by major storm systems that cross the islands from the west between October and March.

The average wind speed measured at Pioneer Mill is 1.6 m/s (3.5 mph). The average annual temperature is 24C (75F), with extremes from long-term of 35.5C (96F) and 9C (48F). Because of the tropical latitude, the annual temperature variation is relatively small. Typical relative humidity ranges from 58 percent in the afternoon to 82 percent at night.

The Hawaiian Islands are characterized by extreme variation in precipitation, but the leeward lowlands are quite dry. Long-term data at Lahaina show an annual average of 34.5 cm (13.6 in.). Most of this occurs during the winter storms, and what little occurs in the summer is generally at night. No direct isolation data were available for the Lahaina area at the initiation of this study. A insolation model was developed and calibrated to several sets of total insolation data from Lahaina and the direct insolation data available from the University of Hawaii at Manoa (near Honolulu). This model predicts an average of 6.85 kWh/m^2-day of direct insolation at the site. A site solar data monitoring program was established with Amfac funding in October 1980 and is continuing. The data collected to date corresponds reasonably well to the predictions of the insolation model.

1.3.4 Existing Plant Process

Pioneer Mill Company. Ltd., operates a sugarcane plantation and raw sugar factory. Since 1895, the factory has been processing sugarcane as it is harvested, and producing molasses and raw crystalline sugar. The factory consumes intermediate-pressure steam for motive power, low-pressure steam for process heating, and electricity for motors and controls. The major electrical demand on the plantation is for irrigation pumping. Two boilers produce high-pressure steam that is supplied to the main turbine generator. Two controlled extraction points from the turbine supply steam for the factory. Excess electric power is supplied to the Maui Electric Company grid through the mill substation.

Boiler Equipment. Pioneer Mill operates two Combustion Engineering boilers (Type VU-40S), which were installed in 1966. The boilers are in excellent condition and have an expected remaining useful life of 25 years. They are designed for dual-fuel operation with bagasse and No. 6 oil. Bagasse is fired as it is delivered from the mill.

Turbine Generator Equipment. Pioneer Mill has three turbine generators. The main unit is a General Electric 3 600 rpm, double-automatic-extracting/condensing turbine generator rated at 9 375 kVA. The design steam inlet conditions are 5.96 MPa (865 psia) and 399C (750F). It was installed in 1966 and has a remaining service life expectancy of 25 years.

The high-pressure extraction is controlled at 1.82 MPa (265 psia) and the steam is attemperated to 260C (500F). The low-pressure extraction is controlled at 205 kPa (30 psia) and is used at the extraction temperature of 135C (275F).

Process Description. A process diagram of the existing facility is shown in Figure 1-4.

After the cane has been unloaded from trucks, it is cleaned in a two step process. First, it is transferred to a flotation bath which removes some soil and heavy material such as rocks. It is then washed by a series of spray jets which separate small pieces of cane and leafy trash and the remainder of the soil from the cane stalks. Wash water is recycled from a hydroseparator, is sent to the settling basins, and eventually ends up in the irrigation system.

Next, the sugar is extracted. The cleaned cane is processed through a set of rotary knives and two fiberizers in series to shred the cane. The shredded cane then enters the diffuser, where it is washed with a counter-current stream of water. The diffuser extracts about 98 percent of the sugar and yields watery bagasse and cane juice. The bagasse is dewatered to 48 percent moisture (by weight) and sent by pneumatic conveyors to the boilers. After lime is added to the cane juice, it is heated to 100C (212F), and introduced into a clarifier.

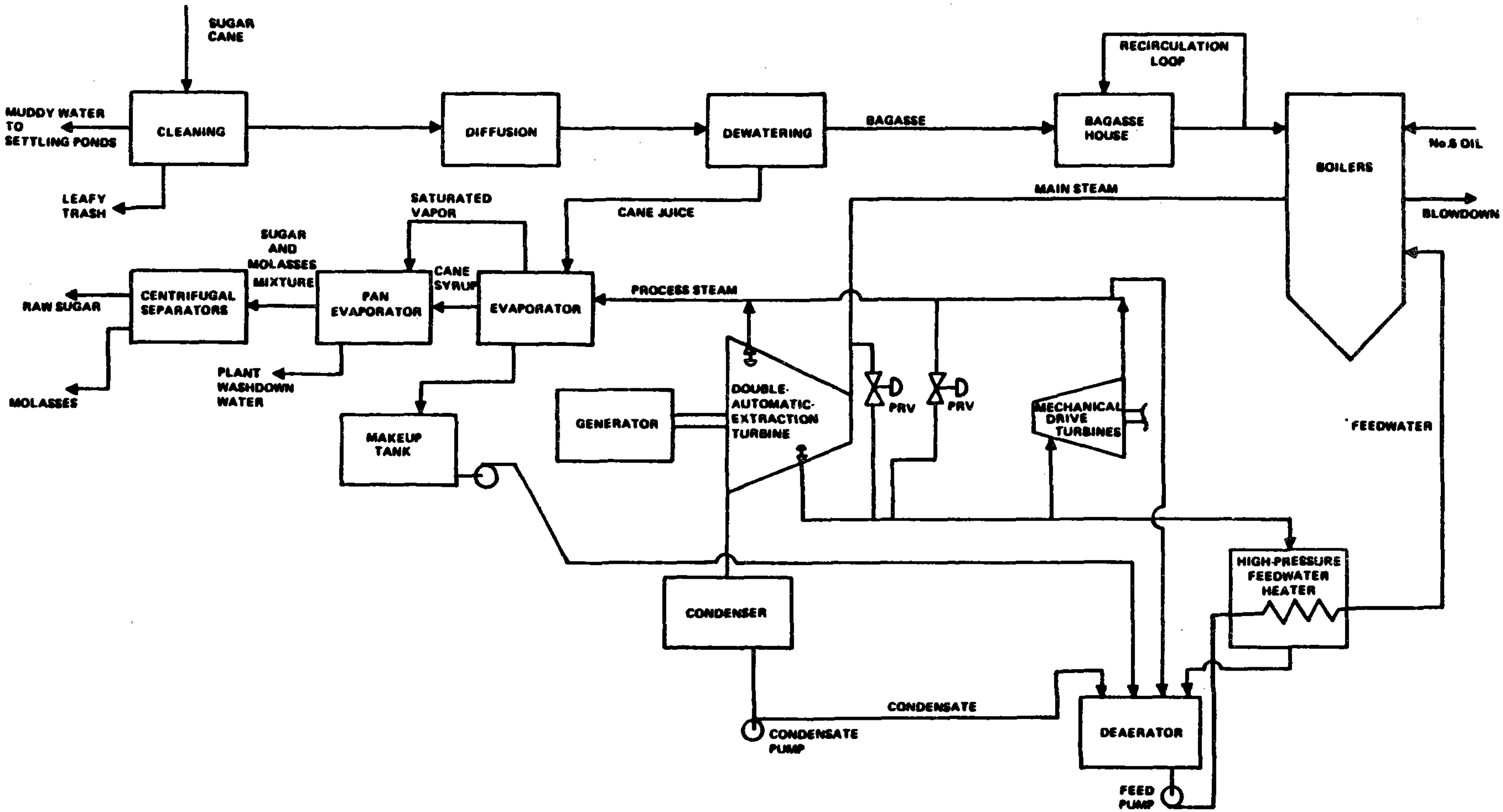

Figure 1-4 PROCESS DIAGRAM FOR THE EXISTING PIONEER MILL

The clarified cane juice is then fed into a five-effect evaporator, which reduces the water content to produce cane syrup. The syrup is further thickened in vacuum pan evaporators with mechanical agitators. The resulting mixture of molasses and sugar is separated in centrifuges, and the raw sugar is finished by further heating in batch crystallizers.

1.3.5 Existing Plant Performance Summary

The factory consumes the available bagasse in the boilers and supplements this with fuel oil to meet the steam and electric demands. Steam demands occur only during factory operation, but electrical demands due to irrigation requirements and Maui Electric Company needs continue throughout the year.

Typical annual performance data for the Pioneer Mill, based on a 10-year average, is as follows:

- Raw sugar produced — 47 314 kg (52,155 tons)
- Molasses produced — 14 720 kg (16,226 tons)
- Bagasse produced and consumed — 112 530 kg (124,042 tons)
- No. 6 fuel oil consumed — 9 641 m^3 (60,588 bbl)
- Electric energy
  - Gross generation — 55 332 MWhe
  - Factory consumption — 18 745 MWhe
  - Other consumption (mainly irrigation pumping) — 31 838 MWhe
  - Sold to Maui Electric — 4 750 MWhe

Factory Operating Schedule. The factory normally operates 40 weeks during the year to coincide with the sugarcane harvest. During this harvest season, the factory operates on a 24 hr/day, 5 day/wk schedule.

The nominal operating rate, based on cleaned cane, is 109 000 kg/hr (120 tons/hr), but outages and interruptions reduce this to an average of 92 500 kg/hr (102 tons/hr). The harvest season is typically March through November.

Boiler and Turbine Operating Cycle. The boilers and turbine generator are operated to meet the needs of the plantation and supply electric power to Maui Electric on demand. During factory operation, each boiler is operated at approximately 40 800 kg/hr (90,000 lb/hr), and the generator produces about 8 MWe. During weekend operation, the factory steam demand is eliminated and the turbine is operated to match electrical demand. The turbine is typically operated between 3 MWe and 6 MWe with only one boiler operating. In the 12-week off season, turbine operation is similar to turbine operation during weekends. The boilers are alternately taken out of service for scheduled maintenance.

1.4 CONCEPTUAL DESIGN DESCRIPTION

Solar repowering for Pioneer Mill consists of adding a collector field, a tower-mounted receiver, and a steam pipeline connecting the receiver with the existing plant and controls, as shown in Figure 1-5. Approximately 815 heliostats, each with 52.8 m^2 (568 ft^2) reflective area, are arranged in a 150° north field which covers about 0.17 km^2 (42 acres) of land. The two-cavity, natural-circulation water-steam receiver is supported upon a 76 m (250 ft) steel tower. The receiver output is 26.2 MWt, supplying about 50 percent of the total main stream energy at the design point. Steam and condensate pipelines, about 1 130 m (3,700 ft) and 1 200 m (3,900 ft) long, respectively, connect the receiver with the plant. A steam mixing station to mix steam from the existing boilers with steam from the receiver is located at the mill. An expanded control room and additional bagasse

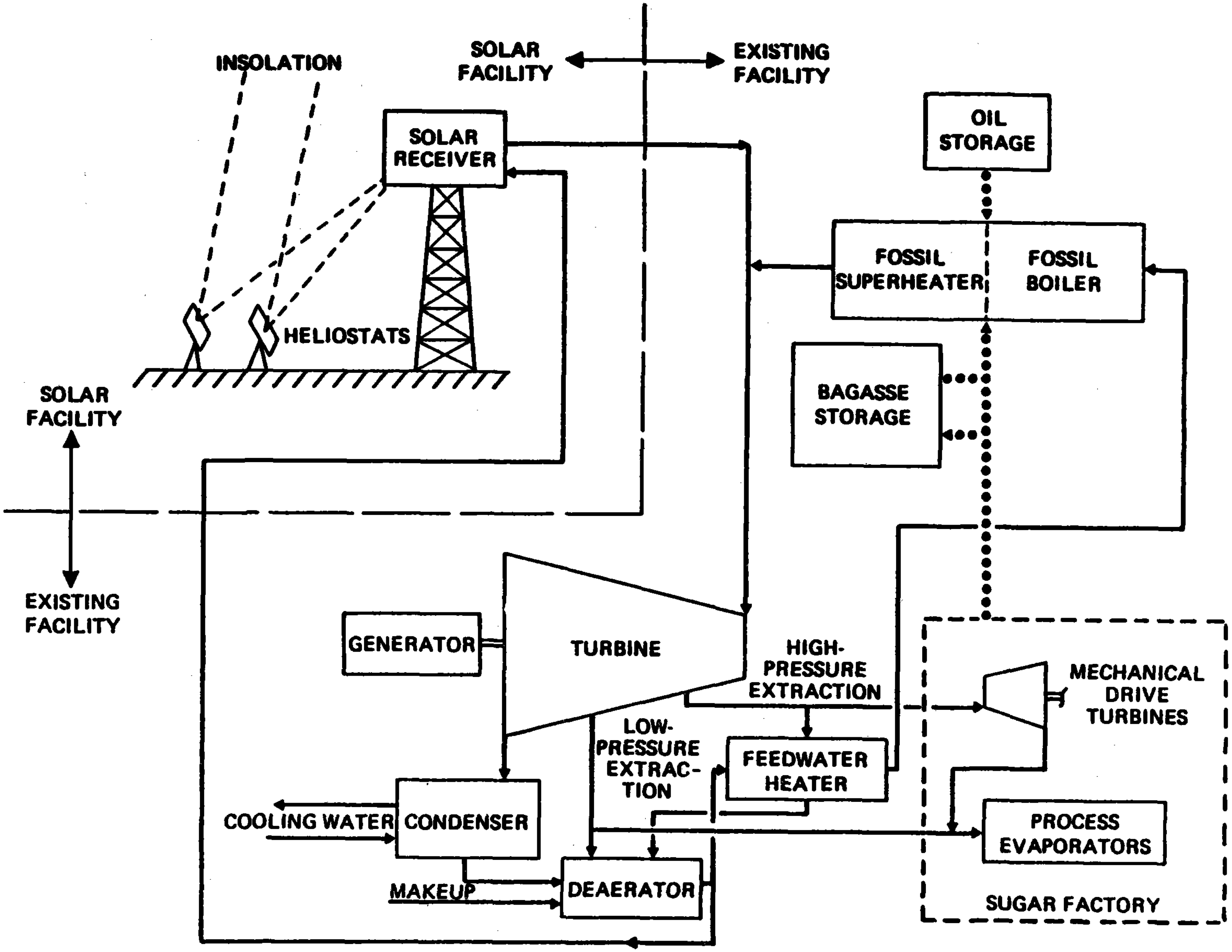

Figure 1-5 SYSTEM FLOW DIAGRAM

storage capacity are needed to accommodate the retrofit. Table 1-1 summarizes the key features of the conceptual design.

The water-steam solar receiver will operate in parallel with the existing boilers. When solar-produced steam is available, bagasse will be diverted from the boiler to the storage house, from which it can be reclaimed when solar steam is not available. This use of bagasse eliminates the need for thermal energy storage and allows the displacement of about 53 percent of all the oil currently consumed during the harvest season. During the 3-month off season, when the factory does not produce bagasse, solar-produced steam will displace a portion of the oil currently burned to meet the year-round irrigation requirements.

The solar cogeneration facility will have two steady-state operating modes: 1) solar steam generation mode, and 2) nonsolar steam generation model. In the solar steam generation mode, the solar water-steam receiver operates in parallel with the existing boilers. The existing boiler's output is reduced so that the maximum available solar-produced steam is used while the total steam demand is being met. In the nonsolar steam generation mode, during period when solar-produced steam is unavailable, the existing boilers satisfy the entire steam demand.

1.4.1 Technical Tradeoff Studies

A number of technical tradeoff studies were conducted prior to the conceptual design. These evaluated major options to allow selection of the preferred system configuration. A brief summary of the scope and conclusions of these studies is presented below:

- Collector Field Site - Three field sites were considered, one on a south-facing hillside of nonagricultural land

Table 1-1

CONCEPTUAL DESIGN SUMMARY

Prime Contractor:	Bechtel Group, Inc. P.O. Box 3965 San Francisco, CA 94119 Project Manager - Jack R. Darnell
Major Subcontractors:	Amfac Sugar Company Project Manager - George E. St.John Northrup, Inc. Project Manager - Roy L. Henry Foster Wheeler Development Corp. Project Manager - S.F. Wu
Site Location:	Pioneer Mill Company, Ltd., a subsidiary of Amfac Sugar Company, is adjacent to Lahaina, Maui, Hawaii (20.9°N, 156.7° W)
Facility Characteristics:	General Electric 3 600 rpm, double-automatic-extracting/condensing turbine generator rated at 9 375 kVA. Turbine design inlet conditions are 5.96 MPa (865 psia) and 399C (750F). High pressure extraction at 1.82 MPa (265 psia) supplies steam for feedwater heater and mechanical drive turbines. Low pressure extraction and exhaust from mechanical drive turbines at 205 kPa (30 psia) supply process steam to factory evaporators.
Design Point:	Equinox, 1 p.m., 950 W/m^2 insolation.
Receiver:	Receiver fluid: water-steam Configuration: twin-cavity Type: natural circulation Elements: boiler, superheater Power output at design point: 26.2 MWt Inlet and outlet fluid temperatures: 113C (235F); 438C (820F) Inlet and outlet fluid pressures: 7.75 MPa (1125 psia); 6.85 PMa (994 psia) Tower Type: Steel with three main columns Tower height: 76 m (250 ft) to aperture centerline Incident receiver panel flux: Average: 0.21 MWt/m^2; Peak: 0.75 MWt/m^2
Collector Field:	Number of heliostats: 815 Individual mirror area: 52.8 m^2 (568 ft^2) Cost: $383/$m^2$ installed (including foundations, wiring, etc.) (1980 dollars) Type: Northrup second generation Field configuration: 150° North field Total mirror area: 43,000 m^2 Total collector field area: 171,000 m^2 (42 acres)
Storage:	No thermal storage. Bagasse storage is used in lieu of thermal storage.
Project Cost:	Cost of project construction in 1980 dollars at an installed heliostat price of $383/$m^2$): $31,096,000 Cost of project construction in 1980 dollars at an installed heliostat price of $260/$m^2$: $25,807,000
Construction Time:	2 years
Solar Facility Contribution-Design Point:	Receiver output: 26.2 MWt (50 percent) Electric power: 3.4 MWe (50 percent) Mechanical power: 0.3 MWm (50 percent) Process heat: 17.1 MWt (50 percent)
Solar Facility Contribution-Annual:	Receiver output: 57,100 MWt (13.6 percent) Electric power: 7,364 MWhe (13.6 percent) Mechanical power: 423 MWhm (13.6 percent) Process heat: 2,221 MWht (13.6 percent)
Solar Fraction:	Design point: 0.50 Annual: 0.136 - all fuels 0.48 - oil only
Annual Fossil Energy Saved:	36,582 barrels (barrels of crude oil equivalent@ 5,800 x 10^6 Btu/barrel)
Type of Fuel Displaced:	No. 6 fuel oil
Ration Of Annual Energy Produced/ Total Heliostat Mirror Area:	1.33 $MWht/m^2$
Ration of Capital Cost/Annual Fuel Displaced:	$494 (1980 dollars)/MWht
Site Insolation (Direct Normal):	Design point: 950 W/m^2 Annual average: 2500 kWh/m^2 Source: ASHRAE model with site measurements and University of Hawaii data Site Measurements: Beginning October 1980, global and direct normal insolation has been continuously recorded and is continuing
Annual Cogeneration Utilization Efficiency:	$\frac{MWhe + MWhm + MWht}{MWh_{total\ input}} = 0.526$

about 1500 m (5,000 ft) from the mill and two in relatively flat sugarcane fields adjacent to the mill. One flat site and the hill side site were evaluated in considerable detail and the flat site was selected on economic bases. The other flat site was finally selected for the design because of reduced land availability and visual impact.

- Dual Use of Land - Since the selected site involved heliostats displacing sugarcane, the possibility of raising the heliostats above the crops was investigated. Two crops, alfalfa and seed cane, were evaluated. Dual use was not found to be the practical choice for this project, but the economic difference was not large enough to rule out the possibility for other crops or other sites.

- Heliostat Field Layout - A 90° north field with a single cavity receiver was evaluated for the hillside site, and a 150° north field with a twin cavity receiver was evaluated for the flat site. The wider field was selected due to shorter tower height, which reduces visual impact.

- Tower Height - Several tower heights were evaluated for the selected field and a 76 m (250 ft) tower was chosen for economic reasons. A steel tower was also found to be cheaper than a concrete tower.

- Collector Field Size - A detailed operational analysis of the factory operating conditions led to the finding that the weekend maximum throttle flow limit controlled the maximum size of the solar facility. A minor modification to the existing plant was included in the conceptual design to increase the field size, but the amount of possible oil displacement is still limited for operational reasons.

1.4.2 Design and Operating Characteristics

Collector System. The function of the collector system is to reflect solar radiation to the receiver. The collector system consists of an optimized layout of 815 ARCO-Northrup second generation heliostats on individual pipe foundations, control and power wiring, and heliostat controls.

The heliostats are the major components of the collector system. Each heliostat has 52.8 m^2 (568 ft^2) of reflective area, composed of 12 second surface silvered glass mirror modules measuring 1.2 m (4 ft) by 3.7 m

(12 ft). The overall dimensions of the heliostat are 7.6 m (25 ft) high by 7.4 m (24.3 ft) wide. The desired focal length is achieved by canting the flat mirror modules. Each heliostat is mounted on a 0.6 m (2 ft) diameter by 6.7 m (22 ft) long steel pipe which is placed in an augured 3 m (10 ft) deep hole and set in concrete. Front and back views of a typical heliostat are shown in Figures 1-6 and 1-7. The site of the collector field is located approximately 670 m (2,200 ft) north of the mill in a sugarcane field, as shown in Figure 1-8.

The heliostat layout is based on a radial stagger pattern to minimize shading and blocking of adjacent heliostats. There are 24 concentric rows of heliostats, the farthest being 360 m (1,180 ft) ftom the tower. The radial centerline of the collector field points 15° east of north from the tower. This results in a peak geometric efficiency at approximately one hour after noon.

The collector system provides the heat input to the receiver and is the primary control element for receiver thermal input. At the design point it delivers 30.2 MWt to the aperture planes of the receiver cavities. The heliostats are controlled through a three-level, open loop control system to track the sun to supply the maximum amount of power available to the receiver. The power supplied varies with both the daily and seasonal variation in sun position.

Receiver System. The selected receiver concept is a twin-cavity, natural-circulation steam generator with separate superheat circuitry. Water/steam was chosen as the receiver working fluid because of the simple interfact with the existing facility. In addition, the technology is well

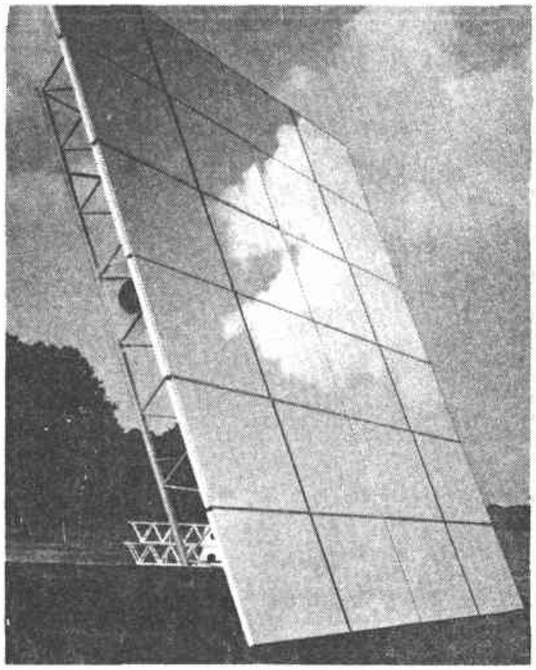

Figure 1-6 FRONT VIEW OF THE ARCO-NORTHRUP SECOND-GENERATION HELIOSTAT

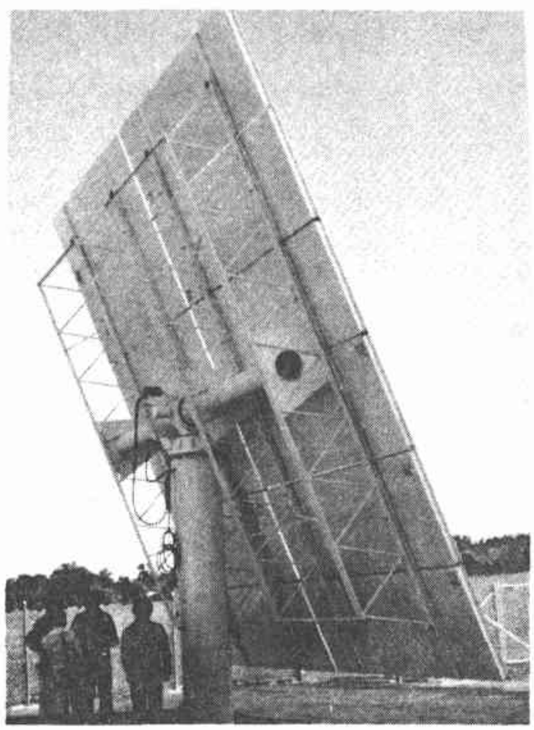

Figure 1-7 REAR VIEW OF THE ARCO-NORTHRUP SECOND-GENERATION HELIOSTAT

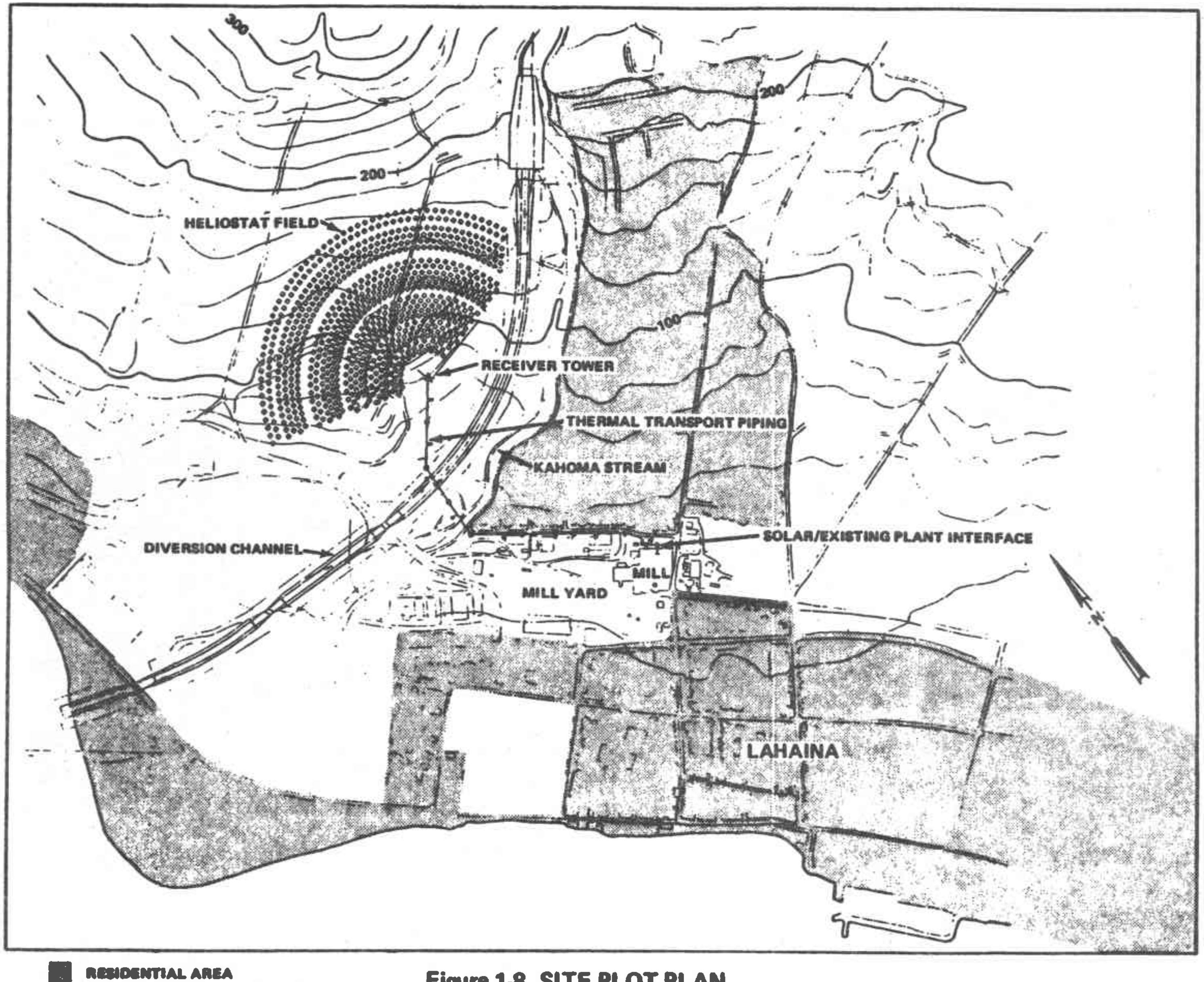

Figure 1-8 SITE PLOT PLAN

developed and is available to support the operation of the solar cogeneration facility by 1985. Natural circulation has a history of high reliability in fossil-fueled boilers, and a great deal of experience exists regarding the design, construction, and operation of similar conventional boilers at the pressure and temperature required for Pioneer Mill. The boiler circuitry of a natural circulation receiver is inherently self-compensating for energy input variations with both time and location in the receiver. Testing of natural-circulation water-steam solar receivers with 1 MWt and 5 MWt capacities has demonstrated their thermal and hydraulic stability and ease of control under steady state and transient conditions. The cavity configuration has a high energy absorption efficiency and lower thermal losses than an external design while in operation and during overnight situations when the aperture door is closed.

The selection of the cavity receiver configuration was also strongly influenced by the belief that it is the lower risk design with more flexibility to adapt to the overall requirement at Pioneer Mill.

The configuration of the twin-cavity receiver is shown in Figure 1-9. The receiver is symmetric with respect to a panel passing through the common wall that partitions the two cavities. Since the selected heliostat field varies slightly from the north of the tower location, the common wall is rotated 15° east from due north. The square aperture of each cavity is 6.52 m (21.4 ft) on a side with its centerline extending at an angle of 37.5° from the common wall.

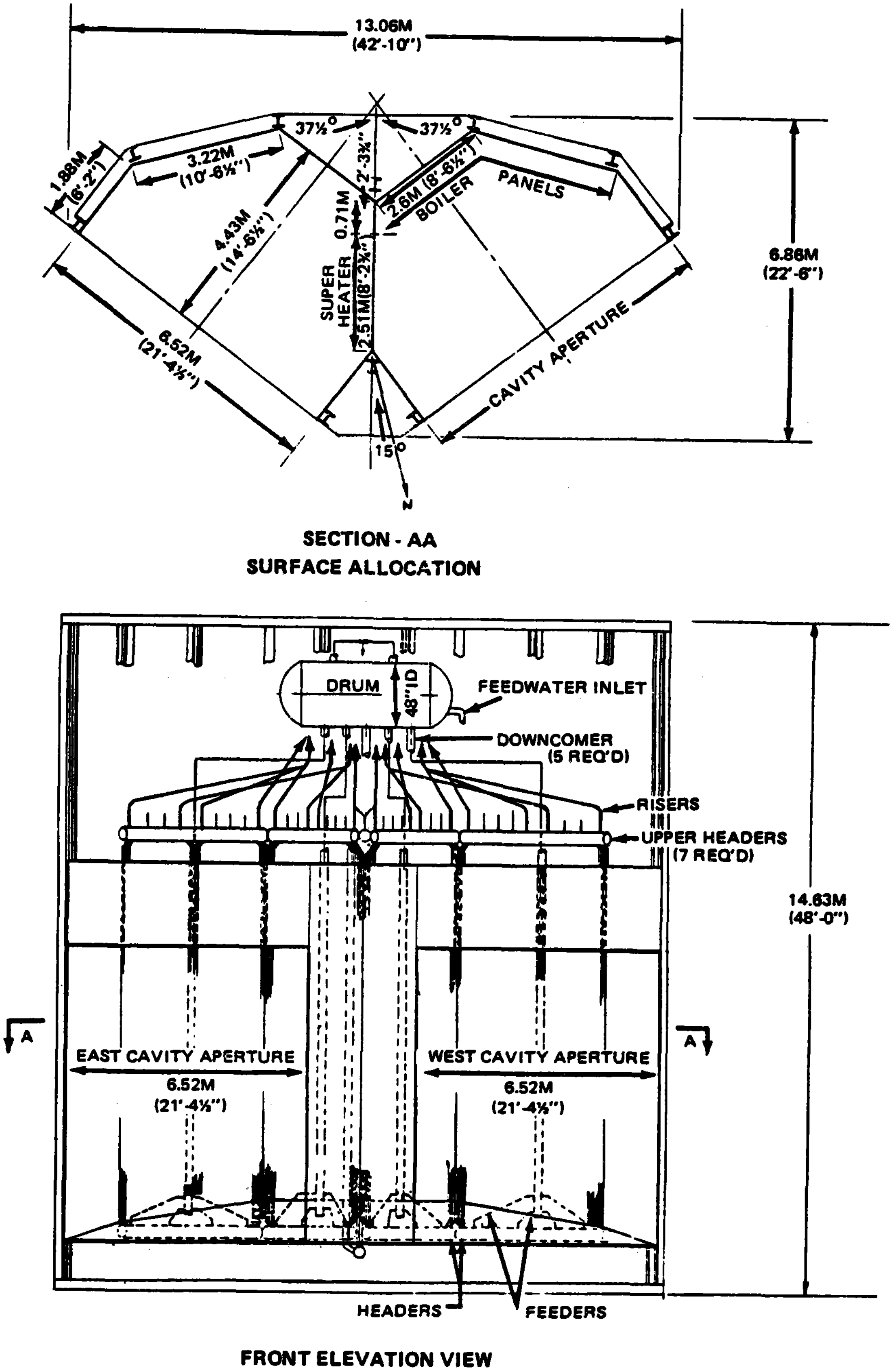

Figure 1-9 TWIN–CAVITY RECEIVER CONFIGURATION

The superheater is located in the forward portion of the common wall. The remaining portion of the common wall, two rear walls and two side-walls are lined with boiler panels. All boiler and superheater panels are made of tubes that are joined along their length by continuous weld integral fins to form vertical flat Monowalls™. Carbon steel (SA-210 A1 boiler tubes of 50.8 mm (2.0 in) O.D. were selected for the boiler panels and 31.8 mm (1.25 in) O.D. stainless steel (SA 213 TP316H) tubes for the superheat panels.

The superheater consists of four vertical passes in series. The steam is heated by absorbing incident solar flux from both sides of panels in the successive passes until it reaches its specified outlet temperature. A spray attemperator is used for steam temperature control.

During normal operation, receiver outlet steam pressure is regulated by the steam matching control equipment located at Pioneer Mill. The startup flow regulator is activated during the startup periods in order to bring up drum pressure at an optimum rate. Feedwater flow is controlled by a conventional three-element feedwater regulator of the type used on fossil-fueled drum-type boilers.

The receiver was sized to produce 33 500 kg/hr (73,900 lb/hr) of superheated steam at a pressure of 6 854 kPa (994 psia) and a temperature of 438C (820F), with a thermal output of 26.2 MWt. For a feedwater temperature of 113C (235F), approximately 18.2 percent of the total thermal output is required to superheat the steam.

The three-sided tower that supports the receiver aperture at the 76 m (250 ft) elevation and the tower piping is fabricated from steel pipe sections.

The tower foundation consists of three pedestal-type spread footings. Access to the top of the tower is provided by a lightweight equipment elevator and by stairs supported by the elevator guides.

Thermal Transport System. The thermal transport system provides the physical interface between the existing mill facility and the new solar systems. The thermal transport system includes the steam and condensate pipes between the receiver system and the mill facility, condensate transfer pumps, receiver feed pumps, a condensate holding tank, a warmup loop with heater and circulating pump, a steam mixing station with electric steam superheaters and pressure reducing valves, and a small emergency steam turbine generator.

The condensate transfer pumps are located in the existing mill boiler house. The steam mixing station also is at the mill in a building adjacent to the steam turbine generators. The rest of the thermal transport system equipment is installed in a building at the base of the receiver tower.

Both steam and condensate pipes from the tower to the mill are above ground on metal supports. The route of the pipes crosses sugarcane fields and runs along one side of the mill yard.

The thermal transport steam piping is 15 cm (6 in) in diameter with 11.4 cm (4.5 in) of insulation and is 1 130 m (3,700 ft) long. The condensate pipe is 10 cm (4 in) in diameter with 3.8 cm (1.5 in) of insulation and is 1 190 m (3,900 ft) long. Low alloy steel is used for the steam pipe and carbon steel is used for the condensate pipe. Thermal expansion is accommodated by expansion loops. Drains are provided at four points in the steam pipeline.

During startup, the mixing station ensures that the receiver steam is compatable with the mill boiler steam as early as possible and to minimize wasted energy. After an overnight shutdown, the receiver metal and water is heated up by mill steam that is obtained from the thermal transport steam line. While the steam is below the design temperature, four vertical electric steam superheaters, each rated at 400 kWe, are used to top off the temperature of the receiver steam to the same temperature as the mill steam. If the factory is operating, another option is to dump the steam into the intermediate pressure or low pressure extraction headers, or to the main condenser.

A single-stage, solid wheel, non-condensing 500 kWe emergency steam turbine designed to provide power for safe shutdown of the solar facility on loss of electrical power, draws steam from the receiver superheater.

The solar receiver generates superheated steam at a pressure of 6.85 MPa (994 psia) and a temperature of 438C (820F). Due to losses, the conditions at the mill end of the pipe are 5.96 MPa (865 psia) and 422C (792F). A desuperheater is used to obtain the mill temperature of 399C (750F) by adding 900 kg/hr (2000 lb/hr) of mill boiler feedwater. At a receiver flow rate of 25 percent of normal operational flow, the losses are such that main steam conditions are obtained at the mill without the use of the desuperheater.

Master Control System. The primary function of the master control system is to integrate the operation of the solar facility with the mill and to acquire and store data. The major components and elements of the master control system are contained in an extension to the existing mill control room and in a new solar control room at the base of the receiver tower. The main control point for the operation of the collector and receiver systems is the solar control room. The solar operator has visual feedback of collector field operation and weather through closed circuit TV cameras. Operator action is not required for safe operation since automatic coordination is necessary for protection of the receiver.

The controls for the mill end of the thermal transport system are located in the expansion of the existing mill control room. The mill operator will have control of the mixing station so that the stability of the mill operation can be maintained. Automatic startup sequences are programmed into the controls but the mill operator can select options such as routing of startup steam from the receiver.

Nonsolar Energy System. The nonsolar energy system includes the modifications to the existing mill facility to accommodate the solar retrofit. Two new pipe connections at the mill are required for condensate and main steam. In addition, there are pipe connections from the mixing station to the intermediate pressure and low pressure process headers and to the condenser.

The capacity of the existing bagasse storage building and bagasse handling equipment must also be increased. This requires an additional storage building which is located near the present bagasse house. The new building is 49 m (160 ft) by 24 m (80 ft) and about 10 m (32 ft) high with a storage capacity of 45 000 kg (490 tons). The new bagasse house is connected to the existing bagasse house by conveyors.

1.4.3 Cost Estimates

Capital Cost. A capital cost estimate of the conceptual design was prepared. The total construction cost was estimated to be $33,800,000 in first quarter 1981 dollars. The largest single account is the heliostat field at $17,885,000, or a total installed cost of $416/m^2.

Operating and Maintenance Cost. The annual additional O&M cost for the solar retrofit was estimated to be $406,000 in first quarter 1981 dollars.

1.5 SYSTEM PERFORMANCE

1.5.1 Design Point

The solar facility is designed to deliver 25.9 MWt to the main steam line at the turbine inlet at 1 p.m. on the equinox day. With 815 heliostats and 950 W/m^2 insolation, the incident solar power is 40.9 MWt and the individual loss mechanisms are shown on the design point stairstep efficiency diagram, Figure 1-10. Solar energy provides 50 percent of the energy in the main steam at the design point. The remainder is supplied by the existing boiler burning bagasse during factory operation. The fired-boiler efficiency is approximately 70 percent in this mode.

The net outputs are also shown in Figure 1-10. The largest portion is process heat, delivered from both extraction headers. A small amount of mechanical power is produced in the factory-equipment-drive turbines. The additional power required by the solar facility (225 kWe) is included in the computation of the net electrical output. The miscellaneous losses shown include equipment efficiencies, thermal losses in piping and equipment, and other power plant steam demands such as soot blowers and oil heaters.

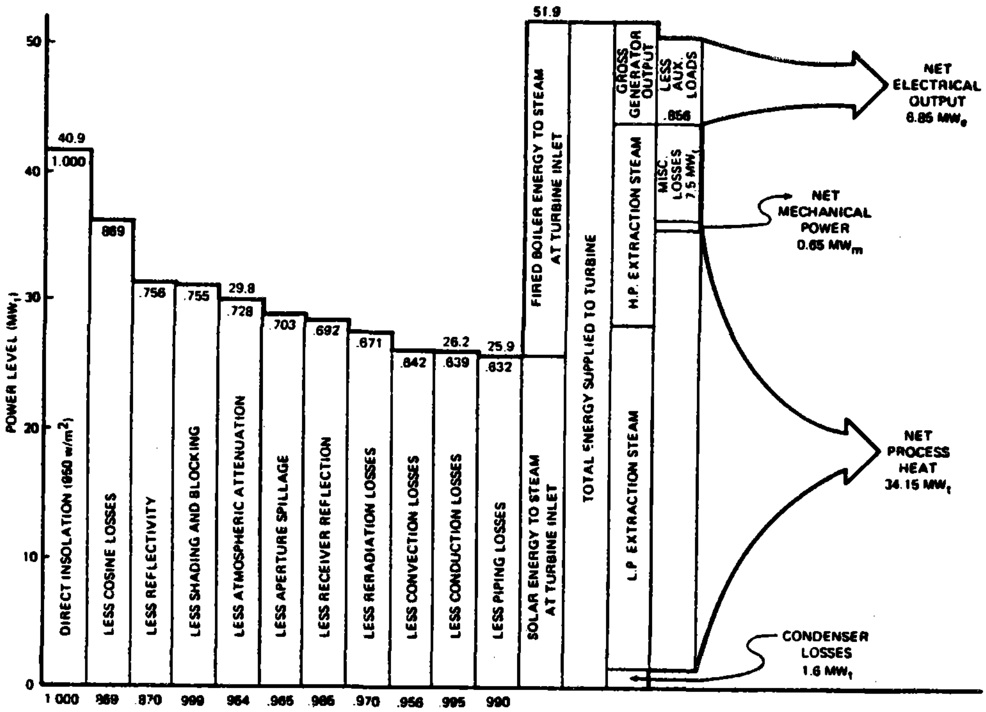

Figure 1-10 STAIRSTEP EFFICIENCY DIAGRAM – DESIGN POINT

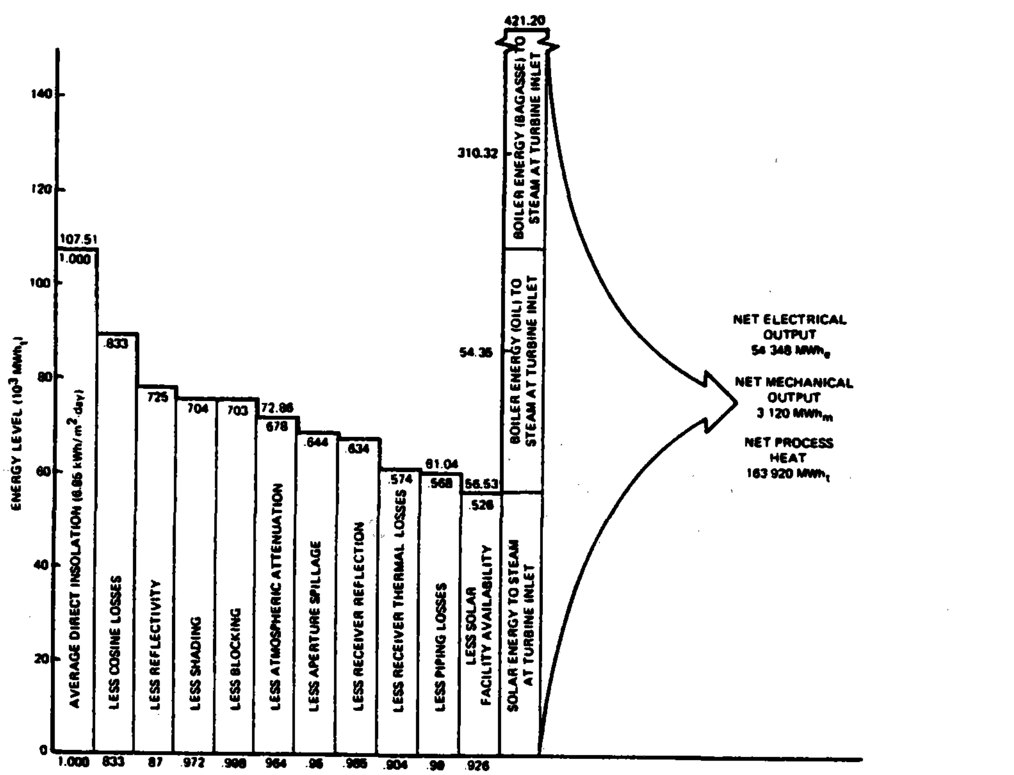

Figure 1-11 STAIRSTEP EFFICIENCY DIAGRAM – ANNUAL AVERAGE

1.5.2 Annual Average

The annual average stairstep efficiency diagram is shown in Figure 1-11. The average solar input of 6.85 kWh/m^2-day results in 56 530 MWht annually supplied to main steam line. The stairstep efficiencies which vary with time were determined with the STEAEC program.

The solar input to the main steam is equivalent to a savings of 5 817 m^3 of oil at 38.6 X 10^6 kJ/m^3 (36,582 bbls at 5.8 X 10^6 Btu/bbl) using a boiler efficiency of 0.905. The actual displacement of No. 6 fuel oil (6.45 x 10^6 Btu/bbl) from the Pioneer Mill boilers is 4 580 m^3 (28,800 bbl). The additional gross electrical generation is 1 696 MWhe, but after accounting for solar auxiliary power, the net added electrical generation is 133 MWhe.

1.5.3 Energy Load Profile

The energy load profile has both a weekly and a seasonal pattern which must be included in the operational analysis of the plant. The factory, and hence the cogeneration portion of the mill, only operates 5 days/wk during the 40-week grinding season. During weekends of the grinding season and the off-season, only the power generation equipment is operated, primarily to satisfy irrigation requirements or demands from Maui Electric Company.

The daily energy profile for a grinding day, corresponding to the design point, is shown in Figure 1-12. The outputs are constant throughout the day with only the electrical auxiliary load varying because of solar operation.

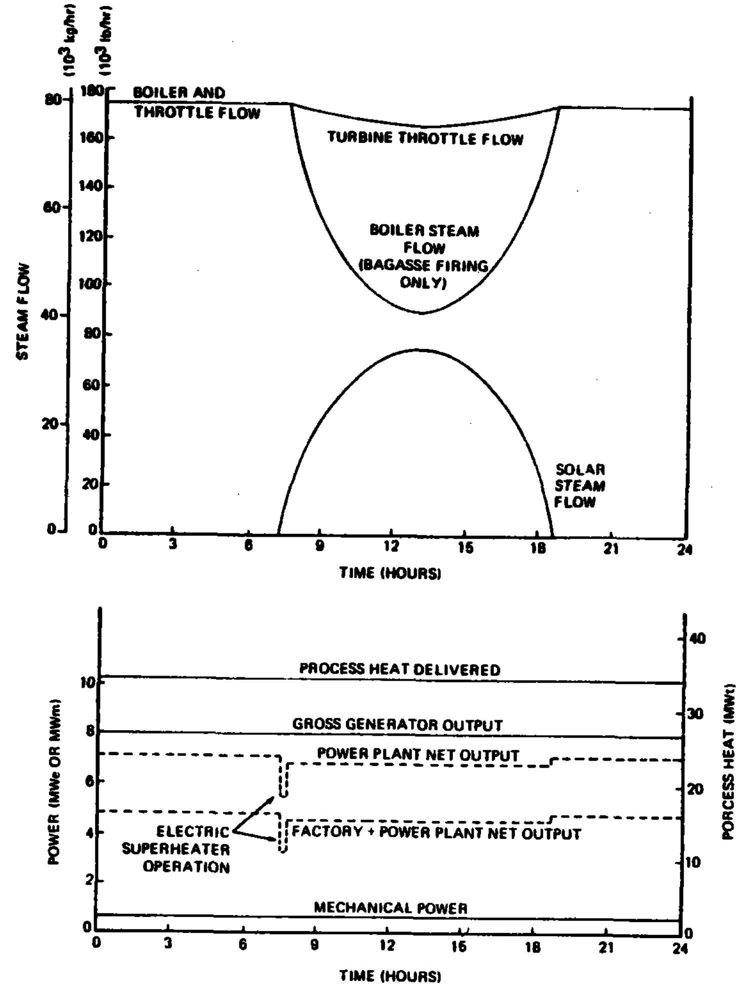

Figure 1-12 DAILY ENERGY PROFILE – GRINDING SEASON WEEKDAY (CLEAR WEATHER)

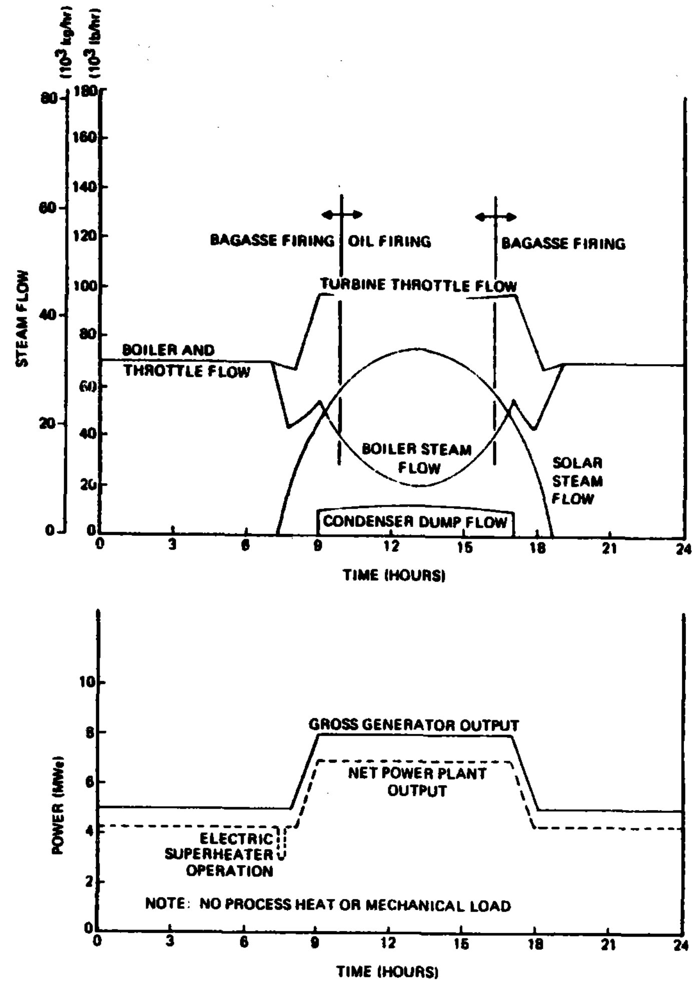

Figure 1-13 DAILY ENERGY PROFILE – GRINDING SEASON WEEKEND (CLEAR WEATHER)

Without factory operation on the weekend, as shown in Figure 1-13, there is no process heat or mechanical drive output, but there is some residual factory electrical load. Although only 5 MWe is usually needed for this time period, the generator gross output is increased to 8 MWe and the condenser dump valve is actuated during solar operation to utilize all the solar steam flow. Bagasse is burned in the boiler when available, except for boiler flows less than 18 150 kg/hr (40,000 lb/hr) when oil must be burned.

1.6 ECONOMIC FINDINGS

The analysis of the economic viability of the solar retrofit at Pioneer Mill was based on typical Amfac criteria and methodology. Two evaluation criteria were applied:

- internal rate of return
- the investment that Amfac could support while achieving the project-specific hurdle rate.

The choice of a 20 percent hurdle rate by Amfac with with equity financing represents an investment in a developing technology with which Amfac has no direct experience. The analysis of the after-tax discounted cash flows included the following elements:

- Capital costs distributed over the construction period
- Annual operating and maintenance costs
- Lost revenues from sugar and bagasse displaced by the the solar retrofit
- Annual savings in No. 6 fuel oil
- Revenues from Maui Electric Company for additional electric energy sales

The assumptions used for the base case analysis are listed in Table 1-2. First quarter 1981 dollars were used as the basis for the calculations.

The results for the base case show a calculated IRR of 4.5 percent, well below the required hurdle rate for the project. For the base case, Amfac would consider investing only about 10 percent of the total required investment.

Sensitivity analyses were performed to determine the effect of changes in major parameters on the economic results. The following factors were found to improve the project's economic viability:

- Lower capital costs of heliostats and other equipment
- Longer project operating lifetime
- Higher fuel oil costs
- Shorter project construction period
- Accelerated depreciation methods
- Improved solar facility performance
- Higher fuel escalation rate
- Higher general escalation rate.

An economic scenario incorporating improvements in several of these parameters was developed and analyzed. The results indicated that for a more mature stage of solar technology development, with higher costs of displaced fuel, higher escalation rates, and a longer project lifetime, this type of system has the potential for meeting Amfac's investment criteria. Other considerations, including the desirability of Hawaii and U.S. energy independence and the possibility of "creative" financing of such a project, were also found to be important in the overall assessment of the project's viability.

Table 1-2

Baseline Assumptions for Economic Analysis

Item	Assumption
Capital cost + owner's cost	$37,000,000
Construction period	3 years
Initial operation date	February, 1986
Operating lifetime	20 years
Annual O&M cost	$406,000
Displaced sugar value	$3,300/acre/yr (42 acres displaced)
Displaced bagasse value	$20,000/yr
Fuel savings	28,800 bbl/yr of No. 6 fuel oil
Additional electricity sales	133 MWhe
Value of electricity	(0.85) ($.066253/kWhe)
General inflation, capital and O&M escalation rates	10 percent
Fuel and bagasse escalation rate	12 percent
Hurdle rate	20 percent
Tax credits	Federal - 25 percent State - 10 percent
Tax rates	Federal - 46 percent State - 10 percent
Depreciation method	Double declining balance
Tax life	14 years

1.7 DEVELOPMENT PLAN

A development plan was prepared for the project to define all necessary steps to progress from this conceptual design study to an operating demonstration project. A project schedule was also developed and is presented in Figure 1-14. The preliminary design phase was assumed to start 6 months after completion of this study and the goal was to be operational in early 1985. This schedule is achievable, assuming licensing proceeds in a straight-forward manner and the heliostat manufacturing facilities to support this project are available during 1984.

The role of Amfac, as site owner/operator, is to direct the design and operation of the solar facility, to ensure that it is representative of a typical commercial application of solar central receiver technology. Amfac will also contribute a portion of the total required investment which is consistent with a reasonable rate of return. The government must also contribute to this project because this technology is not yet mature enough to stand by itself in the commercial marketplace. The government will also provide valuable technical guidance during the design and joint operation phases.

1.8 SITE OWNER'S ASSESSMENT

Amfac's overall project evaluation is positive, especially for an emerging technology. Amfac's assessment can be divided into three related but but separate areas - technology, operations, and economics.

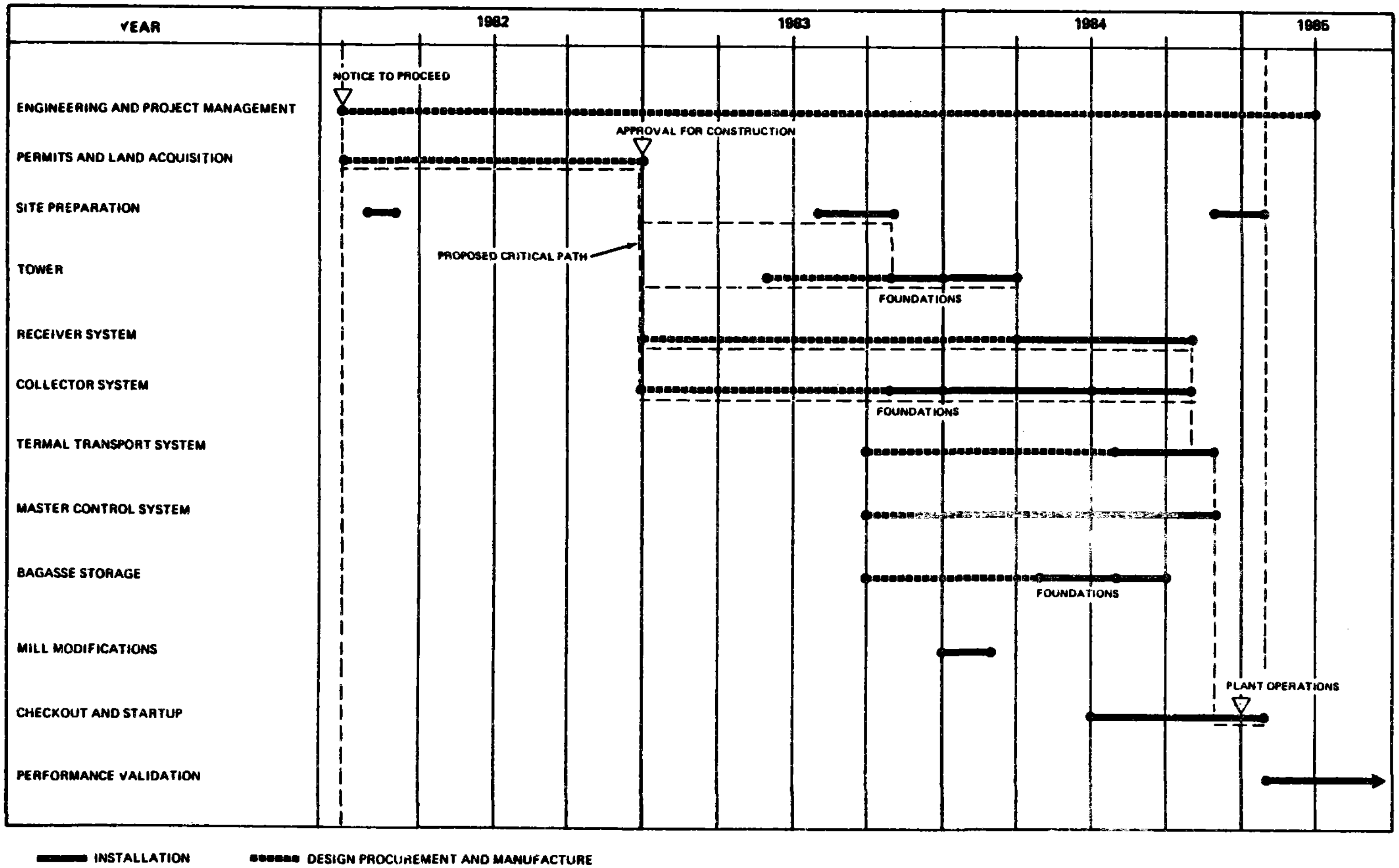

Figure 1-14 PROJECT SCHEDULE

1.8.1 Technology

The basic technology is perceived to be sound and worthy of Amfac's continued efforts in attempting to reduce our severe oil cost. The interface with existing equipment and the utilization of familiar technology (water/steam) raise the level of acceptance of the technology. The design incorporates features which allow existing mill operations to continue uninterrupted despite supply uncertainties with the solar system. All of these features increase the confidence level in the technology.

1.8.2 Operations

In the decisions pertaining to actual operations of such a system with partial government funding, the operational flexibility provided in the design should remain under the control of the mill operating personnel to maximize sugar production. The inclusion of a visitors center is a most desirable feature to reduce visitors interference with mill operations.

Additional site specific data is required on heliostat life, cleaning requirements, etc. to reduce the level of uncertainty in operations and maintenance (O&M) cost estimates. While additional data are also needed on long term receiver cycling effects and O&M cost, these data need not be site specific and will likely be available from the Barstow pilot plant.

1.8.3 Economics

The economic considerations of the project will almost exclusively determine Amfac's equity participation in the construction of the project.

If Amfac's initial risk could be reduced by equity participation tied to actual final demonstrated results, then greater Amfac equity participation would potentially be possible. This could be accomplished through reimbursable grants tied to actual realized revenues or savings. Such an unique financing arrangement would result in the government asuming a greater portion of the risk on this first project using new technology but not necessarily assuming a disproportionate share of the total investment. Greater industry participation would be possible under these circumstances and, with a portion of the initial government funding being returned on successful projects, it is likely that more projects could be funded within given budget limits.

Section 2

INTRODUCTION

This report was prepared by Bechtel Group, Inc., to present the results of a study entitled "Conceptual Design of a Solar Cogeneration Facility at Pioneer Mill Company, Ltd." The study was performed for the San Francisco Operations Office of the United States Department of Energy (DOE) under Contract Number DE-AC03-80SF11432. The study began on September 30, 1980 and was completed on July 31, 1981, at a total cost of $437,558. Project direction was provided by Sally Fisk, Larry Prince, and Keith Rose of DOE, with technical advice by John S. Anderson of Sandia National Laboratories, Livermore.

The Bechtel project manager was Jack R. Darnell, and the project engineer was Robert L. Lessley. The Bechtel mailing address is:

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P.O. Box 3965
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2.1 STUDY OBJECTIVE

The overall objective of the DOE Solar Cogeneration Program is the development of site-specific conceptual designs that:

- Make effective use of solar thermal energy from a solar central receiver system integrated with a cogeneration facility
- Can be constructed and can provide high-reliability operation by 1986
- Give the best overall economics for the particular application and offer the potential for wide commercial success
- Have the potential for significant savings of critical oil and gas fuels.

The specific objectives of this project are to develop a conceptual design, to prepare performance and cost estimates, and to outline a development plan for the retrofit of a solar central receiver steam supply system to the existing cogeneration facility at Pioneer Mill Company, Ltd.

2.2 TECHNICAL APPROACH AND SITE SELECTION

2.2.1 Technical Approach

The study was organized into six technical tasks and a management task:

- Task 1 - Preparation of system specification
- Task 2 - Selection of site-specific configuration
- Task 3 - Facility conceptual design
- Task 4 - Facility performance estimates
- Task 5 - Facility cost estimates and economic analyses
- Task 6 - Development plan
- Task 7 - Project management.

The system specification defines the requirements for the solar facility and the site. The latest version of the system specification is included as Appendix A of this report.

The selection of the site-specific configuration was the main focus of the first several months of the study. After the decision had been made to use a cavity-type receiver and water-steam as the working fluid, two potential sites for the collector field were selected and compared. Appropriate collector field and receiver configurations were chosen for each site, and the concurrent use of one site for both the collector field and agricultural activities was evaluated. The best size for the solar facility was also determined. A number of smaller tradeoff studies were performed in support of these major evaluations. The selection process is described in Section 3 of this report.

This conceptual design is based on the configuration selected in Task 2. Major equipment and piping were designed, the interfaces with the existing plant were defined, and the operational characteristics of the solar facility were determined. Performance and cost estimates were prepared for the completed conceptual design, and the economics of the solar facility were analyzed. These tasks are discussed in Sections 4, 5, and 6 of this report. A development plan and schedule was prepared and is presented in Section 7 of this report.

2.2.2 Site Selection

The Pioneer Mill Company, Ltd., facility was chosen for this study for two reasons: it can furnish an excellent demonstration of solar cogeneration, and it has the potential of achieving all the objectives of the Solar Cogeneration Program.

Pioneer Mill is an existing cogeneration facility. Steam generated in the boilers is supplied to the main turbine generator (which produces electric power), to mechanical drive turbines (which supply shaft power for mill equipment), and to the evaporators as process heat. When these three uses are combined, the overall efficiency of energy use, or cogeneration efficiency, is significantly higher than for a large modern power plant, which generates electricity only.

The Hawaiian sugar mills have a long history of cogeneration experience in cooperation with the utilities on the islands. There is no electrical interconnection of the islands; each island has a small, isolated utility grid. The sugar mills contribute significantly to the electrical power generation, supplying about 31 percent of the annual generation on Maui and approximately 10 percent of the annual generation of the entire state.

With a total steam production capacity of 131 500 kg/hr (290,000 lb/hr) and a total generation capacity of 13.5 MWe, Pioneer Mill is comparable in size with a large number of industrial facilities. The basic design concept of using extraction steam from a turbine generator is also very flexible, and can be adapted to many types of industrial plants. This combination of size and flexibility of design permits a cost-effective and credible demonstration of a solar central receiver retrofit to an industrial plant.

The State of Hawaii depends on imported oil for more than 90 percent of its electrical generation. This fact, along with the small size of the typical generating units on the islands, causes utility rates to be among the highest in the United States. Hawaii is also especially vulnerable to a disruption of its oil supply, and, as a result, is aggressively pursuing a policy of renewable energy resources and development. Hence, the political climate in the state is supportive of this type of demonstration project.

The Lahaina area has an excellent solar resource. Since the area is shielded from the tradewinds and is very dry, Pioneer Mill is the only Hawaiian sugar plantation that must irrigate its fields throughout the entire year. As a result, the impact of agricultural seasons on the design of the solar facility is not very significant. Also, because of the 21^{o} latitude, there is less annual variation in daily insolation than in most areas of the country.

The operations at Pioneer Mill produce a by-product biomass fuel called bagasse, which provides about 76 percent of the annual energy input to the steam produced. The remainder of the energy is supplied by No. 6 oil. Bagasse can be stored for a few days, and can therefore be used in place of thermal storage for the solar facility, which would be designed to displace the maximum possible oil consumption at Pioneer Mill. The solar cogeneration facility has the potential of utilizing a very high percentage of the energy derived from the sun.

A demonstration project would increase public awareness. Maui is visited by approximately 1.4 million people annually. Thus, a solar cogeneration facility at Pioneer Mill would expose a large number of people to solar central receiver systems who would not otherwise visit a demonstration plant.

2.3 SITE LOCATION

As shown in Figure 2-1, Pioneer Mill Company is located on the west coast of Maui in the Hawaiian Islands. It is adjacent to the town of Lahaina at coordinates 20.9° north latitude and 156.7° west longitude.

2.4 SITE GEOGRAPHY

Maui is the second largest island in the State of Hawaii. It is 77 km (48 mi) long and 42 km (26 mi) wide, and its total land area is 1 886 km^2 (728 mi^2). The island was formed by two volcanoes that are now connected by the isthmus of central Maui. East Maui is dominated by the 3 056 m (10,025 ft) Haleakala volcano, which has been dormant since 1790. West Maui is a deeply dissected, extinct volcano that rises to 1 765 m (5,788 ft) at Puu Kukui. Kahului, the major city on the island, is located at the northern end of the isthmus and has a commercial airport and a deep-water harbor. The population of Maui is approximately 63 000.

Pioneer Mill is located adjacent to the town of Lahaina on the west coast of west Maui. The town has been designated a national historical landmark because it was a major whaling port in the 19th century. The current population is approximately 6 000. The Lahaina-Kaanapali area is a well-known tourist resort area.

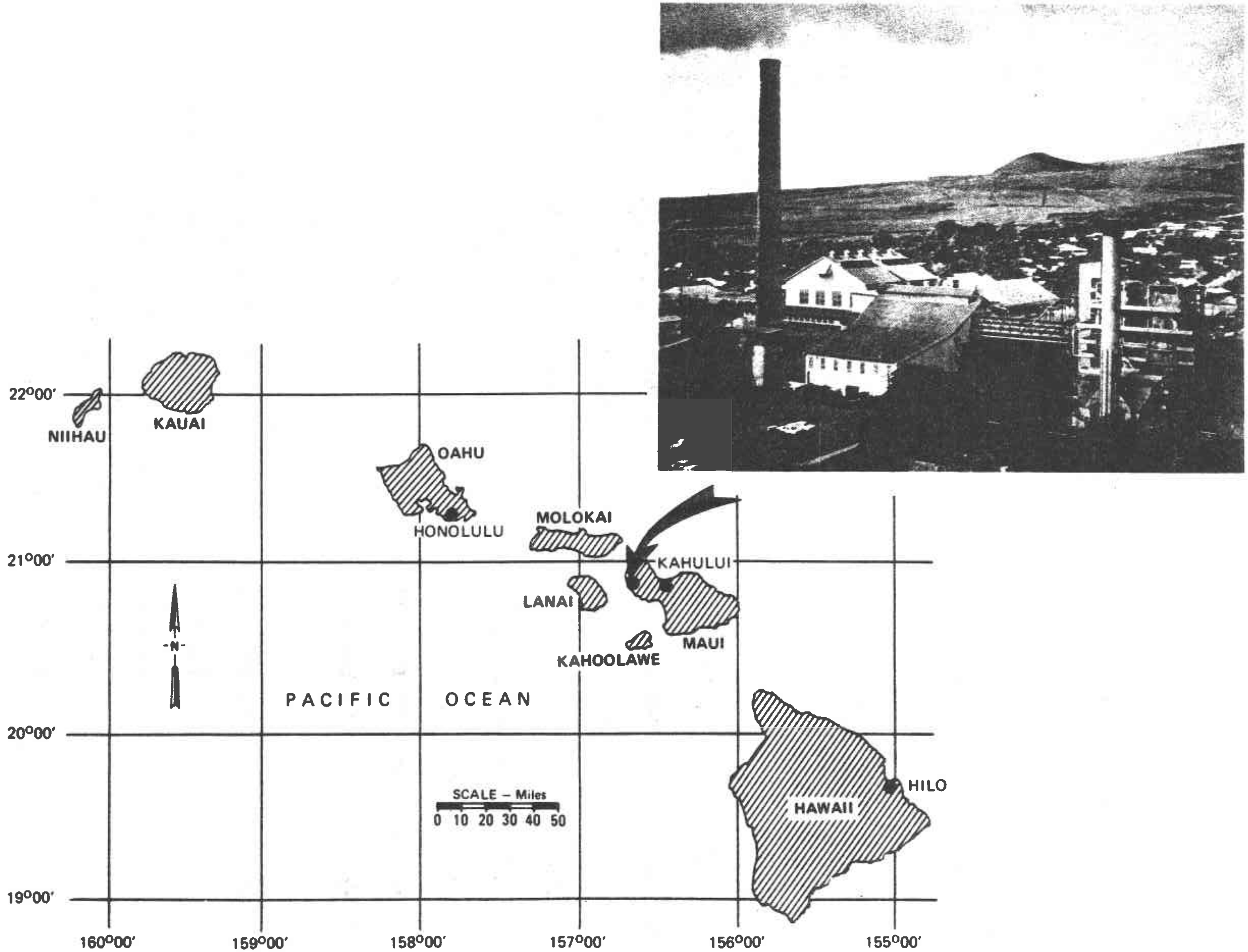


Figure 2-1 LOCATION OF PIONEER MILL

The area has a general west-facing slope, which ranges from gradual near the coast to steep ridges and stream valleys in the foothills. The summit of Puu Kukui is located 10 km (6 mi) east of Pioneer Mill. Because the mountain blocks the view of the sun early in the morning, the actual horizon for determining sunrise is about 10° above the true horizon.

The primary use of the alluvial plain is sugarcane agriculture. Pioneer Mill cultivates a total of 35.5×10^6 m^2 (8,776 acres) of owned or leased land in this area. The cane fields extend 28 km (17.5 mi) along the coast, with an average width of 2.5 km (1.5 mi) and up to 4 km (2.5 mi) up the slopes. The elevation of the fields ranges from 3 m (10 ft) above mean sea level to approximately 585 m (1,925 ft).

Access to Pioneer Mill is via the Honoapiilani Highway, the main coastal road in west Maui.

A new commuter airport is proposed for construction by 1984 near the coast highway about 6.5 km (4 mi) south of Pioneer Mill. Restrictions of flight paths over the town of Lahaina will cause most air traffic to remain over the water rather than over the area of the proposed solar facility.

The mill yard is bounded on the north by Kahoma Stream, on the east by a residential housing area, on the south by sugarcane fields, and on the west by a commercial area along the coast highway.

The Army Corps of Engineers is planning a flood control project for Kahoma Stream to prevent occasional flooding of the residential area.

A catch basin will be built upstream of the mill, and a new channel will direct the stream to the sea. Construction is expected to begin in 1982.

The water supply to the mill comes from wells. The large amount of rainfall on the upper slopes of the mountains is absorbed in the porous soil and flows underground. A series of pumps and tunnels convey water to the mill and supply the irrigation pumps. The site is quite dry.

The geology of the area is volcanic. The soil in the alluvial plains is well drained and contains some coral layers. On the steeper slopes, a thin soil covering is over hard basaltic rock. The island is designated as Seismic Zone 2 in accordance with the Uniform Building Code.

2.5 SITE CLIMATE

The general climatic pattern at the site is dominated by the trade winds that blow consistently from the northeast. Because of its location relative to the West Maui Mountains, the Lahaina area is classified as a leeward lowland (Ref. 2-1). These areas are typically sunny and dry and have relatively light winds. The only exception to this pattern is caused by major storm systems that cross the islands from the west between October and March. These storms are usually of several days' duration and characterized by high winds and heavy rainfall.

The 4-year average wind speed measured at Pioneer Mill is 1.6 m/s (3.5 mph). The maximum recorded wind at the mill from 1964 to 1968 was 15 m/s (33 mph). There are reports of rare conditions where winds reach 40 m/s (90 mph). The direction of the wind at the mill is generally upslope during the day and downslope at night.

The site has a mild tropical climate. The average annual temperature is 24C (75F), with extremes from long-term data at the Kahului Airport of 35.5C (96F) and 9C (48F). Because of the tropical latitude, the annual temperature variation is relatively small. Typical relative humidity ranges from 58 percent in the afternoon to 82 percent at night.

The Hawaiian Islands are characterized by extreme variation in precipitation. The top of the West Maui Mountains receives more than 7.6 m (300 in) annually, but the leeward lowlands are quite dry. Long-term data at Lahaina show an average of 34.5 cm (13.6 in). Most of this occurs during the winter storms, and what little occurs in the summer is generally at night. Typical annual variation in environmental data is shown in Table 2-1.

The peaks and windward slopes of the mountains normally have a dense cloud cover, and completely cloudless days are rare. During most of the year, the leeward lowlands have only scattered clouds.

No direct insolation data were available for the Lahaina area at the initiation of this study. An insolation model was developed and calibrated to several sets of total insolation data from Lahaina and the direct insolation data available from the University of Hawaii at Manoa (near Honolulu). This model predicts an average of 6.85 kWh/m^2-day of direct insolation at the site, and is described in Appendix B.

Table 2-1

SITE ENVIRONMENTAL DATA

Month	Precipitation, in.			Temperature, F			Wind Speed, mph(a)	
	Normal(b)	Extremes(b) High	Extremes(b) Low	Normal(c)	Extremes(c) High	Extremes(c) Low	Mean	Maximum
January	2.79	13.66	0.35	71.7	84	48	4.7	20
February	2.09	8.31	0.12	71.6	87	50	4.2	24
March	1.93	8.31	0.12	72.2	87	55	3.8	16
April	1.05	2.93	0.08	73.8	88	57	3.6	18
May	0.35	2.66	0.00	75.4	91	57	3.1	10
June	0.06	2.50	0.00	77.1	92	60	3.0	10
July	0.11	1.13	0.02	78.2	93	58	2.9	10
August	0.42	1.33	0.02	78.8	94	61	2.8	10
September	0.29	1.17	0.02	78.4	95	61	2.6	10
October	1.00	3.94	0.03	77.3	96	58	2.9	17
November	1.21	9.27	0.24	75.3	92	55	3.4	20
December	2.29	9.46	0.14	72.6	89	53	4.4	33
Annual	13.59	-	-	75.2	96	48	3.5	33

(a) Pioneer Mill Pump "E", hourly data, Sept. 1964 to Sept. 1968.
(b) Lahaina, Maui, 1931 to 1960.
(c) Kahului Airport, Maui, 1941 to 1975.

A site solar data monitoring program was established in October 1980. This was considered essential to the study because of the lack of site-specific direct insolation data. This program is sponsored by Amfac, with the cooperation of Dr. Paul Ekern of the University of Hawaii. Both analog traces and hourly integrated values are being gathered. Typical data collected to date are presented in Appendix C.

2.6 EXISTING PLANT DESCRIPTION

Pioneer Mill Company, Ltd., operates a sugarcane plantation and raw sugar factory. The factory processes sugarcane as it is harvested and produces molasses and raw crystalline sugar, which is shipped to California for refining and sales. A by-product of this operation is bagasse, the cellulose residue of the sugarcane. The bagasse is burned as a fuel.

The factory consumes intermediate-pressure steam for motive power, low-pressure steam for process heating, and electricity for motors and controls. The major electrical demand on the plantation is for irrigation pumping. The boilers consume bagasse and No. 6 oil to produce high-pressure steam that is supplied to the main turbine generator. Two controlled extraction points supply steam for the factory. Excess electric energy is supplied to the Maui Electric Company grid through the mill substation.

2.6.1 Boiler Equipment

Pioneer Mill operates two Combustion Engineering boilers (Type VU-40S), which were installed in 1966. The boilers are in excellent condition and have an expected remaining useful life of 25 years. They are designed for dual-fuel operation with bagasse and No. 6 oil. Bagasse is fired as it is delivered from the mill; its moisture content is 48 percent. Its higher heating value is approximately 9 300 kJ/kg (3,980 Btu/lb).

Each boiler is rated for a maximum steaming capacity of 65 800 kg/hr (145,000 lb/hr) on oil or dual fuel. The maximum steam capacity with bagasse only is approximately 45 400 kg/hr (100,000 lb/hr). The rated steam conditions at the superheater outlet are 5.96 MPa (865 psia) and 404C (760F). Minimum steaming rates are 18 100 kg/hr (40,000 lb/hr) with bagasse and 9 050 kg/hr (20,000 lb/hr) with oil. The efficiency of the boilers is about 70 percent with bagasse and 90.5 percent with oil.

Each boiler is equipped with an economizer, fly ash arrestor, Ljungstrom rotary air preheater, and an attemperator on the superheater outlet. Makeup water is supplied to a common deaerator, and there is one common high-pressure feedwater heater. All auxiliaries are electric-motor-driven, except for one standby boiler feed pump.

The boilers feed steam into a common main steam header. The boilers are controlled from one single-element, steam-header-pressure master controller with a three-mode control. The master signal goes to a dynamic balancing device, which sends to both boiler controls a signal that compensates for any difference in firing rate. Each boiler control system has a preferential fuel feature that will automatically feed bagasse up to an operator-set capacity, then feed fuel oil to maintain header pressure. This is an Amfac-designed system that can automatically control bagasse or dual-fuel firing without exceeding EPA smoke opacity limits.

Fuel oil is delivered to the site by Pioneer Mill's 18 m^3 (113 bbl) tank truck over a 40 km (25 mi) route from the Union Oil Company storage depot. Fuel is purchased as required without a long-term contract. The oil storage capacity is 290 m^3 (1,810 bbl) for No. 6 oil and 45 m^3 (286 bbl) for No. 2 oil, which is used as igniter fuel.

Bagasse is dewatered in the factory, pneumatically conveyed to the boiler conveyors, and introduced by mechanical means into the boiler. There, 95 percent is burned in suspension; the remaining material falls on a traveling grate and is consumed, except for about 1 percent ash.

To accommodate rapid load changes, excess bagasse is maintained on the boiler conveyors. Bagasse beyond boiler demand is diverted to the bagasse house for storage. An operator with a front-end loader reclaims the bagasse and places it on the the reclaim conveyor. The bagasse house is located adjacent to the boilers and has a capacity without manual compaction of 4 400 m^3 (156,000 ft^3). This is equivalent to 35 000 kg (390 tons) at a density of 80 kg/m^3 (5 lb/ft^3), although gravity compaction would increase this bulk density. The bagasse house is 37.2 m by 22 m (122 ft by 72 ft) and the supply conveyor is 10.8 m (35.5 ft) above the floor.

2.6.2 Turbine Generator Equipment

Pioneer Mill has three turbine generators. The main unit is a General Electric 3 600 rpm, double-automatic-extracting/condensing turbine generator rated at 9 375 kVA. The design steam inlet conditions are

5.96 MPa (865 psia) and 399C (750F). It was installed in 1966 and completely overhauled in 1980 after it had suffered damage. It has a remaining service life expectancy of 25 years.

The high-pressure extraction is controlled at 1.83 MPa (265 psia) and the steam is attemperated to 260C (500F). The high-pressure extraction steam supplies the high-pressure feedwater heater and the mechanical drive turbines in the factory. The low-pressure extraction is controlled at 205 kPa (30 psia) and is used at the extraction temperature of 135C (275F). The low-pressure extraction steam supplies the deaerator and the remainder of the factory steam requirements not satisfied by the exhaust of the mechanical drive turbines.

The main condenser is rated to provide 7.5 kPa (1.08 psia) back pressure for the turbine at 37 000 kg/hr (81,000 lb/hr) exhaust flow with 24C (75F) cooling water. The maximum turbine exhaust flow is limited to 29 000 kg/hr (64,000 lb/hr). The cooling water is pumped from an irrigation tunnel to the condenser and is returned to the irrigation system. Condenser vacuum is maintained with a two-stage steam ejector.

The two other turbine generators are old, and though serviceable, are not operated unless necessary. They are both supplied by the 1.83 MPa (265 psia) steam header. One is an Allis-Chalmers 3 750 kVA turbine generator with a single automatic extraction at 205 kPa (30 psia). The other is a General Electric 3 750 kVA, straight-condensing turbine generator.

2.6.3 Process Description

A schematic diagram of the existing facility is shown in Figure 2-2.

Sugarcane Production. Sugarcane is a 2-year crop in the Hawaiian Islands. The field planting times are staggered so that half of the field acreage, or about 17.8 km^2 (4,400 acres), is harvested each year. Irrigation is stopped several weeks before the harvest of each field to dry out the crop. The fields are burned under controlled conditions to minimize handling weight just prior to harvest. Harvesting is carried out with a rake-equipped dozer, and a mobile crane loads the sugarcane into large utility trailers which are hauled to the mill for processing. From November to February, the fields are typically too wet for harvesting.

Cane Cleaning. After the cane has been unloaded from the trucks, it is transferred to a flotation bath which removes some soil and heavy material such as rocks. The cane is then washed by a series of spray jets which separate small pieces of cane and leafy trash and the remainder of the soil from the cane stalks. Wash water is recycled from a hydroseparator, is sent to the settling basins, and eventually ends up in the irrigation system.

Sugar Extraction. Next, the cleaned cane is processed through a set of rotary knives and two fiberizers in series to open the fibrous cells of the cane. The crushed cane then enters the diffuser, where it is washed with a counter-current stream of water. The diffuser extracts about 98 percent of the sugar and yields wet bagasse and

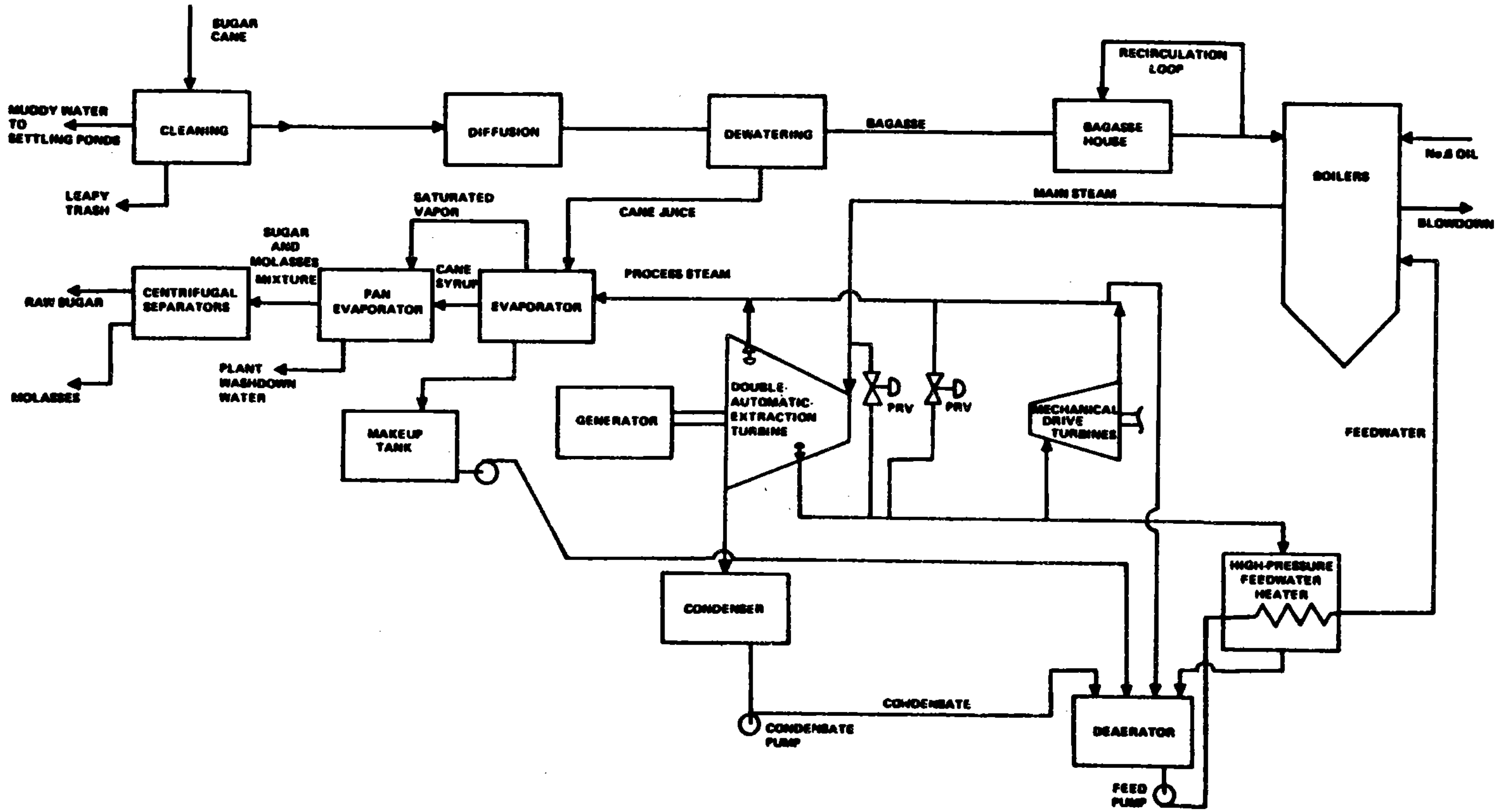


Figure 2-2 PROCESS SCHEMATIC DIAGRAM FOR THE EXISTING PIONEER MILL

cane juice. The bagasse is dewatered to 48 percent moisture (by weight) in screw presses and sent by pneumatic conveyors to the boilers. Lime is added to the cane juice, heated to 100C (212F), and introduced into a clarifier.

Evaporation. The clarified cane juice is then fed into a five-effect evaporator, which reduces the water content to produce cane syrup. The syrup is moved to vacuum pan evaporators with mechanical agitators.

Separation. The resulting mixture of molasses and sugar is separated in centrifuges, and the raw sugar is finished by further heating in batch crystallizers.

2.6.4 Factory Equipment

In a solar retrofit, the following steam-consuming factory components are of principal interest: the mechanical-drive turbines, the evaporators, and the process heaters. There are three drive turbines in the factory, two rated at about 750 kW (1,000 hp) on the fiberizers and one 950 KW (1,250 hp) drive on one of the bagasse dewatering screw presses. A fourth mechanical-drive turbine is connected to the backup boiler feed pump. These turbines are supplied with steam from the 1.83 MPa (265 psia) header and exhaust into the 205 kPa (30 psia) header. Steam at 1.83 MPa (265 psia) is also supplied through a pressure-reducing valve (PRV) to the makeup evaporator. Steam from the 205 kPa (30 psia) header is supplied to the first stage of the multi-effect evaporator and to the juice heater. A lower pressure vapor header at 143 kPa (21 psia) supplies steam to the pan evaporators, to the second stage of the multi-effect evaporator, and to other process heaters.

2.7 EXISTING PLANT PERFORMANCE

The operating goal of Pioneer Mill is to maximize sugar output from the fields under cultivation as economically as possible. The primary variable in the annual output is the agricultural operation, since the factory consistently extracts 98 percent of the sugar from the cane processed.

The factory consumes the available bagasse in the boilers and supplements this with fuel oil to meet the steam and electric demands. Steam demands occur only during factory operation, but electrical demands due to other plantation requirements (mainly irrigation pumping) and Maui Electric Company needs continue throughout the year. Typical annual operating data are shown in Table 2-2.

2.7.1 Factory Operating Schedule

The factory is expected to operate 40 weeks during the year to coincide with the sugarcane harvest. During this harvest season, the factory operates on a 24 hr/day, 5 day/wk schedule. The nominal operating rate, based on cleaned cane, is 109 000 kg/hr (120 tons/hr), but outages and interruptions reduce this to an average of 92 500 kg/hr (102 tons/hr).

The steam demands during factory operation are approximately 32 200 kg/hr (71,000 lb/hr) from the 1.83 MPa (265 psia) header and an additional 16 800 kg/hr (37,000 lb/hr) from the 205 kPa (30 psia) header. Electrical demand for factory equipment during this condition is 2 300 kWe.

Table 2-2

PIONEER MILL ANNUAL PERFORMANCE DATA

Year	Area Harvested, acres	Net Cane, tons	Start Grinding Season	Stop Grinding Season	Grinding Time, hr	Raw Sugar, tons	Molasses, tons	Bagasse Produced, tons	Fuel Oil Consumed, bbl	Electric Energy, MWh			
										Generated	Factory Consumption	Other Consumption	Sold to Maui Electric
1970	4 695	428 144	Feb 23	Nov 25	4 290	57 520	16 841	133 215	54 053	52 969	20 328	27 425	5 216
1971	4 636	427 899	Feb 23	Nov 18	4 115	56 868	16 295	134 213	65 901	57 316	20 783	31 752	4 782
1972	4 676	412 216	Feb 14	Nov 17	4 026	55 377	15 538	131 582	92 419	60 322	21 119	33 437	5 767
1973	4 760	396 549	Feb 12	Nov 02	3 908	53 462	16 105	124 971	98 378	60 422	20 069	35 753	4 600
1974	4 262	368 626	Feb 14	Nov 25	3 740	49 451	15 307	114 532	65 319	50 133	17 373	29 304	3 456
1975	4 849	402 870	Feb 17	Oct 31	3 880	53 719	16 425	123 445	73 693	58 927	19 080	35.775	4 072
1976	4 494	362 216	Feb 18	Oct 29	3 553	48 425	14 213	109 721	71 705	56 635	17 259	34 498	4 878
1977	4 516	377 775	Feb 03	Nov 23	3 700	49 772	17 400	114 850	71 307	56 699	17 419	34 801	4 479
1978	4 445	372 667	Feb 13	Dec 02	3 637	46 178	17 260	114 913	70 403	54 123	16 156	32 554	5 413
1979	4 402	431 181	Mar 08	Dec 30	4 345	50 775	16 879	138 980	46 325	45 774	17 862	23 083	4 829
10-Year Average	4 574	398 010	Feb 17	Nov 20	3 919	52 155	16 226	124 042	70 950	55 332	18 745	31 838	4 750

The above values were used during the Task 2 selection of system size as discussed in Section 3.4. Subsequent and more detailed analysis of the actual factory operating conditions are given in Appendix E. The change in operating flows did not affect the sizing of the solar facility, because that was controlled by weekend conditions. The updated flows were used in the performance calculations for the conceptual design.

On weekends, the factory production is stopped and the equipment undergoes maintenance, if necessary. There are no steam demands on weekends, but the electrical load continues at the 250 kWe level (the weekend factory house load).

2.7.2 Boiler and Turbine Operating Cycle

The boilers and turbine generator are operated to meet the needs of the plantation and supply electric power to Maui Electric on demand. During factory operation, each boiler is operated at approximately 40 800 kg/hr (90,000 lb/hr). The operating conditions of the turbine are shown in Figure 2-3. The conditions shown are generator-limited; the maximum electrical output is 8 400 kWe with a 0.9 power factor. When a reduced electrical output is required while the factory steam demands remain constant, the main steam flow and the other non-factory steam flows are reduced to match the reduction in power generation.

During weekend operation, the factory steam demand is eliminated and the turbine is operated to match electrical demand. The maximum condition in this mode is shown in Figure 2-4. The output is limited by the low-pressure turbine section flow limit of 29 000 kg/hr

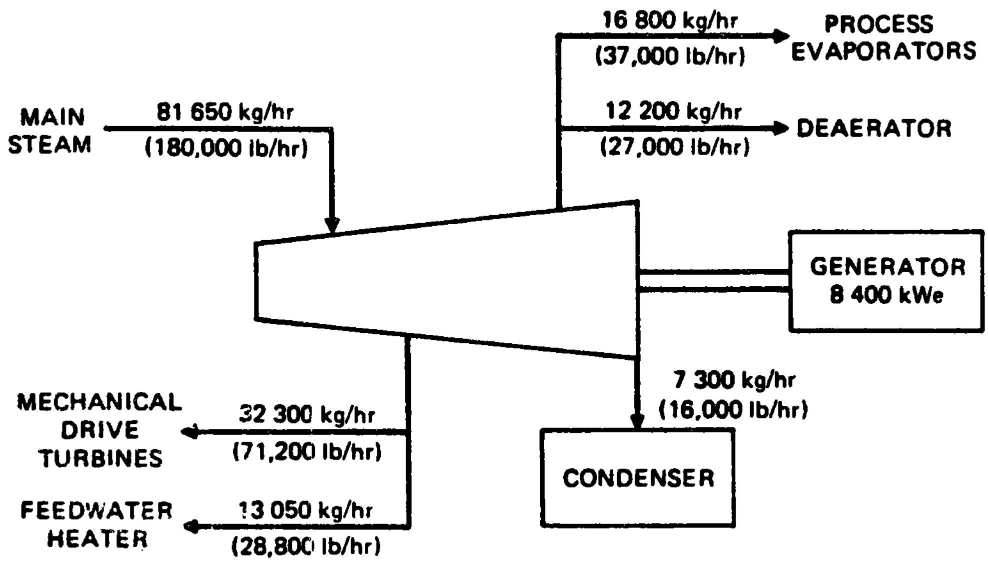


Figure 2-3 TYPICAL MAXIMUM TURBINE CONDITIONS FOR FACTORY OPERATION

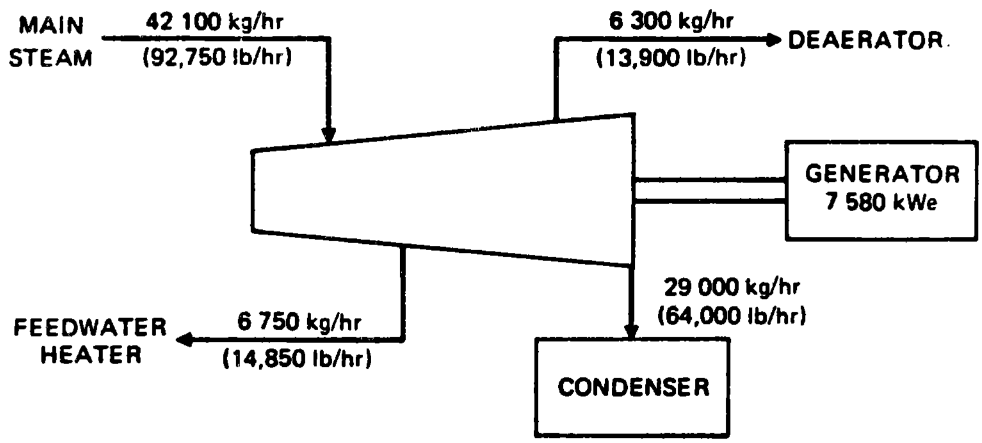


Figure 2-4 TYPICAL MAXIMUM TURBINE CONDITIONS FOR WEEKEND OR OFF-SEASON OPERATION

(64,000 lb/hr). The turbine is typically operated between 3 MWe and 6 MWe with only one boiler operating.

In the off-season, turbine operation is similar to turbine operation during weekends. The boilers are alternately taken out of service for scheduled maintenance. The main turbine has a maintenance schedule that requires a 1-week inspection each year and a 4-week outage every fourth year. Pioneer Mill attempts to draw enough power from Maui Electric during this turbine outage to meet irrigation requirements, but usually one of the older turbine generators must be brought into operation.

There is a monthly variation in energy consumption which is dependent on irrigation requirements and Maui Electric demand. This pattern is illustrated in Table 2-3. Oil provides about 24 percent of the total energy input, measured as energy supplied to main steam. The remainder is supplied by bagasse. The monthly variation of oil consumption is important to the sizing of a solar retrofit and is discussed further in Subsection 3.4.

2.7.3 Operation and Maintenance Experience

The seasonal nature of operations at Pioneer Mill is a significant advantage in the scheduling of outages. Therefore, unscheduled outages are kept to a minimum. One notable exception was a turbine incident in 1980 that resulted in significant turbine outage. Table 2-4 shows the scheduled, unscheduled, and economy outages for 1980.

Table 2-3

PIONEER MILL MONTHLY PERFORMANCE DATA
(1975 to 1980 Average)

Month	Bagasse Production, tons/wk	Fuel Oil Consumption, bbl/wk	Total Energy Consumption as Main Steam, 10^9 Btu/wk	Oil Percent of Total Energy as Main Steam	Rainfall, in.
Jan	0	934	4.5	100	3.2
Feb	3 101[(a)]	1 127	12.9	42	3.8
Mar	2 237	1 393	19.2	35	1.5
Apr	2 603	1 228	20.4	29	2.0
May	3 156	1 146	23.1	24	0.4
June	3 476	1 091	24.6	21	0.1
July	3 493	981	24.2	20	0.1
Aug	3 800	1 054	26.3	19	0.1
Sept	3 245	958	22.7	20	0.1
Oct	3 404	1 462	26.0	27	0.4
Nov	2 387[(b)]	1 226	14.8	40	1.1
Dec	0	1 535	7.4	100	1.5
Year Total			992.9		14.3
Year Average	3 183[(c)]	1 177		24	

(a) After harvest season begins.
(b) Before harvest season ends.
(c) During harvest season.

Table 2-4

MAJOR EQUIPMENT OUTAGES FOR 1980
(Hours)

	Boiler #1		Boiler #2		Turbine #1	
Planned outages	Off-season overhaul High-voltage switch-gear inspection Off-season overhaul	1 114.0 11.2 939.7 2 064.9	Off-season overhaul Off-season overhaul	1313.6 934.5 2 249.1	Clean condenser Off-season overhaul	20.4 910.5 930.9
Forced outages	Pressure-reducing valve failure Relay failure in the burner control ID fan motor failure Steam flow transmitter failure	16.3 6.0 65.0 0.5 87.8	Relay failure in the burner control	22.9 22.9	Turbine damage Loss of boilers Rupture disk leak Faulty trip device	1 493.3 5.5 1.5 0.5 1 500.6
Economy outage		645.2		738.4		175.5
Total		2 797.9		3 009.4		2 607.0

The actual O&M costs for 1979 and 1980 were $590 000 and $887 000, respectively. During 1980, the unusual turbine repairs account for the significant increase over 1979 and are considered nonrecurring. The O&M cost is expected to escalate in line with the general inflation rate for the remaining 25-year life of the existing facility, with a levelized annual cost of $1,370,000.

2.8 PROJECT ORGANIZATION

Bechtel Group, Inc., was the prime contractor in this study and heads the team composed of Amfac Sugar Company, Foster Wheeler Development Corporation, and Northrup, Inc. An organization chart showing the key individuals is presented in Figure 2-5.

As prime contractor, Bechtel was responsible for the overall project management and coordination, the technical direction of the project team, the integration of the output of the team into the technical reports, and the design, analysis, and costing of all those parts of the solar cogeneration facility not within the scope of the subcontractors.

Amfac Sugar is the owner of Pioneer Mill Company, Ltd., and is the end user of this study. Amfac provided data on the existing facility, parameters for economic analyses, a review of the technical products, and interface information with Maui Electric Company. Okahara, Shigeoka & Associates assisted Amfac in developing performance data for the facility and in preparing environmental and licensing inputs.

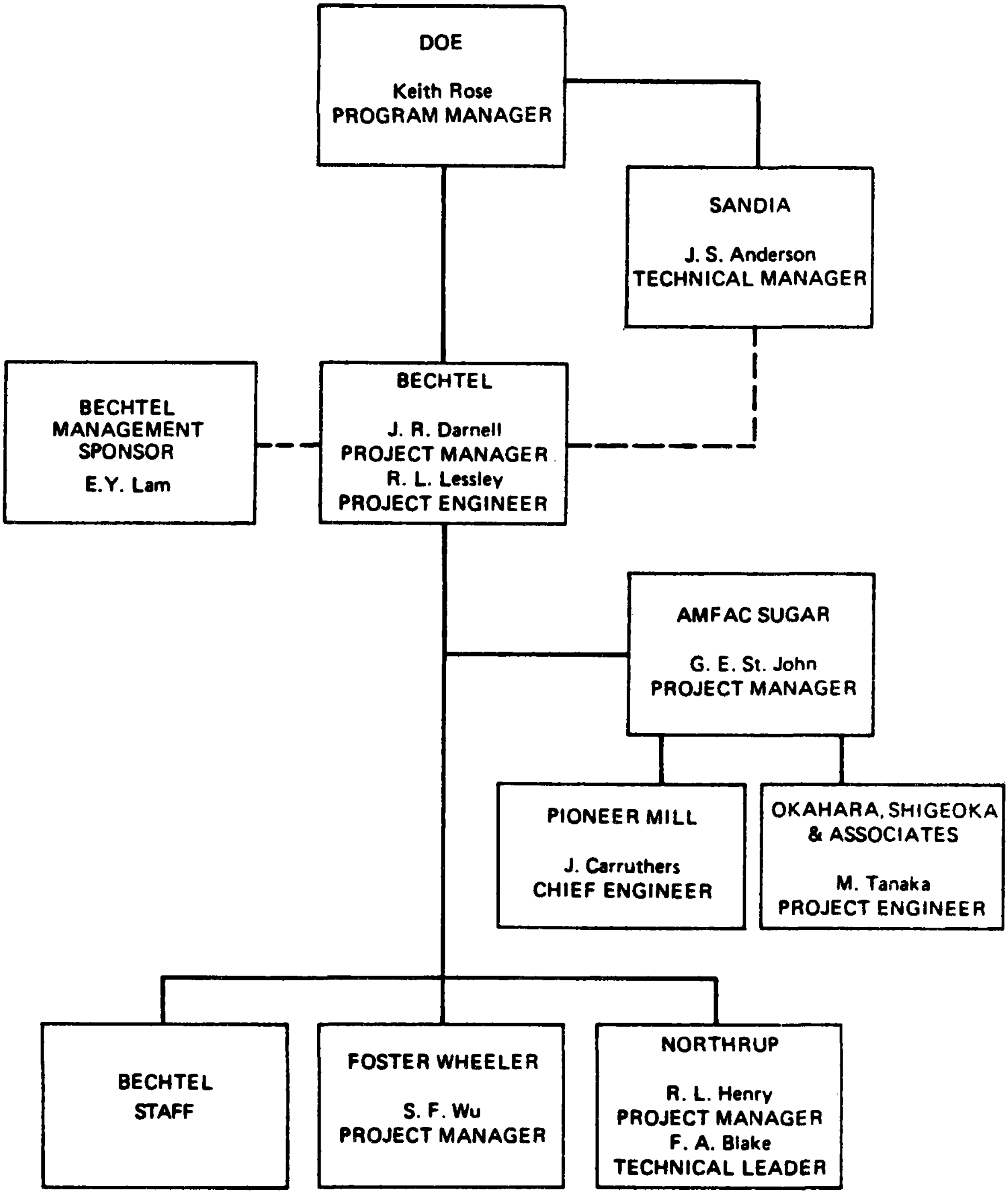


Figure 2-5 PROJECT ORGANIZATION CHART

Northrup furnished the design and analysis of the collector field and supplied information on the design and cost of second-generation heliostats. Foster Wheeler provided the design and analysis of the solar receiver and supplied cost figures for this receiver.

2.9 FINAL REPORT ORGANIZATION

The final report is presented in one volume which includes the executive summary and appendices. The report presents and discusses the results of the six technical tasks which were identified in Section 2.2.1.

Section 1, the executive summary, gives an overview of the project, the general objectives, results, and the site owner's assessment. Section 2 of the report provides background information on the site, the existing facility, and the project organization. Section 3 reviews the rationale and selection process for the site-specific configuration. Section 4 defines the features and performance of the selected conceptual design. In Section 5 the characteristics of the major systems are detailed. The economic analysis of the conceptual design is given in Section 6. Section 7 is the project development plan for the major activities required for the transition from a conceptual design to an operating facility. The appendices include the system specification and other data and analysis used for the conceptual design study.

Section 3

SELECTION OF THE PREFERRED SYSTEM

3.1 INTRODUCTION

The general guidelines for the conceptual design of the Solar Cogeneration Facility at Pioneer Mill included the following:

- The use of the existing turbine and plant equipment
- The displacement of as much oil as feasible
- Minimum interference with plant operations

This section covers Task 2 — the selection of a site-specific configuration. The principal subtasks of Task 2 were as follows:

- Selection of a working fluid
- Selection of a receiver concept
- Selection of one of the two alternative heliostat field sites
- Determination of the appropriate size of the solar facility
- Determination of the role of thermal storage

Of the above subtasks, the two key ones were the determination of solar facility size and the selection of the heliostat field site. These two questions were studied concurrently and independently. Other questions, such as control system design and minimizing of the impact on existing plant operation, were reserved for the Task 3 conceptual design, along with a more complete engineering design for all parts of the solar facility.

To select the plant size, the Pioneer Mill harvesting records were studied in order to determine the variation and timing of bagasse production. Past records on the timing and amounts of oil consumption were also evaluated. The various operating modes of the mill during the harvest season and the off-season were identified. Finally, estimates of the annual energy production of a solar facility by month of the year made it possible to determine the maximum solar facility size that does not exceed the capacity of existing mill plant equipment. The sizing analysis is discussed in Subsection 3.4.

The selection of the heliostat field site was based on preconceptual plant designs for each candidate site, with greatest emphasis being placed on design aspects that are different for the two initial candidate sites. Plant and capital costs, annual charges, energy production, and revenues were estimated for each site, and a comparison was made based on dollars per million Btu at the required turbine steam inlet conditions. The selection of the preferred site is discussed in Subsection 3.5. Toward the end of this siting study, a third site was added to the consideration and was selected for conceptual design.

3.2 SYSTEM CONFIGURATION

The simplicity of the required system configuration is one of the most attractive features of the solar facility for Pioneer Mill. This simplicity is largely due to the fact that (1) Pioneer Mill is already a functioning cogeneration plant using bagasse and fuel oil to generate electricity while supplying the sugar mill with extraction steam, and (2) no thermal energy is stored. To displace oil, the solar facility must simply deliver 5.96 MPa

(865 psia), 399C (750F) steam to the existing turbine. The solar facility configuration required to accomplish this is shown in Figure 3-1. It consists of the following major components:

- A heliostat field
- A water-steam solar receiver and supporting tower
- Steam and condensate piping connecting the mill and the receiver
- A steam mixing station at the mill
- A condensate transfer pump station at the mill
- A holding tank and receiver feed pump station at the base of the receiver tower

Bagasse, which is normally consumed as it is produced, would be stored during periods of high solar input and consumed during periods of low solar input. Although the use of thermal storage would permit the displacement of slightly more fuel oil, as discussed in Subsection 3.4, it is unlikely that the extra oil displaced would justify the expense and risk associated with thermal storage.

In selecting the interfaces with the existing facility, the principal criteria were minimum impact on existing plant operations and maximum operational flexibility. A solar superheater was found to be preferable to existing boilers in superheating solar-generated saturated steam. There are two reasons for this: the increased operational complexity of operating such a long (over a half mile) saturated steam line to the boilers, and the need to modify the existing boilers. It was felt that the existing deaerator for the receiver supply source would provide better water quality and more efficient operation of the system, using low-pressure extraction steam, than using either condensate from the

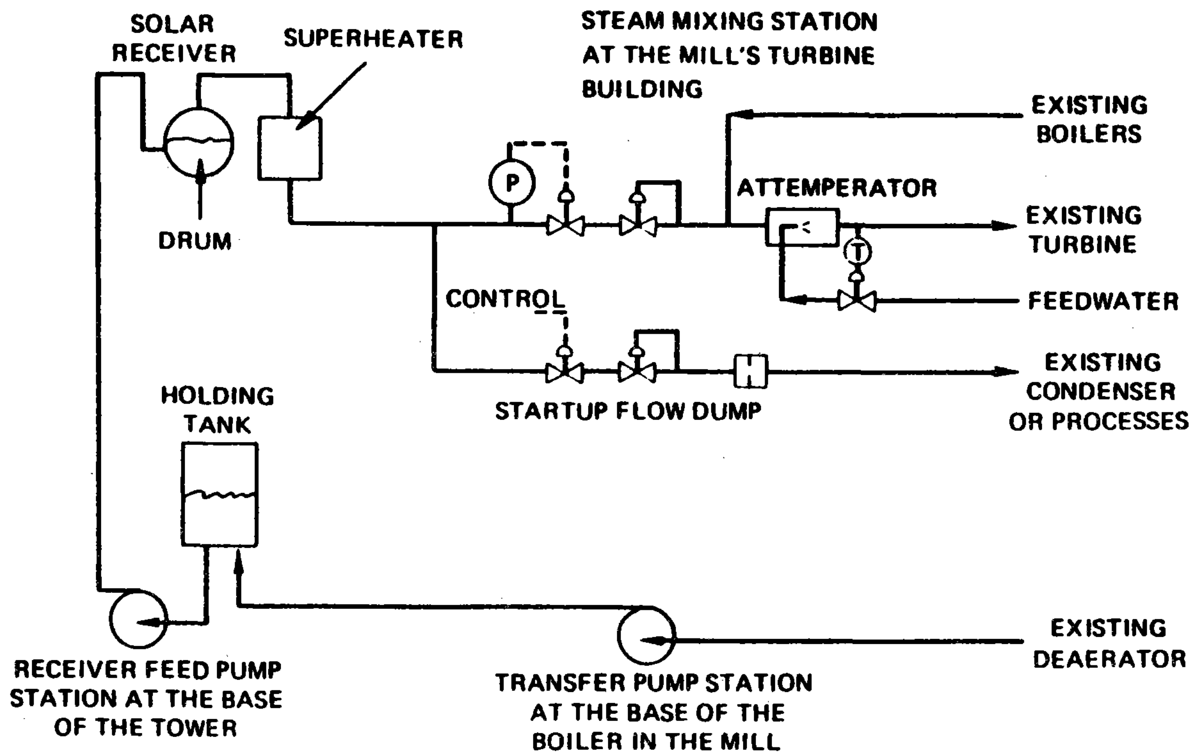


Figure 3-1 SOLAR FACILITY CONFIGURATION

hot well or boiler feedwater. The choice of a holding tank at the base of the receiver allows a low-pressure rating for the long condensate piping run from the deaerator to the tower.

3.3 TECHNOLOGY

The choice of water-steam as a working fluid and of the cavity receiver configuration keeps the solar facility simple and firmly based on existing technology.

Water-steam technology for conventional power equipment is well developed, and the operators of Pioneer Mill are conversant with it. In addition, this technology as applied to solar is available to support the operation of the solar facility by 1985.

By contrast, molten salt technology, while showing promise for applications where thermal storage is essential, is not yet field-proven for this type of application. The molten salt heat transfer loops currently in the process industry do not shut down and start daily, often contain no valves, and utilize reliable but very crude and inefficient pumps. These loops do not operate in the kind of environment existing in solar facilities that use molten salt. The demonstration of molten salt technology involving a suitably large molten salt loop that is thermally cycled daily to serve as a test bed for both components and operating procedures is not currently planned within the DOE solar program. This demonstration could be carried out without solar heat input at lower expense than would be necessary for a solar demonstration project. Until equipment and procedures are proven by a large molten salt loop, molten salt solar facilities may experience higher operations and maintenance costs than otherwise necessary.

The personnel at Pioneer Mill are primarily engaged in running a sugar mill, and would like to minimize the amount of operator attention required to run the solar facility. Therefore, the design emphasizes simple and inherently self-regulating components, redundancy (where cost-effective), and diagnostic instrumentation for major components.

The desire for simple and inherently self-regulating components led to the selection of a conventional, natural-circulation, drum-type water-steam receiver. This type of receiver had been the choice in a number of previous solar receiver designs engineered by Foster Wheeler Development Corporation.

Natural circulation has a history of high reliability in fossil-fueled boilers, and a great deal of experience exists regarding the design, construction, and operation of this type of boiler at the pressure and temperature required for Pioneer Mill. Natural circulation eliminates both the capital and maintenance costs and the power consumption associated with a forced-circulation pump. The boiler circuitry of a natural-circulation receiver is inherently self-compensating for energy input variations with both time and location in the receiver. It is also relatively tolerant of impure feedwater because of its large tubes, large water inventory, and drum blowdown capability. Testing of natural-circulation water-steam solar receivers with 1 MWt and 5 MWt capacities has demonstrated their thermal and hydraulic stability and ease of control under steady-state and transient conditions (Refs. 3-1 and 3-2).

A cavity receiver configuration was selected in preference to an exposed receiver configuration. This was based not on an economic tradeoff study, but on a number of qualitative considerations, such as:

- An external receiver can result in a lower tower height. This is not possible if the field layout is constricted by site topography, as is the case for the hillside site discussed in Subsection 3.5
- An external receiver can be less costly and weigh less than a cavity receiver. However, the uncertainty of heat loss predictions for both configurations makes any tradeoff between capital cost and efficiency only approximate
- The design of a door to reduce overnight heat losses is much easier for the cavity. Excessive overnight cooldown is a special problem for this application because of the relatively long steam line to the turbine

The final selection of the cavity receiver configuration was strongly influenced by the belief that it is the lower risk design with more flexibility to adapt to the overall requirements at Pioneer Mill. The resemblance to the configurations of a conventional boiler also inspired user confidence.

3.4 SYSTEM SIZE

In the selection of solar system size, a number of factors had to be considered, such as the oil and bagasse energy consumption pattern, the operating limits of the existing boiler and turbine, the daily and annual variation in solar energy availability, and the potential impact of thermal energy storage. After the initial consideration of these factors, a set of criteria was developed as a framework for the determination of system size. These criteria are:

- The solar facility will maximize the displacement of oil consumption while permitting the solar equipment to be operated at the most economical capacity factor

- Increased bagasse storage capacity will be used to shift the bagasse consumption pattern to accommodate solar energy input. All bagasse displaced during the 5-day factory week will be consumed the following weekend

- All electric power generated in excess of Pioneer Mill demand will be exported to the Maui electric grid, where it will displace No. 2 oil consumption by Maui electric units

- At least one boiler will be operated at minimum load during solar system operation, and the boiler(s) operating must be able to meet the entire steam demand in the event of a solar interruption

- No new turbine generator capacity will be installed with the solar facility, and the two older turbine generators will not be operated except on a standby basis

The first step in determining system size was to ascertain the relevant equipment operating limits. These are listed in Table 3-1. A typical harvest season operating week was also established, and the bagasse production and oil consumption profiles were calculated for this typical week. These parameters are illustrated in Figure 3-2. Net factory output is the gross electric generation less the power plant auxiliary load and the factory equipment load. Net factory output is used for irrigation pumping and/or sold to Maui Electric.

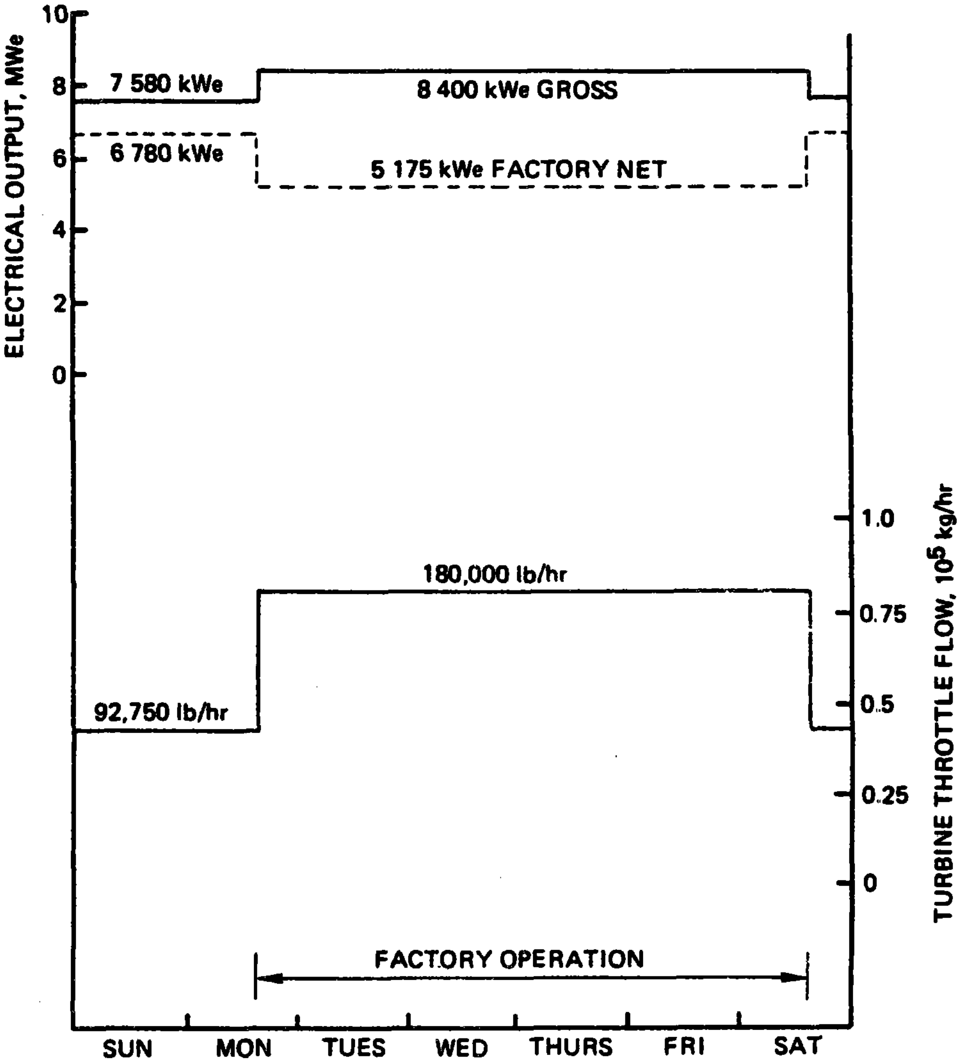
The STEAEC program runs that are discussed in Subsection 3.5 were used to determine the solar steam supply characteristics.

It was necessary to determine whether the weekday or the weekend operating condition controlled the solar system sizing. This was done by comparing

Table 3-1

OPERATIONAL LIMITS FOR SYSTEM SIZING STUDY

Item	Limit
Boiler steam capacity (each)	
Maximum	
Oil	65 800 kg/hr (145,000 lb/hr)
Bagasse	45 400 kg/hr (100,000 lb/hr)
Minimum	
Oil	9 100 kg/hr (20,000 lb/hr)
Bagasse	18 100 kg/hr (40,000 lb/hr)
Maximum generator output	8 400 kWe at 0.9 power factor
Turbine low-pressure section flow	
Maximum	29 000 kg/hr (64,000 lb/hr)
Minimum	1 680 kg/hr (3,700 lb/hr)
Condenser flow	
Maximum	36 700 kg/hr (81,000 lb/hr)



GROSS POWER PLANT OUTPUT	1 372 MWhe
NET FACTORY OUTPUT	946 MWhe
BAGASSE PRODUCTION AND CONSUMPTION	3.43×10^6 kg (3,780 tons)
OIL CONSUMPTION	540 m^3 (1,035 bbl)

Figure 3-2 TYPICAL MAXIMUM OPERATING WEEK FOR EXISTING FACILITY

the maximum turbine throttle flow with the minimum boiler flow for these two conditions. The difference is the maximum solar design point flow, and it depends on the fuel used in the boilers at minimum flow. Table 3-2 compares the four options, weekday vs. weekend and oil vs. bagasse. If the facility were designed for weekday operation, the weekly oil displacement would exceed the current average oil consumption of 540 m^3 (1,035 bbl). Moreover, there would be a relatively low capacity factor for the solar equipment, because the mill cannot accept as much solar steam during weekend and off-season operation as it can during factory operation. Neither weekend case (oil or bagasse) would displace all the oil normally consumed; some oil consumption would be required on the weekend. This would allow the use of an oil-fired boiler at minimum flow as a backup for solar weekend operation, which would result in a larger solar system size than would be possible if bagasse firing at minimum boiler flow during weekend days were necessary (26 800 kg/hr vs. 19 400 kg/hr). During the week, when the factory is operating, bagasse would be used as a backup for daytime solar operation.

Table 3-2

PRELIMINARY SOLAR DESIGN FLOW OPTIONS

Operation	Boiler at Minimum Flow on Oil		Boiler at Minimum Flow on Bagasse	
	Throttle Flow less Boiler Flow[a]	Estimated Weekly Oil Displacement[b]	Throttle Flow less Boiler Flow[a]	Estimated Weekly Oil Displacement[b]
Weekday	55 350 kg/hr (122,000 lb/hr)	847 m^3 (1,623 bbl)	39 500 kg/hr (87,100 lb/hr)	603 m^3 (1,159 bbl)
Weekend	26 800 kg/hr (59,100 lb/hr)	409 m^3 (786 bbl)	19 400 kg/hr (42,800 lb/hr)	296 m^3 (569 bbl)

(a) Equivalent to solar design flow.
(b) Clear weather and 100 percent availability are assumed.

The choice of a maximum solar steam capacity of 26 800 kg/hr (59,100 lb/hr) satisfies all the criteria, but it displaces only about 75 percent of the oil consumption during a typical harvest week with clear weather and 100 percent availability. To determine if additional oil displacement is possible, the operating limits in Table 3-1 were reexamined. A relatively simple cycle modification was found to increase the oil displacement. Figure 3-3 shows the effect of adding a condenser dump line from the 205 kPa (30 psia) extraction line. Condition 2 in the figure shows the maximum case without the dump line. The throttle flow is governed by the flow limit in the low-pressure section of the turbine. The generator output is not at the maximum. To increase generator output and solar steam flow capacity, a dump line is added (Condition 3). The generator output is maximized when the dump flow reaches 6 500 kg/hr (14,300 lb/hr). This allows the solar portion of the throttle flow to increase from 26 800 kg/hr (59,100 lb/hr) to 34 400 kg/hr (75,900 lb/hr), an increase of 28 percent. The condenser can accept this added flow because it has a capacity greater than 35 500 kg/hr (78,300 lb/hr), the sum of the dump and exhaust flows.

This modification reduces the efficiency of the steam cycle, increasing the steam rate from 3.73 kg/kWe to 4.10 kg/kWe. However, the use of the condenser dump line is needed only during the day on weekends and the off-season (when the factory steam demand is zero), about 14 percent of the operational year. This percentage can be further reduced by allowing the turbine to follow the solar input during this time and modulating the condenser dump. An example of this type of operation is shown in Figure 3-4.

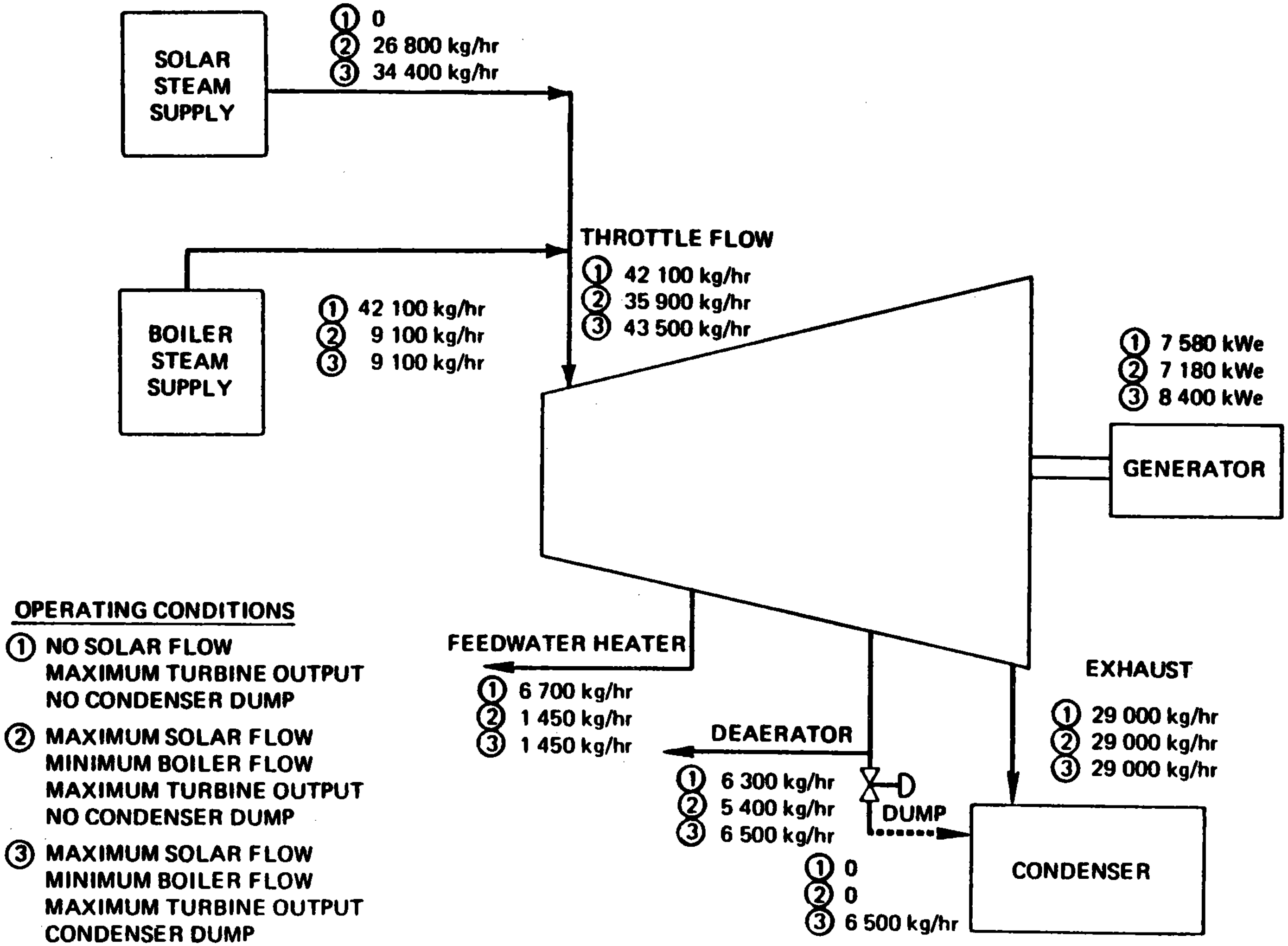


Figure 3-3 WEEKEND OPERATION SIZING ANALYSIS

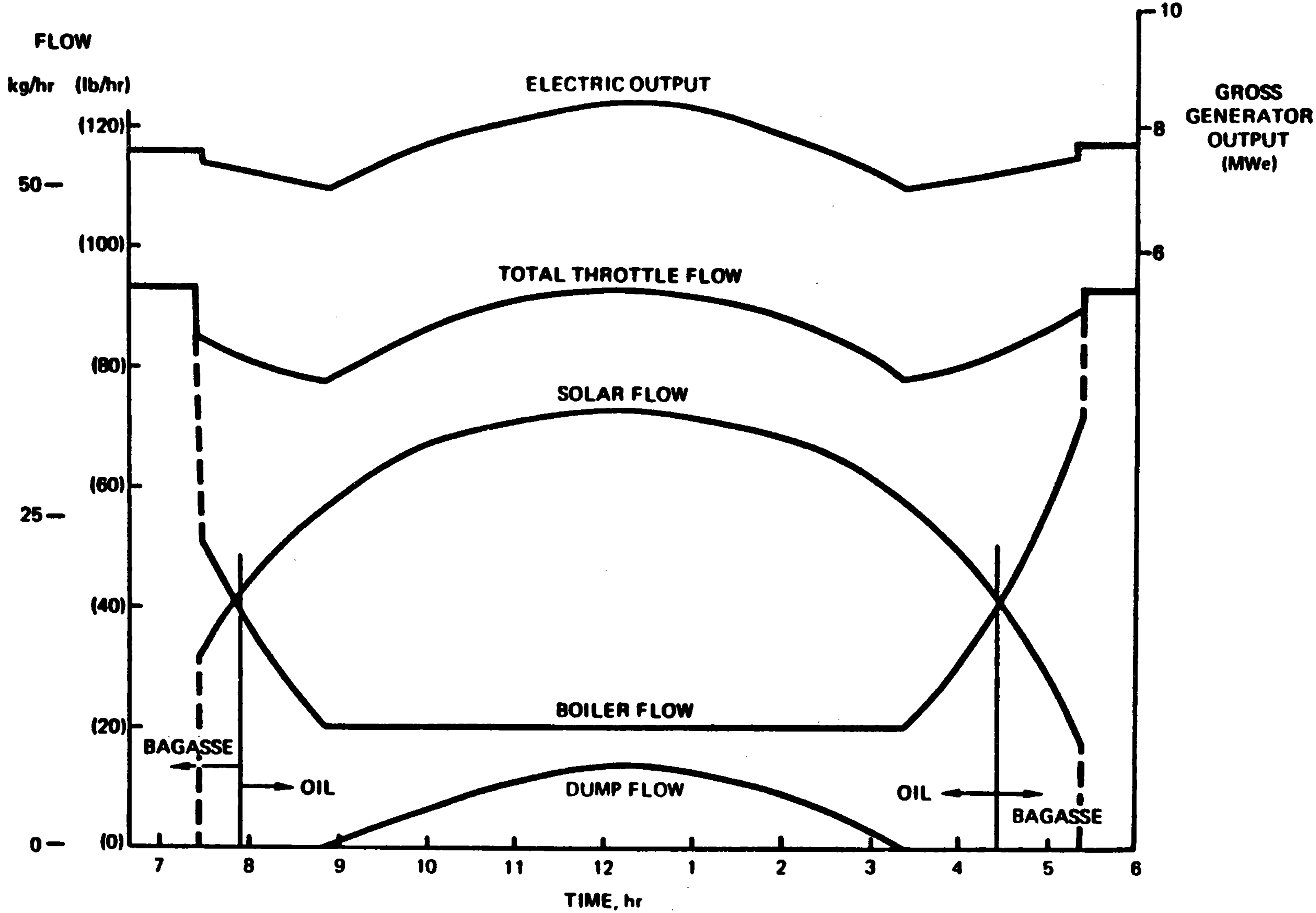


Figure 3-4 WEEKEND DAY OPERATING SCENARIO

The dump can also be operated to provide maximum generator output at any time. For example, with no solar flow and no factory steam demand, the required throttle flow for a generator output of 8 400 kWe is 47 800 kg/hr (105,400 lb/hr) with a dump flow of 3 950 kg/hr (8,700 lb/hr). This contrasts with Condition 1 in Figure 3-3, in which the dump line is not used.

Sizing the solar system for 34 400 kg/hr (75,900 lb/hr) is estimated to displace about 96 percent of the oil consumed in a typical week with clear sky and 100 percent availability. Average weather conditions and a 90 percent availability assumption for the solar facility reduce the average oil displacement to 73 percent. The maximum case (clear sky and 100 percent availability) must be used for sizing, however, to prevent the accumulation of excess bagasse during periods of good weather.

It is appropriate to examine the potential value of thermal energy storage for this system in light of the preceding discussion. Thermal storage could eliminate the maximum turbine flow limit on weekends from consideration by allowing a larger solar steam flow than can be accommodated by the turbine alone. However, during weekdays with factory operation, thermal storage would not be useful, since all the solar steam could be used as generated in the receiver. The resulting utilization factor of thermal storage would be about 40 percent. The benefit that could be achieved would be the displacement of the last 4 percent of the oil used during the typical harvest week. In addition, the thermodynamic disadvantage of thermal storage on a superheated steam system would significantly reduce the turnaround efficiency of the storage system. For these three reasons, thermal storage is judged to offer little improvement to the displacement potential for Pioneer Mill, and it would not be cost-effective with such a low utilization factor. For the Pioneer Mill system, the weekly storage of bagasse offers the best combination of flexibility and cost-effectiveness.

The additional bagasse storage capacity that would be required for a solar system with a 34 400 kg/hr (75,900 lb/hr) peak capacity can be estimated from this analysis. For clear weather and maximum availability, the required additional capacity is approximately 567 000 kg (625 tons).

3.5 HELIOSTAT FIELD SITE SELECTION

3.5.1 Candidate Sites

The initial two sites studied were a southward-sloping hillside site nearly 1.6 km (1 mi) from the mill on land that is too rocky for growing sugarcane, and a relatively level site about 0.8 km (0.5 mi) from the mill on land currently used to grow sugarcane. The hillside site was proposed as the preferred site because it occupies relatively inexpensive and presently unused land and involves the displacement of only a small amount of sugarcane production.

Amfac was also very interested in the economic merits of the alternative site using cane land. If the displacement of a required amount of cane land for the generation of steam with solar energy is economical, then solar energy may be applicable to many other plants in Hawaii and the continental U.S. which are surrounded by agricultural land. However, in an effort to minimize the displacement of cane land, dual use of the alternative heliostat site (by growing of cane or other crops between heliostat rows) was also examined.

The locations of the two heliostat field sites, relative to the mill, are shown in Figure 3-5. The figure shows the two heliostat field layouts, and the routing of condensate and main steam piping. It also shows the location of the sugar mill, the mill yard, and the existing fueled boilers.

3.5.2 Preconceptual Design Features

Preconceptual designs were formulated for each of the candidate heliostat field sites. These designs provided the bases for capital cost estimates which, together with the annual performance estimates and dual-use crop studies, provided the bases for the heliostat field site selection.

Many of the features and criteria for the two preconceptual designs were identical, including:

- 8-inch, Schedule 80 main steam lines with 4-inch calcium silicate insulation
- 4-inch, Schedule 40 condensate lines with 2-inch calcium silicate insulation
- Spacing and design of pipe line supports
- Steam line drain designs
- Transfer and receiver feed pump station equipment cost (but slightly different pumping power requirements)
- Mixing station equipment cost
- Emergency power supply at the base of the tower (each with a Terry turbine and a generator driven by receiver steam)
- A steel tower with costs calculated from the Sandia National Laboratories, Livermore (SNLL) tower model (Ref. 3-3)
- Master control system design and cost
- Heliostat costs, except for the foundations
- A solar design point receiver output of 29.3 MWt

Features that were different for the two sites were:

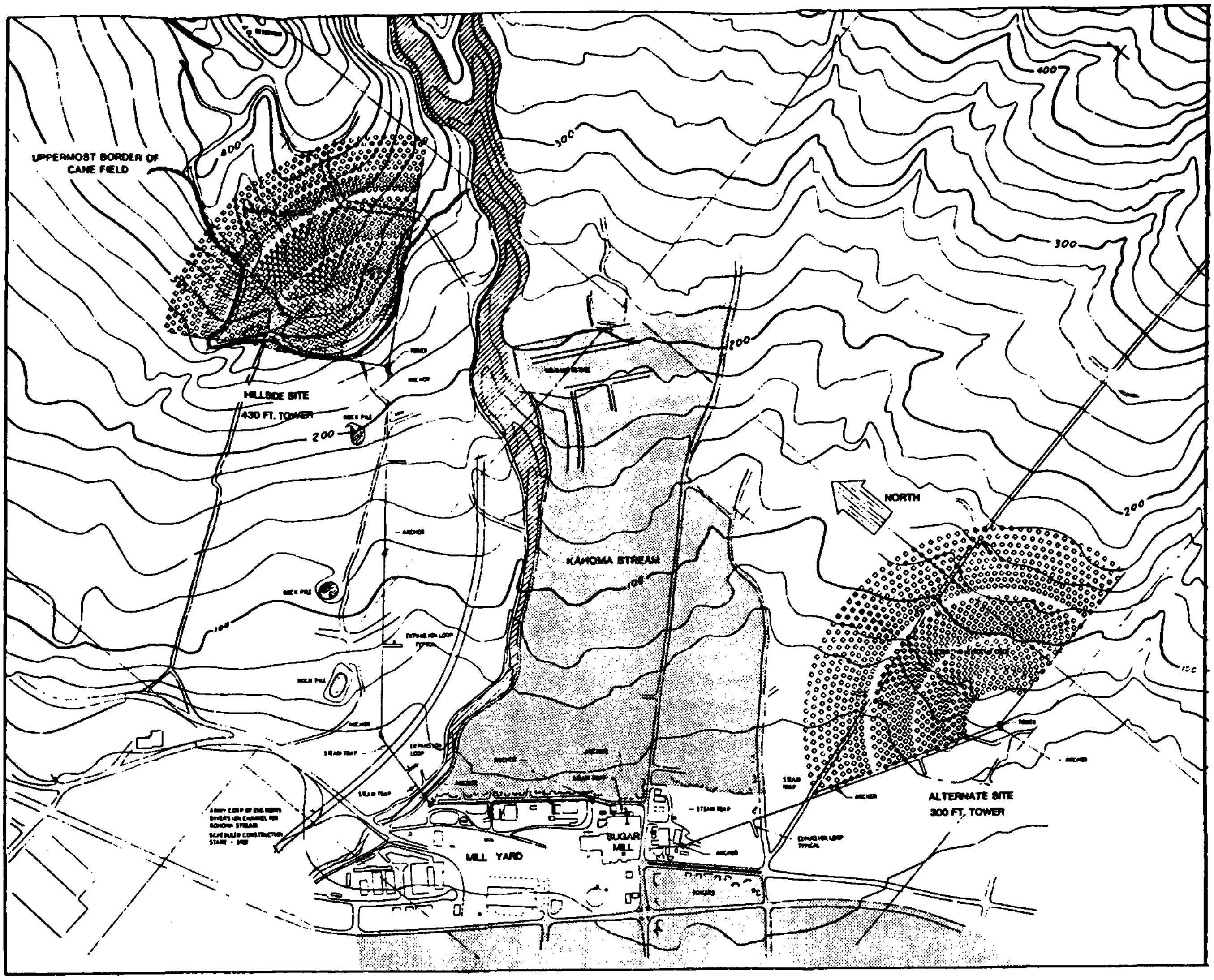
- Heliostat field layouts, number of heliostats, tower heights, and tower foundations
- Receiver designs
- Heliostat foundation designs
- Piping run lengths
- Impact on agricultural operations

3.5.3 Preconceptual Design Descriptions

This discussion of the preconceptual designs covers the receiver designs, heliostat field layouts and performance, heliostat foundations, the piping and pumping systems, and the impact of each site on agricultural operations at Pioneer Mill.

Each design uses the cavity-type water-steam receiver discussed earlier. The adaptability of a single cavity to the southward-sloping hillside site is one factor that led to the selection of the cavity receiver. Accordingly, the hillside site conceptual design is based on the use of a single-cavity receiver with an acceptance angle of 90°. A twin-cavity receiver with a total acceptance angle of 150° was selected for the alternative site. This selection was strongly influenced by the desire for a lower tower height with reduced visual impact for the site that is closer to the mill and the adjacent Lahaina area.

The mountains east of Pioneer Mill delay sunrise by nearly an hour; hence, solar insolation is prevented from being symmetrically distributed about solar noon. As a result, the preferred orientation of the heliostat field varies slightly from the normal north-of-the-tower location. A "1 o'clock"



RESIDENTIAL AREA

Figure 3-5 INITIAL CANDIDATE HELIOSTAT FIELD SITES FOR THE PIONEER MILL SOLAR COGENERATION FACILITY

field orientation, symmetric about an axis that is rotated 15^{o} east from due north, was selected for both candidate heliostat field sites. Such an orientation gives peak performance almost an hour after solar noon.

<u>Collector System Design and Performance</u>. One of the key factors in the selection process was the efficiency of the heliostat array in concentrating the solar energy on the receiver. The field efficiency is a function of several factors:

- Field configuration, orientation, and size
- Heliostat configuration and packing density
- Land availability and topography

Land availability is extremely important in Hawaii and was the principal factor in the selection of the two sites to be evaluated. It was a major influence in establishing the overall field layout and packing factors, which affect the tower height and ultimately influence the receiver design.

For central receiver collector fields in the size range of the Pioneer Mill facility, the radial stagger heliostat array has been shown to be superior to other arrangements and was chosen for this analysis.

The heliostat characteristics used in the study correspond to those of the ARCO-Northrup II, which is one of the heliostat designs being developed for the DOE under the second-generation heliostat program (Ref. 3-4). Each heliostat consists of a square array of 12 mirror modules and has a net reflective surface area of 52.8 m^2 (568 ft^2). The principal features of this heliostat are as follows:

- Total mirror area — 52.76 m^2 (568 ft^2)
- Height — 7.74 m (25.38 ft)
- Width — 7.44 m (24.41 ft)
- Weight, excluding pedestal — 2 260 kg (4,985 lb)
- Mirror modules
  - Mirror surface 1.2 m x 3.66 m (4 ft x 12 ft)
  - Galvannealed sheet steel construction
  - Longitudinal C-web bracing
- Frame structure
  - Four building truss purlins
  - Cross bracing
  - Elevation axis torque tube
- Drive assembly
  - Elevation and azimuth drives
  - Stepper motors
  - Planetary and worm stages for each drive
  - 18 108 reduction ratio
- Pedestal, 0.6 m (2 ft) diameter steel pipe

Figures 3-6 and 3-7 show the front and back views of a prototype at the ARCO-Northrup plant. The collector fields were designed to deliver the same peak power to the mill. As a result, the collector system had to deliver 32.5 MWt and 33.5 MWt to the focal planes of the hillside and alternative field receivers, respectively, since the twin-cavity receiver loss exceeds that of the single cavity. In developing the collector field designs to meet this

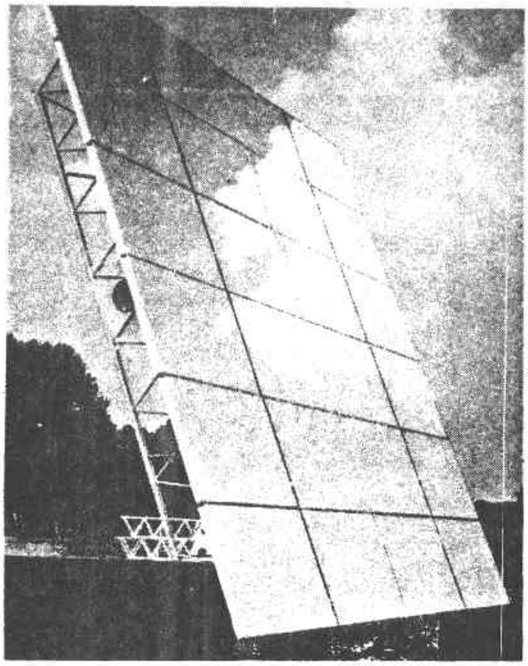


Figure 3-6 FRONT VIEW OF THE ARCO-NORTHRUP SECOND- GENERATION HELIOSTAT

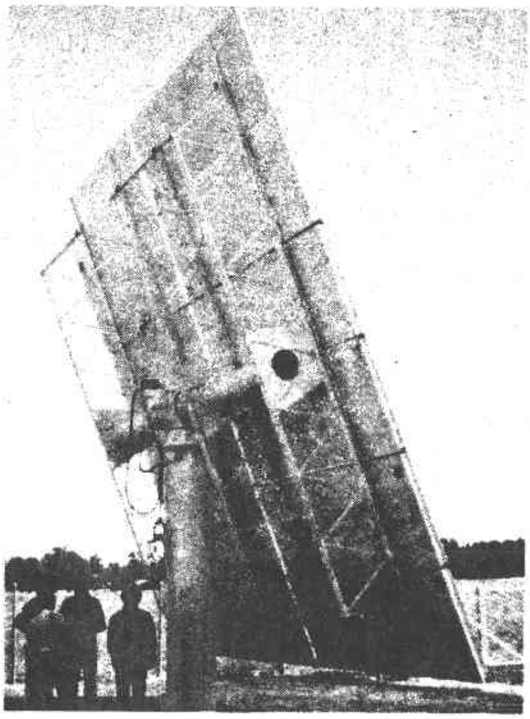


Figure 3-7 REAR VIEW OF THE ARCO-NORTHRUP SECOND-GENERATION HELIOSTAT

power requirement, the optimum number and placement of heliostats at each site were determined. The determination in each case was influenced by land availability, topography, and optimum tower heights.

The primary or hillside site for the collector field lies approximately 1.6 km (1 mi) northeast of Pioneer Mill. This site occupies the south- and slightly west-facing lower slope of an extinct volcanic cinder cone. Because of the presence of large volcanic outcrops and boulders in combination with the relatively steep slope, this land is unsuitable for sugarcane production. The northern part of the field perimeter is approximately 49 m (160 ft) above the tower base. On the eastern boundary the land drops sharply in elevation; the slope to the west is less pronounced but still significant. These features of the terrain, coupled with the boundary configuration of the available land, exerted a strong influence on the collector field design and, in combination with the receiver power rating, resulted in the selection of a single-cavity receiver design. The field was designed to lie within a 90° sector.

After the general field configuration (shape and size) had been established, the unique features of the site were evaluated to choose the best field orientation. The most significant feature was a residential area located due south of the tower. Since the residents of this area could be subject to a beam-pointing hazard, the tower was moved to the west relative to the true north-south axis. In addition to reducing a potential hazard, this move also increases total field performance slightly by increasing field efficiency during afternoon operation (because of the blocking effect of the West Maui Mountains, the day is symmetric about a time in the early afternoon).

Another factor that was considered was the tower-to-rear-heliostat-row elevation difference, which decreased as the tower was shifted to the west. If the field axis were rotated to produce a 3:00 o'clock field (field performance peaks at 3 p.m.), a 116 m (380 ft) tower could be used. However, the overall field performance for this arrangement was regarded as unacceptable because of a low average field cosine.

An evaluation of all of the above factors resulted in a field that is symmetric about an axis that points in a direction 15^{o} east of north (a 1 p.m. field). The field is composed of 36 concentric rows of heliostats that lie within a 90° arc centered at the tower base. Figure 3-5 shows a plan view of the collector field as an overlay on the topographical map of the site.

The layout of the heliostats (row spacing) is a strong function of the tower (receiver aperture centerline) height owing primarily to blocking and shading of adjacent heliostats. The row spacing within the radial stagger field configuration is considered to be optimum at the point where the beam from a heliostat passes just above the top of any heliostat in the two rows in front of it. This is the threshold of blocking. With this spacing, there will be some shading effect, particularly at low sun angles. Although row and heliostat spacing could be increased to reduce the shading, the penalty in land usage would be high.

Field efficiencies for three tower heights (98 m, 116 m, 131 m) were calculated for the hillside site. An evaluation of these data, in conjunction with the site restrictions outlined above, led to the selection of a tower height of 131 m (430 ft).

The alternative heliostat field site is located south of the mill on relatively level ground. The perimeter of the available land at this site permitted a field layout that was significantly different from the layout of the hillside side. Here, the heliostats were placed on 27 concentric rows within an included angle of 150^{o} to accommodate a dual-cavity receiver.

Field layouts incorporating tower heights of 84 m (275 ft) and 92 m (300 ft) were evaluated. The field with the taller tower was chosen for use in the site selection analysis because of the economic advantages of displacing a smaller amount of sugarcane. Here again, several considerations led to the adoption of a 1 p.m. field orientation. In addition to coping with mountain sun blockage, adoption of the 1 p.m. field orientation permits a straight pipe run along the southern edge of the field from the tower to the mill with a continuous slope toward the mill. Thus, pipe length and drainage provisions are both minimized.

The fundamental task in collector field design is to maximize the performance of the field in delivering energy to the receiver within the imposed physical and economic constraints. Field performance is a function of several key factors. The most important of these is the geometric field efficiency. There are four components to the geometric field efficiency: the cosine efficiency, the fraction of energy lost due to shading of the incident beam by the relative positions of the heliostats, the fraction of energy lost due to the shadow of the receiver and tower on the field, and the blocking of the reflected energy by the adjacent heliostats.

The above parameters, which establish the geometric performance, are all functions of the solar elevation and azimuth angles, which are functions of time of day and day of the year. Since the field layout was not symmetric about a true north-south axis, it was necessary to calculate two field efficiency matrices (field efficiency as a function of solar elevation and azimuth), one for the times when the sun in in the morning (eastern) sky and one for the times when the sun is in the afternoon (western) sky. These field efficiencies were used as input to the computer program STEAEC to calculate the annual performance associated with each of the candidate heliostat fields.

Heliostat Foundations. The basic heliostat foundation for the ARCO-Northrup second-generation heliostats at the Central Receiver Test Facility (CRTF) in Albuquerque was a 0.6 m (2 ft) diameter steel pipe driven slightly over 3 m (10 ft) into the ground with a vibratory hammer. The vibratory hammer permits piles to be installed rapidly and inexpensively for soils that do not contain stones. Because the cane land soil of the alternative site contains stones that would refuse a pile driven by a vibratory hammer, the steel pipe pedestal foundations must be installed in augered holes and set in concrete. A special foundation design is required on the hillside site where a 0.9 m (36 in.) layer of rocky topsoil covers a stratum of bedrock.

The heliostat pedestal-foundation designs for the candidate sites are shown in Figure 3-8. The soil survey of the islands of Kauai, Oahu, Maui, Molokai,

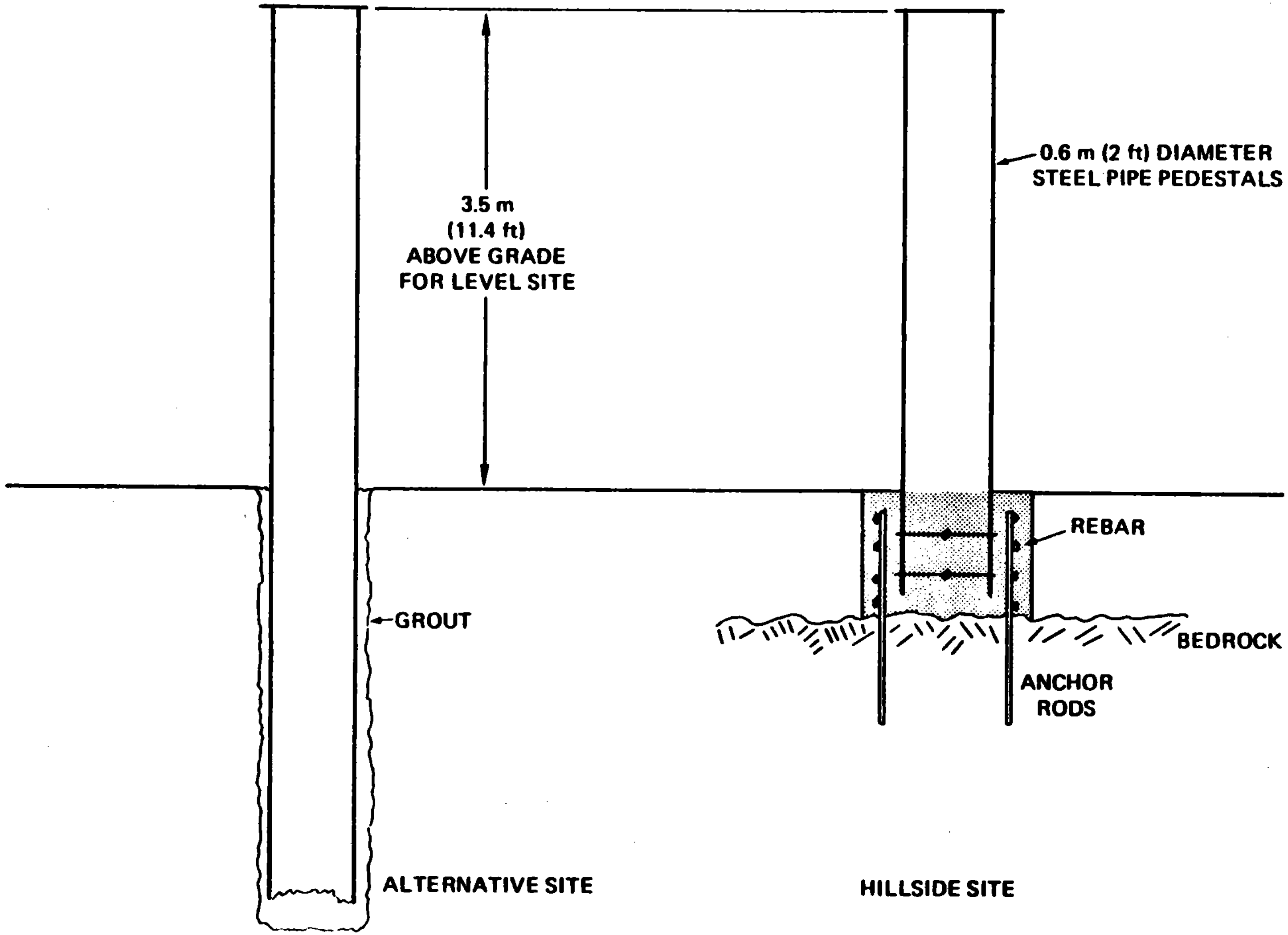


Figure 3-8 HELIOSTAT PEDESTAL-FOUNDATION DESIGNS

and Lanai (published by the State of Hawaii) describes the soil at the alternative site as Ewa silty clay loam (Ref. 3-5). It consists of two layers of silty clay loam extending to a depth of 1.5 m (5 ft) over a substratum of coral limestone or gravelly alluvium. It can be readily penetrated by an auger to provide a hole for setting the heliostat pedestal in grout. The hillside site soil is described as Wahikuli silty clay and consists of 0.5 to 1.0 m (20 to 40 in) of silty clay over bedrock. The bedrock approximately 1 m (3 ft) below grade on the hillside site requires a different foundation design. The designs shown in Figure 3-8 were adopted for the Task 2 preconceptual design.

This foundation is constructed by backhoeing to bedrock and drilling four 3.2 cm (1.25 in) diameter by 0.75 m (2.5 ft) deep holes into the bedrock. Expansion bolts anchored in these holes are welded to the rebar cage of a concrete foundation into which the heliostat pedestal is set.

The 3.5 m (11.4 ft) elevation of the heliostat pedestal flange above grade is sufficient for a level site. An increased pedestal height is necessary on sloping land to ensure clearance of the heliostat on the upslope side. This factor, illustrated in Figure 3-9, required an additional 0.1 m (0.32 ft) of above-grade pedestal height for the alternative site and an average 0.53 m (1.75 ft) of increased pedestal height for the hillside site. A still greater increase in pedestal height was required at the alternative site to clear the dual-use crops (discussed in Section 3.5.4) — an additional 1.2 m (4 ft) for the alfalfa crop and 3.7 m (12 ft) for the seed cane. In addition, proportional increases in the pipe length were provided below grade. The final pipe lengths for each pedestal-foundation are shown in Table 3-3.

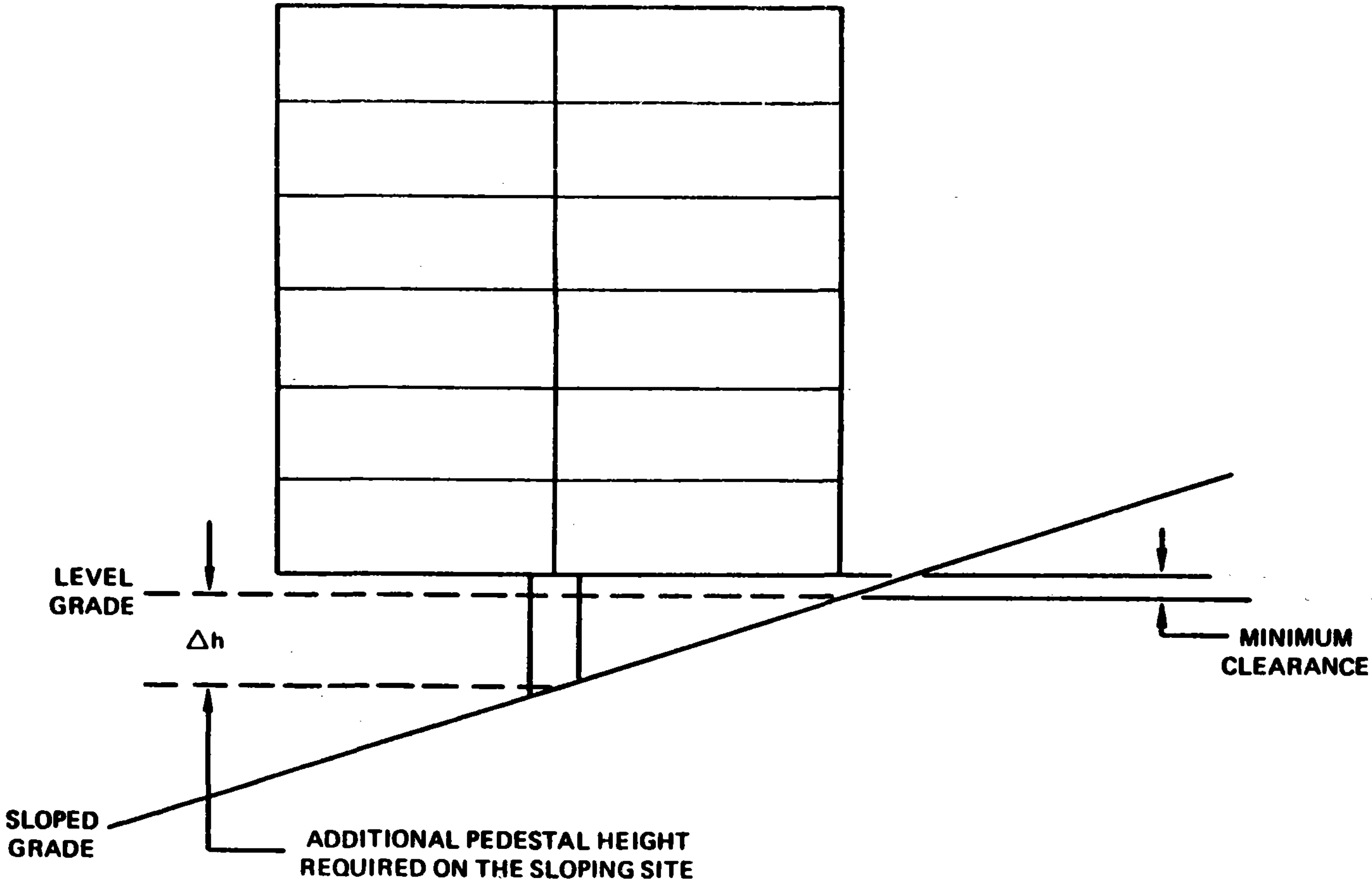


Figure 3-9 EFFECT OF SLOPING SITE ON PEDESTAL HEIGHT

Table 3-3

PEDESTAL-FOUNDATION PIPE LENGTHS

Site	Total Length		Length Above Grade	
	Meters	Feet	Meters	Feet
Hillside	4.77	15.65	4.01	13.15
Alternative – no crop	6.72	22.04	3.57	11.72
Alternative – alfalfa	7.53	24.69	4.79	15.72
Alternative – seed cane	13.57	44.53	7.23	23.72

An unexpected result of the pedestal-foundation analysis was the discovery that elevating the heliostat an additional 3.7 m (12 ft) above grade to clear the seed cane crop did not require an increase in the pedestal pipe diameter or wall thickness. It was found that very little of the pedestal base moment is due to the lateral drag force at the heliostat connection (the portion of the base moment that is amplified by additional pedestal height). The major portion of the pedestal base moment is due to the pure aerodynamic moment about the heliostat elevation axis. This portion of the pedestal base moment is unaffected by pedestal height over the range investigated. As a result, these increases in pedestal height caused only minor changes in the pedestal base moments. No adjustments in pedestal diameter or wall thickness were required.

Receiver System. The receiver system consists of a feed pump station at the base of the tower, condensate piping from the pumps to the receiver, the tower, the receiver, and the main steam piping from the receiver to the base of the tower. The receiver system equipment for the two candidate heliostat fields is the same except for the tower heights and associated pipe runs, and the receiver designs.

The tower heights were determined as part of the heliostat field design discussed earlier. The SNLL tower cost equations indicated that a steel tower should be selected for each of the candidate sites. The foundation costs for the hillside site were increased by 25 percent to account for the placement of the foundation on bedrock.

The basic receiver concept selected for use at Pioneer Mill is a natural-circulation steam generator with separate superheater circuitry. For the hillside site, a single-cavity configuration was adopted for the receiver system. The receiver was sized to produce 38 650 kg/hr (85,200 lb/hr) of superheated steam at a pressure of 6.2 MPa (915 psia) and a temperature of 413C (775F), with a thermal output of 29.3 MWt (100 x 10^6 Btu/hr).

At the initiation of the preconceptual design, inputs regarding cavity dimensions and heat flux distributions were not available. Since only approximate estimates of the receiver weight and cost were sought for this trade study, it was decided that this receiver could be scaled from another existing design having a similar cavity configuration. Subsequently, the internal geometry and dimensions of this single-cavity receiver were scaled down from the pilot plant receiver previously designed by Foster Wheeler for the Central Receiver Solar Thermal Power System (CRSTPS), Phase 1 Study (Ref. 3-2). The maximum absorbed power into this reference receiver was 48.7 MWt at a peak insolation of 1.023 kW/m^2. The candidate receiver for the cogeneration facility requires 29.3 MWt, and a peak insolation of 0.950 kW/m^2 was measured at the site. Consequently, the scaling factor for linear dimensions was established by the following relationship:

$$\frac{L}{L_{ref}} = \sqrt{\frac{29.3}{48.7}} \times \sqrt{\frac{1.023}{0.950}} + \text{(Minor adjustment due to round-off of aperture dimensions)}$$

where L and L_{ref} are linear dimensions of the cogeneration and reference pilot plant receivers, respectively.

The resultant internal dimensions of the cavity for the hillside site receiver are shown in Figure 3-10. The square cavity aperture is 6.1 m (20 ft) on a side. The rear wall and a large portion of both side walls, as indicated in the plan view of the figure, are covered with vertical boiler panels. These panels are made of 38.1 mm (1.5 in) OD carbon steel boiler tubes that are joined along their length by continuous-weld integral fins to form flat Monowalls^{TM}. A preliminary allocation of superheater surfaces was made on the basis of the heat flux distributions generated for the reference pilot plant receiver. The superheater consists of six horizontal passes in series. These passes are placed in front of the vertical boiler panels and aligned horizontally at two elevations as shown schematically in Figure 3-11. Each pass is made of 25 stainless steel tubes, with an OD of 25.4 mm (1 in), arranged side by side on 28.6 mm (1-1/8 in) centers. A spray attemperator located between Pass 3 and Pass 4 is used for temperature control. Preliminary sizing was also performed for drum, downcomers, feeders, risers, headers, and connecting piping.

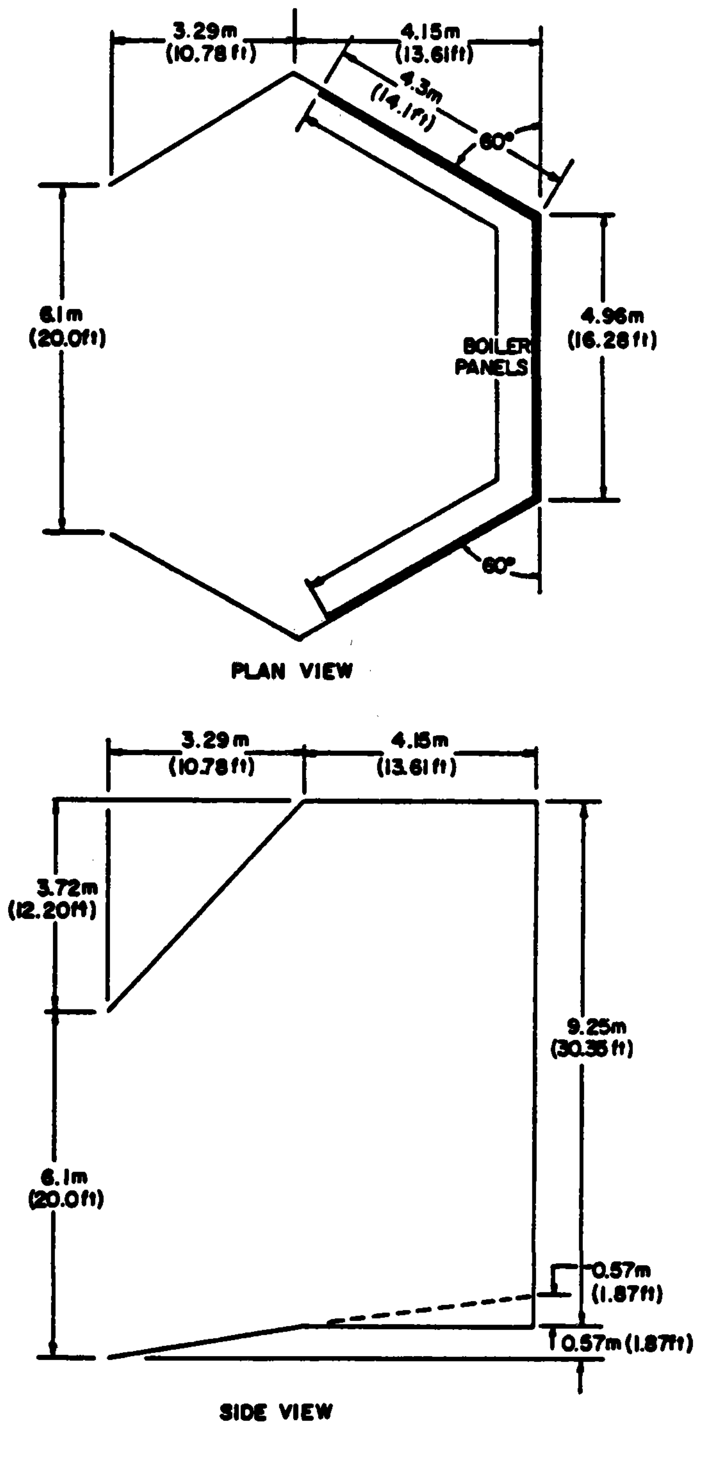
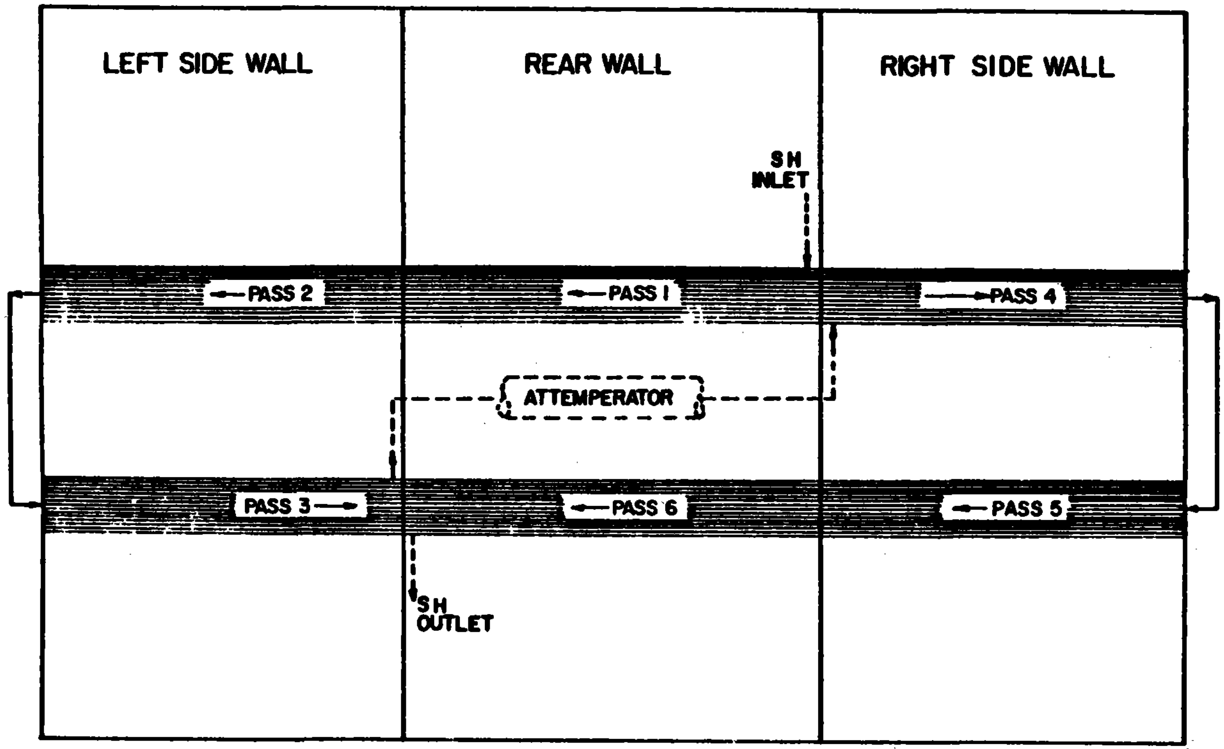


Figure 3-10 SINGLE-CAVITY RECEIVER CONFIGURATION



Superheater passes are numbered in the sequence of steam flow.

Figure 3-11 SCHEMATIC ARRANGEMENT OF SUPERHEATER PASSES FOR THE SINGLE-CAVITY RECEIVER

On the basis of this preconceptual design, the overall receiver dimensions were found to be approximately 12.5 m (41 ft) wide, 8.84 m (29 ft) deep, and 16.76 m (55 ft) high. The whole receiver system weighs approximately 149 100 kg (328,700 lb) empty, and 161 100 kg (355,200 lb) filled with water. The total construction cost of this receiver was estimated to be $2.48 million. The cost includes material, fabrication, erection, and home office expenditures, contingency, G&A and fee.

For the alternative heliostat field site, an integrated natural circulation twin-cavity receiver configuration was adopted, because it is compatible with the wider field layout and provides heating for both sides of the superheater tubes. The sizing of this receiver was based on the same thermal output and steam conditions as those used for the hillside site.

The same approach of estimating approximate receiver weight and cost without calculating the actual cavity dimensions and heat flux distributions from the proposed heliostat field was followed for this alternative receiver concept. The twin-cavity receiver designed for the Martin-Marietta/Exxon Solar Enhanced Oil Recovery System (Ref. 3-6) was selected as the reference receiver. The thermal output of this reference receiver is 29.3 MWt at an insolation of 0.95 kW/m^2, which is identical to the requirement set for the Task 2 receivers at Pioneer Mill. Therefore, for the preconceptual design of the alternative site receiver, the cavity configuration and flux distributions were taken directly from those of the reference receiver. Since no superheater was required in the reference design, it was necessary to modify the surface allocation in order to provide the proposed receiver with appropriate superheating surfaces.

Figure 3-12 shows the key dimensions of the twin-cavity receiver configuration. The receiver is symmetric with respect to a plane passing through the common wall that partitions the two cavities. The square aperture of each cavity is 5.5 m (18.04 ft) on a side with its centerline extending at an angle of 37.5° from the common wall. To illustrate the allocation of the interior surfaces, a foldout sketch of one of the two identical cavities is shown in Figure 3-13. Since a considerable amount of incident solar energy falls on the cavity roof, a large portion of the roof is covered with preheater panels. The rear wall and side wall of each cavity are lined with vertical boiler panels. Carbon steel tubes of 25.4 mm (1 in) and 50.8 mm (2 in) ODs serve as the preheater and boiler panels, respectively. The same type of Monowall™ construction described previously is used for these panels. The superheater, consisting of four vertical passes in series, is located on the common wall. All superheater passes are made of a number of parallel 38.1 mm (1.5 in) OD stainless steel tubes welded side by side to form flat panels. The transfer piping connecting superheater Passes 2 and 3 (not shown in Figure 3-13) contains the spray attemperator used for steam temperature control.

The overall dimensions of this twin-cavity receiver are about 12.5 m (41 ft) wide, 7.0 m (23 ft) deep, and 12.2 m (40 ft) high. The total estimated dry weight of the whole receiver is 127 000 kg (280,000 lb), and the water-filled weight is 137 300 kg (302,600 lb). The total construction cost of this receiver was estimated to be $2.47 million. The fact that the twin-cavity receiver is considerably smaller and weighs less than the single-cavity receiver, but is equal in cost, is attributed primarily to the significant scaling of the single-cavity design and cost from its design point.

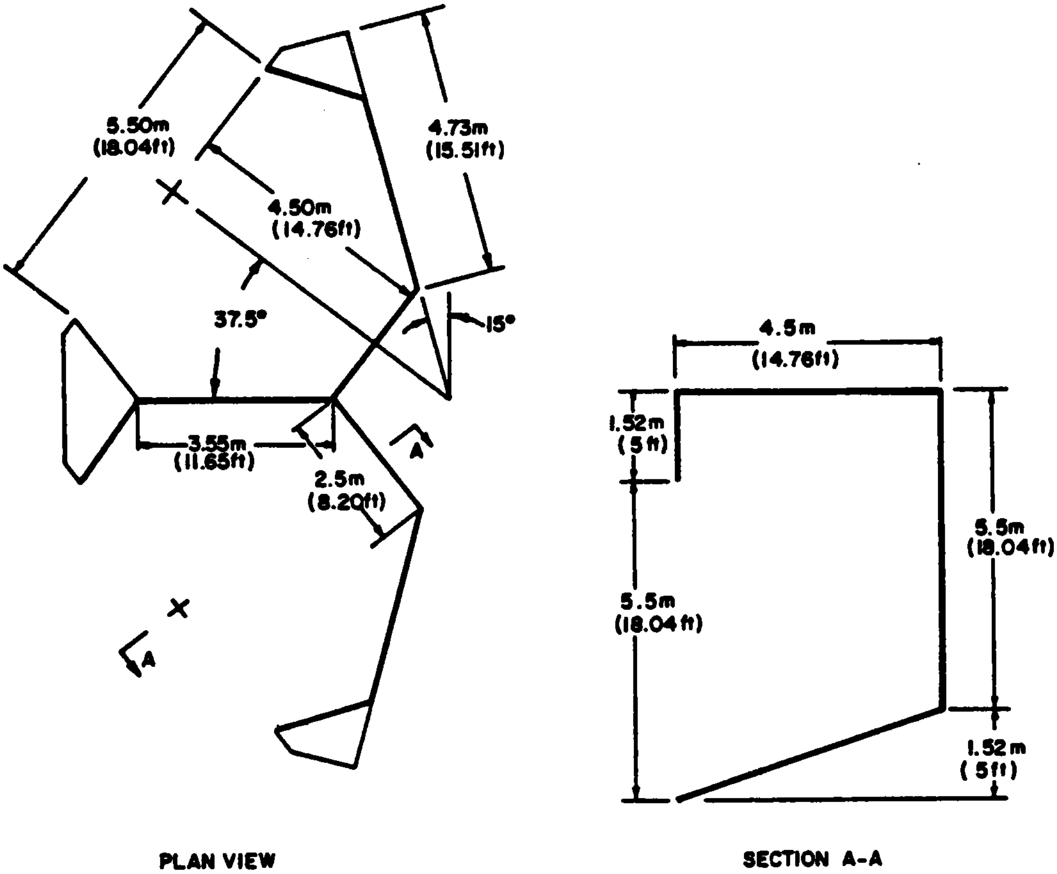
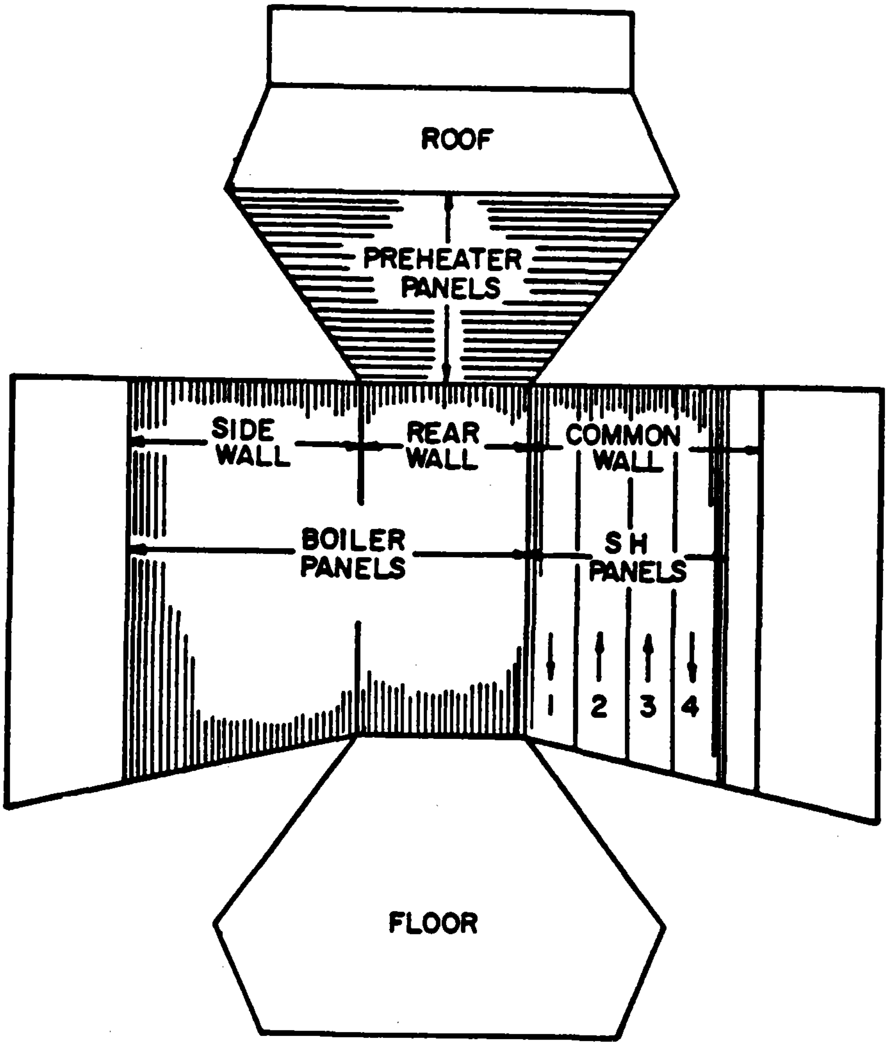


Figure 3-12 TWIN-CAVITY RECEIVER CONFIGURATION



Superheater passes are numbered in the sequence of steam flow.
The attemperator is located between Passes 2 and 3.

Figure 3-13 CAVITY FOLDOUT SHOWING THE SURFACE ALLOCATION OF THE TWIN-CAVITY RECEIVER

Thermal Transport System. All the features of the thermal transport system, other than the lengths of the pipe runs, were the same for each candidate site. The major common features were included in the list in Subsection 3.5.2.

The piping run lengths were 1 855 m (6,087 ft) for the hillside site and 1 000 m (3,280 ft) for the alternative site. These piping runs and the expansion loops used for Task 2 are shown in Figure 3-5. This figure also shows the proposed Army Corps of Engineers' diversion channel for Kahoma Stream (scheduled for construction in 1982), which must be bridged by the hillside site condensate and steam lines. The hillside site lines were assumed to run from the tower to the diversion channel on supports approximately 0.6 m (2 ft) above grade. At the diversion channel, the pipe runs are elevated 3.7 m (12 ft) above grade. After bridging the channel, the pipe run returns to 0.6 m (2 ft) above grade until the present Kahoma Stream bed is crossed. The piping is then elevated 3.7 m (12 ft) above grade as it traverses the northwest edge of the mill yard on its way to the sugar mill. Drain traps are placed at each low point in the line for collection of condensate as the line is heated each morning during startup. The pipe run from the alternative site tower to the boiler building is at 0.6 m (2 ft) above grade everywhere, except where it drops below grade to pass through a culvert beneath a road.

3.5.4 Impact on Agricultural Operations

Each of the alternative sites would have an impact on the agricultural operations on the plantation. The hillside site has significantly less impact than the alternative site; it uses unproductive land for all but 25 500 m^2 (6.3 acres) of the heliostat field.

The alternative site layout is entirely within the cane fields. If the sugarcane were displaced completely, the overall production capacity of the plantation would be reduced unless other available land were brought into production. Although the land area needed for this project is relatively small, widespread use of this type of solar thermal system in Hawaii and other agricultural regions could significantly affect local farm production. Since this is a site-specific problem with broad implications, the possibility of dual use of land for heliostats and agricultural production was studied. For this application, a second local crop, alfalfa, was also investigated.

To accommodate the crops under the heliostats, the following arrangement was found to be most suitable: The crops are planted in curved rows behind the rows of heliostat pedestals (looking from the tower). The crop row width equals the distance between heliostat rows minus a 5.5 m (18 ft) wide roadway and heliostat pedestal area for heliostat access and cleaning. The crop width varies from 5.2 m (17 ft) to 11.3 m (37 ft) for the alternative field layout. One intermediate takeup row has a 17.7 m (58 ft) wide crop strip. The heliostat pedestal was lengthened so that the crop is cleared at its maximum expected growth.

In the harvesting of the sugarcane crop, the field is usually burned and the work is normally done with large pieces of equipment. This type of activity cannot be carried out between heliostats. Seed cane, however, is not burned and is harvested by hand. Pioneer Mill currently has about 0.93 km^2

(230 acres) in seed cane, and the location of the seed cane field is not critical. The seed cane is harvested every 10 months after it reaches a maximum height of about 3.6 m (12 ft). During the growing period, it needs little care except for irrigation and pest control. The changeover to drip irrigation techniques at Pioneer Mill means that irrigation will not present problems for the heliostat mirror surfaces or foundations.

Alfalfa grows rapidly in a tropical climate, yielding 10 crops per year. The maximum height attained before harvest is about 0.75 m (2.5 ft). Because it is not presently grown at Pioneer Mill, this crop requires increased capital investment for harvesting and drying equipment.

Many other crops can be considered for this dual-use application, but were not evaluated in this study. Corn and sorghum, which also have a local market, were suggested. Other crops that do not have a local market were not considered. Pineapples were eliminated from consideration because of strong competition in the area from large producers.

Other issues, such as impact on heliostat operation, were considered only briefly, owing to budget limitations. No significant obstacles were found to this concept of dual land use, but the complications of maneuvering harvest equipment between the heliostats were noted by Pioneer Mill personnel. Table 3-4 summarizes the significant parameters that were used in the economic comparison of the alternative site with the hillside site.

Table 3-4

DUAL-USE CROP PARAMETERS
(Alternative Site)

Item	Seed Cane	Alfalfa
Total heliostat field area	210 000 m^2 (52 acres)	210 000 m^2 (52 acres)
Crop area in heliostat field	92 600 m^2 (22.9 acres)	92 600 m^2 (22.9 acres)
Net surgarcane displacement	117 400 m^2 (29.1 acres)	210 000 m^2 (52 acres)
Value of displaced sugarcane	$1.21/km^2/yr ($3,000/acre/yr)	$1.21/km^2/yr ($3,000/acre/yr)
Gross crop income	$1.21/km^2/yr[a] ($3,000/acre/yr)	$5.66/km^2/yr ($1,400/acre/yr)
Harvesting cost	$0.044/kg ($40/ton)	$.011/kg ($10/ton)

(a) Seed cane income is treated as equivalent reduction in sugarcane displacement.

3.5.5 Performance Comparison

The annual performance of the two fields was computed using the STEAEC program. Twelve typical days were analyzed to approximate the annual energy collection. A monthly weather factor was applied to each day to account for average solar insolation availability. To meet the peak power requirement of 29.3 MWt, the hillside site required 831 heliostats and the alternative site required 864 heliostats. The results of this analysis are given in Table 3-5. The annual energy supplied by the two fields differs by only 0.5 percent.

Table 3-5

HELIOSTAT FIELD PERFORMANCE COMPARISON

Day No.	Month	Days per Month	Weather Factor	Hillside Site		Alternative Site	
				Clear Day Energy, MWht	Monthly Energy, MWht	Clear Day Energy, MWht	Monthly Energy, MWht
15	Jan	31	0.86	214	5 705	221	5 625
46	Feb	28	0.88	226	5 569	224	5 519
74	Mar	31	0.87	231	6 230	231	6 230
105	Apr	30	0.80	229	5 496	231	5 544
135	May	31	0.79	223	5 461	227	5 559
166	June	30	0.81	218	5 297	223	5 419
196	July	31	0.82	220	5 592	225	5 720
227	Aug	31	0.85	225	5 929	228	6 008
258	Sept	30	0.87	230	6 003	231	6 029
288	Oct	31	0.91	227	6 404	226	6 375
319	Nov	30	0.91	218	5 951	216	5 897
349	Dec	31	0.93	208	5 997	205	5 910
Annual			0.84 (average)	222.5 (average)	69 688	223.74 (average)	70 053
At 90% availability					62 719		63 048
No. 6 oil displaced					5 930 m^3 (37,300 bbl),		5 960 m^3 (37,500 bbl)

3.5.6 Capital Cost Comparison

Capital cost estimates were prepared for the two heliostat field sites. The purpose of these estimates was to determine the differences in cost; all major components of the solar facility were included. The estimates were consistent with the level of engineering detail available from the Task 2 effort. Costs were normalized to first-quarter 1981 price and wage levels, and represent direct-hire field construction in Hawaii. Pricing was based on informal vendor quotes obtained by Bechtel and on Bechtel historical cost data, with the following exceptions:

- Heliostat costs were supplied by Northrup
- Receiver costs were supplied by Foster Wheeler
- Tower costs were obtained from the Sandia tower cost equation

Indirect field costs for these estimates include:

- Temporary construction facilities
- Miscellaneous construction services
- Construction equipment and supplies
- Field office costs
- Preliminary checkout and acceptance testing
- Project insurance

Engineering services include engineering costs, other home office costs, and fee. The level of contingency included reflects the limited engineering detail available. The following items were specifically excluded from the estimates:

- Equipment or construction costs other than for the solar facility
- Removal of the solar facility at the end of project life

- Owner's costs
- Environmental reports and licensing
- Allowance for funds during construction
- Training of operators
- Plant startup

The estimate summaries are presented in Table 3-6. Three cases are presented for the alternative site corresponding to the three dual-use options, which differ in heliostat pedestal costs only.

The hillside site was found to be approximately $3.3 million more costly than the least expensive alternative site case. The three primary contributors to this difference are the receiver tower, the thermal transport piping, and the heliostat foundations. These are included with equipment, piping, and heliostats and installation, respectively in Table 3-6.

3.5.7 Economic Comparison

An economic comparison of the two sites was carried out to assess the impact of the other relevant factors, such as lost cane production, on the capital cost advantage of the alternative site. After consultation with Amfac, the following assumptions were made:

- General escalation rate of 10 percent
- Plant operation over 20 years, beginning in 1986
- Plant tax life of 14 years
- Federal tax rate of 46 percent
- State tax rate of 6.021 percent
- Federal investment tax credit of 25 percent
- State investment tax credit of 10 percent

Table 3-6

SITE COMPARISON CAPITAL COST SUMMARY
(in $1,000's)

Item	Hillside Site	Alternative Site[a] 1	2	3
Site preparation	230	270	270	270
Equipment	5,386	4,116	4,116	4,116
Piping	1,900	1,130	1,130	1,130
Electrical	250	240	240	240
Instrumentation	140	131	131	131
Total direct cost	7,906	5,887	5,887	5,887
Indirect cost	634	443	443	443
Total field cost	8,540	6,330	6,330	6,330
Engineering services	850	630	630	630
Contingency	1,700	1,260	1,260	1,260
Construction cost	11,090	8,220	8,220	8,220
Heliostats and installation	12,620	12,230	12,370	12,910
Total construction cost with heliostats	23,710	20,450	20,590	21,130

Price and wage level, first-quarter 1981.

(a) Alternative site cases are as follows:

1. No crop
2. Dual use — alfalfa
3. Dual use — seed cane

From these assumptions, a fixed charge rate of 19.7 percent was calculated using 100 percent equity financing. Operation and maintenance costs were assumed to be 1.5 percent of constructed cost, escalating with the general inflation rate. The land lease costs for the two sites are $5/acre/yr for the hillside site, which is unused land owned by the State of Hawaii, and $2 500/acre/yr for the alternative site, which is owned by the Bishop estate and located adjacent to the town of Lahaina.

The economic analysis is summarized in Table 3-7. The annual added cost using the hillside site is about $710 000 as a result of capital charges; but when all other relevant annual costs are considered, this is reduced to $350 000.

For the alternative site, the no crop case is the practical choice. Although there is a small savings indicated for the alfalfa case, this could be easily reversed when the operational details and the effect of partial shading on crop yield are fully considered. The seed cane case shows no economic advantage with the same potential caveats as the alfalfa case. The design of the facility should be based on the lower risk option of no crop among the heliostats; however, the future consideration of this dual-use approach for more mature plant designs cannot be ruled out.

3.5.8 Site Selection

The selection of the preferred site was based on the economic analysis. The alternative site is the more cost-effective choice, despite its greater impact on the agricultural land of the plantation.

Table 3-7

ECONOMIC EVALUATION SUMMARY
Levelized Annual Costs
(1000's, current dollars)[a]

Site	Capital Costs[b] (10^3, 1981)	Capital Charges[c]	O&M[d] Cost	Net Lost Cane Revenue[e]	Alfalfa Net Revenue[f]	Land Lease Cost[g]	Total Annual Cost	Annual Energy Production, MWht	Levelized Unit Energy Cost, $/MWht ($/MBtu)
Hillside	26,318	5,185	686	44	-	< 1	5,915	62,719	94.3 (27.6)
Alternative									
No crop	22,700	4,472	592	367	-	130	5,566	63,048	88.3 (25.9)
Alfalfa	22,855	4,502	596	367	(41)	130	5,554	63,048	88.1 (25.8)
Seed cane	23,454	4,620	612	205	-	130	5,567	63,048	88.3 (25.9)

(a) The reference year is 1981; i.e., the entire cash flow is shifted to reflect a 1981 plant startup date.

(b) Includes 11% contribution for AFDC based on an 18% discount rate, a 10% escalation rate, and a 2-year construction period before reference year.

(c) Based on an 0.197 fixed charge rate.

(d) Based on 1.5% of construction cost (excluding AFDC) multiplied by a levelizing factor of 1.93 (10% over 20 years).

(e) Lost revenue multiplied by a levelizing factor of 2.35 (10% over 22 years adjusted for a 2-year construction period).

(f) Includes $80,000 initial capital cost. Revenue calculated from the gross income, less harvest cost and capital recovery.

(g) Unescalated.

The factors that make the hillside site more costly were reexamined to be sure that the economic analysis was based on the best available information. The three main contributors were examined separately to determine if any factors had been overlooked.

The tower height for the hillside site was based on an optimization with a constrained field geometry. No reasonable set of conditions was found which could reduce the height significantly without a significant penalty in annual performance. If the slope were more uniform and the latitude of the site greater, the optimum tower height for the hillside site would be considerably shorter. However, for this specific evaluation, the shorter tower for the relatively flat alternative site represents a distinct economic advantage.

The piping length is fixed by the topography. The alternative site is as close to the mill as is reasonably possible, and the hillside site has double the piping length. This factor would always favor the alternative site for this particular facility.

The heliostat foundation costs are another purely site-specific disadvantage of the hillside site. Although the hillside has fewer heliostats, its overall heliostat field cost is greater.

This discussion illustrates that no combination of reasonable assumptions could be found that would overcome the economic advantage of the alternative site. Therefore, this site was preferred for the conceptual design without dual use for agriculture.

During the evaluation of the two sites for the heliostat field, several other factors were uncovered which led to the consideration of a third site. This site is very similar to the alternative site except that it is located northwest of the mill, as shown in Figure 1-1.

The two primary reasons for considering a third site were:

- The tower location for the alternative site is close to the main part of Lahaina, and hence may generate opposition on the part of the citizens of the town
- The land for the alternative site is privately owned by the Bishop estate and is leased to Pioneer Mill. The current lease expires in 1984 and proposed changes in land use must compete with other options, such as housing subdivision. There is also a much higher land lease cost associated with the Bishop lease compared with the state-owned land, such as the hillside site, as can be seen in Table 3-7.

The third site was chosen for consideration because it has nearly the same topography, current use, and proximity to the mill as the alternative site. It also has two other advantages: the tower is located significantly farther from the town, and the site is on state-owned land. The economics of the third site were judged to be better than the alternative site because of the $130,000 difference in annual lease costs. Therefore, the third site was judged to be superior to either the hillside or alternative site and was selected for the conceptual design.

Section 4

CONCEPTUAL DESIGN

The level of detail developed for the conceptual design of the solar cogeneration facility at Pioneer Mill is consistent with the conceptual design phase of an industrial power plant project. Engineering information is developed to the extent necessary to support the conceptual capital cost estimate and to evaluate the technical and economic feasibility of the project.

This section describes the systems, functional requirements, design and operating characteristics, site requirements, system performance, and energy load profile. The capital cost estimates are summarized and the operating and maintenance cost estimates are discussed. Supporting system analyses are also included.

A more detailed description of the individual systems of the solar facility is contained in Section 5.

4.1 SYSTEM DESCRIPTION

The solar cogeneration facility at Pioneer Mill incorporates a water-steam-cooled central receiver in parallel with the existing boilers. The consumption of fuel oil is reduced when solar energy is available. Bagasse, the alternative boiler fuel, is used for energy storage on a weekly cycle to accommodate the variation in solar energy input.

The solar facility consists of the following new systems:

- Collector system
- Receiver system
- Thermal transport system
- Master control system
- Nonsolar energy system

A schematic diagram of the solar cogeneration facility is shown in Figure 4-1 and the artist's rendering is shown in Figure 4-2.

4.1.1 Collector System

The collector system collects and concentrates solar radiation to the central receiver during all periods of sufficient insolation, and responds to commands from its own controls for normal focusing, sun tracking, defocusing, heliostat stow operations, and upset operating modes involving emergency defocusing to protect the receiver. The system is designed to be compatible with the receiver and to provide energy to the receiver fluid consistent with the input requirements of the plant.

The system includes 815 heliostats covering a land area of 0.17 km^2 (42 acres), with a packing efficiency of 25 percent. The heliostats are located in a radial stagger configuration and occupy a 150° circular sector of 360 m (1,180 ft) radius. The field radial centerline points in a direction approximately 15° east of due north. The location of the collector system relative to the existing facility is shown in Figure 4-3.

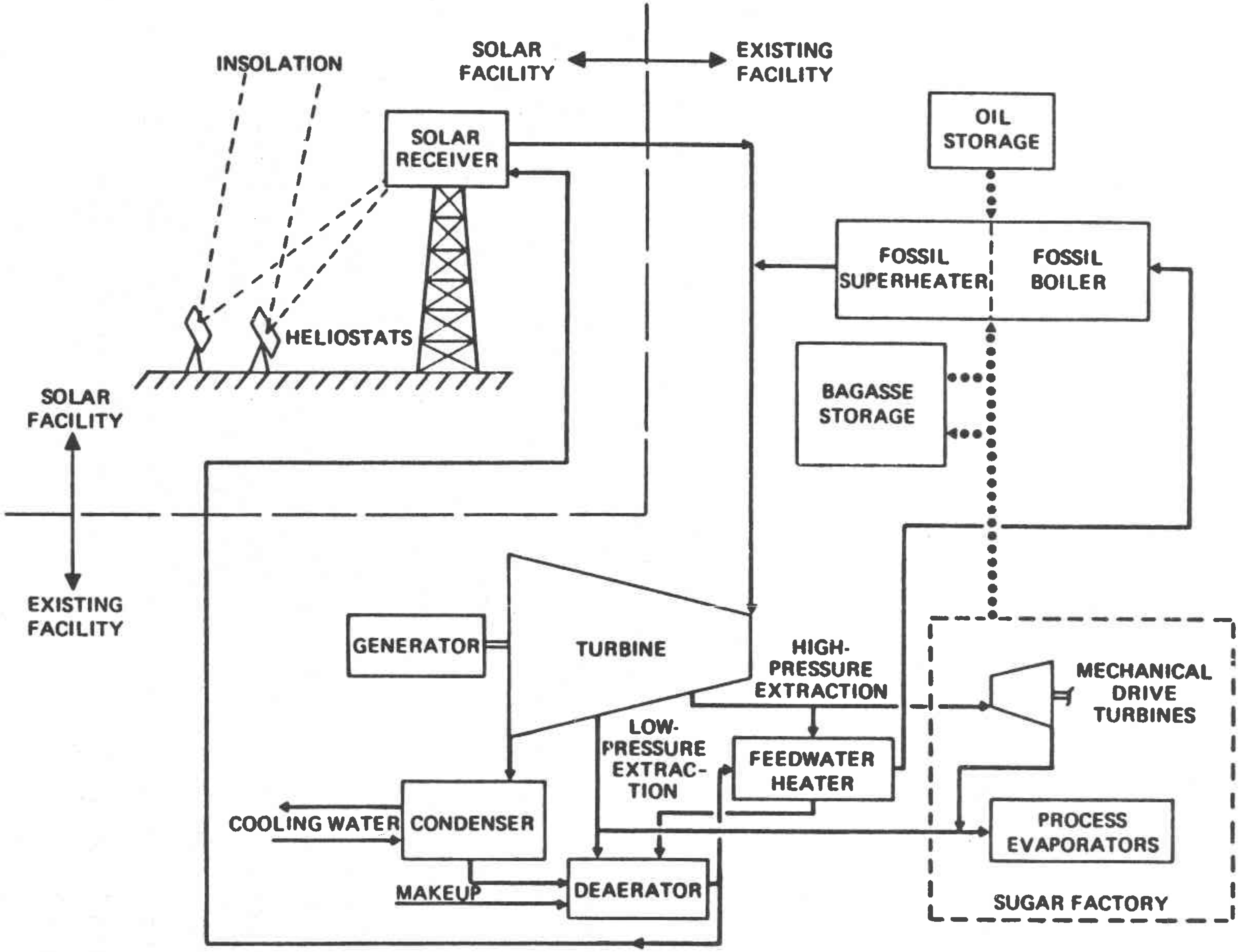


Figure 4-1 SYSTEM FLOW DIAGRAM

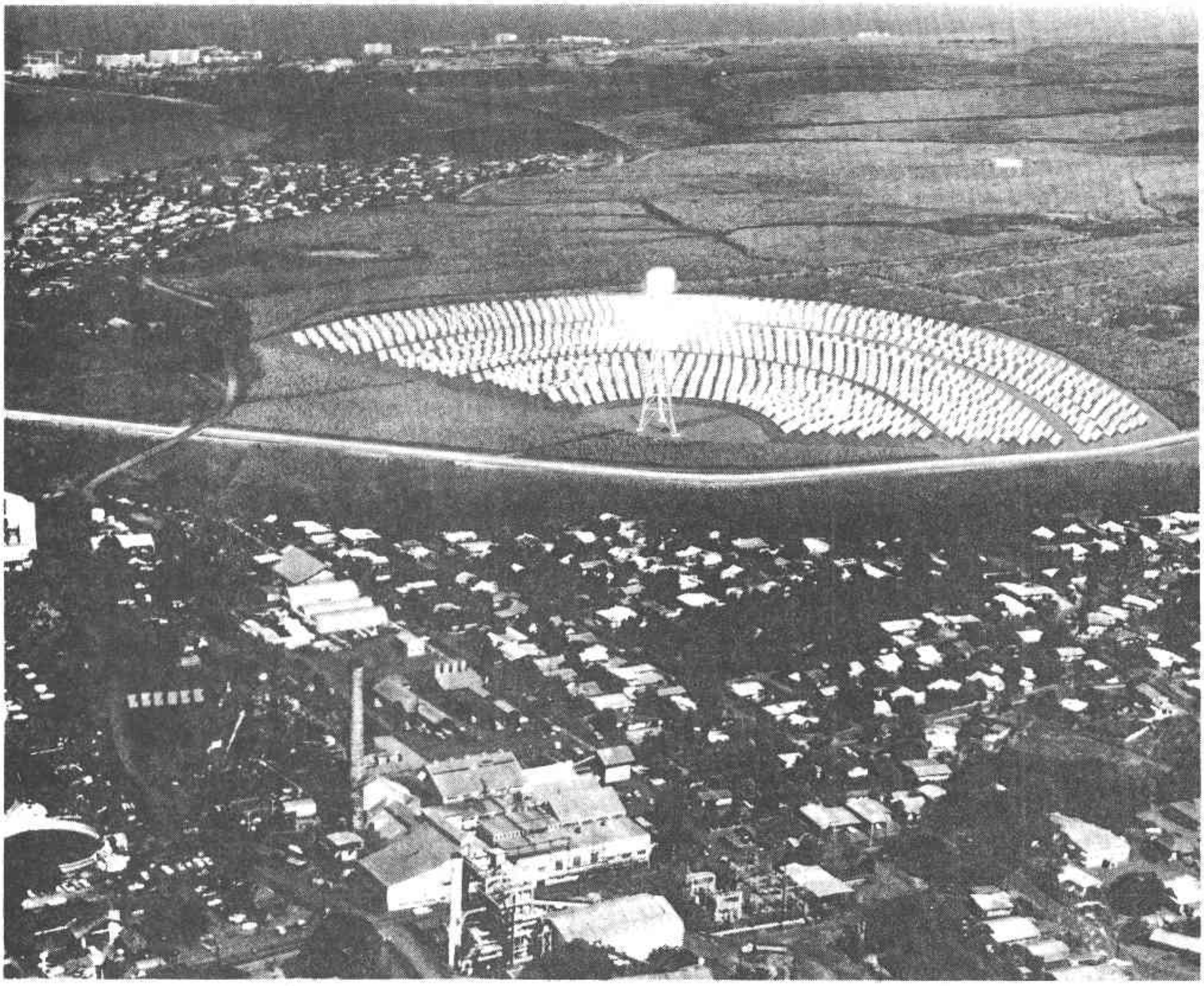


Figure 4-2 ARTIST'S CONCEPT OF SOLAR COGENERATION FACILITY

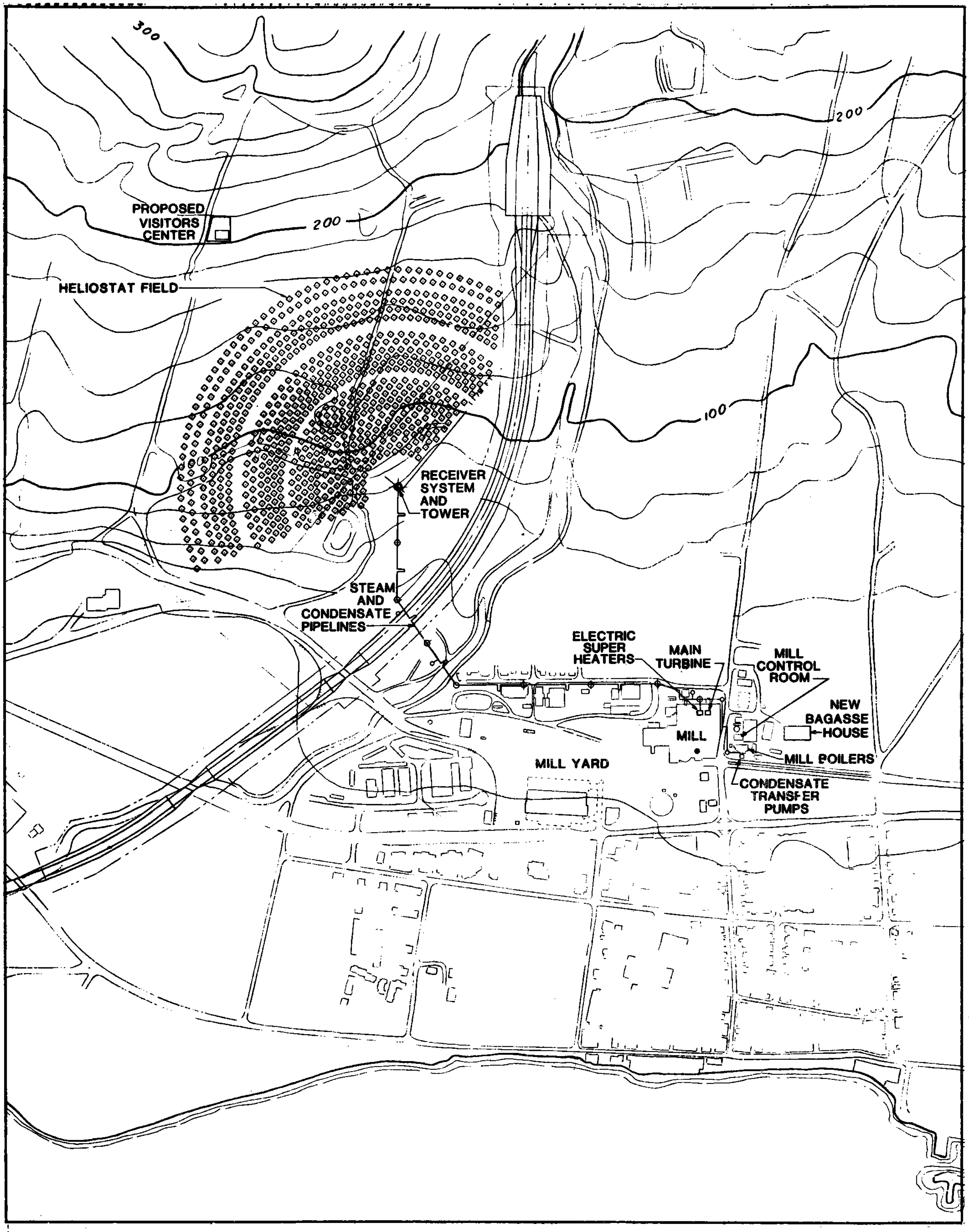


Figure 4-3 PLOT PLAN OF SOLAR COGENERATION FACILITY

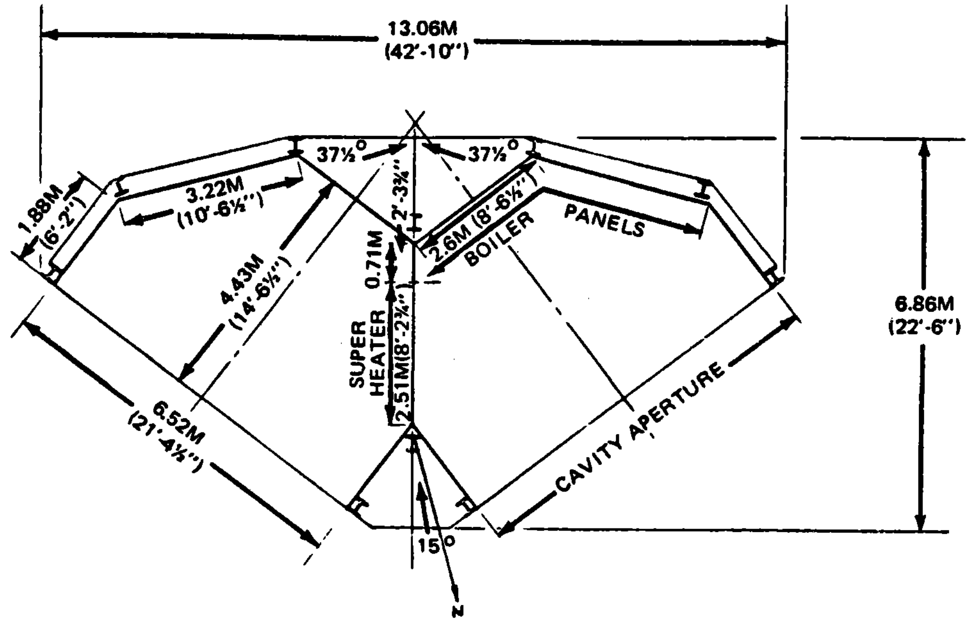
The collector system design is based on the size and performance characteristics of the Northrup II second-generation heliostat. The heliostat contains 12 mirror modules, each of which is 1.22 m x 3.66 m (4 ft x 12 ft), resulting in a total reflective area (allowing for edge molding) of 52.8 m^2 (568 ft^2). The azimuth and elevation drives for each heliostat is mounted on a 0.6m (2 ft) diameter steel pipe pile foundation. The normal stow position is vertical, but under extreme wind conditions, horizontal stow is required.

Control of the heliostats is accomplished through a three level, open loop control system. The redundant computer controls supervise the field operation at the operator's direction, automatically respond to transient signals from the master control system, and allow manual control of individual heliostats for maintenance or calibration.

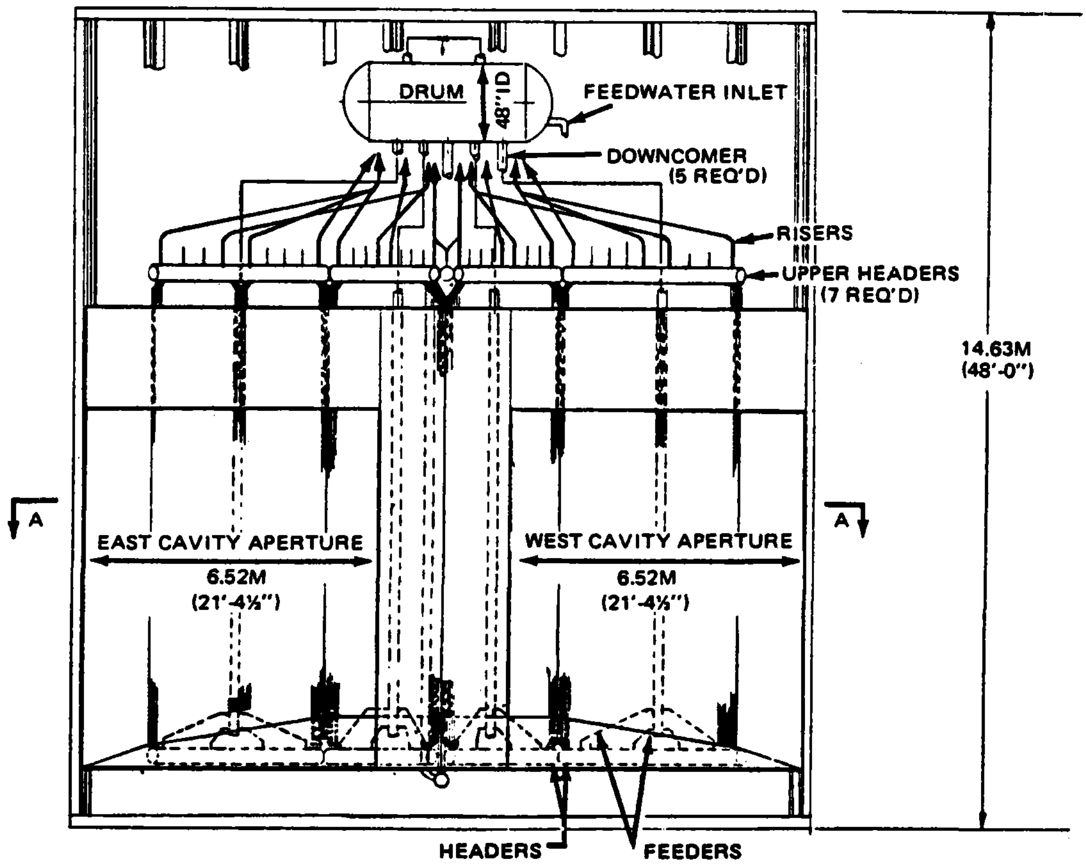
4.1.2 Receiver System

The receiver system permits the reflected radiant energy from the collector system to be transferred into the water-steam working fluid. The system consists of an elevated receiver to intercept the radiant flux, a tower structure to support the receiver, and a control system to regulate the fluid flow, temperature, and pressure in such a manner as to ensure safe and efficient operation of the receiver.

The receiver is a twin-cavity-type, natural-circulation steam generator with separate superheater circuitry as shown in Figure 4-4. It is designed to produce 33 500 kg/hr (73,900 lb/hr) of superheated steam at a pressure of 6.85 MPa (994 psia) and a temperature of 438C (820F), with a thermal output of 26.2 MWt (89.4 x 10^6 Btu/hr). The receiver is fully insulated



SECTION - AA
SURFACE ALLOCATION



FRONT ELEVATION VIEW

Figure 4-4 TWIN-CAVITY RECEIVER CONFIGURATION

to reduce thermal losses to the environment. The aperture of each cavity is provided with an insulated door to reduce the receiver cooldown during overnight shutdown periods. Access to the receiver equipment is provided for inspection and maintenance, and provisions are made for user safety.

The tower which supports the receiver, pipework, cables, and an elevator is fabricated from steel pipe sections and has three main columns. The tower height, to the aperture centerline, is 76 m (250 ft).

4.1.3 Thermal Transport System

The thermal transport system supplies condensate from Pioneer Mill to the receiver system holding tank at the base of the tower, from which the receiver feed pumps supply feedwater to the receiver. The system also carries superheated steam from the receiver system to the mill. The 1 128 m (3,700 ft) long steam pipe additionally serves as a limited-capacity buffer storage system. The steam piping is 15 cm (6 in) in diameter with 11.4 cm (4 1/2 in) of external insulation. The condensate piping is 10 cm (4 in) in diameter with 3.8 cm (1.5 in) of external insulation.

The thermal transport system also includes a steam mixing station near the turbine generator which controls the admission of solar steam into the mill piping. The mixing station includes connections to the condenser and extraction headers for use during startup, as well as four electric superheaters rated at 400 kWe each. These superheaters are used to match solar steam temperature with the mill requirements during morning startup before the relatively long steam piping has reached operating temperature.

4.1.4 Master Control System

The master control system coordinates the collector system controls, the receiver system controls, the thermal transport system controls, and interfaces with the existing mill controls. The solar facility will be controlled by operators in the existing mill control room and in a new solar control room in the tower base. The control consoles will be linked electronically and a voice link also will be provided for operator communication. The master control system includes the supervisory control for the two operators and the data acquisition functions for the solar facility.

The individual controllers that are coordinated by the master control system are part of their respective systems. The heliostat array controller is a central computer that provides all field control under normal operating conditions. Receiver controllers maintain rated steam exit conditions during normal operation and act to protect the receiver during startup, shutdown, and plant upset conditions. The thermal transport system controllers govern the supply of condensate to the tank at the base of the tower, monitor warmup of the steam supply pipe and receiver, supply feedwater to the receiver, and control admission of steam to the cogeneration facility during startup. The mill boilers are controlled by a pressure controller that balances the oil and bagasse firing rate to meet the mill steam demand.

4.1.5 Nonsolar Energy System

The nonsolar energy system consists of modifications to the existing facility as a result of the solar retrofit. To accommodate the solar facility, modifications will be required to the boiler instrumentation and controls, main steam piping, and condensate piping, and the existing control room must be expanded.

As part of the solar system retrofit, the capacity of the existing bagasse storage building and bagasse handling equipment is increased by providing additional enclosed storage and new conveyors. No thermal energy storage is provided.

A visitors center is provided on the hillside north of the heliostat field. This site has an excellent view of the solar facility from the side of the collector field away from the mill. It is served by its own road which is independent of the road to the receiver tower. This arrangement will keep the public away from the existing mill facilities, which are not designed for public access.

4.2 FUNCTIONAL REQUIREMENTS

4.2.1 System Performance

The goal of using solar energy at Pioneer mill is to displace as much oil consumption as economically possible. Due to equipment operating limitations and seasonal factory operation, this displacement amounts to about half of the current oil consumption.

The solar facility shall be capable of delivering 25.9 MWt of steam to the existing main steam line at 1 p.m. on the equinox day with 950 W/m^2 direct insolation. The system shall be capable of operating automatically over the entire range of load between 25 percent and full power while matching the main steam conditions at the mill. The design availability of the solar facility shall be at least 90 percent. The solar facility also shall not adversely impact the operability and reliability of the existing facility.

4.2.2 System Design Life

The existing boilers and main turbine generator at Pioneer Mill were installed in 1966. This equipment is in excellent condition and has an expected remaining useful life of 25 years. The project schedule in Section 7 projects an operational solar facility by early 1985. At that date, the mill power plant has an expected remaining life of 21 years. Therefore, the solar facility is designed for a 20-year lifetime. This requirement is consistent with Amfac's approach to industrial power plant projects and is well within the design lifetime of the solar hardware currently being developed.

4.2.3 Design Point

The collector field is designed so that 29.8 MWt of radiant solar power is delivered from the heliostats to the receiver at 1 p.m. of an equinox day, with a direct normal insolation value of 950 W/m^2.

The feedwater enters the receiver at 113C (235F). At the system design point, steam is generated in the receiver at the rate of 33 500 kg/hr (73,900 lb/hr) with outlet conditions of 6.85 MPa (994 psia) and 438C (820F).

The superheated steam is transmitted by the thermal transport system pipeline to the mill facility. At the mill end of the steam pipeline, the steam conditions are 5.96 MPa (865 psia) and 423C (793F). Before mixing with the boiler steam which is at 5.96 MPa (865 psia) and 399C (750F), the solar steam is attemperated with 113C (235F) boiler feedwater to reduce the steam temperature. This increases the total flow from the solar steam supply to 34 400 kg/hr (75,900 lb/hr).

4.2.4 Plant Instrumentation and Control Philosophy

The solar facility and the mill are controlled independently. However, the master control system coordinates the controls of the collector system, the receiver system, and the thermal transport system and interfaces with the mill facilities. Thus, the master control system with its overall control function senses, detects, monitors, and regulates all system parameters necessary to ensure safe and proper operation of the solar energy systems.

In terms of an overall process strategy, the solar receiver operates in principle as a third fired boiler. The solar receiver operates at maximum capacity, and the fired boilers are modulated to make up the remainder of the plant steam demand.

As this is a first-of-a-kind demonstration of a solar central receiver facility being integrated with an existing commercial process, data is required for analysis and reports. Provision has been made for data to be acquired and stored as part of the master control system. This data acquisition will support the startup through operational phases of the project discussed in Section 7.

4.3 DESIGN AND OPERATING CHARACTERISTICS

The key design and operating characteristics of the solar systems and relative power plant parameters of the existing mill facility are given in Table 4-1. The location of the major components are shown in Figure 4-3, which is a plot plan of the solar cogeneration facility.

Table 4-1

SUMMARY OF KEY DESIGN AND OPERATING CHARACTERISTICS

Existing Mill Facility	
Boilers	
Number	2
Type	Combustion Engineering (VU-40S) dual fuel operation with bagasse and No. 6 fuel oil
Rating (max)	65 800 kg/hr (145,000 lb/hr)
Superheater Outlet Pressure	5.96 MPa (865 psia)
Superheater Outlet Temperature	404C (760F)
Main Steam Turbine-Generator	
Number	1
Type	General Electric, double-automatic-extracting/condensing
Rating	9 375 kVA
Inlet Steam Pressure	5.96 MPa (865 psia)
Inlet Steam Temperature	399C (750F)
High Pressure Extraction	1.83 MPa (265 psia)
Low Pressure Extraction	205 kPa (30 psia)
Exhaust Pressure	7.4 kPa (1.08 psia)
Collector Field	
Number of Heliostats	815
Mirror Area per Heliostat	52.8 m^2 (568 ft^2)
Type	Second generation, ARCO-Northrup II
Field Configuration	North field, 150° sector
Total Mirror Area	43 000 m^2 (462,920 ft^2)
Total Collector Field Area	171 000 m^2 (42 acres)
Receiver System	
Fluid	Water-steam
Configuration	Twin-cavity
Type	Natural circulation
Elements	Boiler, Superheaters (2)
Inlet Water Temperature	113C (235F)
Outlet Steam Temperature	438C (820F)
Outlet Steam Pressure	6.85 MPa (994 psia)
Superheater Pressure Drop	896 kPa (130 psia)
Steam Flow	33 500 kg/hr (73,900 lb/hr)
Thermal Power to Steam	26.2 MWt

Table 4-1 (Continued)

Receiver Tower	
Type	Three-sided with structural steel pipe sections
Height (to aperture centerline)	76 m (250 ft)
Receiver weight (when filled with water)	127 300 kg (302,600 lb)
Storage	
Existing Bagasse House, Capacity	354 000 kg (390 tons)
New Bagasse House, Capacity	445 000 kg (490 tons)
Size	49 m by 25 m (160 ft by 80 ft)

4.3.1 Operating Modes

The solar cogeneration facility is expected to have two steady-state operating modes:

- Solar steam generation mode
- Nonsolar steam generation mode

In the solar steam generation mode, the solar water-steam receiver operates in parallel with the existing boilers. The existing boilers' outputs are reduced so that the maximum available solar-produced steam is used while the total steam demand is being met. Bagasse is displaced from the existing boilers into storage, and the use of oil is curtailed to the maximum extent possible.

In the nonsolar steam generation mode, during periods when solar-produced steam is unavailable, the existing boilers satisfy the entire steam demand, with bagasse if available. Oil is consumed only when necessary to meet the steam demand.

The solar cogeneration facility is also expected to have the following transitional operating modes:

- Normal solar startup mode
- Normal solar shutdown mode
- Emergency solar shutdown mode

In the normal solar startup mode, the solar receiver and thermal transport system are heated from cold or warm shutdown conditions to full operating temperature and pressure.

In the normal solar shutdown mode, the solar receiver and thermal transport systems are transferred from normal steam generation to either a warm shutdown condition (for extended cloud passage or overnight outage) or cold shutdown conditions (for longer outages).

In the emergency solar system shutdown mode, solar energy input to the receiver is reduced as fast as possible to meet operational or safety requirements.

4.3.2 Flow Diagram and Thermal Energy Balance

The system flow diagram shown in Figure 4-1 illustrates the relationship of the solar systems to the existing electric power generation and sugar factory system.

Parameters of the thermal energy balance at the design point are listed in Table 4-1 and relate to the system flow diagram shown in Figure 4-1. More detailed information is provided in Section 5 and Appendix E.

4.3.3 Controls and Instrumentation

The major components and elements of the master control system are contained in an extension to the existing mill control room and in a new solar control room at the base of the receiver tower. In the mill control room, the main control room board will be extended with conventional instrumentation and controls for status indication of the solar facility and controls for the mixing station. The solar control room includes a CRT display with a keyboard input to monitor systems, identify troubles, and control operating modes. The data acquisition console will be separate from the board and will include a mini-computer with peripheral hardware. The digital data transmission lines connect the two control rooms via the overhead electric distribution poles from the mill to the receiver tower. The operators are also provided with a dedicated voice link.

Normally the controls are automatic with the operator monitoring the performance of the solar facility. However, the operator will be expected to give supervisory commands based on perceived weather patterns, and mill requirements. Provision is made for complete redundancy for each critical element in the control system to maximize the overall solar facility reliability.

4.4 SITE REQUIREMENTS

This section discusses the site requirements and includes site preparations, modifications required at the existing mill facility, and the interface between the solar facility and the existing mill.

4.4.1 Site Preparation

Site preparation work for the solar facility includes rough-grading the collector field area and providing access roads and construction services. Two existing large mounds of stones will be removed, crushed, and used as aggregate for the roads. Construction utilities will be provided from the mill. Existing access to the collector field is by a haul road. This road will be upgraded. A perimeter road will be constructed around the collector field with pole mounted lights at about 30 m (100 ft) spacing. A 2.4 m (8 ft) high chain-link security fence with barbed wire will be installed 15.2 m (50 ft) beyond the perimeter road. The present natural site drainage will be preserved with runoff ditches which make use of the slope on the site.

4.4.2 Existing Facilities

In most cases, maintenance and storage facilities are integrated with those already in existence in the mill yard.

A new bagasse house will be provided to supplement the existing storage capacity. The building is 25 m (80 ft) by 49 m (160 ft) and is located south of the existing bagasse house. The new building will be served by conveyors to and from the existing storage facility. This is discussed further in Section 5.5.

4.4.3 Solar Facility Interfaces

The steam line from the solar receiver will be tied into the main steam line in the mill between the boilers and the main turbine. Connections from the new steam mixing station which is located adjacent to the turbine generators are required at the condenser, the low pressure process steam pipe header, and the high pressure extraction steam header. Near the boilers, a branch will be provided in the existing condensate line, after the deaerator, to enable some of the mill condensate to be transferred to the receiver. Details of the thermal transport system pipelines from the mill to the tower are given in Section 5.3.3.

4.4.4 Solar Facility Electric Power

Electric power is provided to the tower and heliostat field from the mill. Two categories of electrical power are required, normal plant alternating current (ac) power, and uninterruptible ac power for the computer controls. Under normal conditions, electrical power is obtained from the existing 13 kV system at the mill. If this power supply is interrupted, electrical power for safe shutdown of the solar facility is obtained from a small emergency steam turbine generator provided at the base of the solar receiver tower.

Figure 4-5, the electrical single line diagram, includes the following major electrical equipment items:

- 12 270 V/480-277 V mill transformer and switchgear supplying the distribution center for the steam electric superheaters, condensate transfer pumps, and lights
- 12 270 V, 3-phase overhead distribution feeder from the mill to tower
- 12 270 V/215-125 V field transformer and switchgear supplying the distribution center for the solar field systems
- 120-240 V tower distribution panel supplying the lights, crane, elevator, and receiver controls

- Fourteen 120-240 V heliostat distribution panels, each supplying 60 heliostats
- 1 500 A transfer switch to transfer power to the distribution center from the emergency generator during power outages

The source of normal ac power for the solar systems is from the existing 13 kV busbar in the mill. This busbar is supplied by the three mill electric generators or the intertie with the Maui Electric Company transmission system.

The source of uninterruptible ac power is redundant standard uninterruptible power supplies (UPS), each consisting of a static inverter, 125 V batteries, and a battery charger.

Emergency power is obtained from a 500 kW, 230-132 V emergency steam turbine generator. The steam turbine is driven by the reservoir of steam contained in the receiver system when it becomes isolated on loss of electric power.

4.5 SYSTEM PERFORMANCE

The performance characteristics of the solar cogeneration facility were estimated and compared to the performance of the existing facility to estimate fuel displacement. This section discusses these analyses and presents the results.

4.5.1 Performance of Existing Facility

At the beginning of the project, the detailed performance information on the existing facility was not available because a number of modifica-

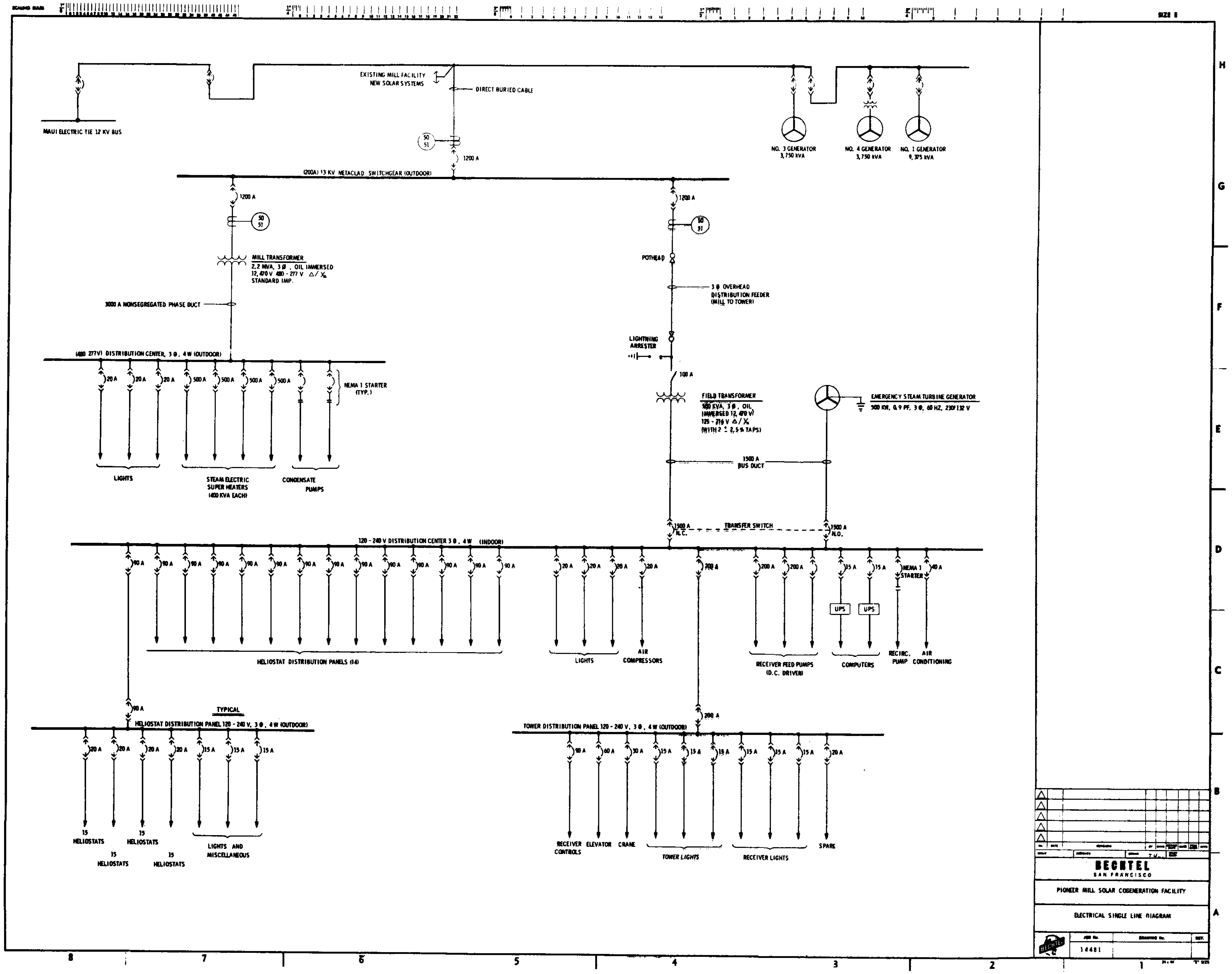


Figure 4-5 ELECTRICAL SINGLE LINE DIAGRAM

tions have been made since the original design calculations were performed. Estimates based on the experience of the operators and other available data were used in the Task 2 studies.

In order to generate the baseline performance information required, Amfac and Okahara, Shigeoka & Associates developed a simple model for plant performance. As a result, flow diagrams of the existing mill were developed and examples are provided in Appendix E. The analysis was based on typical operating assumptions, including a 40-week harvest season, a 12-week off-season, a generator output of 8 MWe during grinding operation, and an average generator output of 5 MWe during factory shutdown. The resulting baseline performance for the existing mill was estimated to be 60 302 MWhe of gross electric generation and 9 633 m^3 (60,588 bbl) of fuel oil consumed annually.

4.5.2 Performance of Solar Facility

Design Point. Figure 4-6 presents the stairstep efficiency diagram for the system at the design point. With 950 W/m^2 insolation, the total incident solar energy is 40.9 MWt and 63.3 percent is delivered to the mill interface as solar-generated steam. The stairstep illustrates the individual loss mechanisms and their contribution to the overall efficiency of the solar facility.

Solar energy provides 50 percent of the energy in the main steam at the design point. The remainder is supplied by the existing boiler burning bagasse during factory operation. The fired-boiler efficiency is approximately 70 percent in this mode.

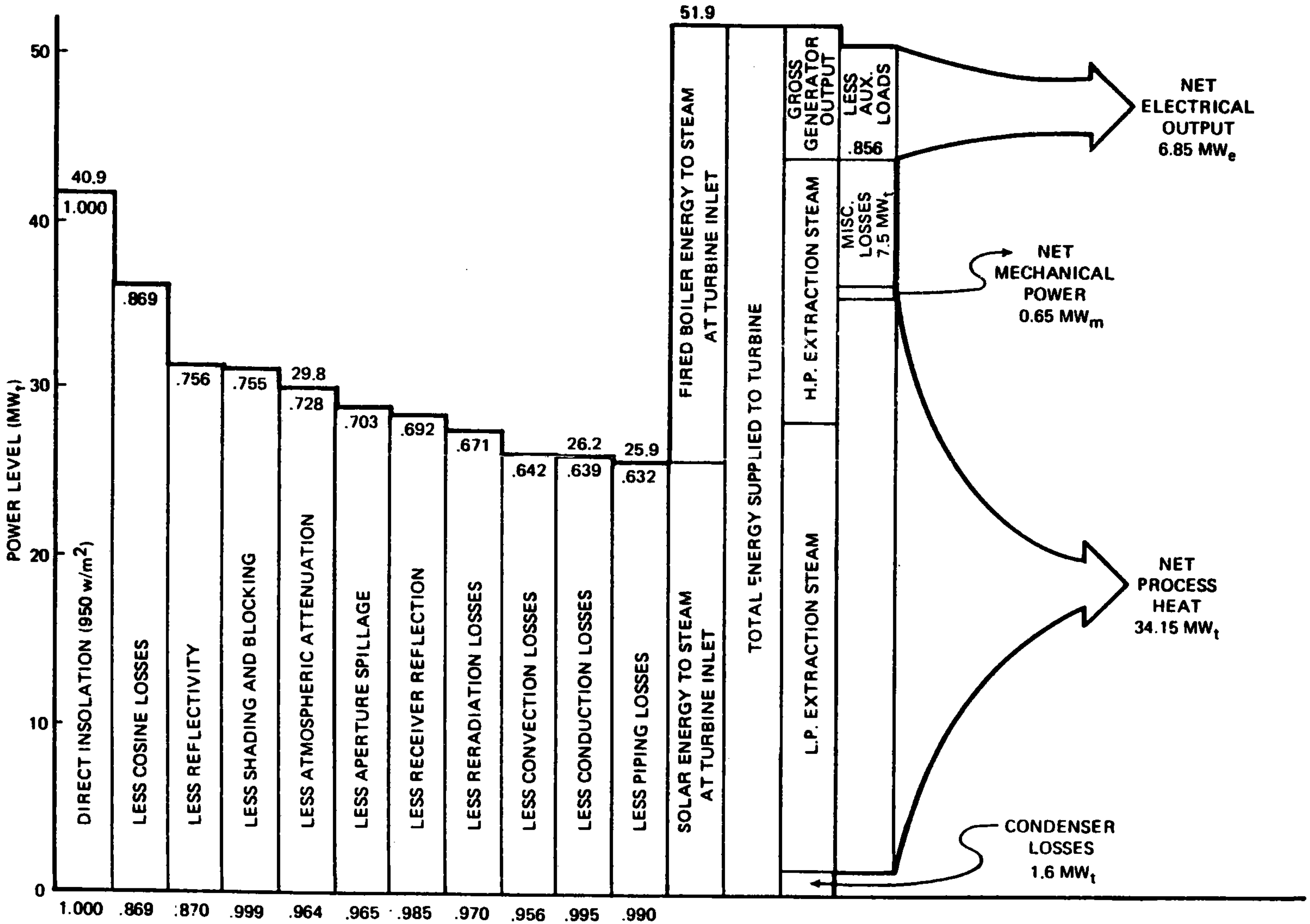


Figure 4-6 STAIRSTEP EFFICIENCY DIAGRAM – DESIGN POINT

The net outputs are also shown in Figure 4-6. The largest portion is process heat, delivered from both extraction headers. A small amount of mechanical power is produced in the factory equipment drive turbines. The electrical auxiliary loads used to compute the net electrical output include both the existing power cycle auxiliaries (925 kWe) and the added power required by the solar facility (225 kWe). The miscellaneous losses shown include power plant steam demands (2.8 MWt) such as soot blowers and oil heaters, makeup water tank losses (2.6 MWt), condenser liquid drains (0.3 MWt), and other losses (1.8 MWt) such as equipment efficiencies and thermal losses in piping and equipment.

The cogeneration utilization efficiency, calculated by the equation below, gives a design point value of 0.803:

$$\text{Cogeneration Utilization Efficiency} = \frac{\text{Total Net Power Outputs}}{\text{Total Power Inputs}} = \frac{\text{MWe} + \text{MWm} + \text{MWt}}{\text{MWt input}}$$

Winter and Summer Solstice. Stairstep diagrams were not developed for these two operating points because the only significant change from the design point is the cosine loss factor. These values are 0.911 and 0.804, respectively, compared to the design point value of 0.869.

Annual Performance. The annual performance of the solar facility, shown in Figure 4-7, was estimated using the STEAEC program. The average daily solar insolation available, according to the revised insolation model discussed in Appendix C, is 6.85 kWh/m^2/day or 2 500 kWh/m^2 annually. A 90 percent availability factor was assumed for the energy delivered to the mill, but since a 74 percent annual average weather factor is already included in the 6.85 kWh/m^2/day, solar input, the numerical

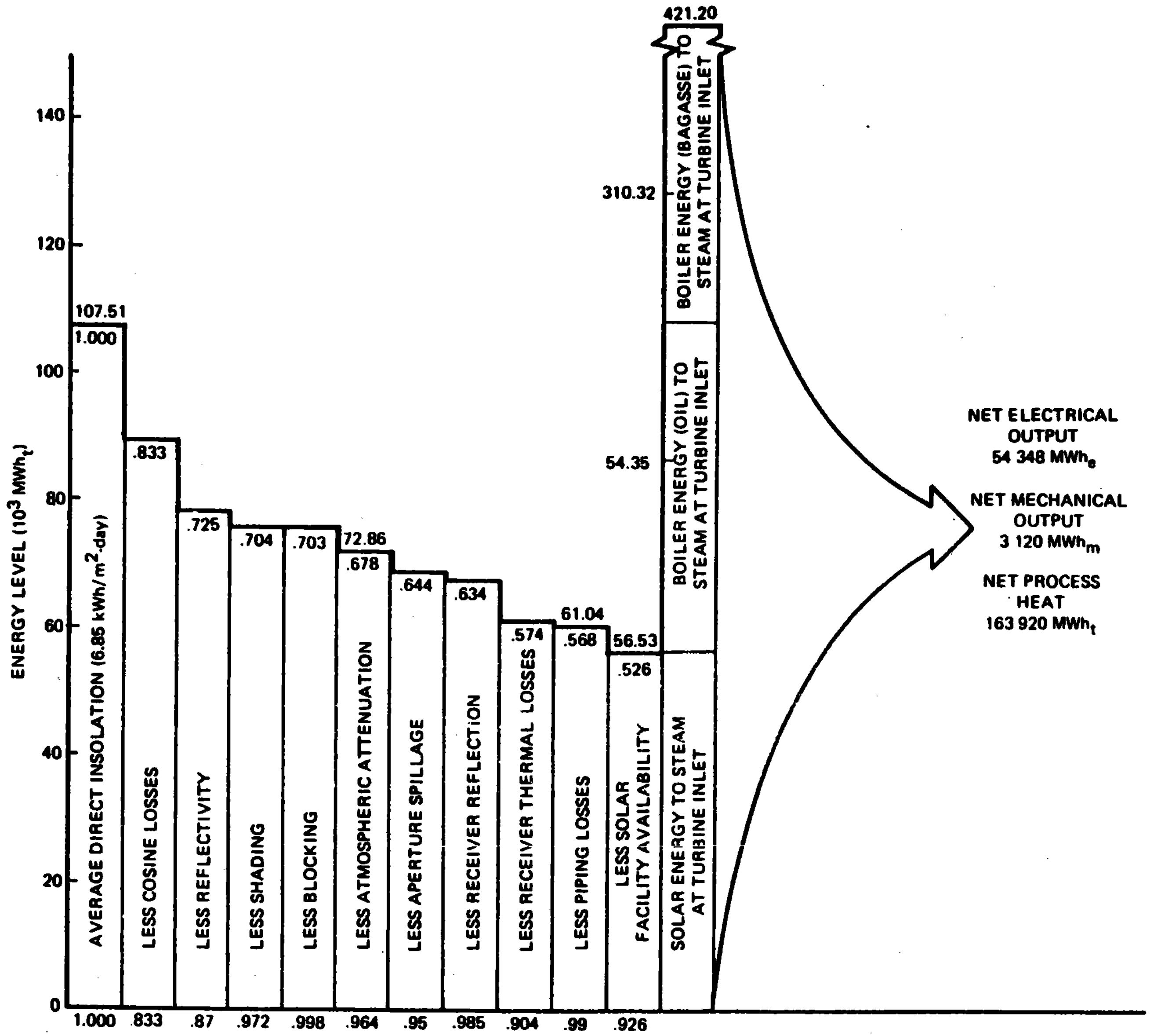


Figure 4-7 STAIRSTEP EFFICIENCY DIAGRAM — ANNUAL AVERAGE

availability value applied in the stairstep was 0.926. This value eliminates the double counting of unavailability due to simultaneous weather and equipment outages which would be the result of a value of 0.90 being used in the stairstep.

The estimated energy delivered to the mill is therefore 56 530 MWht, or 1.31 $MWht/m^2$ of heliostat area annually. The annual stairstep also shows that solar energy contributes 13.4 percent of the energy supplied to the main steam line, with oil and bagasse supplying 12.9 and 73.7 percent, respectively. When the annual operating cycle is considered, an estimated displacement of 48 percent of the typical annual oil consumption, or 4 580 m^3 (28,800 bbl) of No. 6 fuel oil is realized. The solar energy delivered to the main steamline is equivalent to a savings of 5 817 m^3 of oil at 38.6 x 10^6 kJ/m^3 (36,582 bbl at 5.8 x 10^6 Btu/bbl) with a boiler efficiency of 90.5 percent. The difference between these two equivalent estimates is due to the actual energy control of the No. 6 oil used at Pioneer Mill (6.45 x 10^6 Btu/bbl) and the additional electric power generated as a result of solar operation that results in oil savings by Maui Electric Company.

A summary of monthly performance values is given in Table 4-2. The average monthly oil displacement varies from 67 percent in September to 36 percent in December. If the solar facility were sized to displace all the oil consumed with average weather conditions, serious bagasse storage overflow problems would occur during clear weather.

The estimated additional gross electrical generation as a result of the solar retrofit is 1 696 MWhe. After accounting for the additional electrical

Table 4-2

MONTHLY PERFORMANCE SUMMARY

Month	Weather Factor	Average Direct Insolation kWh/m^2/day	Peak Solar Power Delivered (MWt)	Clear Day Energy (MWht/day)	Monthly Average Energy (MWht)*	Clear Month Oil Displacement (%)	Average Month Oil Displacement* (%)
JAN	.75	6.05	26.5	203	4 362	89	62
FEB	.74	6.41	26.5	215	4 122	78	53
MAR	.71	6.62	25.9	221	4 498	65	43
APR	.71	6.95	24.9	221	4 357	74	48
MAY	.73	7.34	23.6	217	4 549	78	52
JUN	.75	7.60	22.8	213	4 447	80	56
JUL	.75	7.56	23.0	215	4 628	90	62
AUG	.76	7.46	24.1	218	4 752	85	60
SEP	.77	7.29	25.3	221	4 719	94	67
OCT	.75	6.77	26.1	217	4 661	61	42
NOV	.75	6.22	26.4	207	4 314	69	48
DEC	.74	5.90	26.4	197	4 192	53	36
Annual Average	.74	6.85	--	213.7	4 711	--	--
Annual Total	--	2 500	--	78 001	56 530	--	--

* Includes 90% availability for solar facility.

auxiliary loads for the solar portion of the facility, primarily heliostat drives, receiver feed pumps and the electric superheaters, the net added electrical generation is 133 MWhe.

The annual cogeneration utilization efficiency, using the values displayed on the annual stairstep diagram, was calculated to be 52.6 percent. This value is significantly lower than that calculated for the design point, primarily because the factory (cogeneration demand) operates only about 200 days/yr (5 days/week during harvest season) while the power generation equipment is operated throughout the year.

4.6 ENERGY LOAD PROFILE

The energy load profile has both a weekly and a seasonal pattern; both must be included in the operational analysis of the plant. The factory, and hence the cogeneration portion of the mill, operates only 5 days/week during the 40-week grinding (harvest) season. During weekends of the grinding season and during the off-season, only the power generation equipment is operated, primarily to satisfy irrigation requirements or demands from Maui Electric Company.

The daily energy profile for a grinding day corresponding to the design point, is shown in Figure 4-8. Solar energy supplies about 50 percent of the energy in the main steam, but less than 50 percent of the flow, because the feedwater heater causes the boiler cycle to have a smaller enthalpy rise than the solar receiver cycle. Total turbine throttle flow drops slightly during solar operation because of lower extraction flow to the feedwater heater. The outputs are constant throughout the day with only the electric auxiliary load varying because of solar operation.

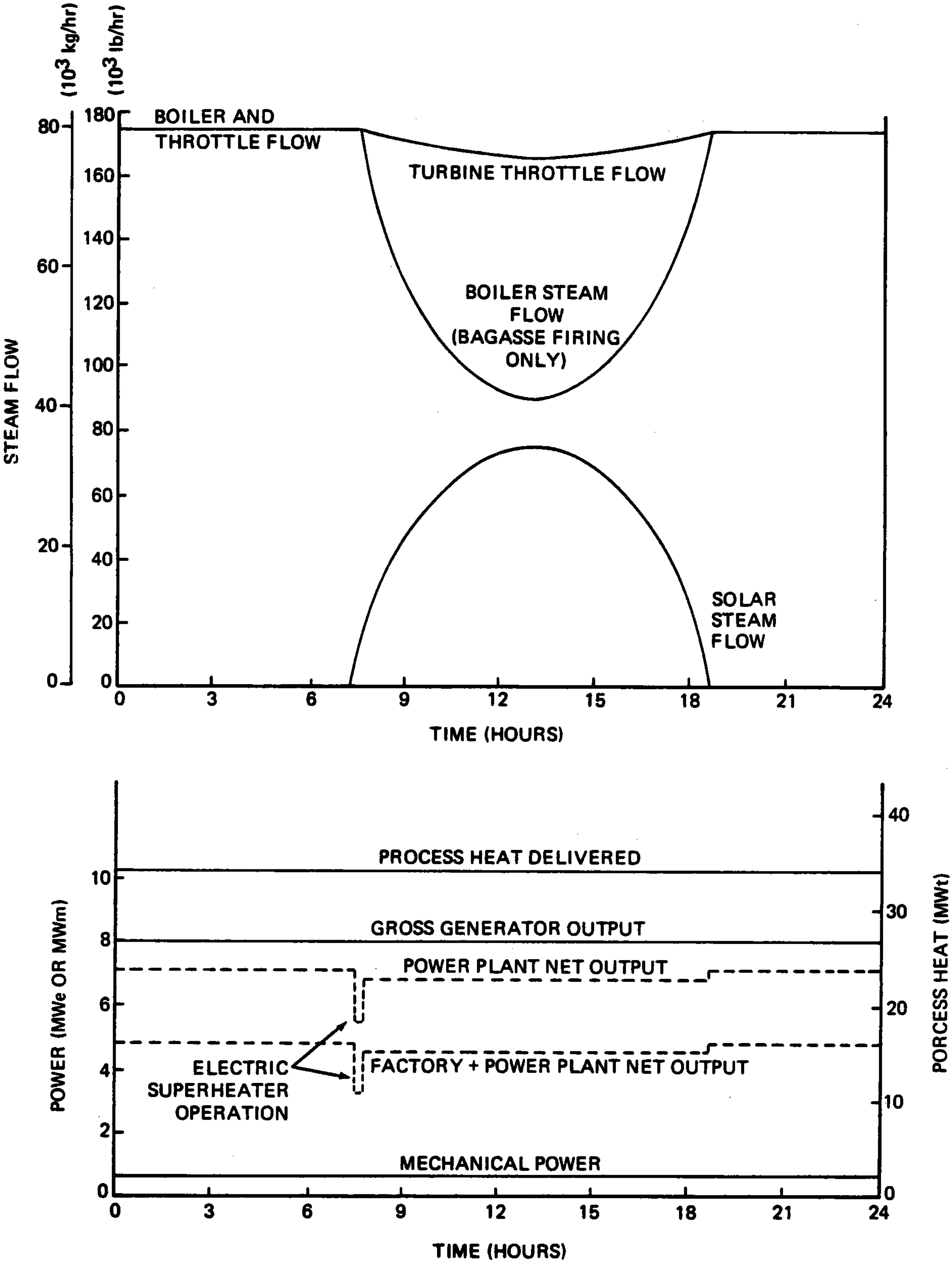


Figure 4-8 DAILY ENERGY PROFILE – GRINDING SEASON WEEKDAY (CLEAR WEATHER)

The energy profile for a weekend day during the grinding season is shown in Figure 4-9. Without factory operation, there is no process heat or mechanical drive output, but there is some residual factory auxiliary load. Although only 5 MWe is usually needed for this time period, the generator gross output is increased to 8 MWe and the condenser dump valve is actuated to allow the turbine to absorb all the solar steam flow. The boiler flow reaches the minimum operating point when the solar input is maximum, illustrating the criteria used for the selection of the size of the solar facility. Bagasse is burned in the boiler when available, except for boiler flows less than 18 150 kg/hr (40,000 lb/hr) when oil must be burned instead.

The energy profile for an off-season day is shown in Figure 4-10. The improved collector field cosine and the shorter solar day are included for the December through February off-season. The turbine throttle flow is higher than for the preceding figure because the makeup water evaporator is routinely operated during the off-season.

Figure 4-11 illustrates the weekly energy profile during the grinding season. The factory normally operates from Monday afternoon through Saturday afternoon. All the fuel oil consumption takes place during the weekend, after the stored bagasse has been consumed. The jagged pattern of the stored bagasse inventory curve is because excess bagasse is available for storage during solar facility operation but the supply of bagasse is slightly below the demand at other times. The large difference in steam flow between factory operation and shutdown is due to the process heat load.

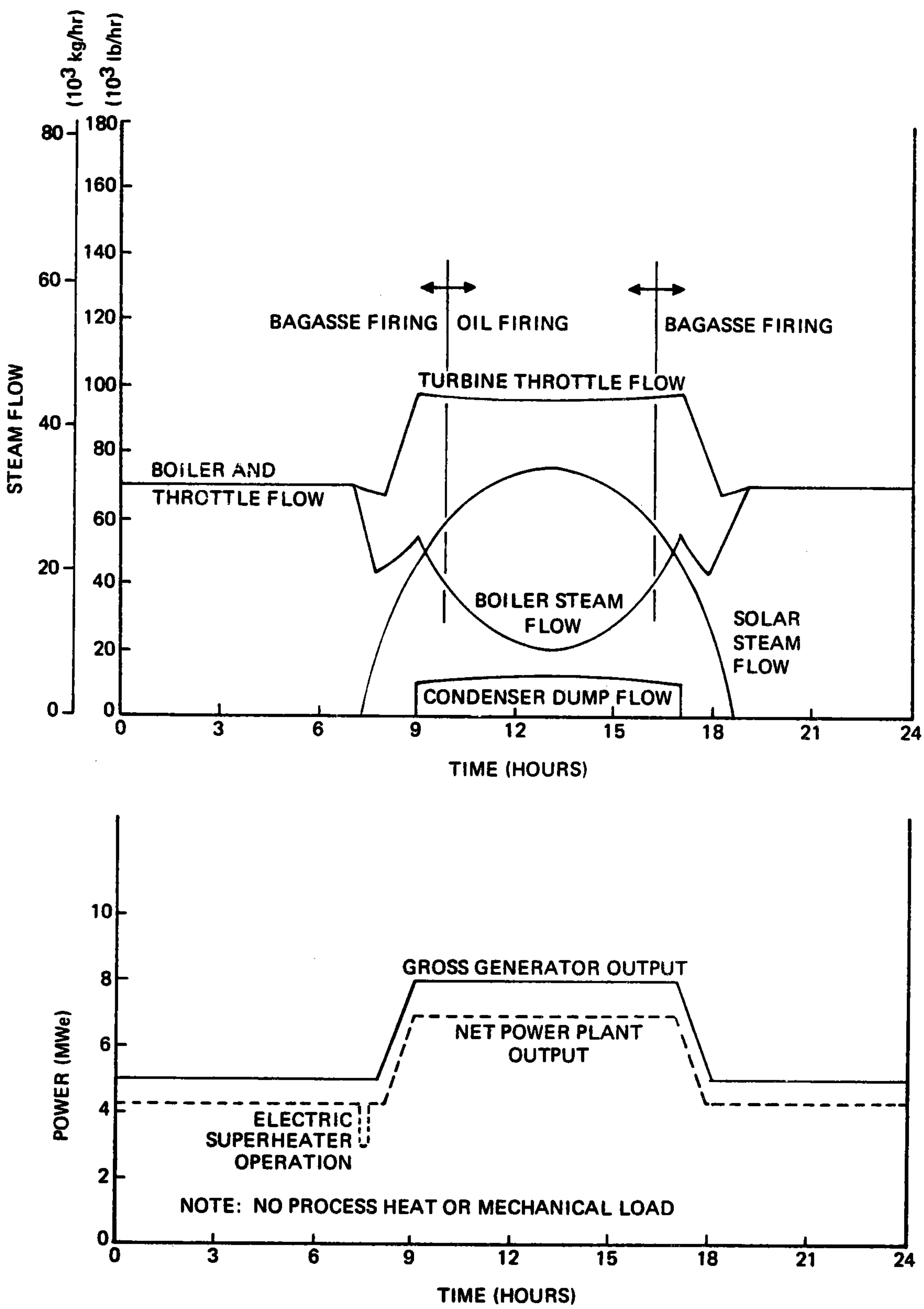


Figure 4-9 DAILY ENERGY PROFILE – GRINDING SEASON WEEKEND (CLEAR WEATHER)

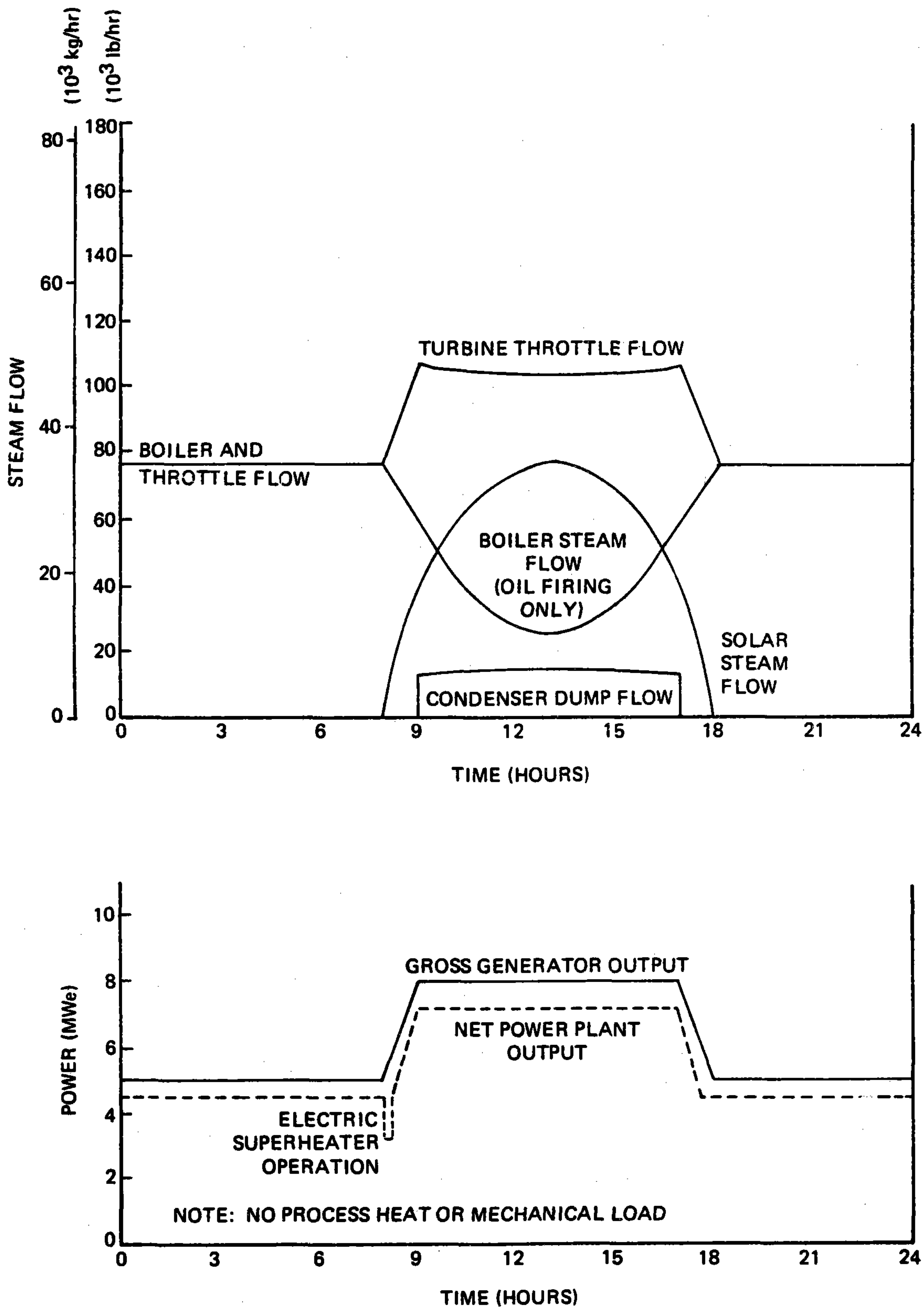


Figure 4-10 DAILY ENERGY PROFILE – OFF SEASON (CLEAR WEATHER)

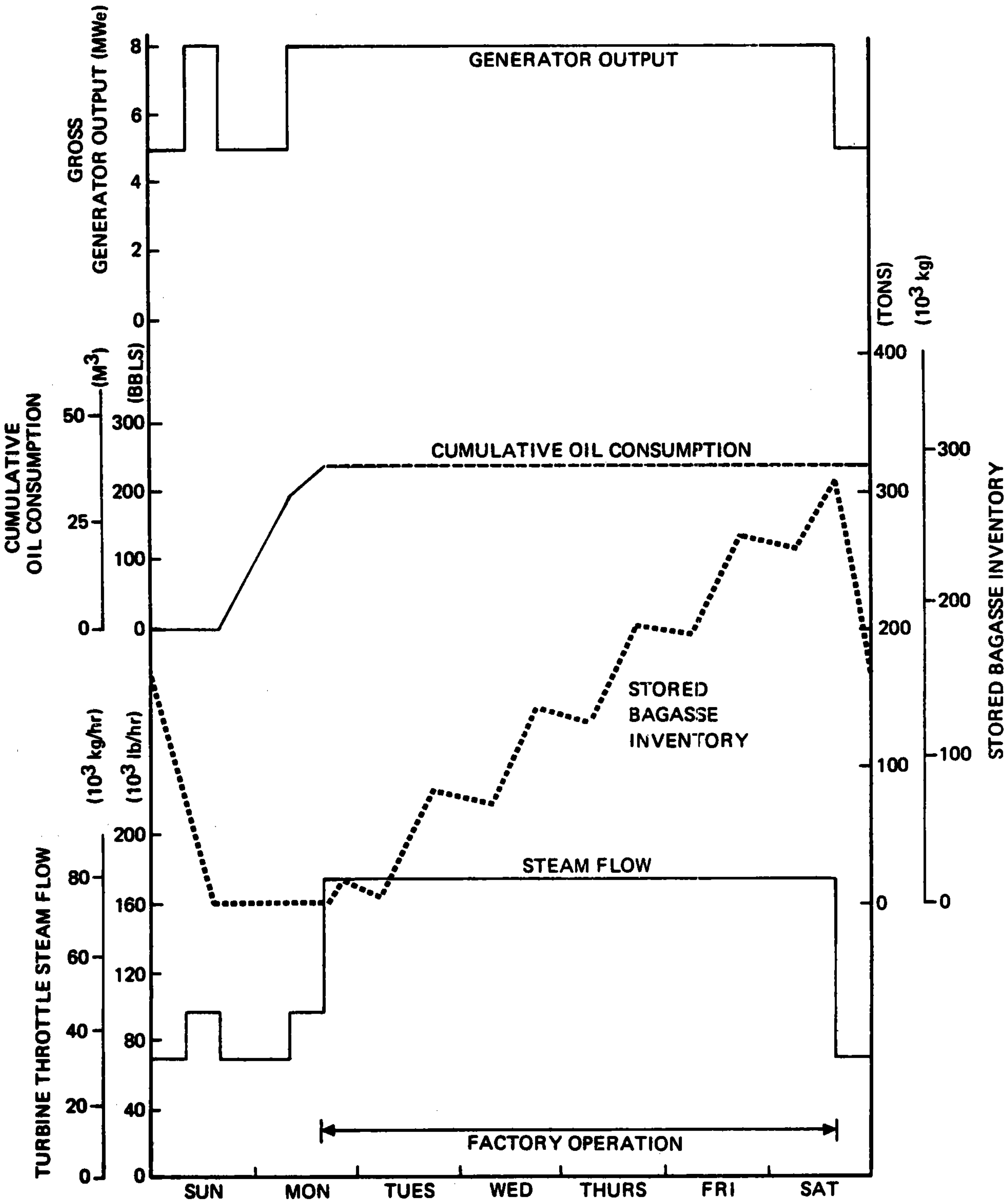


Figure 4-11 WEEKLY ENERGY PROFILE — GRINDING SEASON (AVERAGE WEATHER)

During the off-season, the weekly energy profile is very simple, as illustrated in Figure 4-12. No bagasse is available and much more oil is consumed to satisfy the irrigation demands than for the grinding season.

4.7 CAPITAL COST SUMMARY FOR PROJECT

A summary of the overall capital cost estimate for the solar cogeneration facility at Pioneer Mill is given in Table 4-3. All cost estimates are in first quarter 1981 dollars. To convert to average 1980 dollars, a factor of 0.92 should be used. The detailed construction cost estimates and the assumptions used are given in Appendix A.

Table 4-3

CAPITAL COST ESTIMATE SUMMARY

Cost Code	Item	Cost ($ x 1,000)
5100	Site Improvements	1,412
5200	Buildings	327
5300	Collector System	13,476
5400	Receiver System	3,579
5500	Master Control System	371
5600	Nonsolar Energy Systems	1,860
5700	Thermal Transport System	3,181
Total Direct Cost		24,176
	Indirect Cost	1,424
Total Field Costs		25,600
	Engineering Services	2,600
Total Field and Office Costs		28,200
	Contingency	4,200
	Fee	1,000
Total Construction Cost		33,400

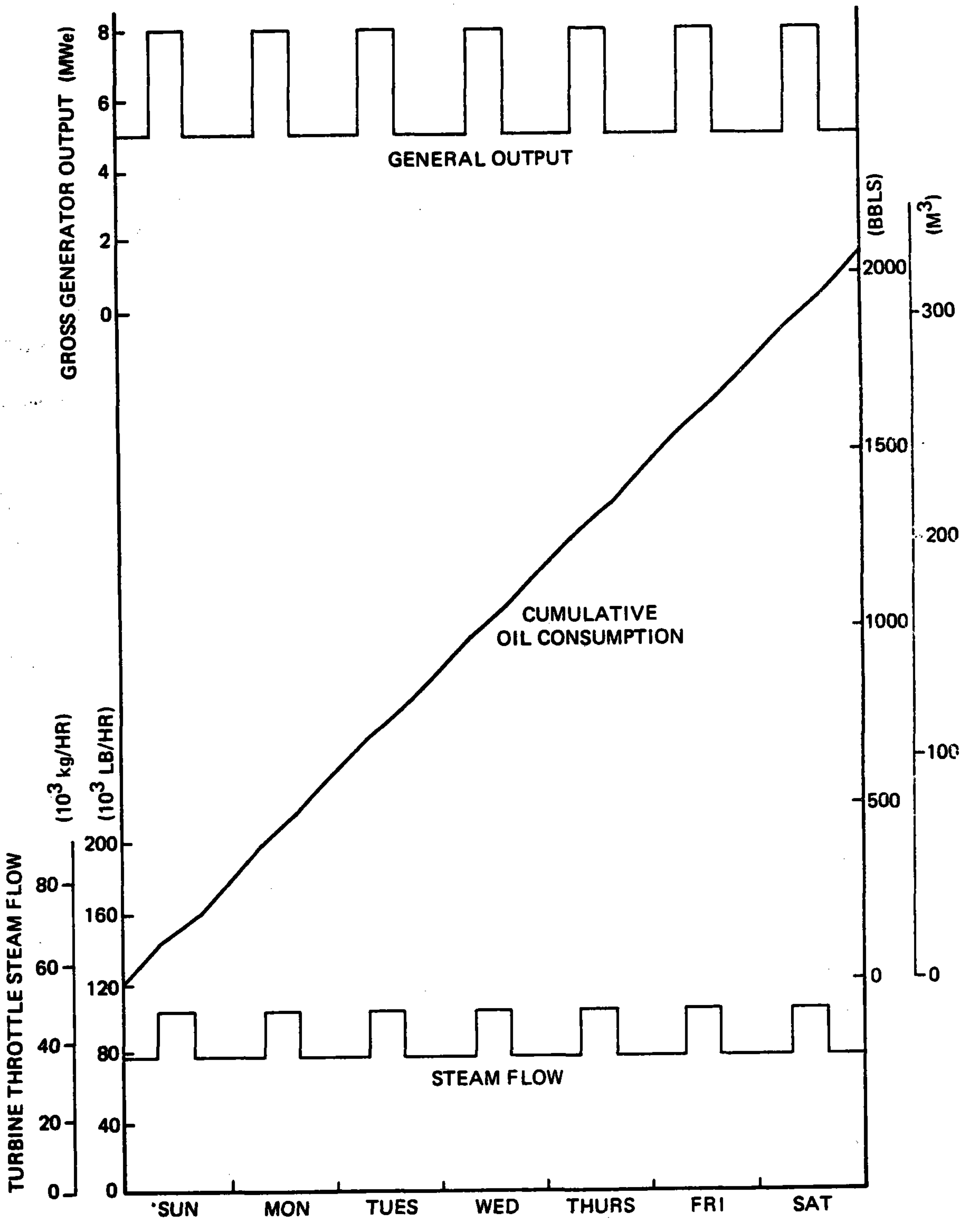


Figure 4-12 WEEKLY ENERGY PROFILE – OFF SEASON (AVERAGE WEATHER)

The construction cost estimates are based on the conceptual design and engineering information prepared for this study, including system descriptions, equipment lists, and drawings.

The cost-code account used in this study follows the standard code given in the system specification for a solar cogeneration facility. The visitors center and the building structure at the base of the receiver tower are included in 5200. The new bagasse house and conveyors are listed under 5600. Figure 4-13 depicts the general cost-code account boundary zones on a functional schematic diagram. Cost-code account number 5100 is excluded from the figure. This is the land and general site preparation not specifically related to or included in other systems. Further details of accounts 5300 through 5700 is included with the system characteristics in Section 5.

Construction cost estimates are based on informal vendor quotations obtained by Bechtel as well as extrapolations from current Bechtel information, with the following exceptions:

- Heliostat costs (less foundations and external wiring) were supplied by Northrup
- Receiver costs were supplied by Foster Wheeler
- Bagasse house and conveyor costs were supplied by Okahara, Shigeoka and Associates

4.8 OPERATING AND MAINTENANCE COSTS AND CONSIDERATIONS

Operating and maintenance (O&M) costs for the solar cogeneration facility at Pioneer Mill have been estimated and are summarized in Table 4-4. Annual costs are estimated at $406,000 per year in first quarter 1981 dollars.

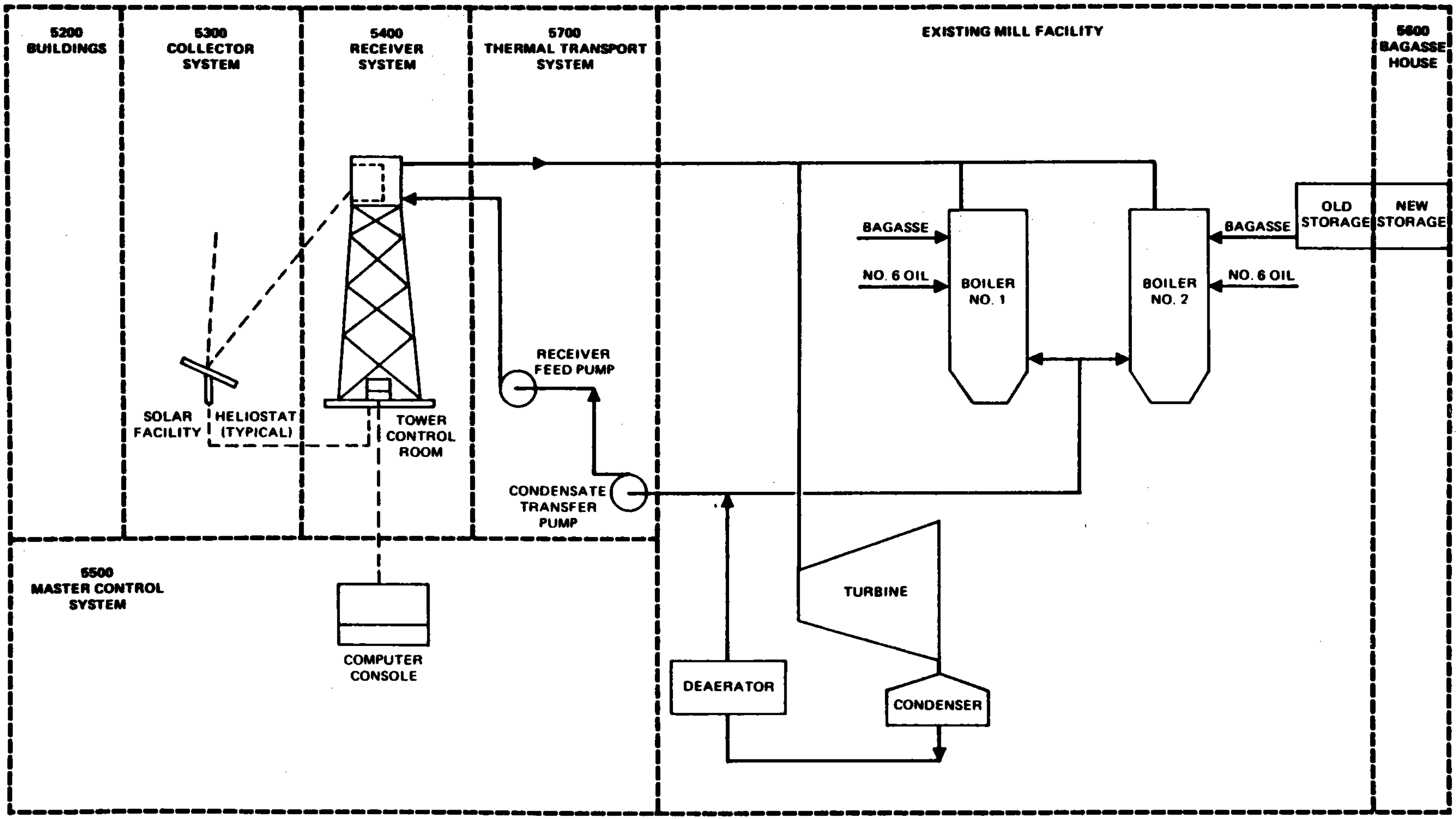


Figure 4-13 FUNCTIONAL SCHEMATIC SHOWING COST ACCOUNT BOUNDARIES

The O&M cost estimates for the solar facility have been developed on a system basis using experience from Bechtel and the subcontractors. Details of the estimates and assumptions are given in Appendix A.

Table 4-4
SOLAR FACILITY OPERATING AND MAINTENANCE COSTS

Item	Costs, $ Per Year
Operations	243,500
Maintenance Material	89,800
Maintenance Labor	72,700
Total O&M Costs	406,000

4.8.1 Existing Mill Facilities

The operation and maintenance experience at Pioneer Mill is discussed in Section 2.7 of this report. No change is expected in the mode of operation of the existing mill facilities except that the existing boilers will be operated at lighter loads with the oil consumption being reduced by about 4 580 m^3/yr (28,800 bbl/yr).

4.8.2 Solar Facility

Operations. Operations include the cost of wages for the solar facility operating personnel and the cost of operating consumables. For operating personnel, even with automated controls, it is assumed that full time operating technicians are based in the control room at the base of the receiver tower. These operators give coverage to the solar facility during its hours of operation. One operator is in the control room at all times. Two other roving operators are involved with the other activities in the solar facility and give backup control room coverage. Operating consumables include water, and supplies.

Maintenance. Maintenance costs include the cost of materials used either as spare parts or for repairs, and the cost of labor either scheduled or unscheduled.

Provision is made for minor solar system repairs to be carried out in the building at the base of the receiver tower where spares, mainly for the collector system, will be kept. Two specialized vehicles also are used for collector field maintenance. One is a vehicle for semi-automatic cleaning of the heliostats. The other vehicle is for electrical-electronic troubleshooting and repair of the heliostats. Larger repairs will be carried out in the existing mill facilities. Some repairs requiring specific techniques will be subcontracted to outside suppliers. Specialized servicing of equipment will be done on a contract basis.

The largest item of scheduled maintenance for the collector system is heliostat washing. The washing will be done by a two-man crew using the semi-automatic vehicle. Unscheduled maintenance estimates for the collector system are based on assumed failure rates per year for the main components.

Due to the significant impact of failure of key pieces of field control instrumentation, such as the heliostat array controller, it is cost effective to maintain complete backup units regardless of low failure rates. Thus complete redundancy is provided for the centralized controller system controls.

The receiver system is similar to a conventional steam boiler and will be subjected to inspection and maintenance procedures similar to the mill boilers. The mill boilers are overhauled during the 3-month mill shutdown period with about 6 weeks being allowed for each planned outage. The present water side condition of the mill boilers, after 15 years of operation, is outstanding. Because the receiver is simpler in design, a two week annual outage for routine maintenance should be sufficient.

Equipment in the thermal transport system requires normal maintenance. These items are mainly pumps, valves, pipework, and instrumentation all of which are routine work to the mill maintenance personnel. Where possible redundant equipment is installed, spares also will be kept on site to cover anticipated failures. To improve reliability, only equipment of proven design and service will be used. In addition, the equipment is designed for easy access.

Maintenance labor is required for scheduled or unscheduled maintenance. The mill maintenance personnel will be used whenever possible, with additional employees for new specialized areas and to cover the increased workload. It is estimated that one heliostat technician and one new control and instrumentation technician are required for the solar systems.

Routine site maintenance also is required at the heliostat field for weed control, painting, and servicing of the elevator and lights on the tower.

The solar cogeneration facility is the first-of-a-kind demonstration of a solar facility being integrated with an existing commercial process. Therefore, additional monitoring, testing, and data recording may be required during the first phase of operation. These requirements could have an impact on the O&M costs. Additional personnel may be required for these tasks as well as analyzing the data and writing reports. No allowance has been included in the annual O&M cost for this factor.

The checkout and startup phase, as well as the training of operators, will requires mill personnel to become familiar with the new systems. This will be an additional O&M cost; no allowance for this item is included in the annual O&M cost summary.

4.9 SUPPORTING SYSTEM ANALYSES

4.9.1 Reliability

The addition of the solar equipment is not expected to decrease the reliability of the existing mill operation. The interfaces are designed to be as simple as possible. All piping connections can be quickly isolated from the mill. The only other major change in the mill is the bagasse house addition. The bagasse handling interconnections with the boiler and existing bagasse house are carefully integrated so that reliable operation can be maintained, since outages of the conveyers result in excess oil consumption.

Careful attention has been paid to reliability in the design of the solar addition. Complete redundancy of the heliostat control computers was included. Design of the receiver to the applicable codes and standards, with provisions for warmup with mill steam and cavity doors to decrease the rate of cooling, will lead to reliable operation during the plant lifetime.

4.9.2 Maintainability

The solar facility will be designed to be compatible with existing plant maintenance practices. Easy access for maintenance will be provided vided and components such as electronic units, motors, and valves will be easily serviced and replaced. In most cases faulty components will be replaced by spare units. A minimum of specialized equipment will be required for plant maintenance. Major repairs and high pressure welding in the mill facility is done with outside contractors; this procedure will be followed in the solar facility.

4.9.3 Commercial Availability

Manufacturing techniques required to fabricate and install the solar facility equipment are not significantly different from those required for industrial equipment. A manufacturing industry of sufficient production capacity will need to be established for the heliostats. Low production rates expected in the beginning years will result in higher unit costs, and government incentives may be necessary to defray costs related to establishing a new industry.

Collector System. All materials and processes used in the heliostats are within the present state of the art and, generally, are commercially available items. The mirror module design, materials, and bonding process are virtually identical to those presently used on the ARCO-Northrup prototype heliostats, which have been built and are currently undergoing testing. While the electronic collector field control and computer software is unique to the heliostat requirements, the subcomponents are commercially available items.

In summary, no unique or advanced-technology materials or processes are required for the collector system.

Receiver System. The solar receiver is a natural-circulation steam boiler with separate superheater circuitry and an integrated twin-cavity configuration. All components use current materials technology, are commercially available, and require little development work. Therefore, the receiver can be manufactured and installed using standard practices.

Other Systems. All other solar facility equipment, including the thermal transport system and the master control equipment, are commercially available items. No restrictions were identified to their application to the solar cogeneration facility.

4.9.4 Safety

The choice of water-steam as the working fluid in the solar cogeneration systems keeps the facility designs as simple as possible. Also, the type of equipment used in the receiver system is familiar to the mill operators. Thus, the safety aspects are simplified, and safe operation of equipment is anticipated when normal industrial safety precautions are enforced. Equipment will be fabricated and installed in accordance with applicable codes, standards, and regulations required for the industrial power plants.

The solar facility design includes provisions for assuring the safety of crews for inspection, maintenance, and repair of equipment on and in the receiver tower and in the heliostat field. Abort switches and manual override switches are located in potentially dangerous areas for the protection of personnel inadvertently placed in hazard. The inclusion of the emergency steam turbine generator ensures that an electric power supply will be available to put the solar systems into a safe shutdown mode.

The potential solar safety hazards to the public are also considered in the conceptual design. The high chain-link security fence around the perimeter of the heliostat field restricts public access to the site. Visitors are allowed to view the solar cogeneration facility only from the visitors center which is north of and away from the heliostat field and mill facility.

The receiver tower is located 610 m (2,000 ft) from the main highway which runs alongside Pioneer Mill. However, the collector field is not in the normal line of vision of the public on the highway. A residential area northeast of the millyard is relatively close to the collector field. It may be necessary to use a solid perimeter fence on the boundary nearest to this property to avoid glare. In addition, the collector field control system is continually monitoring the status of each heliostat for any misalignment and will take corrective action, or alarm any hazard. Another safety hazard from misdirected heliostats is the potential for burns at the focal point of multiple heliostats, either on the ground or in the air. The focal point will be kept well above the ground to eliminate this hazard to the public. Aircraft observing the airspace restrictions over the town of Lahaina and keeping the legal distance away from the tower will not be in danger.

4.9.5 Environmental

The physical aspects of the environment considered in evaluating the impact of the solar cogeneration facility include topography, soils, and ground water quality, air pollution, and ambient noise.

hydrology and surface water management, local drainage patterns, surface Construction of the plant will require surface grading of approximately 0.17 km^2 (42 acres). As the surface of the selected site is relatively flat, large-scale changes in the topographic features are not necessary. Construction will also cause some alteration of the soils on the site. Heliostats shade the soil to varying degrees, which may alter cycles of natural soil heating and cooling or affect air circulation at or near the soil surface. Access roads, constructed with road oil and gravel or asphalt, alter drainage patterns and eliminate these areas as a biological substrate.

The modifications to natural topography may alter the runoff pattern for the site. However, new drainage ditches will be directed so that the ditches will make use of existing slopes and preserve the natural site drainage.

Ground water along the coast is subject to salt water intrusion resulting in nonpotable water. The water resources of the district are high level reservoirs.

Construction and operation of the solar cogeneration plant is not expected to have a direct impact on surface water quality. But since localized erosion may occur, increased turbidity in the nearby diversion channel may result. Soil stabilization measures can reduce erosion and turbidity problems.

The location of the proposed receiver tower and heliostat field appears to be beyond the delineated boundary of the 100 year flood. Moreover, the Corps of Engineers is planning stream improvements to mitigate flooding during heavy rains. The improvements include a diversion channel to be constructed between Kahoma Stream and the tower site.

Mirror washing with solvents or detergents could contaminate the soil, but judicious selection of chemicals, if used, will prevent significant impact on surface water resources.

Makeup water is required for the solar receiver. However, since the quantity required is only 680 kg/hr maximum (1,500 lb/hr), the volume has little impact on the mill process evaporators, the source of the makeup water. The continuous blowdown from the receiver of 680 kg/hr (1,500 lb/hr) is injected into the nearby wells which are used for irrigation water.

In the construction phase, there will be some temporary increase in the site noise level. During operation the ambient noise levels will be high near the emergency steam turbine. However, this equipment will operate infrequently. To reduce the noise, the emergency turbine exhaust is directed away from the residential area and is fitted with a silencer. Other established noise abatement procedures used in conventional power plant systems may be employed to reduce any nuisance to the residential area. These procedures include the use of acoustic insulation on the steam pipelines and specially designed valves.

During construction, the site work is expected to generate some temporary airborne dust, and the facility will have to meet all applicable regulations.

Field surveys will have to be conducted to determine the impact on plants and animals temporarily displaced from the site during construction. No long term impacts on the rodent, bird or insect populations are expected.

Some operating and construction personnel will probably be drawn from the area the facility serves. Other workers will come into the area and will affect housing and other community services. This impact will be minor due to the comparatively small labor force required.

In summary, the environmental impact of the solar cogeneration facility will be similar in nature to other solar power plants and will be minimal compared to other fossil-fueled power generating systems. Major advantages of the solar cogeneration facility over conventional plants include the displacement of fossil fuels with solar energy and the reduced combustion product emissions.

4.9.6 Institutional, Regulatory and Other Considerations

Government constraints can come from federal, state, and county authorities. State and local regulations are often more restrictive than federal regulations. Table A.2-1 of Appendix A summarizes the solar cogeneration facility permits and licenses required by the three authorities.

As shown in Table A.2-1, the list of potential regulators is considerable. The time and cost of licensing represents a major cost which has to be considered with any solar facility. In Section 7, a period of 12 months is allowed in the project schedule for preparing, submitting, reviewing, and approving the permits and licenses.

Potential issues that can arise from the proposed solar cogeneration facility have been considered. The analysis of these issues is based on the General Plan of the County of Maui, the Hawaii State Plan, and the State Functional Plan for Agriculture and Energy. The issues include:

- Energy - The desire to achieve energy self-sufficiency is the main goal. Encouragement is given to the development of alternative sources of energy

- Land Use - The objective is to use the land for the social and economic betterment of the residents. The loss of agricultural land to industry has to be considered against the gains made by the displacement of fossil fuels with solar energy and the reduced emissions

- Location - The proximity of the project to the historical area of Lahaina character and the residential area is an important consideration in tower design

- Environmental - Although significant environmental issues not likely to arise, any areas of concern must be investigated

- Safety - There are two safety issues, affecting either operational personnel or the general public. Hazards at issue are misdirected reflected rays which can potentially cause fires or burns, and glare problems

Section 5

SYSTEM CHARACTERISTICS

This section describes in detail the conceptual design of the solar cogeneration facility at Pioneer Mill, including the collector system, the receiver system, the thermal transport system, the master control system, and the nonsolar energy system. The description of each of these systems includes details of the major components and their locations, functional requirements, design, operating characteristics, performance estimates, and cost estimates.

The conceptual design is based on the second-generation ARCO-Northrup II heliostat and a twin-cavity central solar receiver designed by Foster Wheeler. The solar steam supply is integrated into the operation of the existing mill facility to match the main steam generated by the existing boilers.

5.1 COLLECTOR SYSTEM

The collector system is the portion of the solar facility that includes the heliostat field and control system designed to deliver radiant power to the receiver during periods of sufficient insolation.

5.1.1 Description

Collector Field. The collector field configuration described resulted from field analyses and trade studies conducted to develop, within the physical, environmental and financial constraints, the most cost-effective collector that would deliver the required amount of energy to the receiver fluid.

The site is located approximately 600m (2,000 ft) north of the mill. There is a slight decrease in elevation, amounting to about 30m (100 ft) from the east to the west sides of the field.

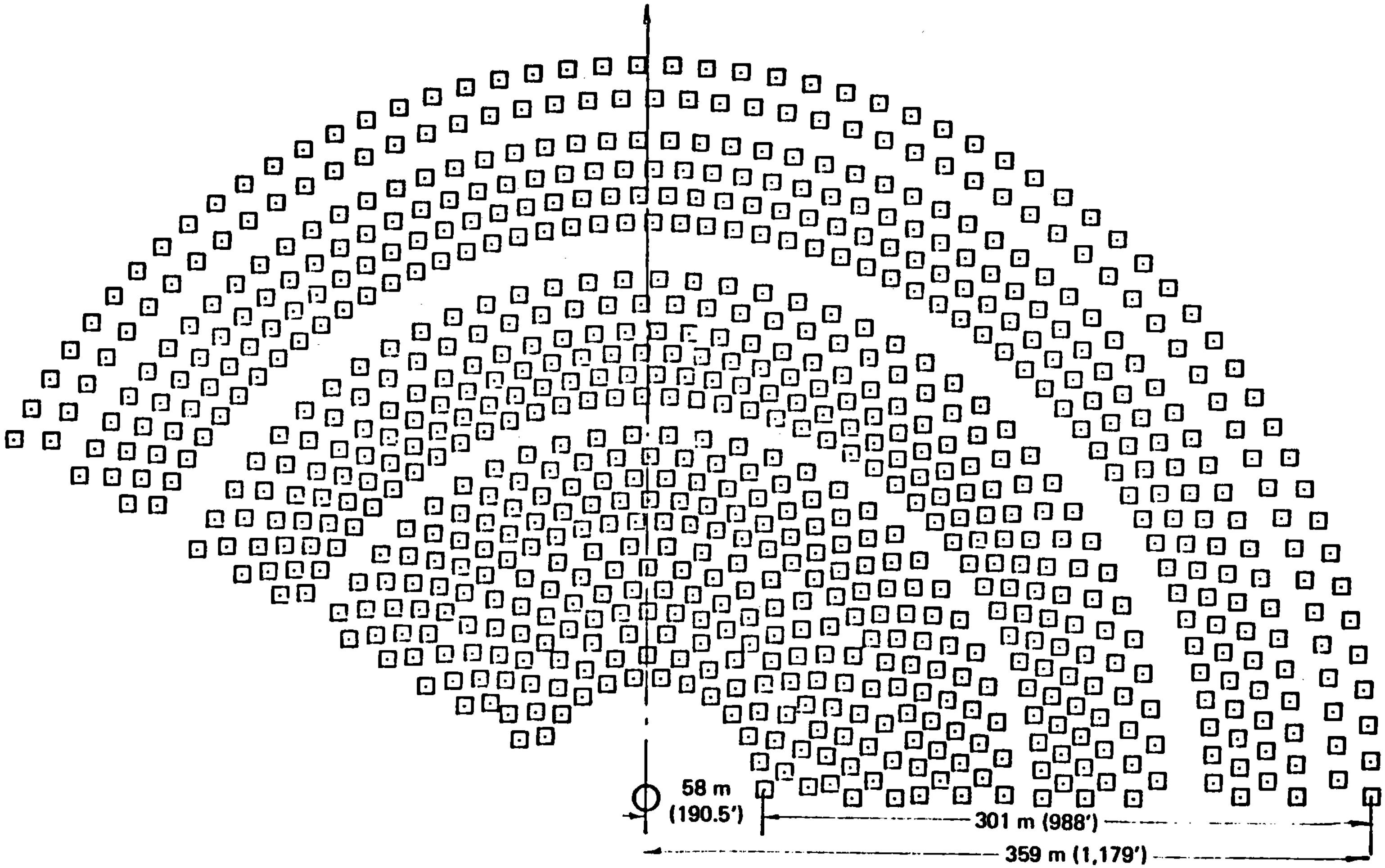
The collector field exhibits a radial stagger arrangement of 815 heliostats located on 24 tower centered arcs that lie within a 150° sector. The circular sector contains 0.17 km^2 (42 acres), which, coupled with the reflective surface area of 43 000 m^2 (462,920 ft^2), produces a packing density of 0.25.

The axis of symmetry of the field lies 15° east of north. This orientation produces peak performance almost an hour after solar noon (1 p.m. field).

Using the threshold of blocking as the basis for heliostat row spacing, four tower heights were evaluated. An empirical cost function was used to derive the relative field costs and resulted in the selection of a 76m (250 ft) aperture centerline elevation.

Figure 5-1 presents a plan view of the Pioneer collector field.

Heliostats. The heliostat characteristics used in the study correspond to those of the ARCO-Northrup II, which is one of the heliostat designs being developed for the DOE under the second-generation heliostat program. Each heliostat consists of a square array of 12 mirror modules. The principle features of this heliostat are presented in Table 5-1. Figures 5-2 and 5-3 show the front and back views of a prototype at the Northrup plant.



815 HELIOSTATS
76 m (250 ft) TOWER

Figure 5-1 PIONEER COLLECTOR FIELD – PLAN VIEW

Table 5-1

ARCO-NORTHRUP II HELIOSTAT CHARACTERISTICS

- Total mirror area 52.76 m^2 (568 ft^2)
- Height 7.75 m (25.38 ft)
- Width 7.44 m (24.41 ft)
- Weight, excluding pedestal 2 260 kg (4,985 lb)
- Mirror modules
  - Mirror surface 1.2 m x 3.66 m (4 ft x 12 ft)
  - Galvannealed sheet steel construction
  - Longitudinal C-web bracing
- Frame structure
  - Four building truss purlins
  - Cross bracing
  - Elevation axis torque tube
- Drive assembly
  - Elevation and azimuth drives
  - Stepper motors
  - Planetary and worm stages for each drive
  - 18 400:1 reduction ratio
- Pedestal, 0.61 m (2 ft) diameter steel pipe

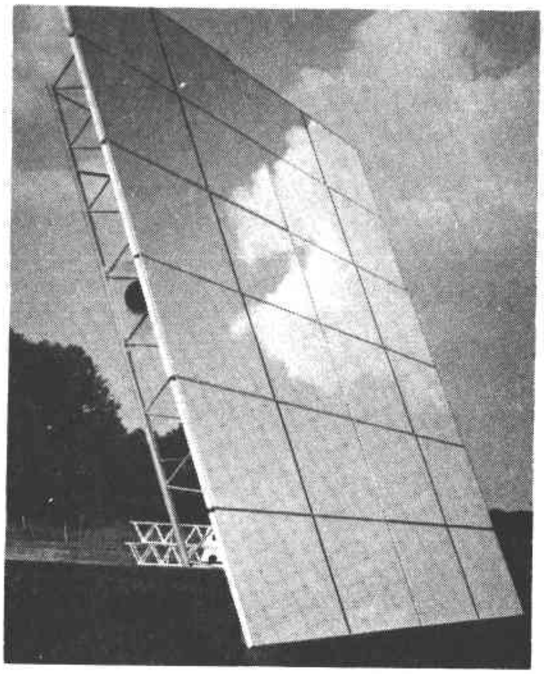


Figure 5-2 FRONT VIEW OF THE ARCO-NORTHRUP SECOND-GENERATION HELIOSTAT

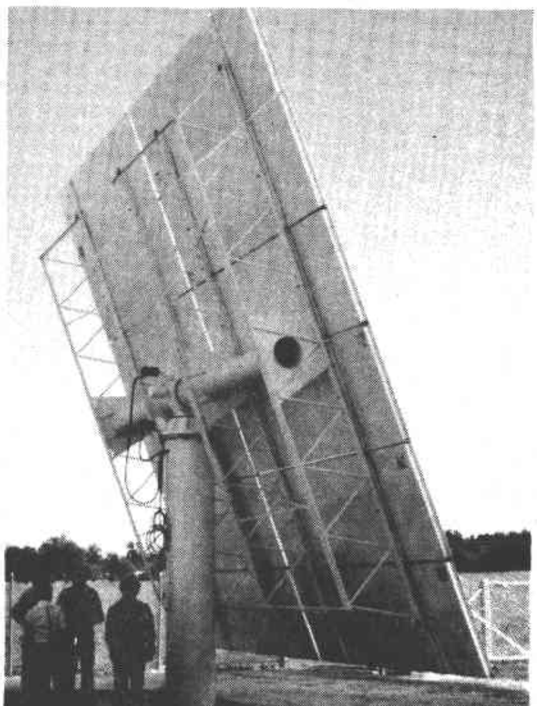


Figure 5-3 REAR VIEW OF THE ARCO-NORTHRUP SECOND GENERATION HELIOSTAT

Controls. Control of the Pioneer collector field is implemented by a computer system that is designed to: 1) bring the field to focus on the receiver in an orderly and predetermined manner; 2) accurately track the sun; 3) move to off-target tracking during lengthy cloud transients and/or receiver flow or temperature levels that fall outside established safety limits; 4) display heliostat status; 5) retire the field to stow position; 6) permit drop-out of individual heliostats for maintenance or calibration. Operation of individual heliostats from the master computer is also provided when field operations are not in progress. Normal manual operation for maintenance is through a hand held box that is plugged into the heliostat electronics package located on the pedestal.

The hardware system is divided into three subsystems; the Heliostat Array Controller (HAC); the Heliostat Field Controller (HFC); and the Heliostat Controller (HC). A block diagram of the system is shown in Figure 5.4.

The HAC consists of a Hewlett Packard (HP) 9825 computer located in the control room. Operation of this computer establishes the field operating mode, initializes mode transition interrupts, computes the sun position, drives the HFC, and interfaces with, and controls all data acquisition electronics. Individual heliostat operating modes are continuously displayed on a CRT Monitor. Modes are defined as: stowed, slewing, linebottom (off target tracking-low), linetop (off target tracking high), tracking and inoperative.

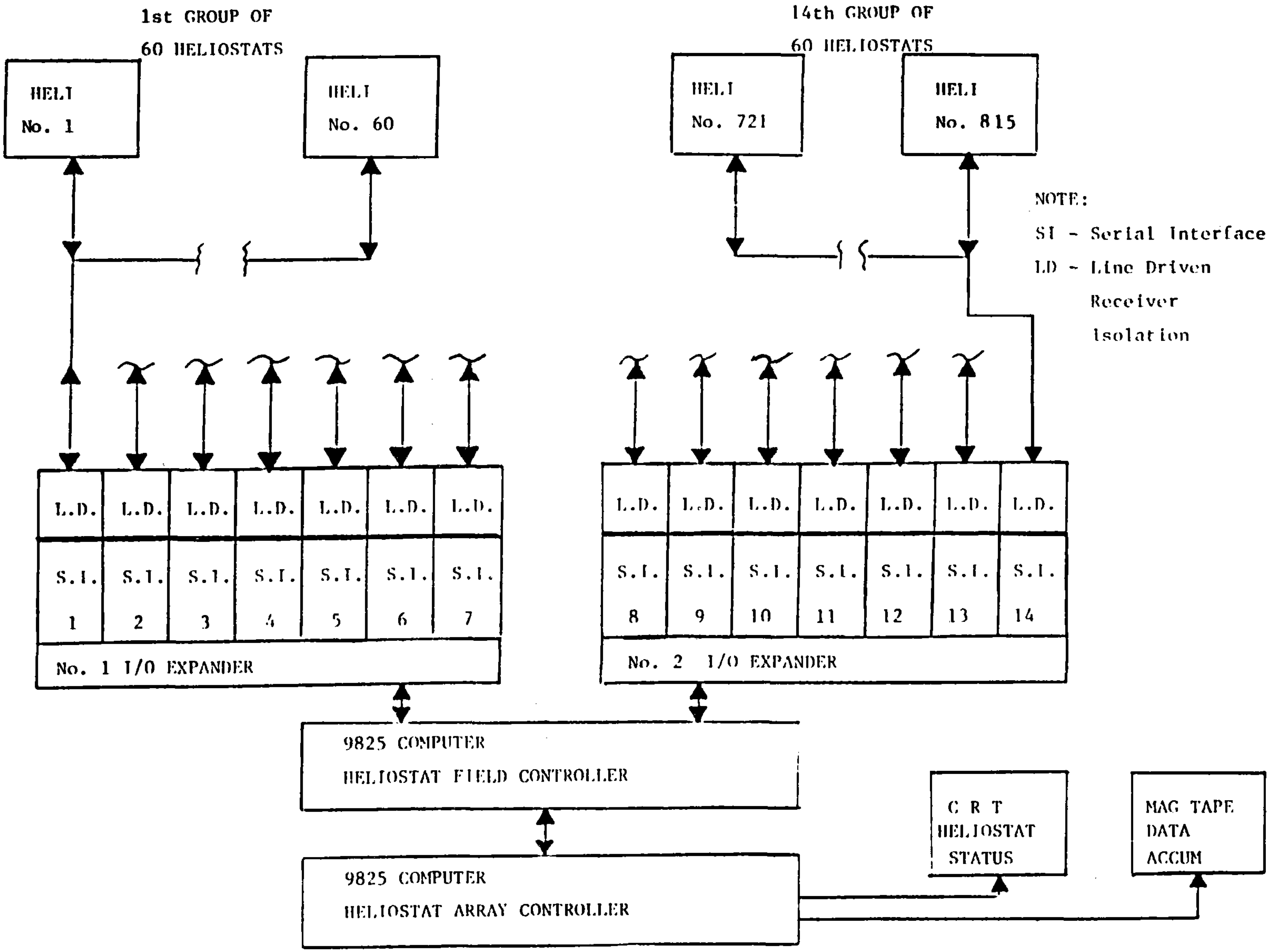


Figure 5-4 BLOCK DIAGRAM OF PIONEER COLLECTOR FIELD CONTROL SYSTEM

The HFC is also a Hewlett Packard 9825 (HP) computer. This computer is equipped with two HP 9878 I/O Expanders. Each I/O expander serves seven Serial Interface (SI) units. Each SI is connected through a RS 232 Line Driver to a data bus that serves 60 heliostats. The capacity of each SI is 64 heliostats but four addresses are reserved for emergency and special purpose requirements. This configuration will serve up to 840 heliostats.

The HFC, utilizing the heliostat and target coordinates and sun position computes the appropriate direction cosines for each heliostat. The HFC further utilizes this data to compute the azimuth and elevation increments required to update the heliostat coordinates. These increments are calculated relative to the heliostats reference position (limit switch).

The HFC routes the data to the appropriate I/O Expander which in turn places the data in the proper SI buffer for transfer to the 60 heliostat data bus.

The HC is located in the pedestal of the heliostat. The HC evaluates each address that arrives on the 60 heliostat data bus. Recognizing its individual address the heliostat processes the associated data. Accumulated azimuth and elevation position data are subtracted from the new update data; the remainder is converted to motor steps and fed to the dc translators for proper motor movement (if required).

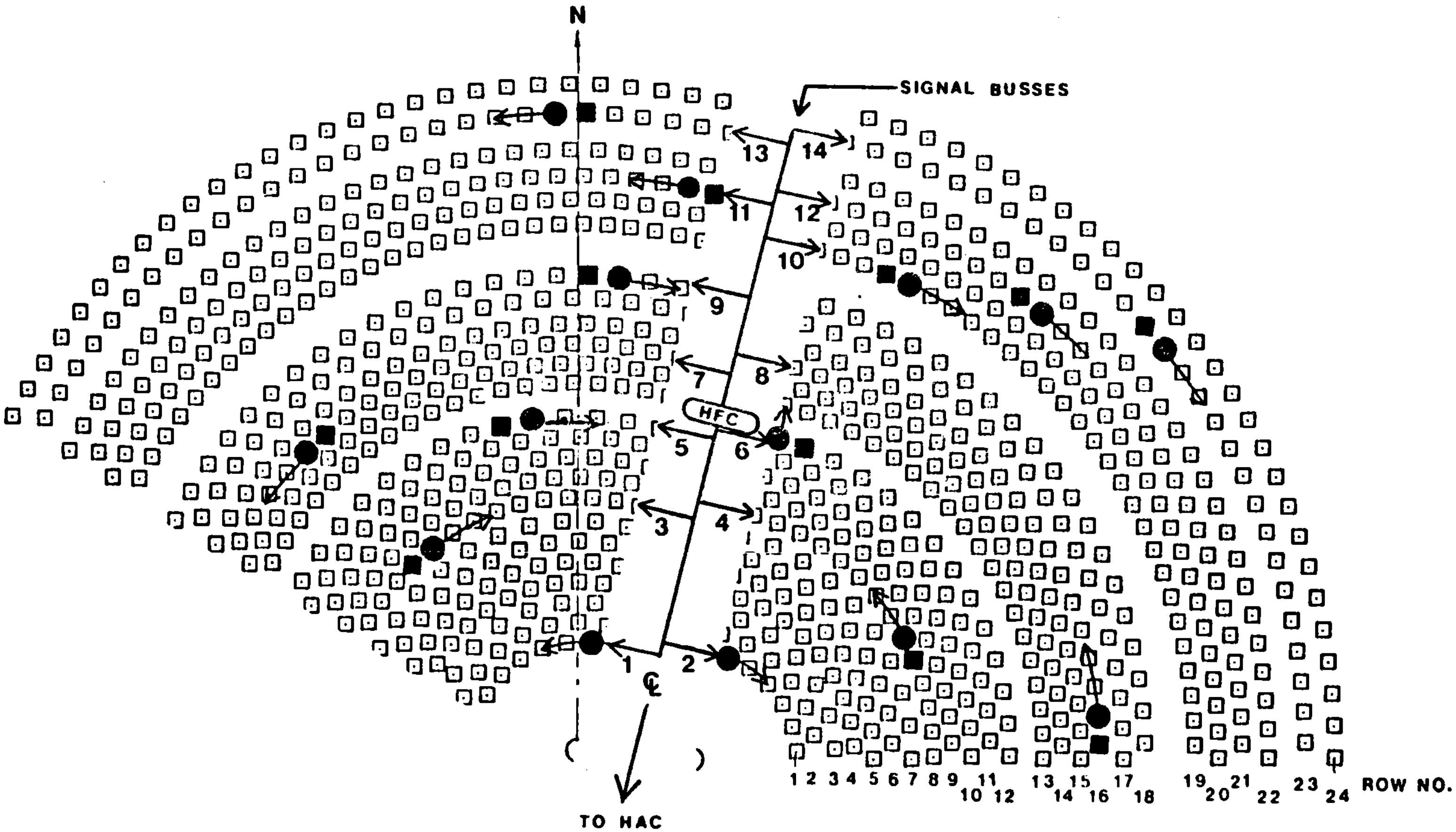
The return data containing the status of the heliostat is received and processed by the SI to the HFC which in turn relays the data to the HAC for display.

Field Signal Wiring. For control purposes the field is divided into two equal parts along the line of symmetry, which lies 15° east of the north-south line. Figure 5-5 shows the relationship of the 14 data buses to the HFC and HAC (at tower). This arrangement permits a convenient method of field control relative to the twin cavity receiver. This layout coupled with the 60 heliostats per data bus limitation requires at total of 14 600 m (47,940 ft) of signal cable. Location of the HFC to the tower increases this requirement by about 10 percent.

5.1.2 Functional Requirements

The fundamental requirements of the collector system are to focus the solar energy into the receiver cavity in a cost effective and safe manner. More specifically the functional requirements of the Pioneer Mill collector system are as follows:

- Rating: 29.8 MWt (102 x 10^6 Btu/hr) radiant solar energy to the receiver
- Rated Operating Conditions
  - Insolation: 0.95 kW/m^2
  - Design Point: Equinox, 1 p.m.
  - Wind: 0 to 6.7 m/s (0 to 15 mph)
  - Temperature: 0 to 50C (32 to 122F)
- Control Modes
  - Tracking
  - "Safe course" wake up traverse



NOTES:

(1) Field shown divided to illustrate manifold connections.

(2) Signal busses do not cross field centerline.

(3) Maximum 60 heliostats per bus.

(4) ● indicates the beginning of a signal bus.
■ indicates the end of a signal bus.

Figure 5-5 PIONEER FIELD SIGNAL WIRING LAYOUT

Emergency defocus to standby

Standby

Partial field track - partial field standby

Vertical stow

Horizontal stow

Slew to any position (manual)

- Heliostat — The heliostat characteristic shall be consistent with the second-generation heliostats being developed under separate contracts to meet the physical and performance requirements of Sandia Specification A 10772 except as noted in Appendix A, "System Requirements Specification"

5.1.3 Collector Field Design

A key factor in the collector field design process is the efficiency of the heliostat array in concentrating the solar energy on the receiver. The field efficiency is in turn a function of several factors such as field configuration, orientation and size, heliostat configuration and packing density, and land availability and topography.

Land availability is very important in Hawaii and was a principal factor in site selection. It was a major influence in establishing the overall field layout and packing factors which effect the tower height and ultimately influence the receiver design.

For central receiver collector fields in the size range of the Pioneer Mill project, the radial stagger heliostat array has been shown to be advantageous over other arrangements and was chosen for this analysis. Also, in the northern hemisphere, heliostats north of the receiver exhibit higher geometric performance efficiencies.

The layout of the heliostats (row spacing) is a strong function of the tower (receiver aperture centerline) height owing primarily to blocking and shading of adjacent heliostats. The row spacing within the radial stagger field configuration is considered to be optimum at the point where the beam from a heliostat passes just above the top of any heliostat two rows in front of it. This is the threshold of blocking. With this spacing, there will be some shading effect, particularly at low sun angles. Although row and heliostat spacing could be increased to reduce the shading, the penalty in land usage would be high.

The 1 p.m. field orientation of the Pioneer Mill field layout was the result of several considerations which included topography, land availability, proximity to existing structures, and the fact that the mountains to the east of the site delay sunrise by almost an hour.

Once the heliostat layout had been established using a nominal tower height, the actual tower height was determined from a cost-effectiveness analysis using an empirical cost function. Four tower heights were evaluated with the following results:

Tower Height	Back Row Radius	Collector Site Area	Cost Function Value
m (ft)	m (ft)	m^2 (acres)	$
68.6 (225)	377 (1,237)	186 150 (46.0)	22,690
76.2 (250)	359 (1,179)	169 150 (41.8)	22,634
83.8 (275)	350 (1,149)	160 650 (39.7)	22,655
91.4 (300)	343 (1,127)	155 000 (38.3)	22,701

Cost Function = 7,600 + (15.86 x No. Helios) + (3.84 x TWR-Ht)
+ (36 x Area)

NOTES: 1) 780 heliostats used in this analysis
2) Function inputs in feet and acres

The cost function shows a shallow minimum for the 76.2m (250 ft) tower.

As a result, this height was selected for the Pioneer Mill field. A plan of the field was presented in Figure 5-1. Field parameters are presented in Table 5-2. The heliostat position coordinates are presented in Appendix A.

5.1.4 Collector Operating Characteristics

Collector operating characteristics on a daily basis consist of a sequence of operating modes activated by the solar system operator. These consist of the normal modes which collect the maximum available solar energy without interruption and the special modes which are entered to accommodate a system irregularity requiring the normal mode to be overridden.

The normal day sequence would consist of 1) the "safe course" wake up traverse, 2) partial track-partial standby heat up, 3) tracking, and 4) "safe course" stow traverse. Stow position for the Pioneer field collector is normally with the heliostats vertical and facing 30° south of East.

Table 5-2

PIONEER COLLECTOR FIELD PARAMETERS — 76 M (250 FT) TOWER

Row Number	Row Radius m(ft)	Row Length (Arc) m(ft)	Dist. To Next Row m(ft)	Cord Dist. Between Heliostats m(ft)
Tower	-------------	-------------	58.1 (190.5)	
1	58.1 (190.5)	152 (498.8)	10.6 (34.9)	13.4 (43.9)
2	68.7 (225.4)	179.8 (590.1)	10.6 (34.9)	15.8 (52.0)
3	79.3 (260.2)	207.7 (681.3)	10.6 (34.9)	18.3 (60.0)
4	89.9 (295.1)	235.5 (772.6)	10.6 (34.9)	13.4 (43.9)
5	100.6 (330.0)	263.3 (863.8)	10.6 (34.9)	15.0 (49.1)
6	111.2 (364.8)	291.1 (955.1)	10.6 (34.9)	16.5 (54.3)
7	121.8 (399.7)	318.0 (1,046.3)	12.3 (40.3)	18.1 (59.5)
8	134.1 (440.0)	351.1 (1,151.8)	10.6 (34.9)	13.4 (43.9)
9	144.7 (474.8)	378.9 (1,243.1)	10.6 (34.9)	14.4 (47.4)
10	155.3 (509.7)	406.7 (1,334.3)	10.6 (34.9)	15.5 (50.9)
11	170.0 (544.5)	434.6 (1,425.9)	10.6 (34.9)	16.6 (54.4)
12	176.6 (579.4)	462.3 (1,516.8)	18.8 (61.6)	16.6 (57.9)
13	195.4 (641.0)	511.5 (1,678.2)	10.6 (34.9)	13.4 (43.9)
14	206.0 (675.9)	539.3 (1,769.4)	10.6 (34.9)	14.1 (46.3)
15	216.6 (710.7)	567.1 (1,860.7)	10.6 (34.9)	14.8 (48.7)
16	227.2 (745.6)	594.9 (1,951.9)	13.4 (43.9)	15.6 (51.1)
17	240.6 (789.5)	630.0 (2,067.0)	12.1 (39.7)	16.5 (54.1)
18	252.7 (829.2)	661.6 (2,170.8)	27.8 (91.3)	17.3 (56.8)
19	280.6 (920.5)	734.5 (2,409.8)	13.4 (44.1)	13.4 (43.9)
20	294.0 (964.6)	769.6 (2,525.2)	13.4 (44.1)	14.0 (46.0)
21	307.4 (1,008.6)	804.8 (2,640.5)	14.7 (48.1)	14.8 (48.4)
22	322.1 (1,056.7)	843.2 (2,766.4)	20.8 (68.3)	15.4 (50.4)
23	342.9 (1,124.9)	897.6 (2,945.1)	16.5 (54.0)	16.4 (53.7)
24	359.3 (1,178.9)	940.7 (3,086.5)	0 0	17.3 (56.9)

"Safe Course" Wake Up Mode. The initial operation during morning start up is the "safe course" wake up traverse. For this traverse the initializing segment of the collector control software contains the target position of a location near the ground to the side of the tower given the name "line bottom". All heliostats being activated for the upcoming operation focus the reflected solar beam to this "software target". The control wiring of the Pioneer field permits "line bottom" positions on both sides of the tower for the east and west portions of the field that correspond to the east and west receivers respectively.

The second stage of the wake up traverse moves the heliostats such that the reflected beams from the east and west parts of the field intersect an imaginary wire on the corresponding side of the tower between "line bottom" and "line top", positions in air space beside the receiver apertures. "Line top" is used as the "Standby" position for operating heliostats not being targeted into the receiver. The "wake up" traverse is complete when all activated heliostats reach and track the "line top" software targets. Normal procedure would be to bring the heliostats to the standby position before sunrise.

Partial Track-Partial Standby Heat Up. Groups of 25-30 heliostats are moved to reflect into the receiver cavity under operator control, based on the temperature of the fluid in the receiver and thermal transport loop, during the partial track-partial standby heat up sequence. The sequence is complete when all active heliostats are tracking the receiver.

Tracking. The operating mode for the vast majority of operating time is the tracking mode, where all active heliostats are targeted to reflect their concentrated beam into the center of the receiver aperture.

"Safe Course" Stow Traverse. At the end of the operating day heliostat beams are moved from the tracking target to "line top", and and then to "line bottom" positions. From line bottom the heliostats are "slewed" to the stow position. This would normally be done at or after sunset.

Special Modes. At the operator's discretion partial or full "standby" tracking can override normal tracking. Typical irregularities which would initiate a partial standby would be high temperature or low flow indicator alarms. During the winter, partial standby is likely to be necessary near midday due to the "over capacity" of the collector resulting from insolation above 950 W/m^2 (301 Btu/hr-ft^2) or geometric performance above the design point value, or both.

Horizontal stow, elevation angle of 90°, will be used whenever windy conditions, above 15.6 m/sec (35 mph), are present or forecast.

Operating speed of the heliostats in the fast motor speed mode is 12° per minute. This will enable 180° of azimuth rotation in 15 minutes and 90° of elevation rotation in 7.5 minutes. Simultaneous operation of the two axes is a normal operating condition. A half speed mode is used by the motors during normal tracking sequences.

5.1.5 Collector Performance Estimates

Performance parameters determined during the conceptual design included the envelopes of cosine, shading, blocking and tower shadowing which combined to generate the geometric efficiency envelope and specific energy, focal plane flux, and receiver cavity flux data needed for receiver design.

Geometric Performance. Data tables spanning the range of solar elevation angles of 5°, 15°, 25°, 45°, 65°, and 89.5° at solar azimuth angles of 0°, 30°, 60°, 75°, 90°, and 110° were generated for collector cosine efficiency, collector shadowing efficiency, collector blocking efficiency, and tower shading efficiency. Normally, a single set of these efficiencies are sufficient for field evaluation. However, the Pioneer Mill field is not symmetric about solar noon. It was necessary to generate a complete set of efficiencies for both a.m. and p.m. sun positions. Collector geometric performance efficiency, the overall measure of the optical performance obtained by the combination of the four individual efficiencies, for both a.m. and p.m. are shown in Figure 5-6.

These tables are the principal input, along with the Pioneer Solar model, to the STEAEC computer program that computes overall field and system performance parameters. The results of these calculations were presented in the form of energy stairstep diagrams in Section 4.5.

Specific Power, Focal Plane Flux, and Cavity Flux. Specific extreme points of the annual performance envelope were analyzed for thermal power, focal plane flux pattern, and receiver panel flux pattern. The calculations

A.M. GEOMETRIC PERFORMANCE EFFICIENCY
PIONEER MILL LTD., COLLECTOR, 76M [250FT] TWR*

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	0.7974	0.7958	0.7962	0.7955	0.7950	0.7944
65	0.8722	0.8492	0.8272	0.7624	0.7576	0.7269
45	0.9107	0.8733	0.8223	0.7620	0.7164	0.6616
25	0.9221	0.8542	0.7667	0.7161	0.6575	0.5836
15	0.7924	0.7373	0.6724	0.6232	0.5760	0.5295
5	0.5291	0.5389	0.5237	0.4767	0.4590	0.4107

*"Threshold of Blocking Layout For 250 Ft Tower"

P.M. GEOMETRIC PERFORMANCE EFFICIENCY
PIONEER MILL LTD., COLLECTOR, 76M [250FT] TWR

AZIMUTH ANGLE, DEGREES

SOLAR ELEVATION, DEGREES	0	30	60	75	90	110
89.5	0.7974	0.7958	0.7950	0.7955	0.7950	0.7944
65	0.8722	0.8727	0.8451	0.8249	0.8013	0.7582
45	0.9107	0.9295	0.8862	0.8329	0.7935	0.7358
25	0.9201	0.8977	0.8479	0.8071	0.7558	0.6835
15	0.7904	0.7835	0.7358	0.7071	0.6553	0.5954
5	0.5291	0.5752	0.5423	0.5287	0.4819	0.4545

Figure 5-6 PIONEER FIELD COLLECTOR GEOMETRIC PERFORMANCE EFFICIENCIES

for this analysis were quite extensive. Flux maps were generated for both the focal plane and cavity (panel) portions of both the east and west receivers for the summer solstice (day 172), the winter solstice (day 355) and the equinox (day 80). Because the field performance is not symmetrical about solar noon, a grid of five time points was used for each of the three days (8 a.m., 10 a.m., 12 noon, 2 p.m., and 4 p.m.), resulting in a total of 60 flux maps.

Figure 5-7 presents examples of the calculated focal plane (aperture) fluxes at both receivers. Figure 5-8 presents perspective plots of these data. Figure 5-9 presents the corresponding receiver panel incident, and Figure 5-10 shows plots of these data.

Receiver flux maps were not specifically generated for the 1 p.m. collector field design point for two reasons. First, the field design point is not the point of maximum flux for either receiver cavity. As shown in Figure 5-11, the west cavity peaks in the morning and the east cavity peaks in the afternoon. The worst case, winter solstice, is used for design and analysis of each cavity. The second reason for only calculating flux maps for five times each day is that the time of the daily peak for the asymmetric field layout changes with solar declination angle. Since the timing of the actual peak was not known before the calculations were done, a large number of iterative calculations would have been necessary to hit the actual peak. This level of detail was not necessary for the conceptual design, since the varia- in actual peak flux are within several percent of the calculated points. Figure 5-12 shows the sum of the power incident on the panels of the two cavities versus time of day.

WEST RECEIVER

TARGET PLANE FLUX -KW/M2

15	0	0	0	1	2	3	2	1	0	0	0
12	0	1	3	8	17	21	17	9	3	1	0
9	0	3	13	44	93	120	93	44	13	3	0
6	1	9	44	157	364	494	365	157	44	6	1
3	2	17	93	364	952	1365	952	365	93	17	2
0	3	21	120	494	1355	2210	1366	494	121	21	3
-3	2	17	93	365	953	1366	953	365	93	17	2
-6	1	9	44	157	365	495	365	157	44	9	1
-9	0	3	13	44	93	121	93	44	14	3	0
-12	0	1	3	9	17	22	17	9	3	1	0
-15	0	0	0	1	2	3	2	1	0	0	6
	-15	-12	-9	-6	-3	0	3	6	9	12	15

10.1M (33FT)

10.1M (33FT)

TOTAL POWER = 15712.22

DAY - 355.20

TIME = 10.20

AZ = 35.22

ELEV = 35.91

EAST RECEIVER

TARGET PLANE FLUX -KW/M2

15	0	0	0	1	2	3	2	1	0	0	0
12	0	1	3	9	18	22	18	9	3	1	0
9	0	3	14	45	95	122	95	45	14	3	0
6	1	9	45	158	363	490	363	159	46	9	1
3	2	18	95	363	940	1351	941	364	95	18	2
0	3	22	122	490	1350	2002	1352	491	123	23	3
-3	2	18	95	363	941	1352	942	364	95	18	2
-6	1	9	46	159	364	491	364	159	46	9	1
-9	0	3	14	46	95	123	95	46	14	3	0
-12	0	1	3	9	18	23	18	9	3	1	0
-15	0	0	0	1	2	3	2	1	0	0	0
	-15	-12	-9	-6	-3	0	3	6	9	12	15

10.1M (33FT)

10.1M (33FT)

TOTAL POWER = 15655.00

DAY - 355.00

TIME = 14.00

AZ =-35.00

ELEV = 36.91

Figure 5-7 RECEIVER FOCAL PLANE FLUXES

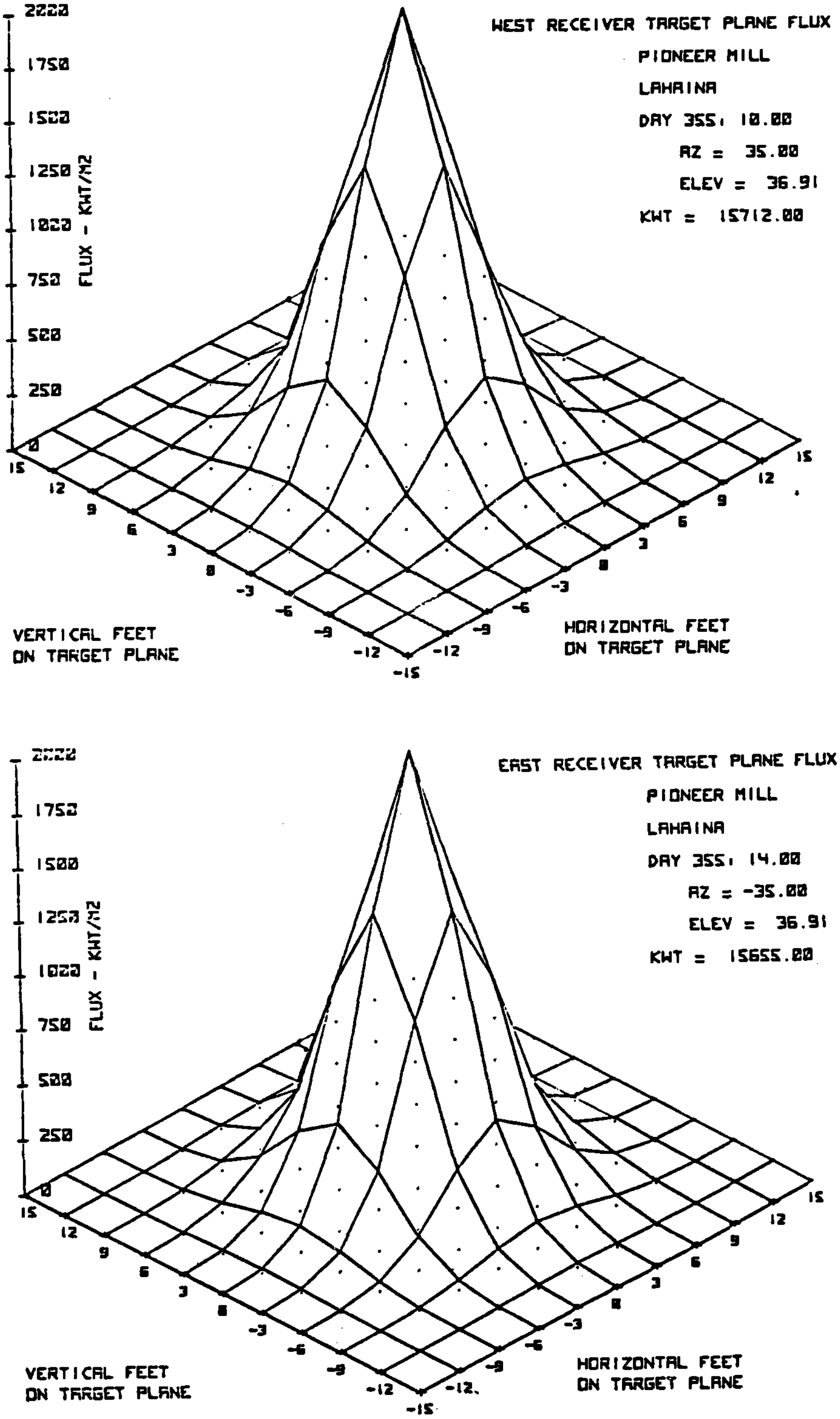


Figure 5-8 RECEIVER FOCAL PLANE FLUX MAP

WEST RECEIVER FLUX, kW/m²

DAY 355

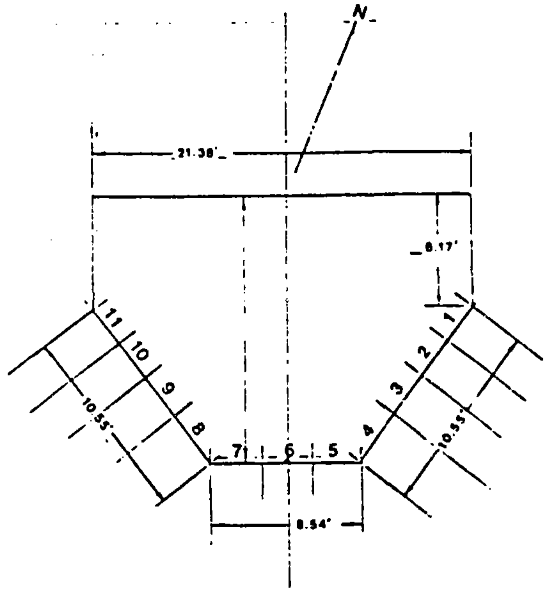
TIME 10:00

POWER 15375 KW

Distance Above Aperture Centerline, Ft.

Distance (Ft.)	11	10	9	8	7	6	5	4	3	2	1
	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	7	12	29	55	99	85	108	56	56	37	15
12	29	64	117	178	226	223	233	187	162	118	51
9	70	186	296	403	480	508	497	436	347	232	107
6	101	306	457	617	678	740	711	682	530	358	175
3	95	305	439	592	603	669	632	653	504	356	185
0	61	199	276	369	353	394	366	398	308	225	122
-3	27	89	119	157	141	157	143	163	126	95	53
-6	8	28	36	46	39	43	39	46	36	27	16

Panel No.



EAST RECEIVER FLUX, kW/m²

DAY 355

TIME 14:00

POWER = 15377.90

Distance Above Aperture Centerline, Ft.

Distance (Ft.)	11	10	9	8	7	6	5	4	3	2	1
	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	6	14	37	81	105	143	156	81	60	29	9
12	27	62	123	162	237	303	305	200	159	94	33
9	78	164	274	359	473	544	538	420	315	182	77
6	137	272	419	511	664	759	743	610	492	303	140
3	150	284	415	480	607	692	661	555	437	323	159
0	106	194	272	299	365	413	384	327	303	212	110
-3	51	90	121	126	149	166	151	130	126	91	49
-6	17	29	38	37	43	46	41	35	36	27	15

Panel No.

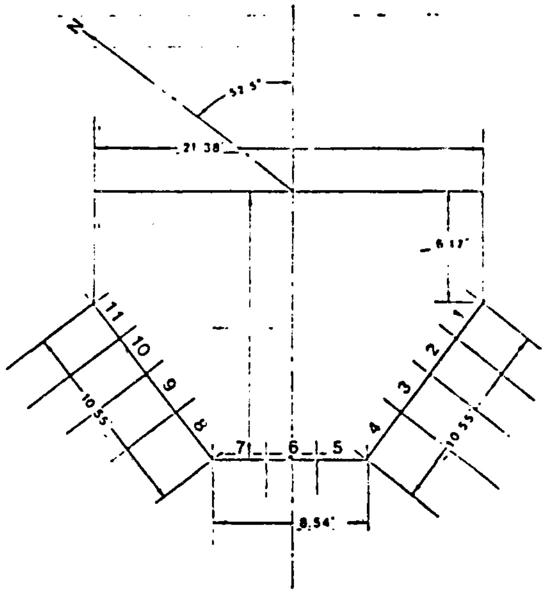
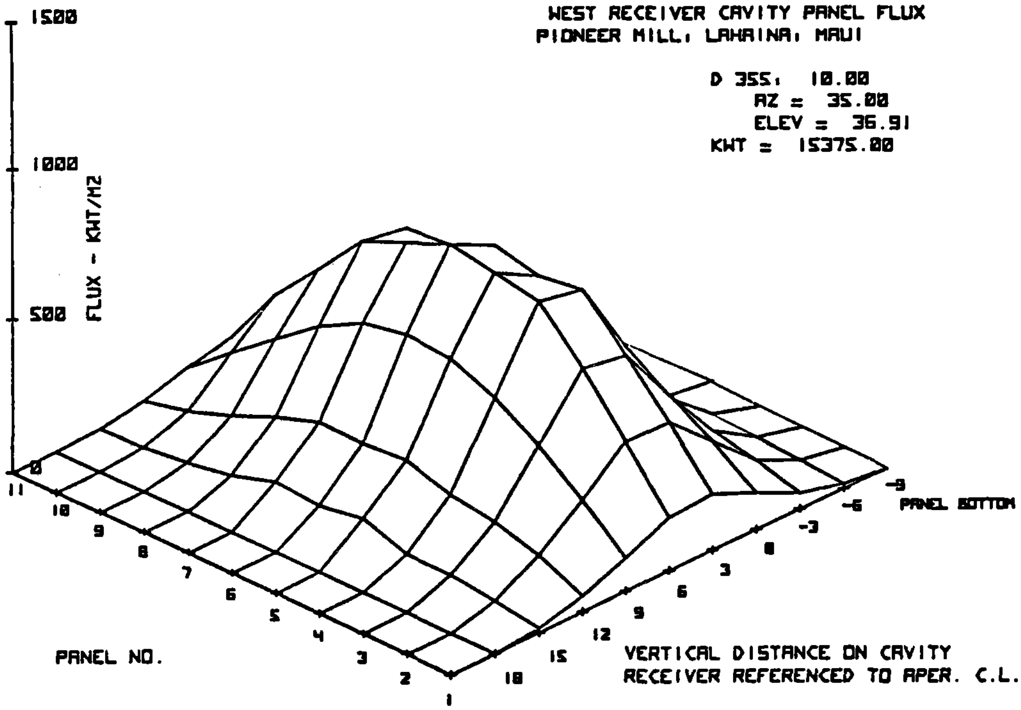


Figure 5-9 RECEIVER PANEL FLUXES



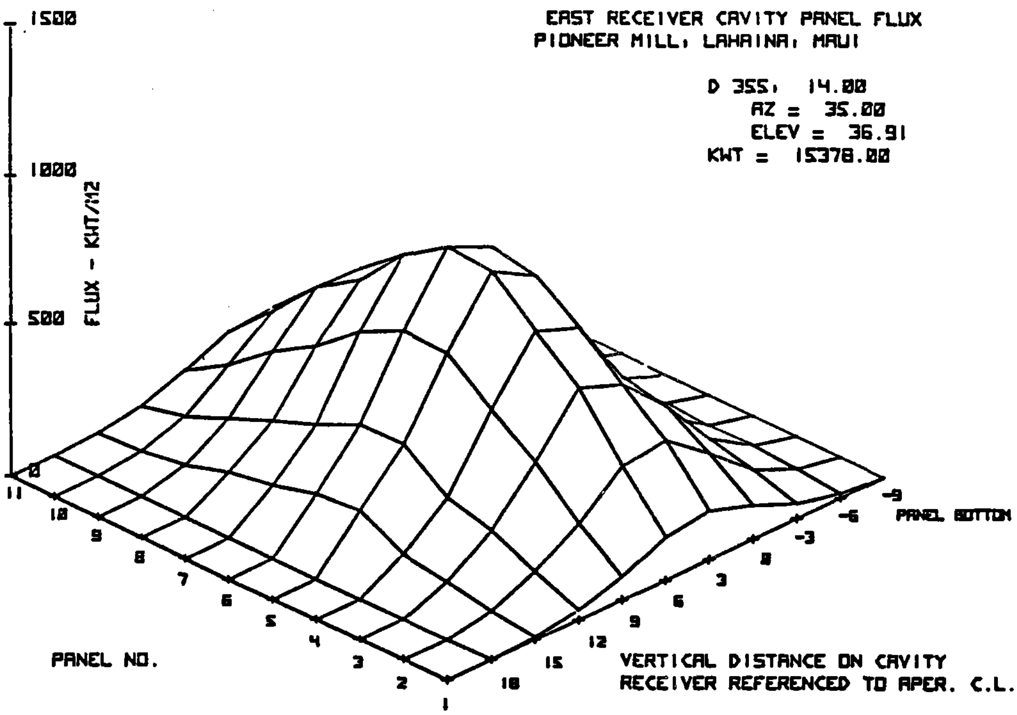


Figure 5-10 RECEIVER PANEL FLUX MAP

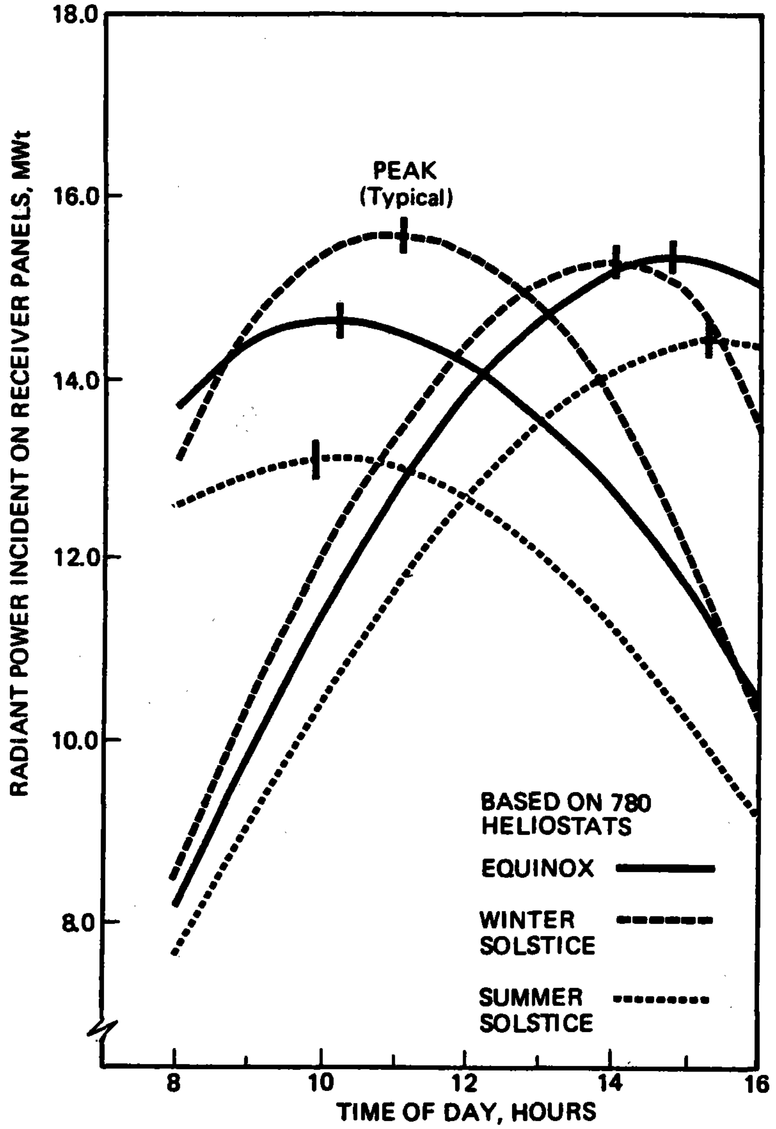


Figure 5-11 TIME VARIATION OF INCIDENT POWER TO EACH RECEIVER CAVITY

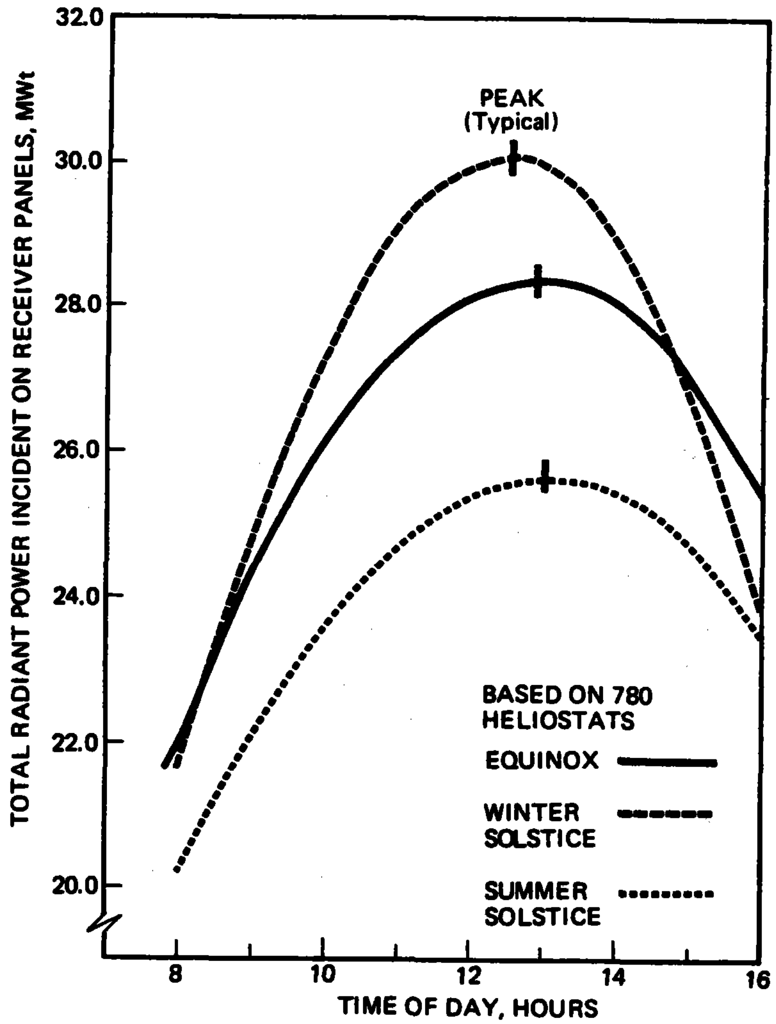


Figure 5-12 TIME VARIATION OF TOTAL INCIDENT POWER TO RECEIVER PANELS

5.1.6 Cost/Performance Trade Studies

The majority of the cost/performance trade studies involving the collector field were made in conjunction with the complete solar cogeneration facility and reported in Section 3. The single cost/performance analysis that was significantly related to the collector field alone was the tower height selection analysis. The results of this evaluation, which was the basis for the selection of the 76 m (250 ft) tower, were reported in Section 5.1.3.

5.1.7 Collector Field Cost Estimate

The collector field cost estimates are based on a production rate of 5 000 heliostats per year. The production facility would be located in Bakersfield, California. The heliostats would be containerized by component at this point and trucked to Oakland, California for shipment to Maui and transported by truck to the site.

An assembly building (Butler type) would be erected at the site. Sufficient tooling and fixtures would be provided to assemble 12 heliostats per day on a three-shift operational basis. The heliostats would be completely assembled (except for pedestals) and mirror alignment performed within this building. From this building they would be transported to the field and mounted on the pedestal at the rate of 12 per day. Electrical power and control electronics terminations would be performed at the same pace (day shift only).

Other cost factors considered were:

- Transportation and major installation equipment rented locally.
- Assembly building would be depreciated to zero over construction period.
- Heliostat specific fixtures and tooling amortized over 10 similar installations.

- Small tools purchased locally and will remain for maintenance.
- 1981 dollars (no escalation)

The total estimated construction cost for the collector system is \$17,885,000, or \$416/m^2. The direct cost for the installed heliostats, excluding wiring and foundations, is \$12,300,000, or \$286/m^2. Cost support detail is provided in Appendix A.

5.2 RECEIVER SYSTEM

5.2.1 Requirements

The receiver system includes the receiver unit and the supporting tower. The receiver provides a means of transferring the incident solar radiation from the collector system into water/steam and producing superheated steam suitable for use in the Pioneer Mill cogeneration facility. The tower supports the receiver, other elements of the receiver system and the piping. The design lifetime of the receiver system is 20 years. Appropriate ASME boiler codes and design standards will be followed in the receiver design. All structures and supports will be designed for the anticipated dead, wind and seismic loads.

The receiver is sized to produce 33 500 kg/hr (73,900 lb/hr) of superheated steam at a pressure of 6.85 MPa (994 psia) and a temperature of 438C (820F), with a thermal output of 26.2 MWt (89.5 x 10^6 Btu/hr). This thermal rating corresponds to the design point condition at 1 p.m. equinox with a direct normal insolation of 950 W/m^2 (301 Btu/hr-ft^2). The key requirements that directly guide the design of the receiver are summarized in Table 5-3.

An accurate prediction of heat-flux patterns within the cavity, particularly

Table 5-3

SUMMARY OF RECEIVER REQUIREMENTS

Design Point	1 p.m., equinox
Thermal Output	26.2 MWt (89.5 x 10^6 Btu/hr)
Steam Outlet Conditions	
Temperature	438 C (820 F)
Presure	6 854 kPa (994 psia)
Flow Rate	33 500 kg/hr (73,900 lb/hr)
Feedwater Conditions	
Temperature	113 C (235 F)
Pressure	8 446 kPa (1,225 psia)
Flow Rate	34 200 kg/hr (75,400 lb/hr)
Drum Operating Pressure	7 757 kPa (1,125 psia)
Drum Continuous Blowdown	680 kg/hr (1,500 lb/hr)
Superheater Duty	4.77 MWt (16.3 x 10^6 Btu/hr)
Environments	
Ambient Temperature	10 to 35C (50 to 95F)
Survival Wind Speed	40 m/s (131 ft/s)
Seismic Zone	UBC Zone 2

the magnitude and location of peak heat fluxes, is vital to the proper design of the receiver. The boiler section of the receiver has a maximum absorbed heat flux limitation of 694 kW/m^2 (220,000 $Btu/hr\text{-}ft^2$), and the superheater section, where tubes are heated from both sides, has a maximum of 552 kW/m^2 (175,000 $Btu/hr\text{-}ft^2$). The internal dimensions established for the selected twin-cavity configuration are shown in Figure 5-13. These dimensions and the heat flux distribution maps described in Section 5.1 and included in Appendix G were used as bases for the conceptual design of the receiver.

The feedwater to the receiver should be of high quality to minimize the possibility of internal receiver corrosion and tube desposits. Tube deposits can lead to tube failures, particularly at the high heat flux levels considered in this design. The concentration of impurities in the feedwater as well as in the receiver water are specified in Appendix A.

The main requirements for the receiver tower are:

- Support the receiver's weight
- Locate the receiver at the best elevation to optimize the heat flux and the system costs
- Hold the position of the aperture within acceptable limits of the heliostat aiming point under normal wind loads
- Provide support for the pipework and cables
- Allow safe access to the receiver, piping and cabling for operation and maintenance
- Blend aesthetically with the surrounding environment to the maximum extent practicable

The general arrangement of the receiver tower is shown in Figure 5-14.

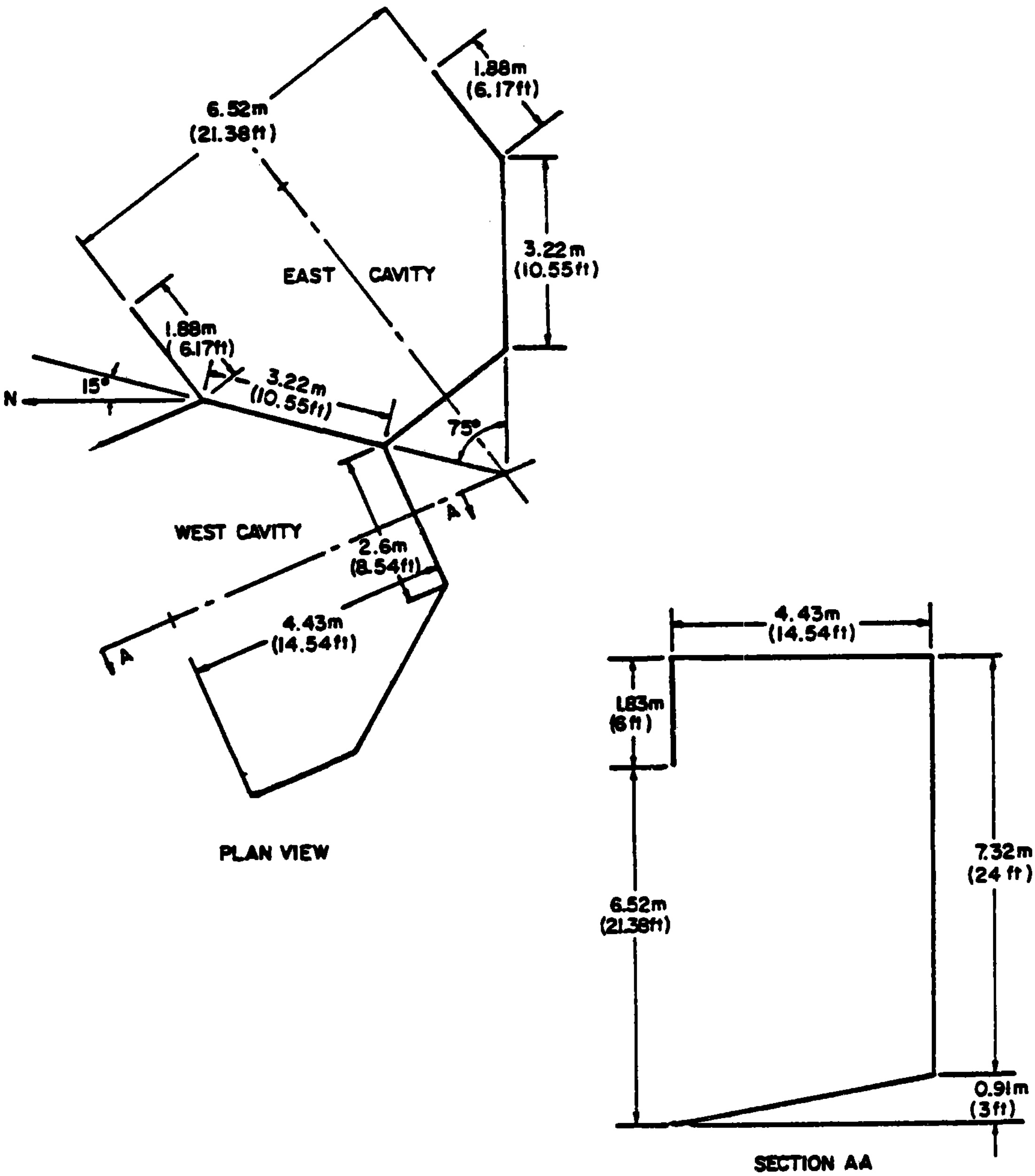


Figure 5-13 INTERNAL DIMENSIONS OF THE SELECTED TWIN-CAVITY RECEIVER CONFIGURATION

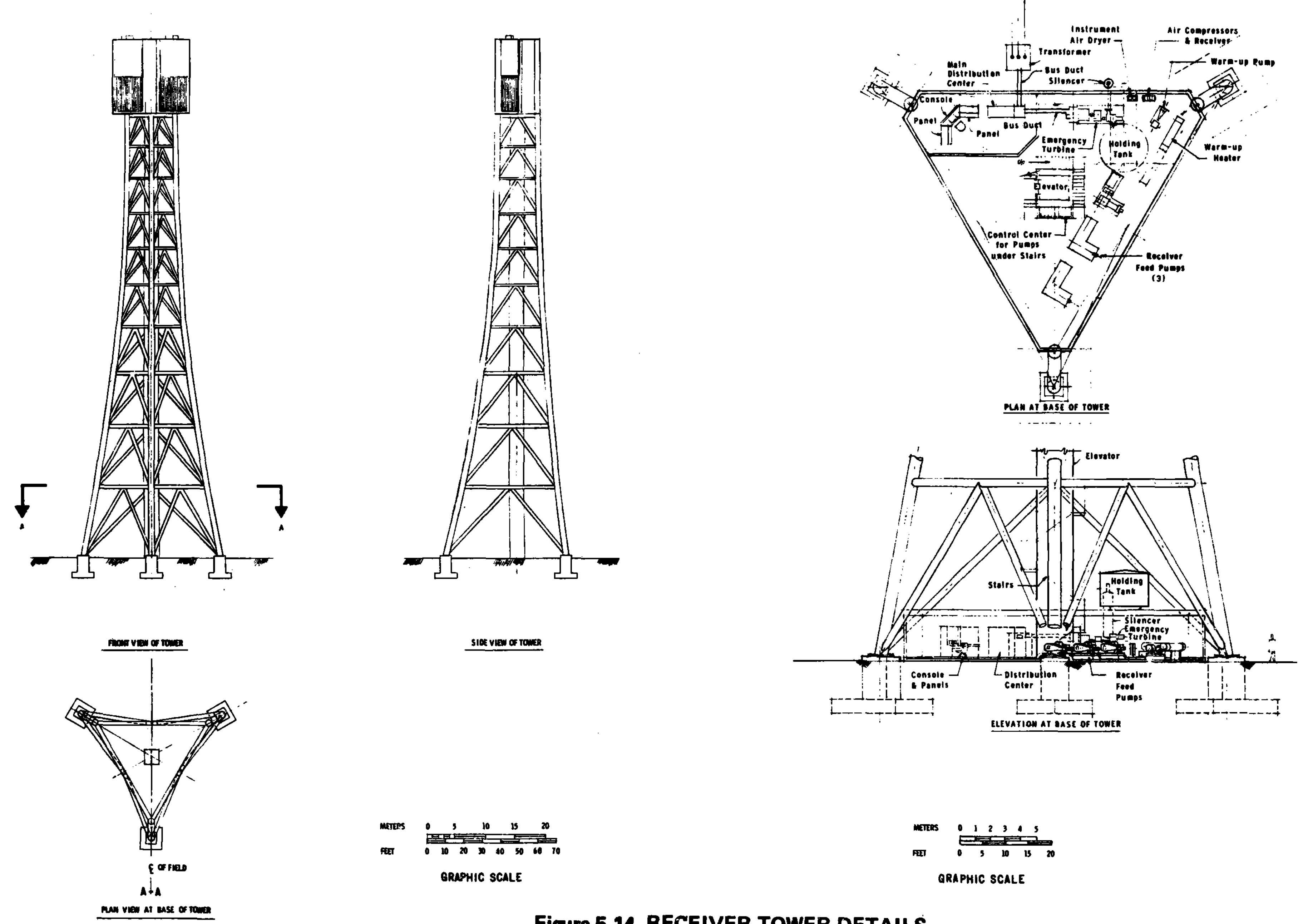


Figure 5-14 RECEIVER TOWER DETAILS

5.2.2 DESCRIPTION

Receiver Unit. The selected receiver concept is a twin-cavity, natural-circulation steam generator with separate superheater circuitry. This integrated twin-cavity receiver was devised for a 150° collector field. The front elevation and plan views of the receiver are given in Figure 5-15. As shown in the Section A-A view of this figure, the receiver is symmetric with respect to a plane passing through the common wall that partitions the two cavities. Since the selected collector field varies slightly from the normal north-of-the-tower location, the common wall is rotated 15° east from due north. The square aperture of each cavity is 6.52 m (21.3 ft) on a side with its normal vector angled at 37.5° from the common wall. The allocation of boiler and superheater surfaces on cavity walls are also illustrated in this view. The superheater is located in the forward portion of the common wall. The remaining portion of the common wall, two rear walls, and two sidewalls are lined with boiler panels. All boiler and superheater panels are made of tubes that are joined along their length by continuous-weld integral fins to form vertical flat Monowalls™. Carbon steel (SA-210 A1) boiler tubes of 50.8 mm (2.0 in) O.D. were selected for the boiler panels and 31.8 mm (1.25 in) O.D. stainless steel (SA-213 TP316H) tubes were selected for the superheater panels. A fin width of 6.4 m (0.25 in) was used for all tube sizes.

As shown in the elevation views, boiler water from the drum flows through five 168 mm (6.625 in) O.D. external dowcomers and branching feeders to the lower headers of the boiler, where the flow is divided among the various upflow boiler panels. As the water flows upward through the tubes, a portion of it is converted into steam by the absorbed heat. The resultant mixture of water and steam leaving the tubes is collected in the upper boiler headers and carried back to the steam drum through risers All headers are of 219 mm (8.625 in) outside diameter. In the drum, the mixture passes through centrifugal separators which separate the steam from water. The water, after mixing with incoming feedwater, enters the downcomers for another trip around the boiler circuits.

The superheater circuitry is better illustrated in the top plan and Section B-B views of Figure 5-15. The superheater consists of four vertical passes in series. The dry saturated steam flows from the drum through two 114 mm (4.5 in) O.D. supply lines to the inlet header of superheater pass 1. From this header, steam flows down through pass 1 and then up through pass 2 while being superheated by absorbing the incident energy along the passes. A 168 mm (6.625 in) O.D. connecting pipe transfers the steam from pass 2 outlet header at the top to pass 3 inlet header at the bottom of common wall panels. A spray attemperator which is located at the lower, vertical portion of the connecting pipe is used for steam temperature control. Steam is further heated successively in passes 3 and 4 until it reaches its specified outlet temperature. The superheated steam is then piped to the receiver/tower interface point where the thermal transport system takes the steam down the tower.

A rear elevation view of the receiver is presented in Figure 5-16, showing the locations of headers, downcomers, and connecting piping. The two plan views depict the routing of boiler feeders and risers and superheater piping. The detailed arrangement of the spray attemperator is also shown in this figure. The attemperator consists of a straight header, thermal

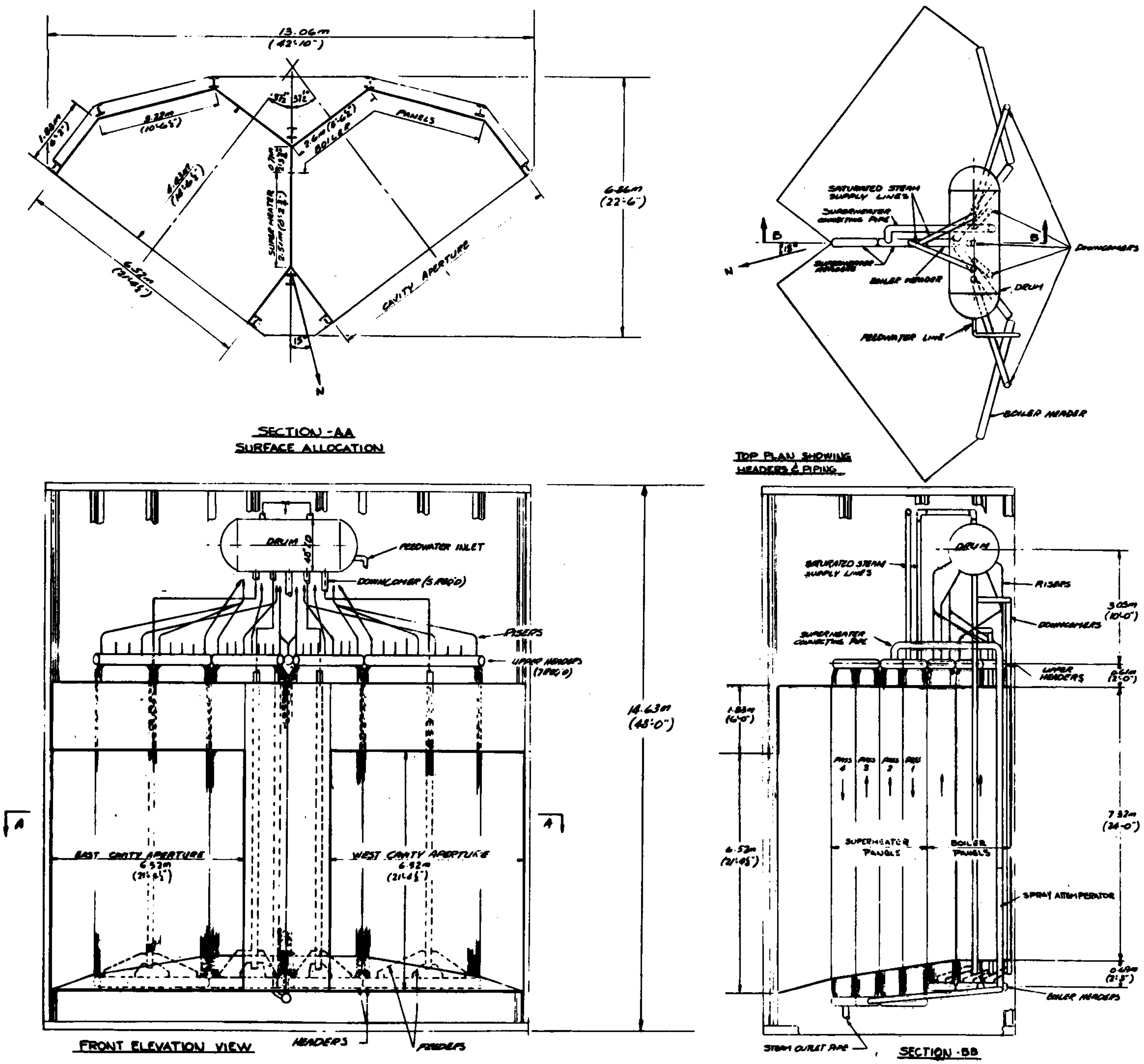


Figure 5-15
TWIN-CAVITY RECEIVER, ELEVATION AND SECTION VIEWS

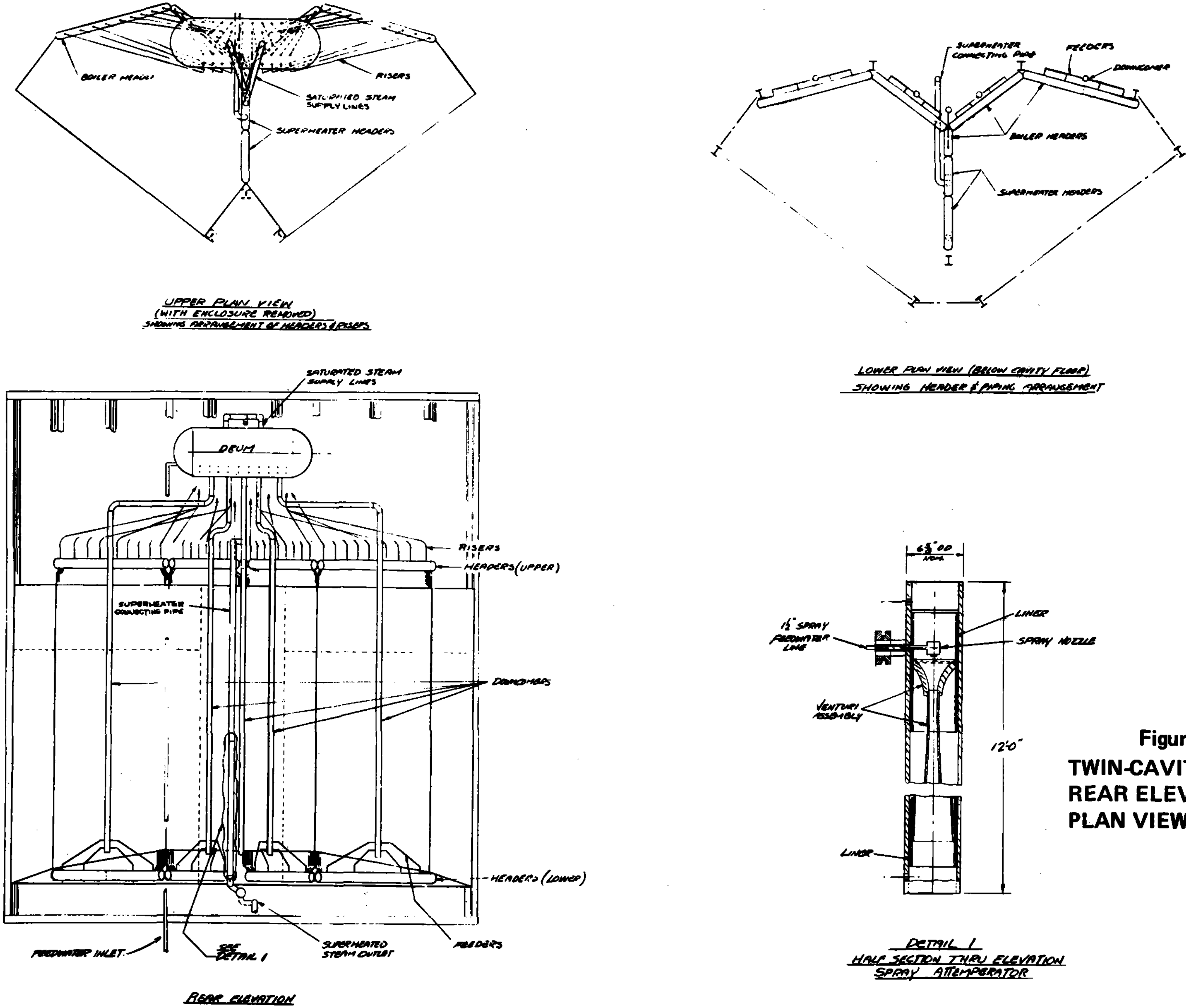


Figure 5-16
TWIN-CAVITY RECEIVER, REAR ELEVATION PLAN VIEW

liners, a spray nozzle and a venturi assembly. Feedwater is mechanically atomized by the spray nozzle into a fine, hollow cone-shaped spray, which is mixed with the steam at the inlet to the venturi assembly.

The shell of the receiver consists of boiler panels, cavity floor and roof plates, enclosure, and stiffeners. Interior surfaces of the cavity that are not covered with boiler or superheater panels are lined with either flat steel plates or Incoloy 800 H plates coated with reflective material. Outside surfaces of the receiver, as well as drum and exterior piping, are insulated to reduce thermal losses to the ambient environment. The conceptual arrangement of the receiver enclosures is shown in Figure 5-17. Aluminum lagging is installed over all enclosure surfaces. Lagging installed on top of cavity roof and upper enclosure surfaces is sloped for water drainage. The aperture of each cavity is provided with an insulated door that can be closed to minimize heat loss and resultant cooling of the receiver during overnight shutdown. An access door through the cavity floor is also provided for each cavity.

The entire receiver cavity is top-supported. All pressure parts of the receiver are free to expand laterally and down. The conceptual support structure for the receiver is shown in Figure 5-18. It consists of 10 support columns interconnected to form a structural steel framework. The upper headers of the boiler and superheater panels are hung from the structural beams shown in plan view B-B. All the columns except the inside two are extended above the drum to form a top support structure, which is used to hang the drum, to support the cavity doors and enclosures, and to make provision for installation of a service crane. A schematic arrangement of the cavity door is also included in this figure.

Receiver Tower. The tower which supports the receiver, pipework, cables, and elevator is made of large diameter steel pipe sections and is three-sided. Pipe sections were selected over other structural shapes because of favorable experience in offshore platform applications. Pipe sections are more weight-efficient in carrying compressive loads and round sections have lower wind drag.

An enclosed receiver equipment room is provided on a platform just below the receiver level near the top of the tower. The area at the base of the tower also is enclosed to accommodate the thermal transport system equipment, a control room, and storage for spares.

Access to the top of the tower is by a personnel and light-weight equipment elevator with capacity for 1 000 kg (2,200 lb). The elevator structure is open and is supported by the tower floor diaphragms; the elevator cage is enclosed. In addition, access to the receiver platform is provided by stairs which are supported by the elevator structure. Light-weight equipment is lifted from the receiver room to the receiver by a small hoist.

Lighting is provided in the enclosed areas, within the elevator, and on the stairs. Obstruction markings and lights are installed on the tower to conform with the Federal Aviation Agency requirements.

The tower is protected from lightning by air terminals on the receiver roof, two interconnecting downcomers, and a below grade ground loop around the tower.

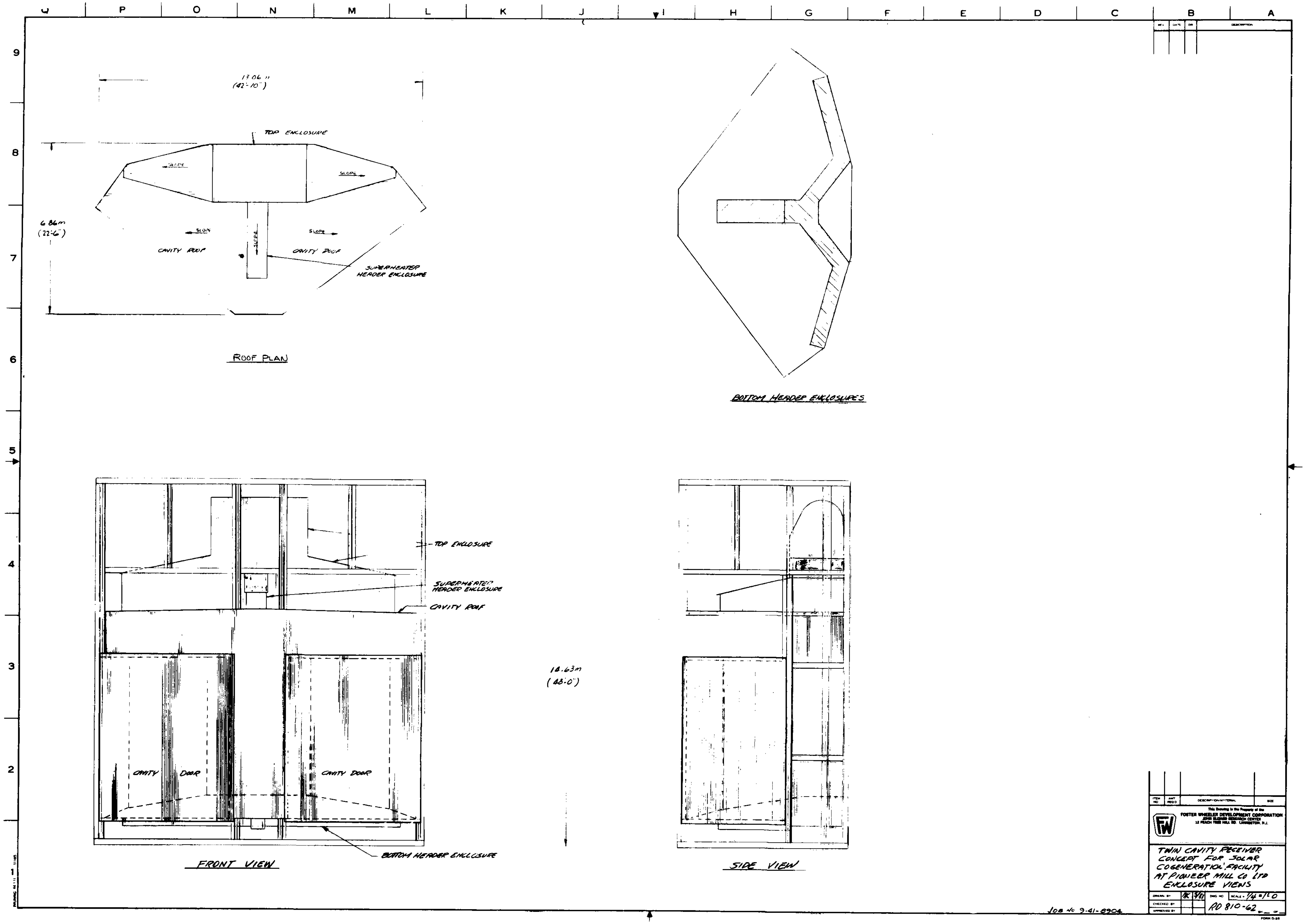


Figure 5-17 TWIN-CAVITY RECEIVER, ENCLOSURE VIEWS

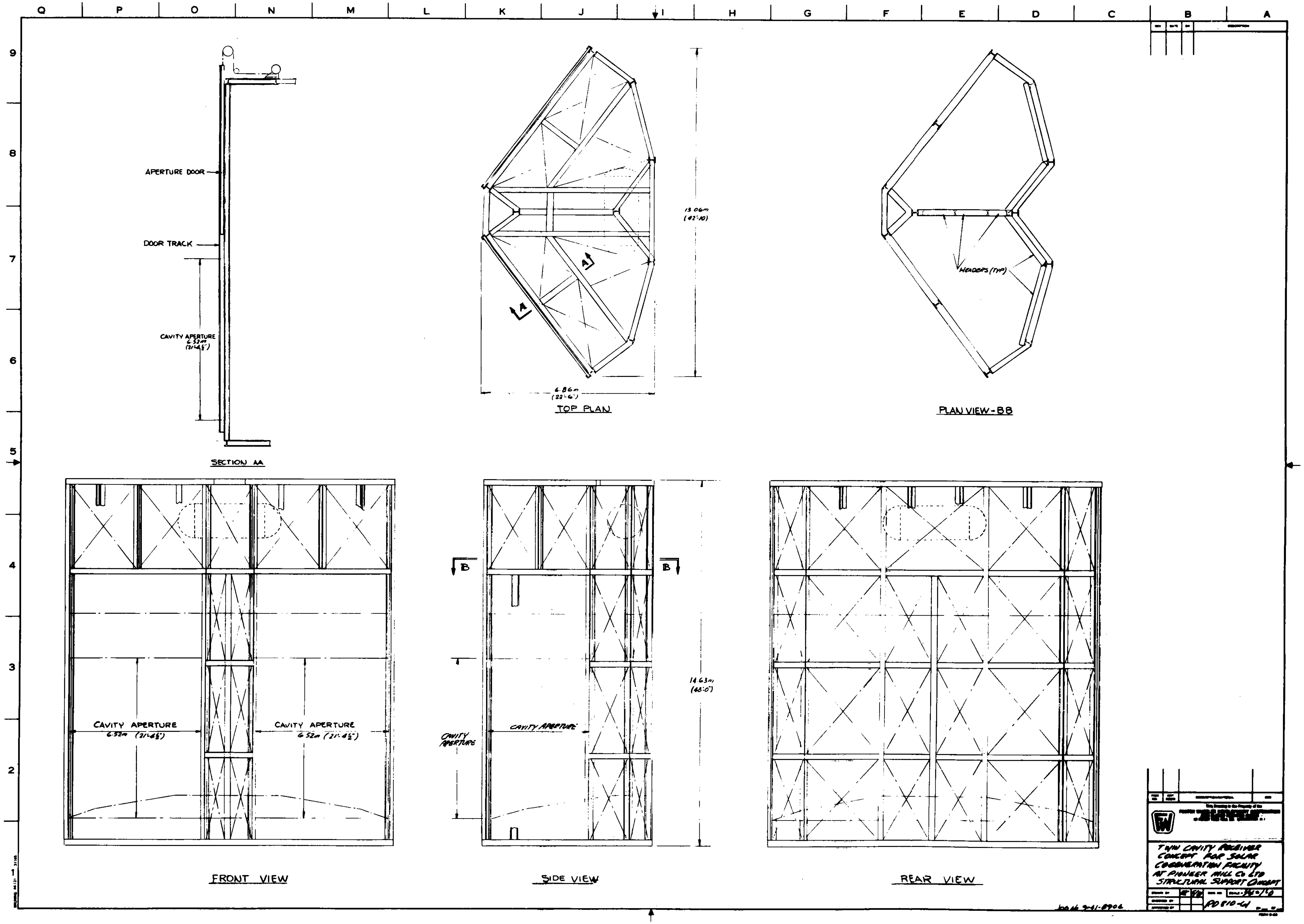


Figure 5-18 TWIN-CAVITY RECEIVER, STRUCTURAL SUPPORT

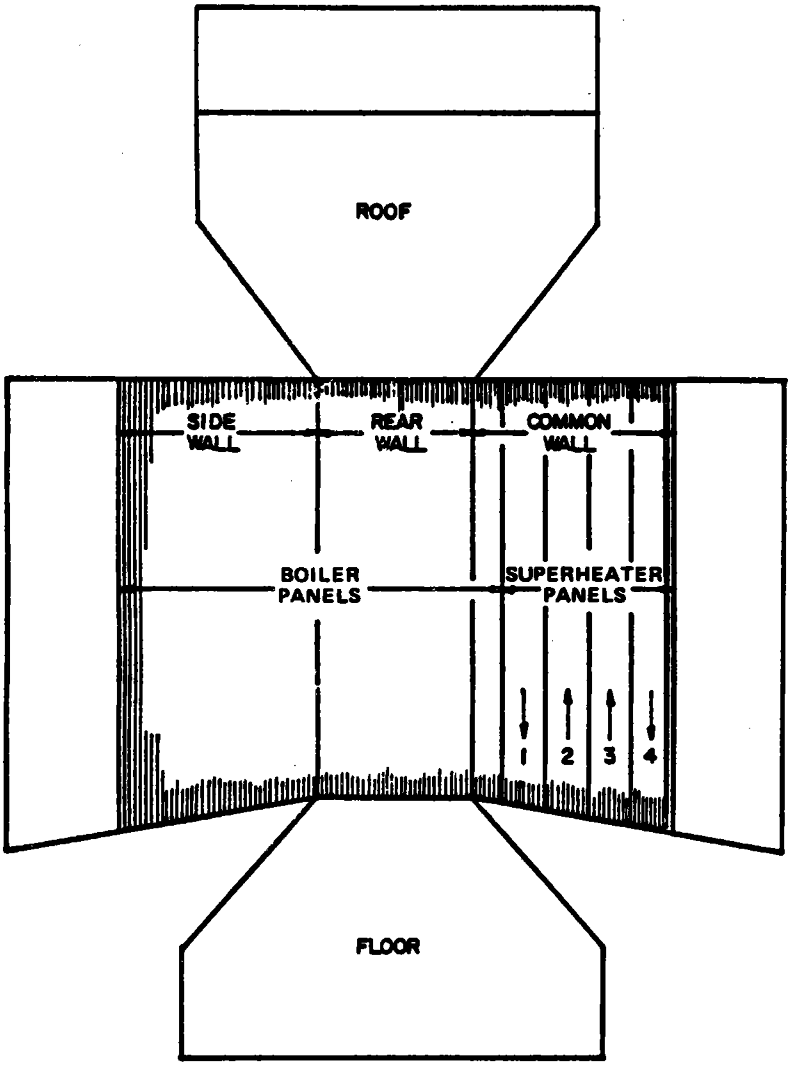
The thermal transport pipework is hung from the tubular supports with loops to allow for thermal expansion. Power and control cables are supported on cable trays attached to the tubular supports.

5.2.3 Design Characteristics

Thermal/Hydraulic. Detailed thermal/hydraulic design and analyses were performed for the selected twin-cavity receiver. The results obtained for both boiler and superheater performances are described as follows.

The active surfaces of the receiver must be correctly proportioned between superheater and boiler sections to obtain the designed superheater conditions. At the design point conditions, the superheater section requires approximately 18.2 percent of the total thermal duty. The approach was to locate all the superheater surface on the common wall and to keep it as far away from the highest heat flux zones as possible. The surface allocation selected is shown schematically in Figure 5-19. Calculations were then made to assure that energy absorbed by the superheater surface met the input requirement for different time points during the year. The results for the selected superheater surface arrangement are shown in Table 5-4. As can be seen from this table, the superheater surface was slightly oversized. While the additional thermal input can be offset by spray attemperation, this superheater oversizing can accommodate the shift of radiant power away from the superheater during other insolation conditions without degrading the superheater outlet temperature.

The selected receiver concept uses the natural-circulation principle.



SUPERHEATER PASSES ARE NUMBERED IN THE SEQUENCE OF STEAM FLOW. ATTEMPERATOR IS LOCATED BETWEEN PASSES 2 & 3

Figure 5-19 SCHEMATIC SURFACE ALLOCATION OF THE SELECTED RECEIVER

Table 5-4

ENERGY PROPORTIONS ON SUPERHEATER PANELS

Day of Year	Time of Day	Percent of Energy on Superheater Panels								
		Pass 1		Pass 2		Pass 3		Pass 4		Total
		E	W	E	W	E	W	E	W	
Day 80 (Spring Equinox)	0800	2.0	5.29	1.69	4.56	1.55	3.83	1.15	2.1	22.17
	1200	3.19	3.65	2.61	3.1	2.1	2.62	1.35	1.64	20.26
Day 172 (Summer-Solstice)	1200	3.39.	3.59	2.81	3.08	2.31	2.78	1.46	1.8	21.22
Day 355 (Winter Solstice)	0800	2.02	4.94	1.68	4.19	1.5	3.46	1.03	1.84	20.66
	1000	2.43	4.51	2.0	3.57	1.75	2.94	1.16	1.59	19.95
	1200	2.96	3.6	2.39	3.02	1.95	2.55	1.2	1.51	19.18
	1400	3.44	3.25	2.59	2.87	2.0	2.5	1.12	1.64	19.41

In a natural-circulation system, the rate of flow that can be produced is governed by flow resistances and differences in density between the downcomer passages and the heated upflow passages. Control of these resistances enables the designer to apportion an adequate flow of water to parallel circuits. For the circulation analysis, the boiler section was divided into different circuits having similar heat absorption characteristics. After several repetitive calculations, during which changes were made to the number and size of tubes, feeders and risers in the individual circuits, an acceptable arrangement was obtained.

The numbers and sizes of the selected boiler circuits are summarized in Table 5-5. For the circulation calculation, the side walls were divided into two parallel circuits because the heat flux distributions on these walls vary considerably in the horizontal direction from inboard to outboard tubes. Circulation analyses were made for selected heat input conditions of 12 p.m. and 8 a.m. winter solstice and an assumed condition with 25 percent heat input of that for 12 p.m. winter solstice. Evaluation of these few conditions was considered adequate for the conceptual design. Table 5-6 summarizes the circulation results for 12 p.m. winter solstice condition. The ratio of the total circulating flow rate to the total steam generation rate at this condition (overall circulation ratio) is found to be 14.4. The key circulation parameters are depicted in Figure 5-20. The steam flow is directly proportional to the heat input, while the circulation ratio increases rapidly with heat input at the lower load range and tends to flatten out toward the higher load range. The velocities entering boiler tubes at the high absorption (common wall panel) and the low absorption

Table 5-5

SUMMARY OF BOILER CIRCUITRY

Description	No. of Downcomers 168 mm O.D. (6.625 in O.D.)	No of Feeders 76 mm O.D. (3 in O.D.)	No of Tubes 50 mm O.D. (2 in O.D.)	No. of Risers 76 mm O.D. (3 in O.D.)
Common Wall	1	2	12	3
Rear Wall East	1	4	45	9
Rear Wall West	1	4	45	9
Side Wall East	1	4	56	9
Side Wall West	1	4	56	9
Total	5	18	214	39

Table 5-6

BOILER CIRCULATION CHARACTERISTICS AT NOON WINTER SOLSTICE

Circuit Description	Circulating Flow kg/hr(lb/hr)	Velocity Entering m/s (ft/s)	Exit Quality % by Wt.	Steam Generated kg/hr (lb/hr)
Common Wall	47 630 (105,000)	1.04 (3.4)	7.1	3 380 (7,460)
Rear Wall East	113 400 (250,000)	0.67 (2.2)	7.9	8 890 (19,600)
Rear Wall West	113 400 (250,000)	0.67 (2.2)	7.9	8 890 (19,600)
Side Wall, East Inboard Panel	64 410 (142,000)	0.55 (1.8)	7.5	4 840 (10,660)
Outboard Panel	37 650 (83,000)	0.41 (1.3)	3.3	1 240 (2,740)
Side Wall, West Inboard Panel	64 410 (142,000)	0.55 (1.8)	7.5	4 840 (10,660)
Outboard Panel	37 650 (83,000)	0.41 (1.3)	3.3	1 240 (2,740)

Total Circulaton Rate = 478 550 kg/hr (1.055 x 10^6 lb/hr)
Steam Generation Rate = 33 500 kg/hr(73,460 lb/hr)

Overall Quality, % by Wt.=7.0
Overall Circulation Ratio = 14.4

Drum Pressure = 7.72 MPa (1,125 psia)

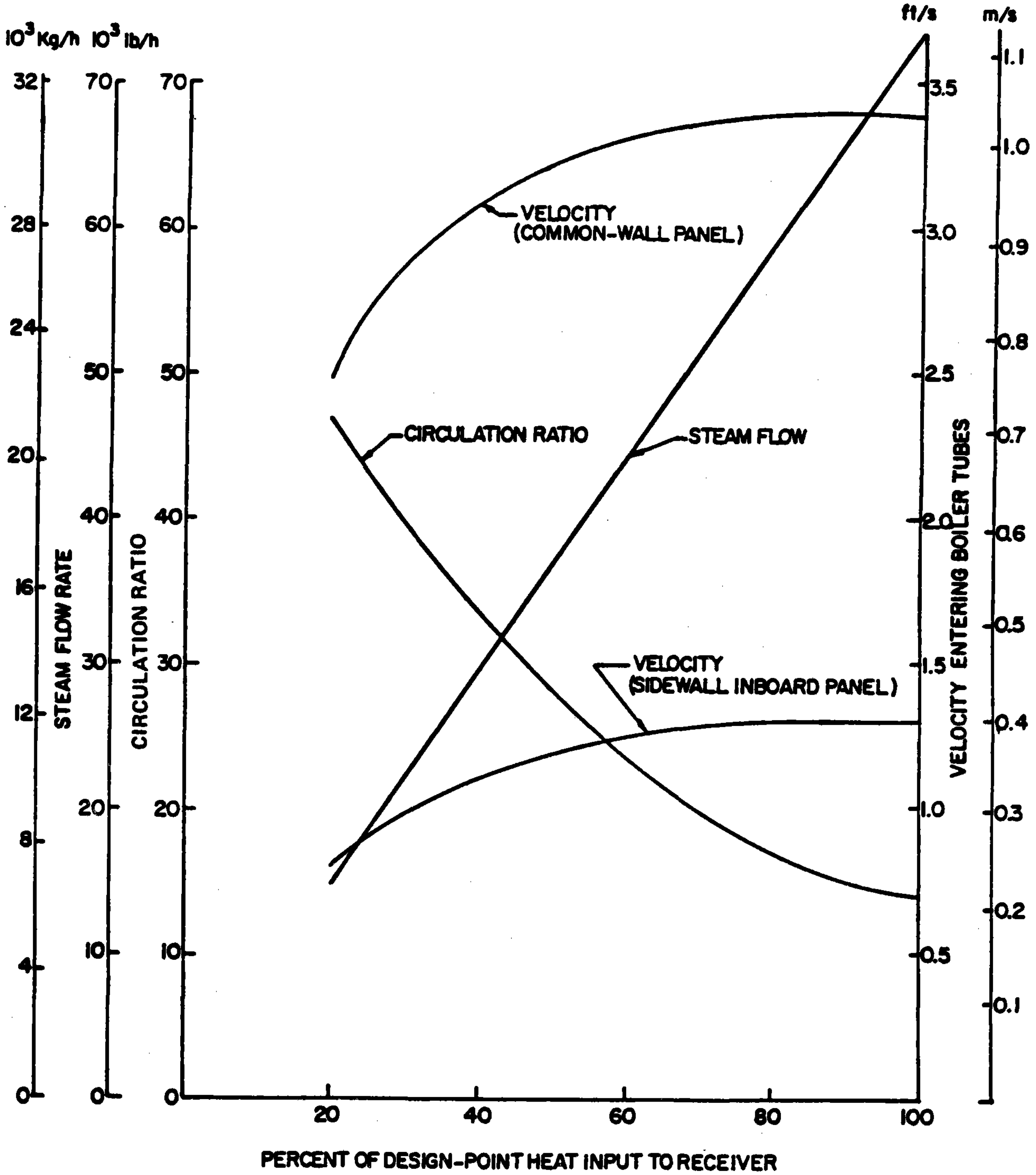


Figure 5-20 BOILER CIRCULATION CHARACTERISTICS AT DIFFERENT HEAT OUTPUT CONDITIONS

(sidewall outboard panel) regions are also shown in this figure. Evaluation of these results indicated that all circuits satisfy the circulation design criteria imposed on the entrance velocity, steam quality and absorbed heat flux.

The selected superheater arrangement consists of four vertical passes in series with a spray attemperator located between Passes 2 and 3. Each pass is made of 32 mm (1.25 in) O.D. stainless steel tubes on 38 mm (1.5 in) centers. Temperatures of the steam and tube wall along the length were calculated for the 12 p.m. winter solstice heat flux conditions. In calculating these temperatures, the following heat flux conditions and flow imbalance effects were considered:

- Tube metal temperature based on the incident heat flux values rather than absorbed values
- Steam temperature based on the absorbed heat flux values
- Heat flux variation among tubes of the same pass
- Flow imbalance because of manufacturing variations in tube wall thickness (+10 percent, -0 percent on minimum wall)

The results are shown in Figure 5-21. The maximum mean metal temperature was based on the worst combination of heat flux and flow conditions (i.e., the highest heat flux and lowest flow among the tubes of the same pass).

The mass velocities, average heat transfer film coefficients, and pressure drops for all superheater passes at 12 p.m. winter solstice condition are listed in Table 5-7. The total pressure drop across the superheater, including the connecting pipe and attemperator, was predicted at 896 kPa (130 psi).

<u>Structural Design and Analysis.</u> In order to ensure the structural integrity of the receiver during its 20-year lifetime, a stress analysis of the receiver components was performed. The resulting stresses and strains were evaluated

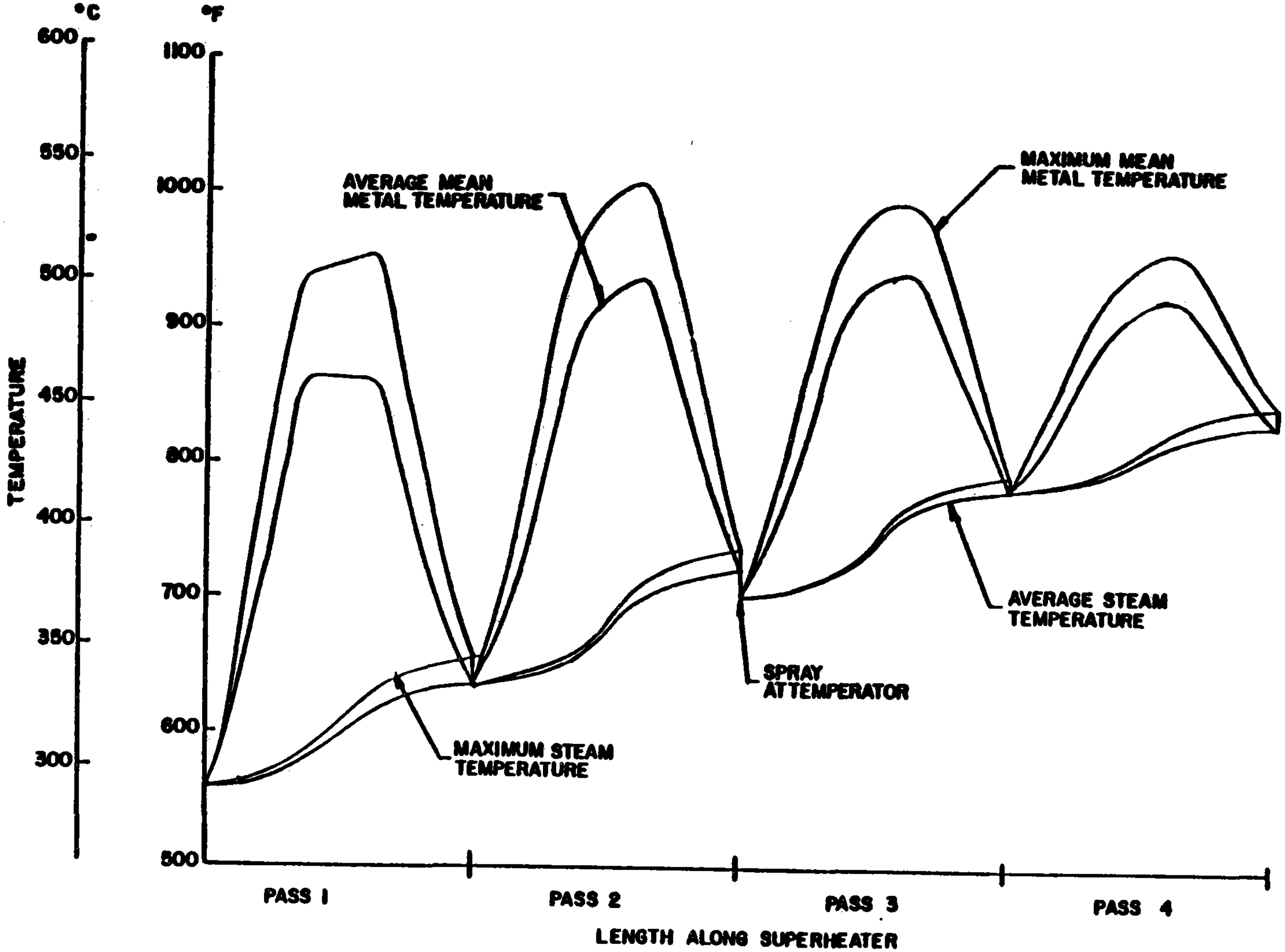


Figure 5-21 TUBE WALL AND STEAM TEMPERATURES ALONG THE LENGTH OF SUPERHEATER

Table 5-7

SUPERHEATER PERFORMANCE CHARACTERISTICS

AT NOON WINTER SOLSTICE

Superheater Pass No.	Tubes Per Pass	Mass Velocity 10^6 kg/hr-m^2 (10^6 lb/hr-ft^2)	H. T. Coefficient W/m^2-C (Btu/hr-ft^2-F)	Pressure Drop[1] kPa (psi)
1	16	4.795 (0.982)	5,390 (950)	159 (23)
2	15	5.117 (1.048)	5 340 (940)	221 (32)
3	17	4.560 (0.934)	4 710 (830)	200 (29)
4	18	4.306 (0.882)	4 490 (790)	193 (28)

(1) interconnecting piping pressure drop not included

using the criteria set forth in the ASME Boiler and Pressure Vessel Codes and other applicable standards.

The structural design requirements of the receiver can be placed into two categories. The first relates to internal prssure and temperature distribution. The second refers to external influences such as wind and seismic loading.

This section first describes the structural analysis and design of the receiver panels and other pressure components such as risers, feeders, downcomers, headers, and the drum. The methods used in structural analysis, the computer programs, the criteria used in the evaluation and the important results are discussed below.

The requirements of the ASME Boiler and Pressure Vessel Code, Section I are fully met in the receiver design. Fatigue and creep-fatigue interactions are important failure modes in the receiver design. However, Section I has no criteria to evaluate these failure modes. Hence, Section I is supplemented by using the fatigue curves of Section VIII, Division 2 in the sub-creep regime. The elevated temperature fatigue curves of Code Case N-47 of the ASME Boiler Code, Section III are used wherever the temperatures exceed those given in Section VIII. The Interim Structural Design Standards prepared by Foster Wheeler for Sandia Laboratories (Ref. 5-1) is also used as a guideline in this design.

One of the critical components (in terms of structural integrity and fatigue life) in the receiver is the superheater panel. The superheater panel is composed of 32 mm (1.25 in) O.D., 3.8 mm (0.148 in) minimum wall, stainless steel (Type 316) tubes on 38 mm (1.5 in) centers using Monowall™ construction in which the tubes are joined together along their length by continuously welded fins to form a flat panel.

The tube thickness was calculated from the Section I formula for seamless tubes. The temperature distribution and stress distribution were determined by using the finite element program (Ref. 5-2). Because of symmetry only one-half of the tube and the fin was analyzed. This half was modeled by a fine mesh consisting of 116 isoparametric elements. Generalized plane strain conditions were assumed in the tube. It has been shown that in a panel supported by multiple buckstays this model would predict the stresses accurately. In the common wall panel, which is heated from both sides and which has no intermediate supports, this model would be conservative. The analysis was done by first performing a plane strain analysis and then relaxing the axial forces at the ends. A postprocessor computer program called FINTUBE, developed by Foster Wheeler, was used to do this relaxation of end forces and to calculate the bending stresses as well as peak stresses.

The temperature and stress distributions for two typical steady state conditions are shown in Figures 5-22 and 5-23. Figure 5-22 corresponds to symmetrical heating from both sides. The parameters used for the calculations are as follows:

Heat flux $q_1"$ = 0.55 MWt/m^2 (175,000 $Btu/hr\text{-}ft^2$)

Heat flux $q_2"$ = 0.55 MWt/m^2 (175,000 $Btu/hr\text{-}ft^2$)

Film Coefficient h = 4.83 $kW/m^2\text{-}C$ (850 $Btu/hr\text{-}ft^2\text{-}F$)

Thermal Conductivity k = 21.52 W/m-C (12.44 Btu/hr-ft-F)

Fluid Temperature T_f = 343C (650F)

Coefficient of Thermal Expansion = 18.54 x 10^{-6}/C (10.3 x 10^{-6}/F)

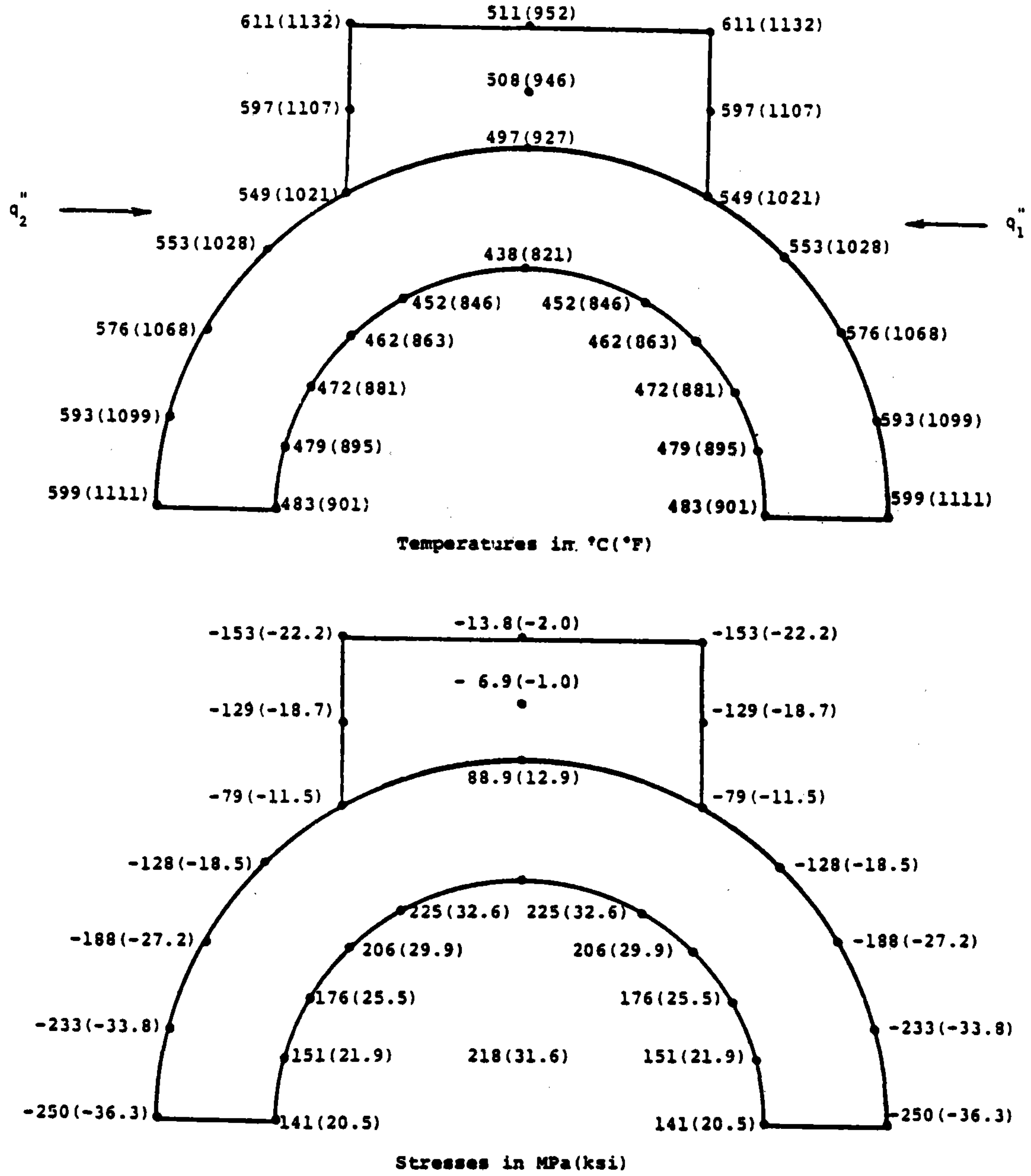


Figure 5-22 TEMPERATURE AND AXIAL STRESS DISTRIBUTION IN SUPERHEATER TUBE WITH SYMMETRICAL HEATING

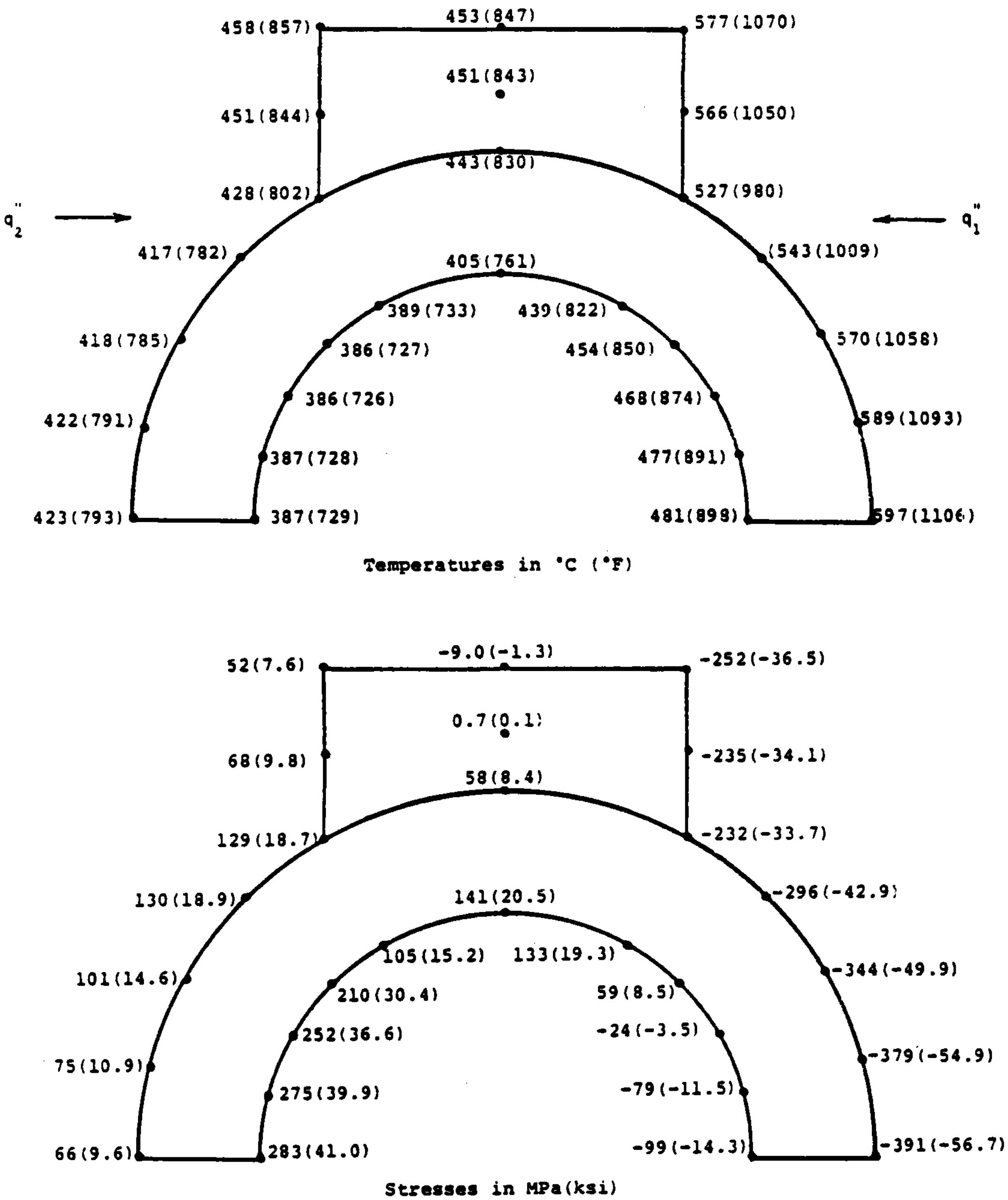


Figure 5-23 TEMPERATURE AND AXIAL STRESS DISTRIBUTION IN SUPERHEATER TUBE WITH NONSYMMETRICAL HEATING

Modulus of Elasticity $E = 1.555 \times 10^5$ MPa (22.55×10^6 psi)

Poisson's Ratio $\mu = 0.3046$

Figure 5-22 corresponds to a nonsymmetrically heated condition. The parameters used in this analysis are identical to the one mentioned above except that $q_2'' = 0.166$ MWt/m^2 (52,500 Btu/hr-ft^2)

The stresses and strains obtained in this analysis were evaluated using the following criteria:

- Limit the primary stresses due to pressure to the allowable stresses given in Section I of the ASME Code
- Limit the primary plus secondary stresses (thermal stresses) to twice the yield stress or 3.5 s_m (s_m is the allowable stress)
- Evaluate the fatigue life using Section VIII Division 2 for temperatures below creep range. For temperatures in the creep range, use the fatigue curves of Code Case N-47.

Using this approach it was found that the design of the receiver panels was structurally adequate.

Other pressure parts such as the downcomer, headers, feeders and risers, drum, etc. were sized according to the requirements of Section 1 of the ASME Code.

The general arrangement of the support structure is shown in Figure 5-18. The support structure consists of 10 columns interconnected by beams and braces. The loadings considered in the design of the support structure are as follows:

- Dead Load: For the first iteration the dead load was assumed to be 1.42×10^6 N (320 kips)

- Wind Load: The survival wind speed is 40 m/s (90 mph) at a reference height of 10 m (30 ft). The corresponding wind pressure at the centerline of the receiver is estimated as 2.16 kPa (45 psf) according to ANSI A58.1 (Ref. 5-3). The operational wind load considered was the one corresponding to a wind speed of 6.67 m/s (15 mph) at the reference height.

- Seismic Load: Uniform Building Code Zone 2 values were used in the design. The maximum ground acceleration for Zone 2 was assumed to be 0.1 g.

The support structure was designed to withstand the above loads and other applicable loads. Since the support structure design is conceptual and not every member was individually sized, there is room for further optimization and possible reduction in the weight of the support structure.

The superheater and boiler panels that form the partition wall between the two cavities are heated by radiant flux from both sides during operation. This reduces the circumferential temperature gradients of the tubes and results in much less thermal stress. Preliminary calculations indicated that no intermediate horizontal support in the heating zone is required for withstanding wind and seismic loads.

Tower Design. The receiver tower is 72 m (236 ft) high and supports a 14.6m (48 ft) high solar receiver for a combined height of 86.5 m (284 ft). The solar receiver weights 131 100 kg (288,500 lb) and its aperture centerline is located 76 m (250 ft) above ground. The horizontal cross sections of the tower are equilateral triangles with widths ranging from 7.6 m (25 ft) at the top to 23 m (75 ft) at the base. All structural members are fabricated of steel.

Primary structural members (columns, chords, and diagonals) are 0.3 m (12 in) to 0.9 m (36 in) diameter pipes that are field welded to prefabricated joints to simplify field erection. Secondary structural members (horizonal bracing, stringers, elevator framing, and miscellaneous supports) are rolled sections with bolted connections. In additon to supporting gravity loads, the tower is designed to withstand wind loads and seismic loads.

The design wind loads are based on ANSI A58.1-1972 and correspond to a design wind speed of 40 m/s (90 mph) at 9.1 m (30 ft) elevation in open country terrain. The seismic loads are based on 1976 UBC and correspond to an equivalent lateral force of 0.1 g. A dynamic analysis, although more accurate than the equivalent lateral force method, was judged unnecessary because the design seismic loads are significantly less than the design wind loads.

The receiver tower foundation consists of three pedestal-type concrete footings. Each tower column is supported on a concrete pedestal 2.7 m (9 ft) high by 1.8 m (6 ft) wide by 1.8 m (6 ft) long. The pedestals are in turn connected to and supported from below by concrete mats 0.9 m (3 ft) thick by 4.9 m (16 ft) wide by 4.9 m (16 ft) long. Soil is backfilled over the mats to the level of the tower column bases. In addition to resisting downward loads, the foundations also provide resistance against uplift (overturning) caused by winds and earthquakes.

5.2.4 Receiver Performance

The performance of the receiver at the design point was determined by calculation of the individual loss mechanisms using correlations available from experience or the solar literature. The reflection, reradiation, and convection losses were estimated by Bechtel, while Foster Wheeler estimated conduction losses and overnight cooldown. Annual performance of the receiver was estimated with the STEAEC program.

Reflection Loss. One of the advantages of a cavity configuration is that it approximates a black body, which absorbs all incident energy. However, the relatively large aperature area to interior surface area ratio, approximately 0.29, results in an effective cavity emissivity of 0.985, or a reflection loss of 1.5 percent (Ref. 5-4).

Reradiation Loss. The receiver panel heat fluxes were analyzed by Foster Wheeler to determine the resulting surface temperature distribution in the cavity. These temperatues were averaged using the fourth power of the absolute temperature to estimate the effective reradiation temperature. The result was 380C (716F). The design point reradiation loss was therefore calculated to be 0.87 MWt.

Convection Loss. The convection loss was calculated using a relationship determined in Reference 5-5. The effective cavity temperature above and the one standard deviation windspeed, 2.4 m/s(5.4 mph), were used to calculate convection loss of 1.2 MWt.

Conduction Loss. The conduction loss was estimated from more detailed analyses in earlier studies to be approximately 0.4 percent of the absorbed energy.

Overnight Cooldown. Overnight cooldown rate of the receiver was estimated using an initial temperature of 293C (560F), an ambient temperature of 10C (50F), a wind velocity of 6.7 m/s (22 ft/s), and a cooldown period of 14 hours. A simplified lumped-mass computer model which included heat capacities of all pressure parts, the water contained within, the insulation and enclosure casing was set up for this analysis. Aperture doors were assumed to be completely closed and the evaluation of radiation and convection losses was based on the total outside surface area of the receiver. The cooldown rate of the receiver with aperture doors closed is shown in Figure 5-24. For a 14-hour cooldown period, the receiver was found to experience a 68C (123F) temperature drop, measured in the drum.

5.2.5 Operating and Control Characteristics

The receiver control consists of an outlet pressure regulator, a feedwater regulator, a steam temperature regulator, and a startup flow regulator. A schematic flow diagram illustrating the essential instrumentation, valving, and controls of the receiver is shown in Figure 5-25.

During normal operation, receiver outlet steam pressure is regulated by the mixing station control equipment located at Pioneer Mill. The startup flow regulator is activated only during the startup periods in order to bring up drum pressure at an optimum rate. When the full superheater outlet pressure is reached, the startup control system will be deactivated and the outlet pressure will be regulated in the same manner as that during normal operation.

Feedwater flow is controlled by a conventional three-element feedwater regulator of the type used on fossil-fueled drum-type boilers. This regulator

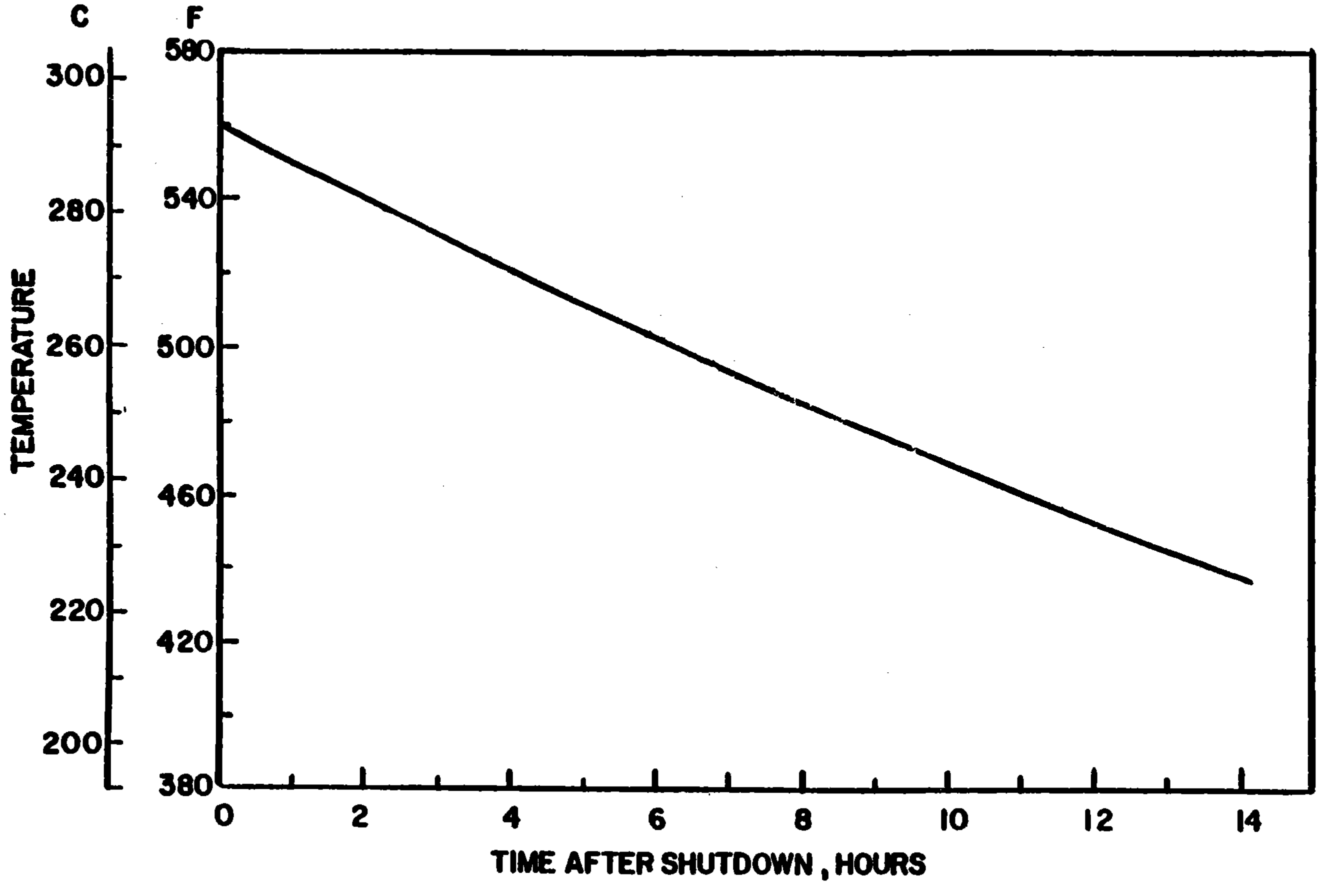


Figure 5-24 RECEIVER OVERNIGHT COOLDOWN

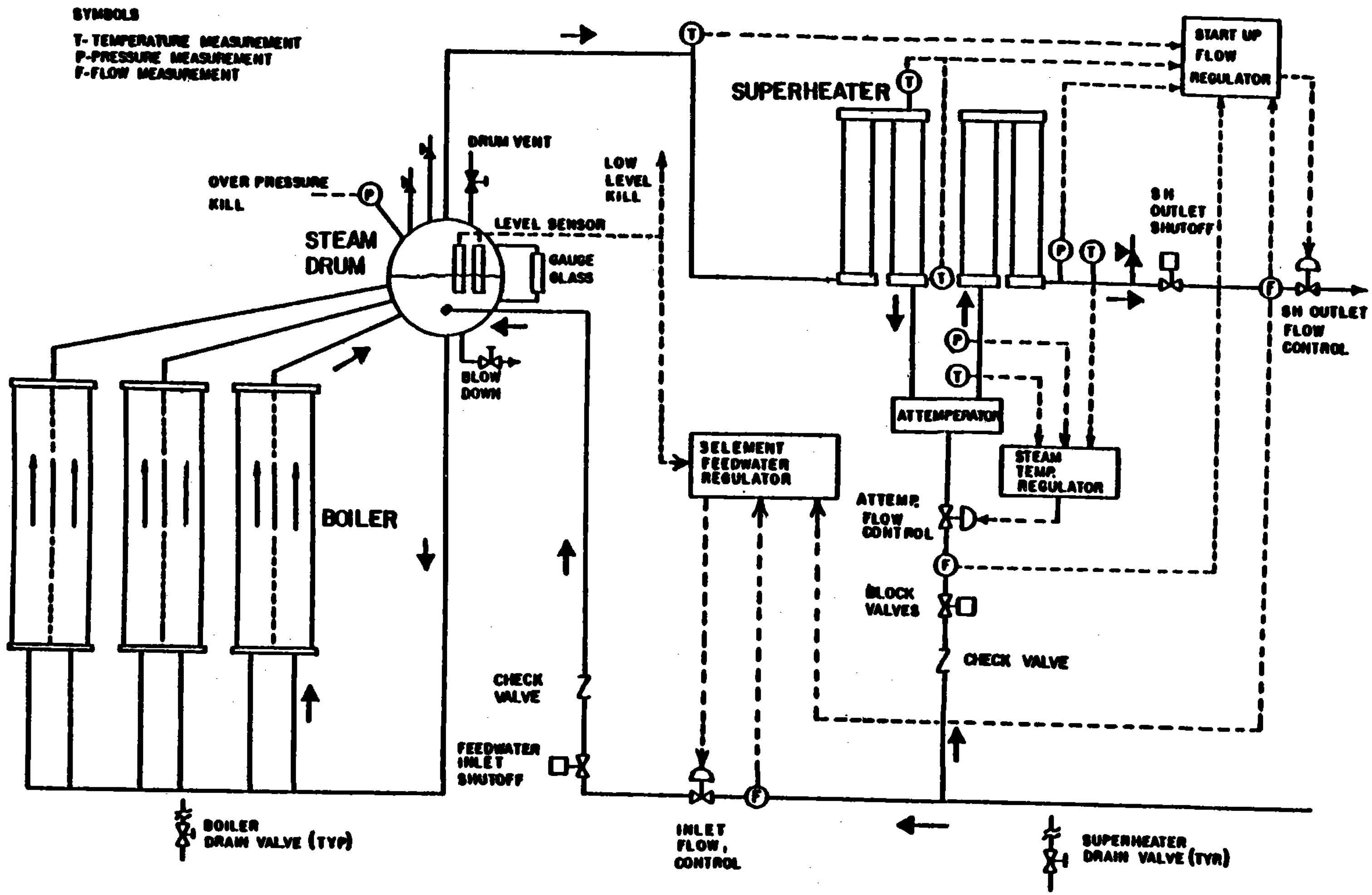


Figure 5-25 SCHEMATIC FLOW AND CONTROL DIAGRAM OF RECEIVER

is responsive to drum water level, steam flow, and feedwater flow. Through the control logic, the steam flow signal is algebraically summed with the feedwater flow signal. The difference between the flows is used as a feed-forward signal through a proportioning level controller to regulate the feedwater supply valve in anticipation of drum-level variations. A signal from the drum-level transmitter also feeds into the level controller, where it is compared with the drum level set point to generate a signal that causes the level controller to modulate the feedwater valve and restore drum level to the set point. The modulation of the feedwater valve, resulting from combined effects of level and flow signals, maintains a constant drum level during wide and rapid load changes.

The superheater outlet steam temperature is controlled by an attemperator located between superheater passes 2 and 3. In the attemperator, feedwater is sprayed into the superheated steam and evaporated, thus lowering the steam temperature. The control logic in the steam temperature regulator adjusts and monitors the spray flow to achieve the desired superheater outlet temperature. Pressure sensed at the outlet of the attemperator is used in the control logic to determine the saturation temperature at this point. Maximum spray flow is limited so that the steam temperature leaving the attemperator will not fall below 11C (20F) above saturation. Since the receiver must be started up at least once a day, the startup must be automated to bring the receiver on line in a minimum time consistent with safe operation. The fundamental requirement during startup is to maintain sufficient steam flow through the superheater during the pressure ramp-up to keep superheater tube temperatures and front-to-back tube-wall temperature differences within safe limits. The startup flow regulator, shown in Figure 5-25, controls flow through the superheater by modulating a valve in the superheater outlet line. Inputs to the regulator are signals of steam flow, attemperator water flow, saturation temperature at the drum, steam temperature rise across a selected superheater pass, and superheater outlet steam pressure. The control system operates in response to a startup function which relates the acceptable drum water temperature rise to the instantaneous heat absorbed and the drum water temperature. This startup function can be generated by an analytical computer model simulating the anticipated startups. The actual operation of this control system will have to be fine-tuned during preliminary operaticn of the receiver.

All receiver controls can be operated either in a fully automatic mode or by manual override at the operator's discretion. Sensors are provided to activate alarms so that the operator can defocus the heliostats in the event of high superheater outlet steam temperature, high drum pressure, or low water level in the drum.

5.2.6 Weight and Cost Estimates

Receiver Unit. Table 5-8 summarizes the weights and materials for the key components of the receiver. The whole receiver unit weighs 121 700 kg (267,900 lb) empty, and 131 100 kg (288,500 lb) filled with water. The cost estimate of this receiver was based on the receiver conceptual arrangement drawings, design information, list of materials, estimated weights, and site location. Costs of shop fabrication, subcontracted fabrication, and general accessories, as well as home-office expenditures, were estimated by Foster Wheeler Energy Corporation's (FWEC) Equipment

Table 5-8

SUMMARY OF MATERIAL AND ESTIMATED WEIGHT

OF THE RECEIVER

	Material	Weight, 10^3 kg (10^3 lb)	
1. Pressure Parts			
Steam Drum	SA-516 Gr 70	10.0 (22.0)	
Downcomers	SA-106 C	1.8 (4.0)	
Boiler Panels	SA-210 A-1	11.3 (24.9)	
Boiler Headers	SA-106 C	2.0 (4.4)	
Feeders & Risers	SA-210 A-1	1.2 (2.6)	
Superheater Panels	SA-213 TP 316 H	2.1 (4.7)	
Superheater Headers & Piping	SA-335 P-2	1.4 (3.0)	
Miscellaneous Piping	SA-106-C	0.9 (1.9)	
Subtotal Pressure Parts			30.7 (67.5)
2. Cavity Enclosure & Doors			
Casing Plate & Stiffeners	Carbon Steel	21.5 (47.3)	
Insulation	Mineral Wool	6.9 (15.1)	
Lagging	Aluminum	2.7 (6.0)	
Subtotal Enclosure & Doors			31.1 (68.4)
3. Structural Steel	Carbon Steel		37.2 (82.0)
4. Platforms & Ladders	Carbon Steel		9.1 (20.0)
5. Miscellaneous Accessories			13.6 (30.0)
Total Receiver Dry Weight			121.7 (267.9)
Contained Water Weight at 15.6C (60F)			9.4 (20.6)
Total Estimated Weight			131.1 (288.5)

Estimating Department. Field erection cost was estimated by FWEC's Construction department. Standard commercial estimating methods were used for these estimates. The total direct cost of the receiver alone, not including support tower, in 1st quarter 1981 dollars is $2,700,000. Supporting cost data sheets which provide more detailed breakdown are included in Appendix A. The receiver is listed under cost code number 5400.

Receiver Tower. The total direct field cost estimate for the receiver tower with foundation is $908,000. Backup data for the receiver tower is also listed under cost code number 5400.

5.3 THERMAL TRANSPORT SYSTEM

The thermal transport system provides the physical interface between the existing facility at Pioneer Mill and the added solar equipment. Condensate from the mill facility is pumped to the receiver system. Superheated steam is returned from the receiver system to the existing mill steam system. This subsection describes the thermal transport system characteristics. Schematic flow diagrams of the thermal transport system and connections to the mill are given in Figures 5-26 and 5-27.

5.3.1 Major Components, Functional Elements, and Physical Location

The major components of the thermal transport system include the steam and condensate pipelines connecting the receiver system at the top of the tower with the existing mill facilities at the boiler or turbine generator room. The major equipment includes condensate transfer pumps and receiver feed pumps, a holding tank, a warmup loop with heater and recirculation pump, a steam mixing station which consists of electric steam superheaters and pressure let-down stations with silencers, and an emergency steam turbine generator. At the mill the condensate transfer pumps are located near the existing boilers and the mixing station is located near the existing steam turbine. The rest of the equipment is located in a room at the base of the receiver tower.

5.3.2 Functional Requirements

During normal operation the thermal transport system is designed to:

- Pump the condensate from the existing deaerator in the mill to a holding tank at the base of the tower

- Boost the water pressure to cover the losses in the receiver system so that the receiver outlet steam pressure is 6.85 MPa (994 psia)

- Supply superheated steam at 399C (750F) and 5.96 MPa (865 psia) to the mill facility

During startup the system is designed to:

- Warm up the receiver system before startup

- Control the steam conditions to the mill facility through the mixing station, which

  - dumps low quality steam to the condenser

  - transfers medium quality steam to the mill process headers if there is sufficient demand

  - superheats high quality steam to the normal mill operating conditions

In addition, on loss of electric power supply the system generates emergency electric power to safely shut down the collector field and the receiver.

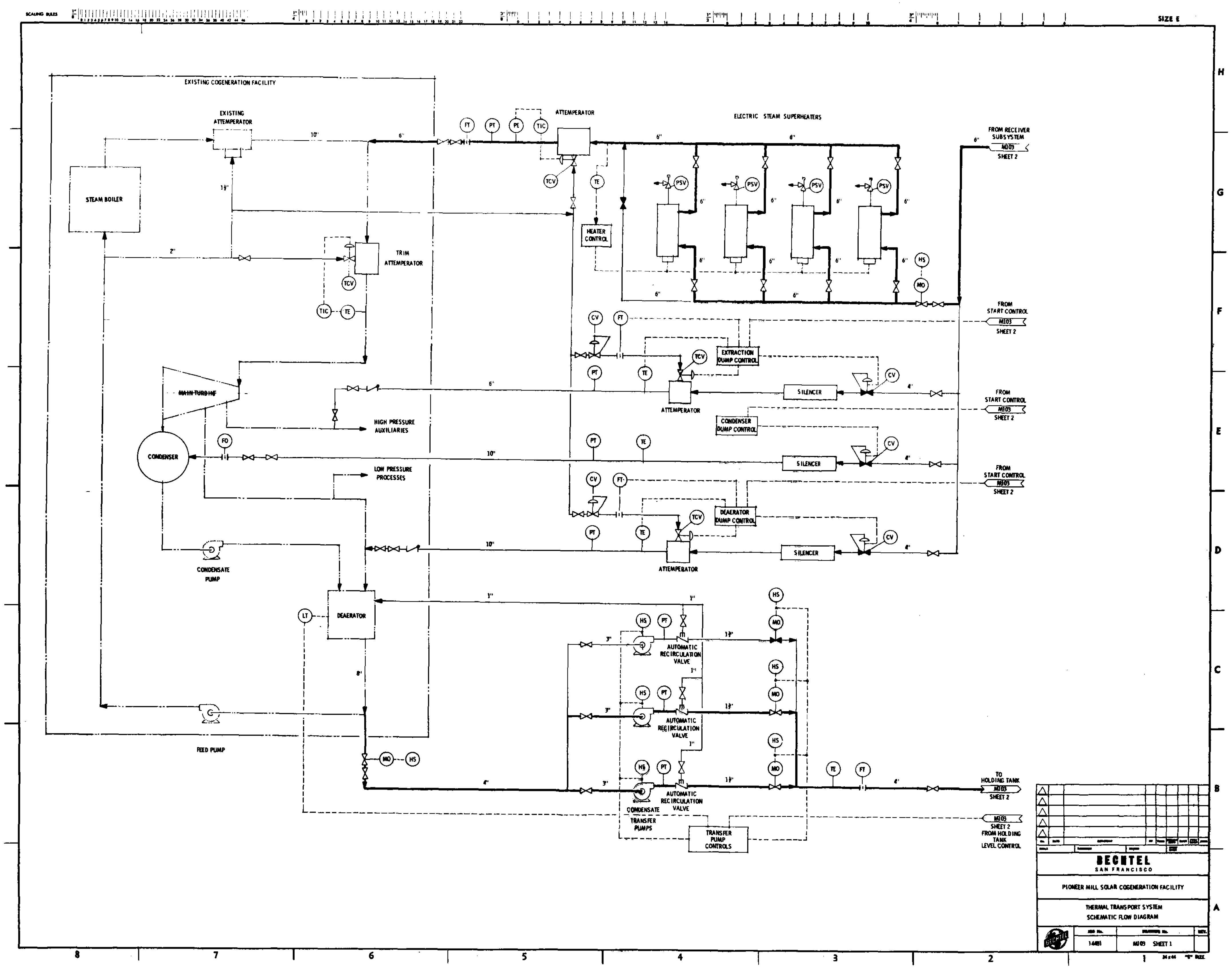


Figure 5-26 THERMAL TRANSPORT SYSTEM SCHEMATIC FLOW DIAGRAM, SHEET 1

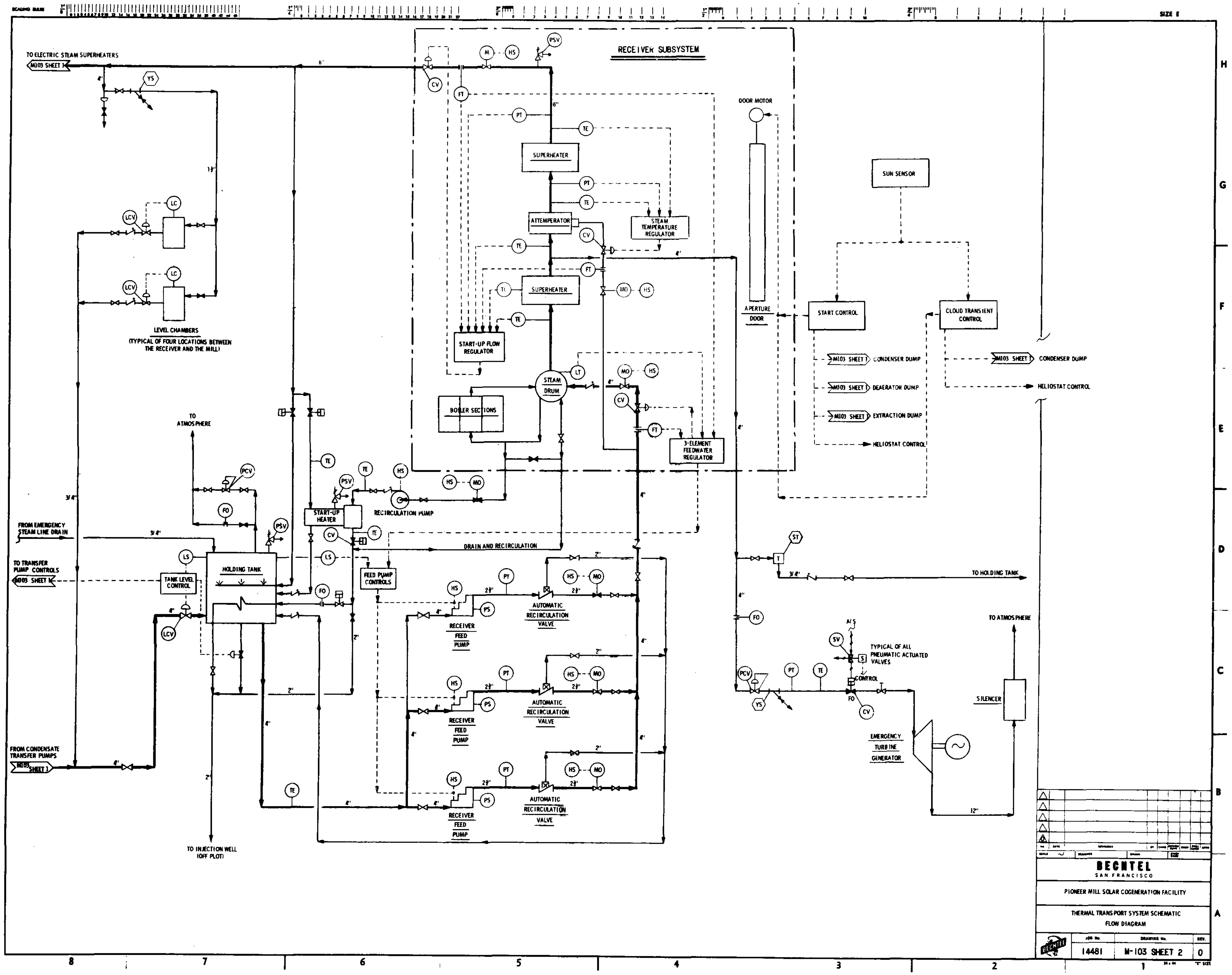


Figure 5-27 THERMAL TRANSPORT SYSTEM SCHEMATIC FLOW DIAGRAM, SHEET 2

5.3.3 Design

The developed profiles of the thermal transport system pipelines between the mill and the receiver are shown in Figure 5-28. The system piping includes the risers and downcomers in the tower to the steam and water interfaces with the receiver system. At the mill the steam pipeline connects to the existing main steam piping from the boilers. The steam pipeline is 15 cm (6 in) in diameter and is 1 130 m (3,700 ft) long. An economic analysis of the steady state heat losses from the steam pipeline under design operating conditions shows that the optimum insulation thickness is 11.4 cm (4.5 in). The long steam pipeline additionally serves as a limited-capacity buffer storage system for the solar steam. The water pipeline supplying condensate to the receiver is 10 cm (4 in) in diameter with 3.8 cm (1.5 in) of external insulation and is 1 190 m (3,900 ft) long. At the mill the water pipeline is supplied with condensate from the mill deaerator.

Drains are provided at four points in the steam pipeline. The drains are used to collect condensed steam at saturation temperature during startup and to drain any moisture during periods of extended shutdown. The condensate is collected in level-controlled tanks and is returned to the adjacent low-pressure water pipeline.

The thermal transport system pipes and valves are designed in accordance with the ANSI Power Piping Code B31.1.

The main steam pipe diameter is selected to keep the maximum steam velocities between 15 and 30 m/s (50 and 100 ft/s). This velocity gives a reasonable piping pressure drop for the long pipe length. The steam-pipe material is ASTM A335 P22, a low alloy steel, and schedule 80 wall thickness is used. The condensate piping operates at a low pressure and is ASTM A53, grade B, schedule 40 seamless carbon steel pipe. Thermal expansion is accommodated by expansion loops. This applies particularly to the steam pipeline which is heated from ambient temperature to 438C (820F) and has either 91 m (300 ft) or 110 m (360 ft) between anchor points.

The pipes from the tower base to the mill are above ground on metal supports. From the edge of the millyard to the tower, where the pipelines cross the sugarcane fields, the supports are 0.9 m (3 ft) high. The diversion channel proposed for the area between the mill yard and the collector field is spanned by a 21 m (70 ft) long latticework bridge which is constructed specifically for the pipes. Along the mill yard perimeter, the supports are raised to 3.7 m (12 ft) so that they do not interfere with the mill yard driveways. At the mill, the condensate pipeline extends to the boiler and uses the existing pipe support bridge to cross Lahainaluna Road. Provision is made to allow for movement, required by thermal expansion, between the pipes and the supports. The pipe supports are from 7.6 m (25 ft) to 13.4 m (44 ft) apart. The pipe anchors are similar to the pipe supports, except that the pipes are welded to the top of the support.

Three 50 percent capacity condensate transfer pumps, each rated at 0.05 m^3/s (80 gpm) at a differential head of 26 m (85 ft) are installed at the

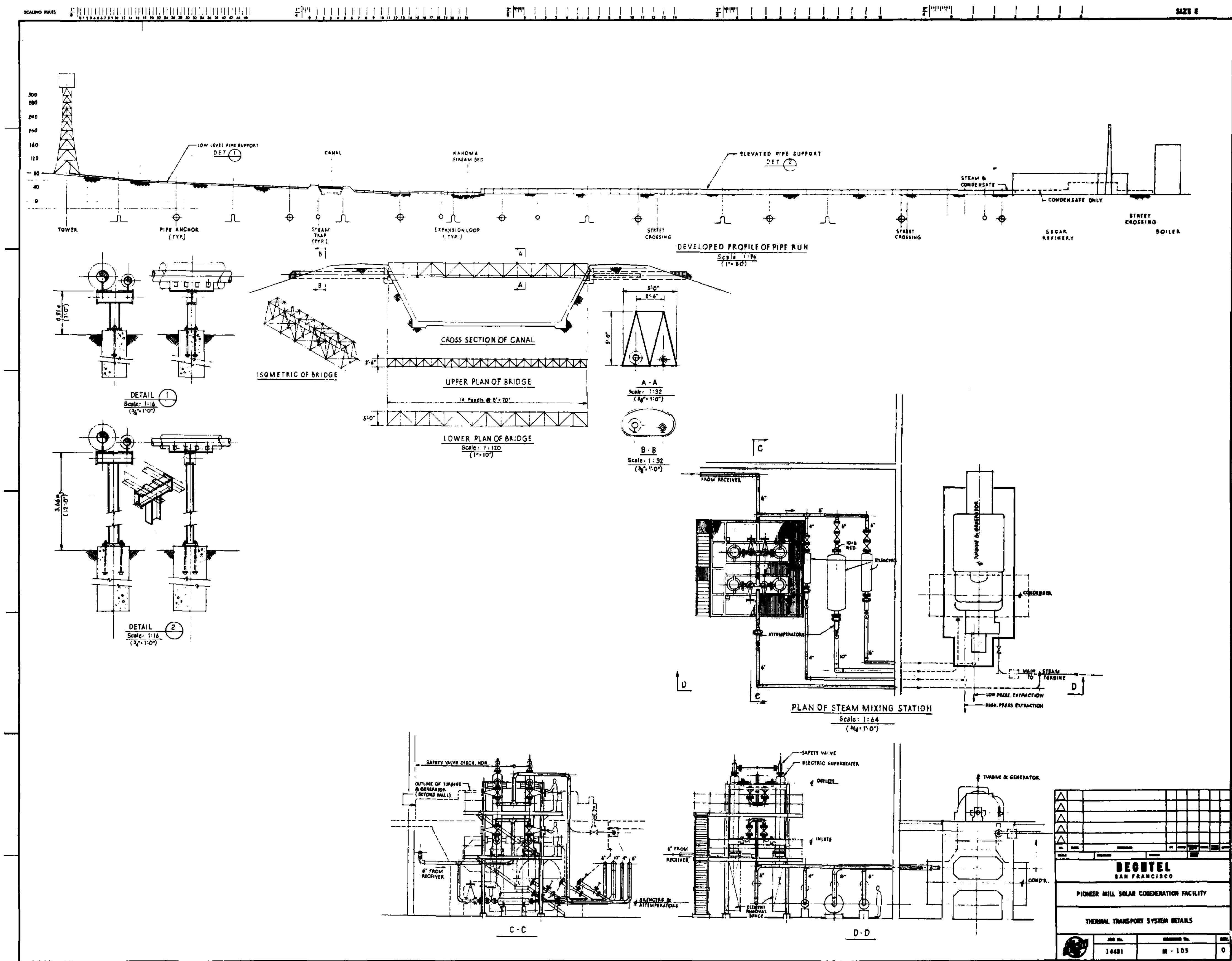


Figure 5-28 THERMAL TRANSPORT SYSTEM, DETAILS

base of the existing boilers, near the main feedwater pumps. These horizontal centrifugal transfer pumps are fed from the boiler feedwater line from the existing deaerator vessel, and transfer the condensate to the holding tank at the base of the receiver tower.

The equipment at the base of the tower is housed in a building that results from enclosing the area between the tower legs. The location of the building and equipment is shown in detail in Figure 5-14. Figure 5-29 gives a perspective of the building layout. The condensate holding tank is supported on the roof of the building. The tank can be deaerated using steam from the receiver or heated after shutdown by steam coils using steam from the mill's main steam line. Condensate level in the tank is maintained by interconnecting controls between the condensate transfer pumps, the receiver feed pumps, and the tank.

Three 50% positive displacement feed pumps each rated at 0.05 m^3/s (80 gpm) and a total differential head of 892 m (2,930 ft) supply the condensate at a high pressure to the solar receiver at the top of the tower. These pumps, which are horizontal triplex plunger type, were selected to supply a constant feedwater pressure over a wide range of flows with the highest efficiency. The slow speed drive required by the pumps is obtained through integral reduction gears driven by adjustable speed dc motors. The controller is a solid state silicon-controlled rectifier bridge converting the applied ac line voltage into adjustable dc voltage. The pumps operate in response to the flow-modulating signal from the receiver three-element control.

Equipment for the receiver recirculation warmup loop is located at the tower base. The equipment consists of a recirculation pump, rated at 0.05 m^3/s (80 gpm) and a total differential head of 43 m (140 ft), and a warmup heater. The warmup heater is a surface condensing heat exchanger with a tubular surface area of 17 m^2 (183 ft^2). After an overnight shut-down of 14 hours, the receiver drum temperature has decayed about 68C (123F) below saturation temperature. By warming up the water and the receiver metal with mill steam it is possible to reduce the morning startup time for the receiver. In the loop, receiver water is obtained from the bottom headers of the boiler elements, pumped through the warmup heater, and recirculated back to the boiler drum using the line which normally acts as the drum drain line. The water is heated in the heat exchanger by mill steam that is used to preheat the thermal transport steam pipeline.

In the event of loss of electric power, the collector and receiver systems need to be shut down in a safe manner. In particular the heliostats must be directed to move in orientation that removes all heat flux from the receiver and ensures the reflected solar radiation does not produce any safety hazard. Since the heliostats are positioned by electric motors, emergency power is essential for their operation. This emergency electric power is obtained from a 500 kWe steam driven turbine generator which is located at the base of the tower. The electric power produced by this unit secures the collector field, operates the receiver feed pumps, controls the steam outlet valve from from the receiver, and relays essential information to the mill. The emergency steam turbine operates on steam drawn from the receiver superheater outlet. The steam is reduced in pressure and supplied to the single-stage, solid wheel, non-condensating type turbine, which is designed to operate

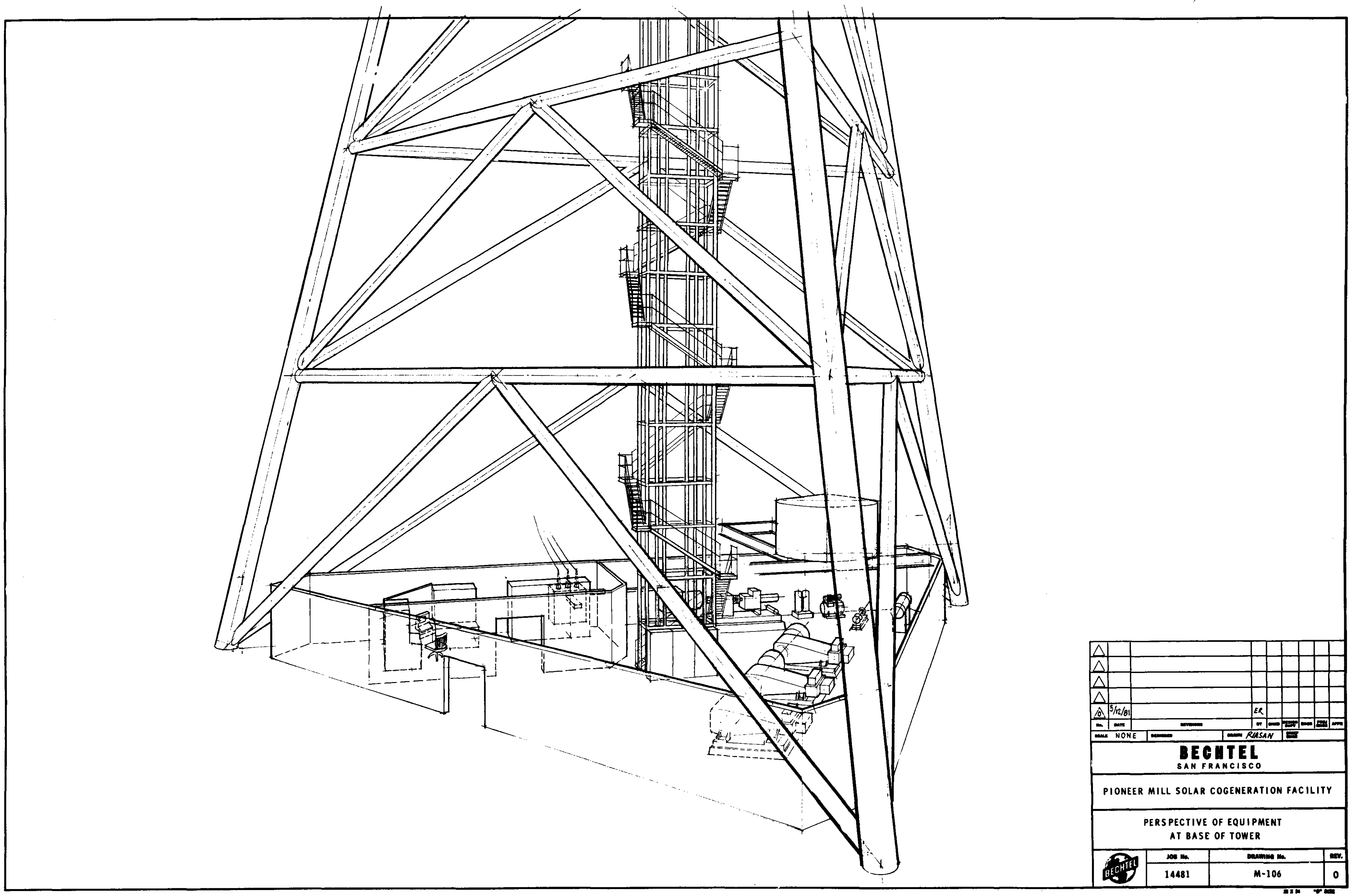


Figure 5-29 PERSPECTIVE OF EQUIPMENT AT BASE OF TOWER

on variable-quality steam and to withstand repeated fast, cold starts. The steam quality available is the initial volume contained in the receiver plus the additional steam produced from residual heat in the receiver. The turbine operates at a maximum pressure of 4.48 MPa (650 psia) and temperature of 343C (650F).

A panel is included in the control board at the base of the tower for the thermal transport system equipment. Instrumentation and control of the thermal transport system uses conventional technology that is applicable to industrial power plants. This makes use of analog signals to control the flow of condensate, feedwater, and steam during all stages of system operation. The control is either fully automatic or by manual override at the discretion of the operator. The thermal transport system also can be controlled from the mill control room extension. In addition, relevant data from the thermal transport system panel is transmitted to the master control system.

A compressed air system is located at the base of the tower. The air is used by the pneumatic instrument and control equipment in the receiver and thermal transport systems. The compressed air system includes redundant heavy-duty compressors, coolers, moisture separators, dryers, and receiver tanks. Air is supplied at a pressure of 793 kPa (115 psia) with a capacity of 0.13 standard m^3/s (25 scfm).

The steam mixing station, which is shown in detail in Figure 5-28, includes the electric steam superheaters and steam dump lines. The mixing station is located in the mill facility in an area adjacent to the main steam turbine. This mixing station ensures that the receiver steam is compatible with the mill boiler steam as early as possible during startup to minimize wasted energy. The four vertical electric steam superheaters, each rated at 400 kWe, have their own support structure and are elevated to allow the removal of the heating element assembly. When the steam is below the design temperature the electic steam superheaters are used to raise the temperature of the receiver steam to the same temperature as the steam from the mill boilers. The steam dump lines also are used during startup, before the receiver steam is at an operating pressure level that is compatible with the main steam. Steam is dumped to the condenser, transferred to the low-pressure process header or the high-pressure steam header, depending on receiver steam conditions and factory operation. The valve station in each dump line reduces the pressure and where necessary desuperheats the steam to match the header conditions.

5.3.4 Operating and Performance Characteristics

Steady State. During normal operation, feedwater is supplied to the receiver drum at 113C (235F). The solar receiver generates 33 500 kg/hr (73,900 lb/hr) of superheated steam at a pressure of 6.85 MPa (994 psia) and a temperature of 438C (820F). Due to losses, the conditions at the mill are 5.96 MPa (865 psia) and 422C (792F) at design flow. An attemperator is used to obtain the mill temperature of 399C (785F) by adding 900 kg/hr (2,000 lb/hr) of mill boiler feedwater at a temperature of 113C (235F). At a receiver flow rate of 25 percent of design flow, the thermal losses are such that main steam conditions are obtained at the mill without the use of the attemperator.

Table 5-9 gives the steady state pressures and temperatures at both ends of the thermal transport pipe for various steam flows.

Table 5-9

THERMAL TRANSPORT STEAM PIPE OPERATING CONDITIONS

Flow - % Maximum	25	50	75	100
Pressure @ Receiver Outlet - MPa (psia)	6.03 (875)	6.21 (900)	6.48 (940)	6.85 (994)
Temperature @ Receiver Outlet - C (F)	438 (820)	438 (820)	438 (820)	438 (820)
Pressure @ Mill - MPa (psia)	5.96 (865)	5.96 (865)	5.96 (865)	5.96 (865)
Temperature @ Mill - C (F)	400 (752)	416 (781)	421 (789)	423 (793)
Steam Flow Through Pipe - kg/hr (lb/hr)	8 389 (18,490)	16 774 (36,980)	26 161 (55,470)	33 500 (73,900)
Attemperating Flow - kg/hr (lb/hr)	0 (14)	350 (630)	640 (1,100)	900 (2,000)
Flow to Turbine - kg/hr (lb/hr)	8 393 (18,504)	17 060 (37,610)	25 660 (56,570)	34 400 (75,900)
Turbine Inlet Temperature - C (F)	399 (750)	399 (750)	399 (750)	399 (750)

Startup. It is estimated that the thermal transport steam pipeline and the solar receiver cool down to about 221C (430F) during an overnight shutdown. At sunrise, when the solar receiver is started up from this condition, the receiver takes about 30 minutes to reach its design outlet temperature of 438C (820F). If the steam pipe also starts from 221C (430F), it takes about 30 minutes before 5.96 MPa (865 psia) steam pressure is available at the mill end of the steam pipes, and it is not until 74 minutes after sunrise that the steam delivered to the mill reaches 399C (750F). During these 74 minutes the solar steam is not compatible with the mill main steam for use in the turbine generator. However, some of this steam's energy can be recovered in the mill in high and low pressure extraction steam headers. Steam that can not be utilized is dumped to the condenser. This startup transient can represent a significant energy loss.

To reduce the energy loss, various options for increasing the amount of solar steam that can be admitted to the main steam header at the mill during the typical morning startup period were evaluated. The methods considered include:

- Trace heating of the thermal transport steam pipe
- Preheating the thermal transport steam pipe and the receiver to 275C (527F) by condensing steam from the mill
- Preheating the thermal transport steam pipe to an average 390C (735F) by circulating main steam from the mill through the pipe and back to the mill via an additional steam return line
- Superheating the solar steam at the mill to 399C (750F) with electric heaters

An oil-fired superheater was not considered for two reasons. First, the purpose of the solar retrofit is to displace oil consumption. Also the superheater cannot be joined with the existing boilers for operational reasons and would therefore represent a new emission source on the other side of the street from the existing boilers.

A computer simulation was used to model the transient characteristics of the thermal transport system steam pipe. This code was then used for evaluating the alternatives listed. Early morning solar data for March was used as input to the analysis.

Trace heating of the pipe to offset heat lost to the environment during the night was found to require a great deal of energy, about 3.5 MWhe on the longest nights. This is equivalent to about 14 060 kg (31,000 lb) of main steam. In addition, the initial low temperature steam flowing from the receiver to control superheater temperature during the startup before the receiver reaches operating temperature will cool down the pipe. This eliminates most of the advantage gained by starting with the pipe at a higher temperature.

Preheating the pipe and receiver to saturation temperature by condensing main steam from the mill shortens the receiver startup transient from 30 minutes to 5 minutes. Also, the length of time between sunrise and the delivery of 399C (750F) steam to the mill is reduced from 74 minutes to 68 minutes. In order to preheat the solar receiver boiler and thermal transport system steam pipe by condensation, the pipe must be dead-ended at the solar receiver end and opened to the main steam line at the mill end. When the warmup procedure is started 45 minutes before sunrise, the pipe and boiler have heated up to 274C (525F) by sunrise.

A warmup heater for the solar receiver boiler is required. The heater is a surface condensing heat exchanger with a tubular surface area of 17 m^2 (183 ft^2). The initial steam flow rate will be 6 030 kg/hr (13,300 lb/hr). This rate will reduce to 2 720 kg/hr (6,000 lb/hr) after 45 minutes. The total main steam requirement is 3 570 kg (7,860 lb).

If an additional 10 cm (4 in) steam return line is run from the receiver to the mill, main steam from the mill can circulate through the 15 cm (6 in) steam pipe. At a flow rate of 18 140 kg/hr (40,000 lb/hr), after

55 minutes the 15 cm (6 in) pipe will have a temperature profile ranging from 382C (720F) at the receiver to 399C (750F) at the mill. (Average pipe temperature is 390C (735F).) This reduces the time required to produce 399C (750F) solar steam at the mill by only 4 minutes, from 68 minutes to 64 minutes. The amount of main steam required to heat the pipe up in this manner is 16 630 kg (36,630 lb) and the steam returned to the mill cannot be returned to the main steam line because it has been cooled and is at a lower pressure. It should be noted that the total amount of solar steam generated in the first 68 minutes is only 14 090 kg (31,000 lb). Therefore, preheating the thermal transport system steam pipe by circulating main steam from the mill is not an adequate solution.

For the selected design approach, the electric steam superheaters located at the mill end of the thermal transport system steam pipe are used to superheat the steam to mill temperature. The superheaters operate during startup after the main steam pipe and the receiver are preheated to 275C (527F). This method allows solar steam to be fed to the mill header almost immediately. The maximum superheater power required is 1 590 kWe. The total energy required per day by the superheaters is 1 030 kWhe. Only 4 090 kg (9,000 lb) of main steam are needed to produce this much electric energy. The total amount of steam that can be used for producing electric energy as a result of using the superheaters is 13 640 kg (30,000 lb). This shows there is a significant energy return on the energy invested in electrically superheating the solar steam during the first 68 minutes of receiver operation after sunrise.

The four options that were compared are illustrated in Figure 5-30, which shows steam temperature delivered to the mill as a function of time from sunrise. The power absorbed by the electric superheaters compared to the net power produced with solar steam is shown in Figure 5-31.

Although the selected design option of using electric superheaters may appear unconventional and inefficient at first glance, the use of relative expensive electric power for topping the receiver steam temperature was evalated to be the best solution of those examined. The other options allowed much greater energy losses because they concentrate on heating the pipe rather than heating the solar steam. The pipe has such a large surface area that it looses more energy than is required to simply heat the steam that has already travelled through the pipe.

5.3.5 Thermal Transport System Capital Cost

The direct capital cost estimate for the thermal transport system is $3,181,000. Included in this estimate is the piping, pipe supports, (including risers and downcomers in the tower) equipment, electrical, and instrumentation. Backup detail is included in Appendix A. This system is listed under cost code number 5700.

5.4 MASTER CONTROL SYSTEM

The primary function of the master control system is to integrate the operation of the main solar systems with the mill facilities and to acquire and store data. A block diagram of the master control system with its relationship with the other system controls is shown in Figure 5-32.

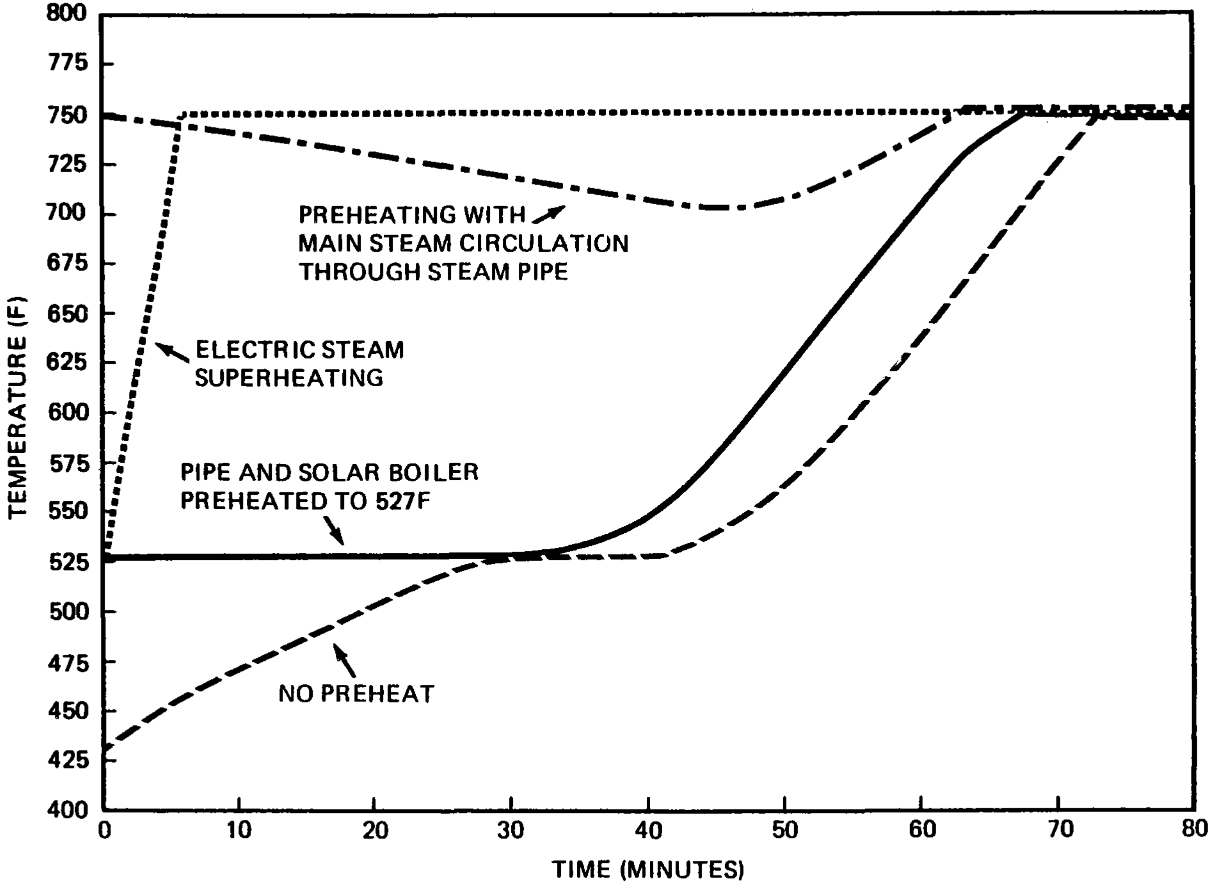


Figure 5-30 TEMPERATURE VERSUS TIME FOR SOLAR STEAM AT PLANT

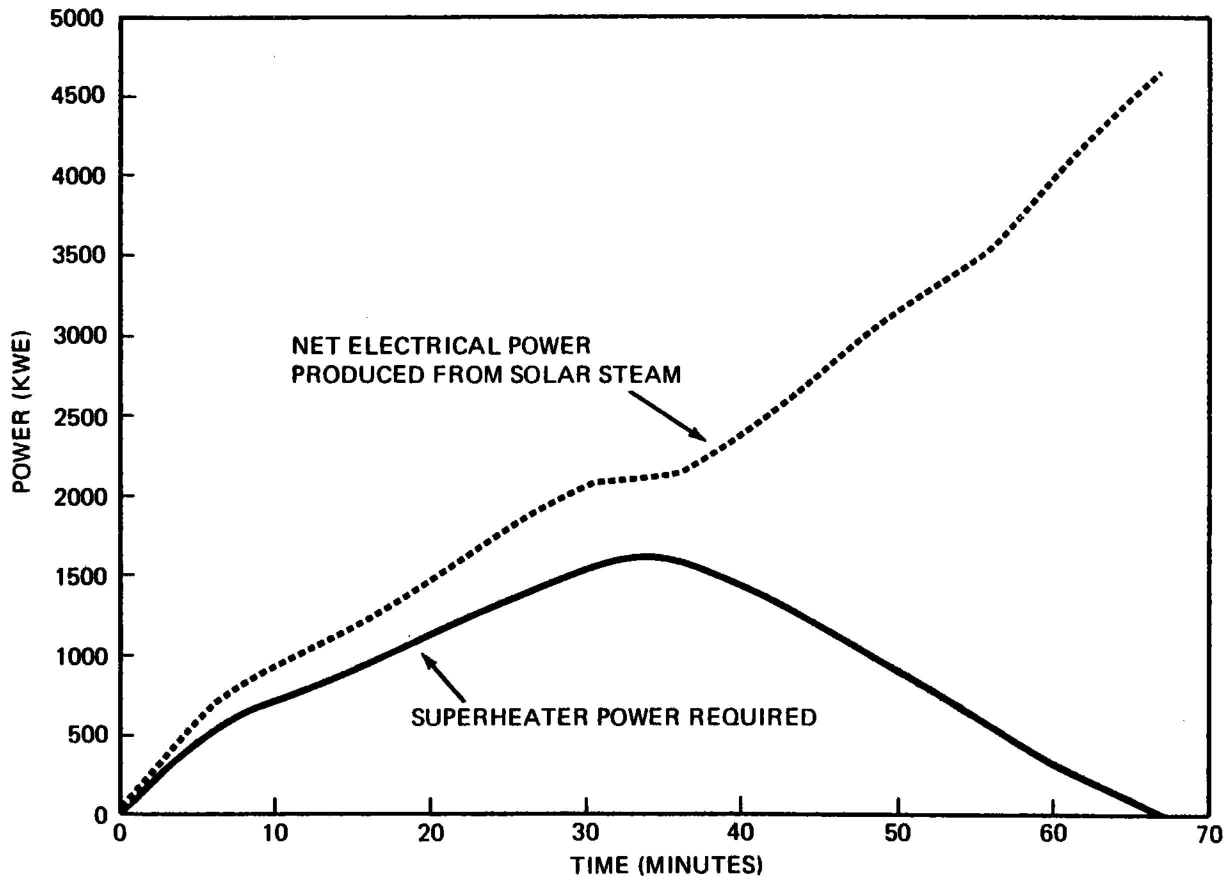


Figure 5-31 SUPERHEATER POWER REQUIRED AND NET POWER PRODUCED VERSUS TIME

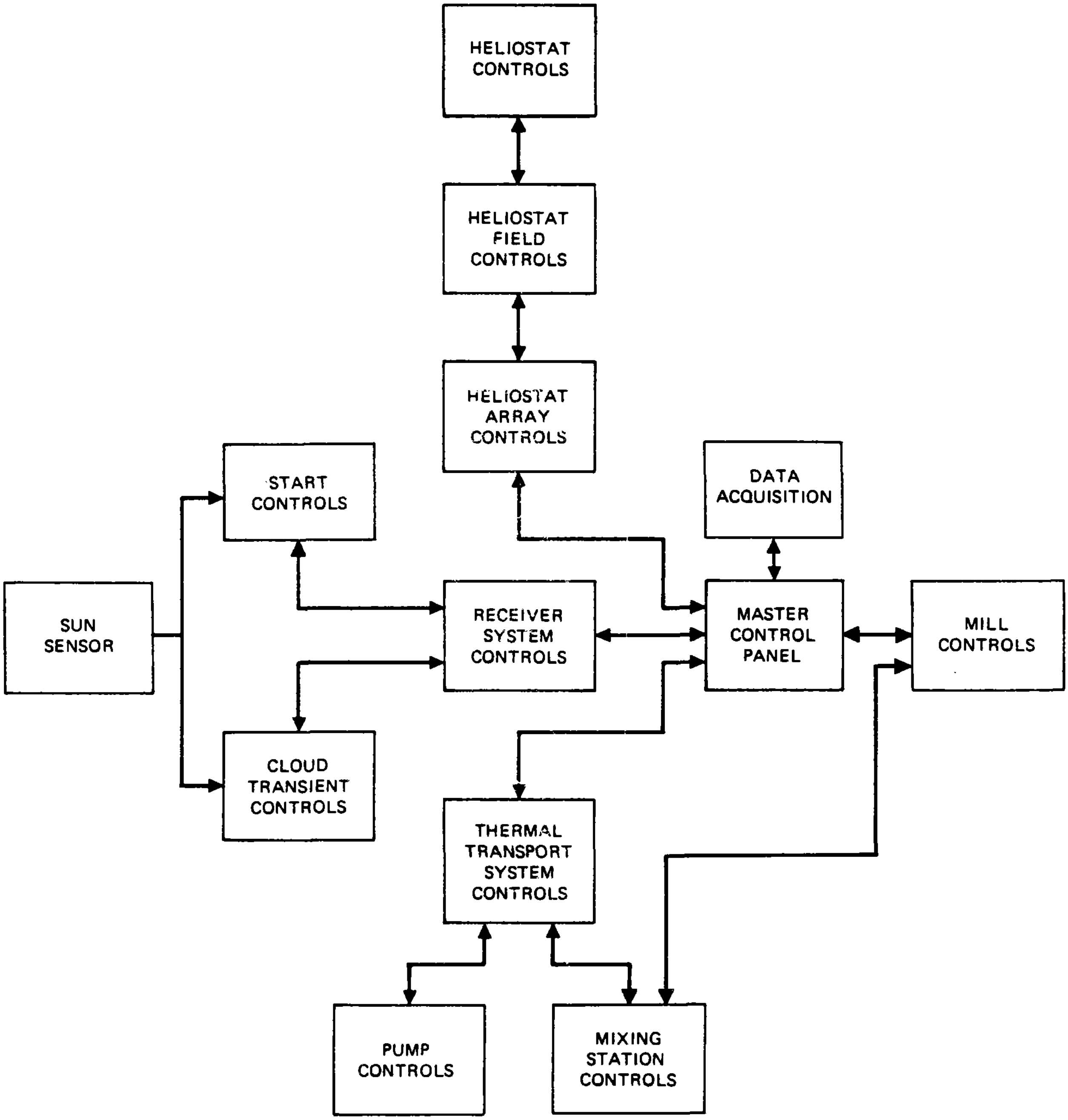


Figure 5-32 MASTER CONTROL BLOCK DIAGRAM

5.4.1 Major Components, Functional Elements, and Physical Location

The main control point for the operation of the collector system, the receiver system, and part of the thermal transport system is a solar control room in the base of the tower. This room, manned by the solar operator, contains the heliostat array controller for the collector field. It also contains the collector control peripheral equipment for operator interface and data logging. The operator has visual feedback of collector field operation through closed circuit TV cameras mounted on the tower and can observe cloud approach with another skywatch camera. Operator action is not required for safe operation, however, since automatic coordination is necessary for protection of the receiver. A minicomputer provides the interface between the digital collector controls and the pneumatic analog controls of the receiver. All critical control equipment is redundant. Thus, there are two collector system panels in the new control room at the base of the receiver tower.

The controls for the mill end of the thermal transport system are located in the expansion of the existing mill control room. The existing power plant operator will have control of the mixing station so that the stability of the mill operation can be maintained. Automatic startup sequences are programmed into the controls but the operator can select options such as routing of startup steam from the receiver. The two control room operators are linked by voice link in case problems develop and for anticipation of cloud transients.

The existing control board is modified only where necessary to interface with the new solar facility. The extension of the mill control board has the same type of instrumentation and controls as the existing board for operator familiarity. In addition, the new board has a CRT display with a keyboard input to monitor systems, identify troubles, and control operating modes. The data acquisition console at the mill is separate from the control board and consists of a minicomputer with peripheral hardware.

The digital data transmission and communication lines between the two control rooms are carried on the overhead electrical distribution poles.

5.4.2 Functional Requirements

The solar systems and the mill facility are controlled independently with the master control system coordinating and interfacing with the existing cogeneration facility. The master control system must therefore be able to integrate the following functions of the other systems' controls.

The collector system controls are capable of:

- Relaying time of day and aim point instructions to the heliostat and changing the operating mode to the heliostat as required
- Starting up, shutting down, and stowing the heliostats using preprogrammed automatic sequences compatible with the system condition of the solar facility
- Providing status indication and data-logging capability for the collector system.

The receiver system controls are capable of:

- Maintaining pressure, temperature, and flow control of the receiver during all normal operating modes
- Detecting problems in the receiver operation and providing an alarm when these problems occur
- Starting up and shutting down the receiver using preprogrammed automatic sequences

- Sending emergency signals to the thermal transport system and collector system to protect the receiver from damage
- Providing receiver status for the operator.

The thermal transport system controls are capable of:

- Delivering the working fluid between the receiver and the existing facility during all normal operating modes
- Starting up and shutting down the thermal transport system in conjunction with the receiver system and the existing facility
- Providing system status for the thermal transport system.

The mill controls, after modification, are capable of:

- Integrating the solar system steam into the mill facilities during all operating modes
- Providing status of the solar facility to the mill operator.

5.4.3 Design

The controls and instrumentation are designed for simplicity, reliability, and cost effectiveness. The solar systems and the mill facility are controlled independently with coordination by the master control system. Two control rooms are used. The mill control room is extended to accomodate the mill interface controls. A new control room, at the base of the receiver tower, supervises the individual solar systems. Control interface between the two control rooms is kept to major interdependent operations. Both control rooms use panels and components which are similar to the existing mill board. These components are proven, are commercially available, and are familar to the mill operators. Automatic controls are programmed into the systems with manual override capability for calibration or complete manual operation.

Whenever it is cost-effective, redundancy is built into the controls and instrumentation. In addition, modular spares are kept on site to facilitate quick repairs of faulty components.

Data acquisition and evaluation is kept separate from operational functions and is carried out at a separate console in the mill control room.

These design criteria enable standard control practice to be used by industrial power plant operators to give a safe and reliable solar cogeneration facility.

5.4.4 Operating Characteristics

The solar receiver operates in parallel with the two existing fossil-fueled boilers. The receiver produces steam at its maximum capacity, which varies over the normal day, and the fossil-fueled boilers are modulated to make up the balance of the process load. There is no restriction of receiver output unless the fossil-fueled boilers are at minimum output. Both boilers feed steam into a common header and then to the main steam turbine. Normally the master controls are automatic with the operator monitoring the performance of the solar systems. However, keyboard access is provided to initiate adjustments or mode changes in any of the systems.

5.4.5 Master Control System Capital Cost

The direct capital cost estimate for the master control system is $371,000. Backup detail is provided in Appendix A. This system is listed under cost code number 5500.

5.5 NONSOLAR ENERGY SYSTEM

5.5.1 Bagasse Storage Building

With the incorporation of the solar systems in the cogeneration facility, bagasse accumulates during the process week. To accommodate the increased volume of bagasse, the capacity of the existing bagasse storage building is increased by the addition of a new enclosed storage area with increased bagasse handling equipment.

Existing Bagasse Storage and Handling. Bagasse is presently pneumatically conveyed from the factory through a cyclone to the main boiler Conveyor 1 shown in Figure 5-33. Openings in the bottom of Conveyor 1 allow bagasse to enter metering boiler hoppers that provide fuel to both boilers automatically. Excess bagasse is transferred from Conveyor 1 to Conveyor 2 and distributed through bottom gates to the existing bagasse house floor below. Some bagasse is allowed to be recirculated via Conveyors 3 and 4 back to Conveyor 1. Excess bagasse in this conveying system serves as a buffer for sudden stoppages of bagasse flow from the process plant. It allows time for the boiler operators to activate bagasse reclaim operations from the bagasse house using a manual front end loader. Stored bagasse is pushed into Conveyor 4 from the bagasse house. The capacity of the existing bagasse storage house is 354 000 kg (390 tons).

New Bagasse Storage and Handling. The proposed additional bagasse storage system includes a new 25 m wide by 49 m long (80 ft x 160 ft) pre-engineered metal building with a capacity of 445 000 kg (490 tons) and a series of infeed and return conveyors from an extended Conveyor 1.

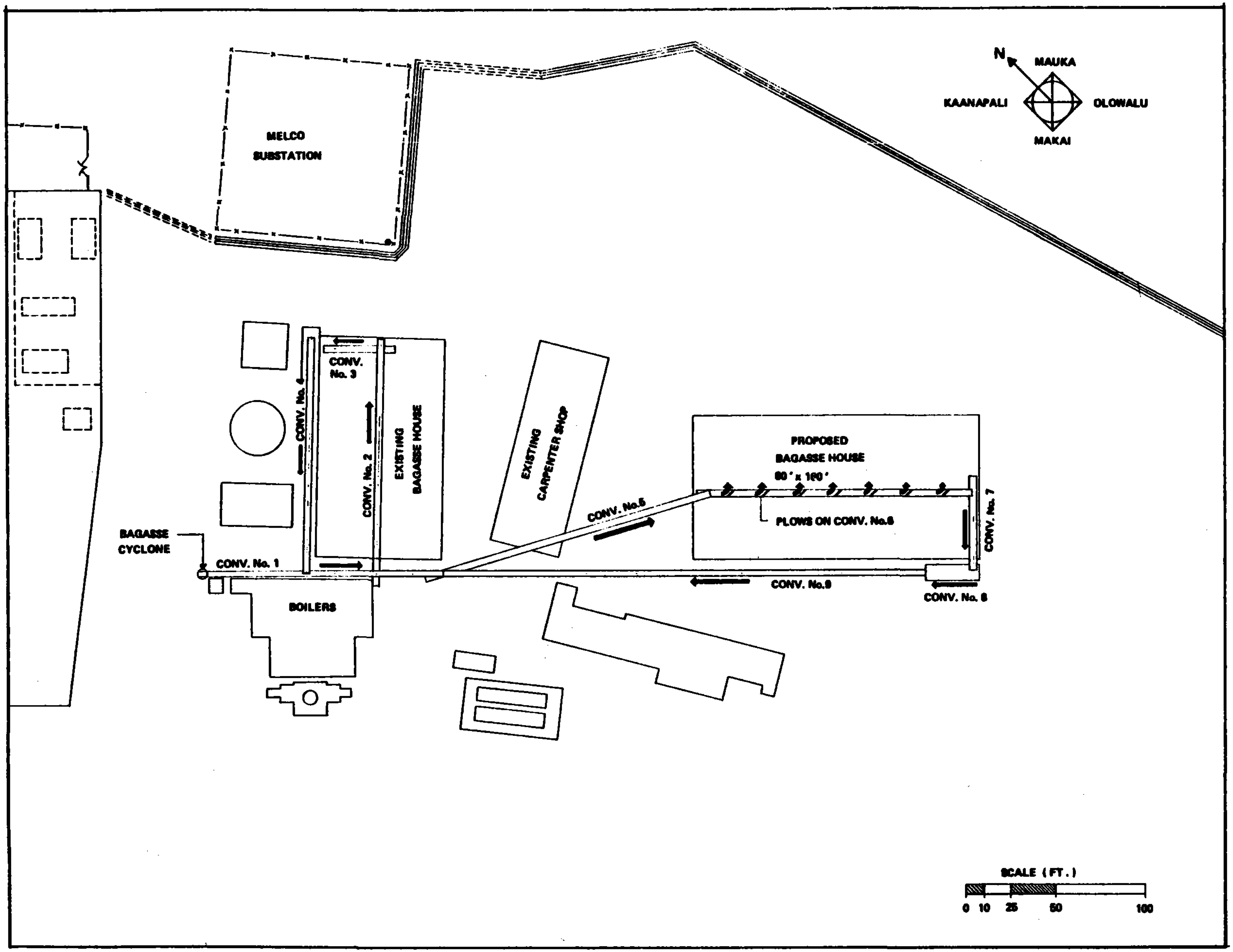


Figure 5-33 BAGASSE STORAGE FACILITIES

A sliding bottom gate on Conveyor 1 will be installed at the present conveyor 2 infeed allowing bagasse to be either directed to Conveyor 2 (open gate position) or pass on to Conveyor 5 (closed gate position). In this manner, the existing and additional bagasse storage facilities can operate independently of each other.

Bagasse is conveyed to the new bagasse house via Conveyor 5 and transferred to belt Conveyor 6. Material can be discharged at any of seven points by plows remotely controlled from the boiler control room.

Bagasse pile height will be monitored by closed circuit television and plows will be activated in a controlled sequence.

Recirculated bagasse can be allowed to continue onto 1.2 m (48 inch) wide Conveyors 7, 8, and 9, to the extended Conveyor 1 top deck, and back to the boiler. Should bagasse flow stop from the factory, the manual front end loader will be able to reclaim from either bagasse house using Conveyor 4 or 8.

Bagasse Storage House and Handling Equipment Cost. The total capital cost estimate for the new bagasse storage house and the handling equipment is $1,900,000. Backup detail is provided in Appendix A. This system is listed under cost code number 5600.

5.5.2 Mill Facility Modifications

As part of the solar system retrofit, relatively minor modifications are required at the mill facility. The modifications are required to connect receiver steam and water piping, to interconnect with the master control system, and to tap the existing electrical distribution system.

Details of these modifications are discussed in earlier sections of this report under their respective systems. Also, the capital cost estimates of the modifications are calculated as a detail for each of the system costs.

5.5.3 Visitors Center

A visitors center is recommended for the solar cogeneration facility. As the facility is the first-of-a-kind demonstration plant and is located in a tourist area, it is anticipated that there will be an interest from the public and a desire to view the facility.

The site of the visitors center is outside the solar collector field boundary, on the side of the field away from the mill. As this location is at a higher elevation than the cogeneration facility, it is possible to obtain a panoramic view of the solar facility and the mill. Access to the visitors center is by upgrading an existing haul road that serves the cane fields. This road starts from a point on a light-duty road from Kapunakea.

The visitors center is a simple air-conditioned building with a shaded observation platform. Water and electrical power supplies are brought to the center by extensions from the base of the receiver tower. A paved parking area is provided alongside the building.

The direct capital cost estimate for the visitors center including services is $122,000. This cost item is listed under cost code number 5200. No allowance was made in the annual O&M cost estimate for operating the visitors center.

SECTION 6

ECONOMIC ANALYSIS

6.1 METHOD

The economic analysis of the Pioneer Mill solar cogeneration facility involves calculating the internal rate of return (IRR) on the project investment given varying assumptions about cost, schedule, escalation rates, and other pertinent parameters. The internal rate of return the rate of return on the unrecovered balance of plant capital expenditures, is one measure of expected project profitability. The IRR can be compared directly with a hurdle rate which a firm might establish for new investments having a certain perceived risk. The hurdle rate for this project has been set by Amfac at a nominal value of 20 percent. This value exceeds hurdle rates typical of new investments in proven technologies and reflects the greater perceived risk of the solar thermal technology.

Another useful result from the economic analysis is the project capital cost that yields an IRR equal to the hurdle rate. This cost is referred to here as the "hurdle-rate investment", and represents the portion of the actual project capital cost that Amfac could contribute with the 20% hurdle rate under a cost-shared program with DOE.

The IRR is found by the iterative calculation of the net present value of the project's after-tax discounted cash flow. The IRR is the discount rate that yields a net present value of zero. For this project, the cash flow is negative during early years and positive thereafter. Such a cash flow has a single IRR and it can be found by straight forward trial and error solution. Similarly, the hurdle-rate investment is found by trial and error solution, holding the discount rate constant and varing the project capital cost to obtain a net present value of zero.

All cash flows used in the analysis are incremental cash flows arising from the project. For example, the revenues from electricity sales are the revenues from the incremental power available by adding the solar facilities to the existing cogeneration plant. Revenues from the power produced by the existing cogeneration plant are not included. Similarly, land lease costs are not included in the analysis, since it is assumed the lease costs are the same whether heliostats or sugar cane cover the land.

Cash flows considered in this analysis include:

- Capital costs, distributed over a three year construction period.
- Operating and maintenance costs during the project lifetime.
- Lost revenues from sugar and bagasse displaced by the solar collector field during construction and operating phases of the plant.
- Fuel cost savings during the life of the plant.
- Revenues from Maui Electric Company for incremental power produced by the solar facility.

The cash flow analysis reflects these revenues and expenditures adjusted for escalation, taxes (including depreciation) and investment tax credits. All cost and revenue data are expressed in first quarter, 1981 dollars. In the net present value calculations, cash flows are escalated to give

The choice of 1981 for the net present value base year is arbitrary; any base year will yield the same IRR.

The following equation was used to calculate the net present value (NPV) of the incremental after-tax cash flow for the project:

$$NPV = \sum_{i=1}^{3} (ETCR_i \cdot CC_i \cdot R_1^{\,i+s-1})$$

$$+ (1-t) \left[(R_2^{\,s+3}) \cdot \frac{(R_2^{\,n}-1)}{(R_2-1)} (F+AV) - R_2^{\,s} \cdot DB \frac{(R_2^{\,n+3}-1)}{(R_2-1)} \right.$$

$$\left. -(R_1^{\,s+3}) \cdot OM \frac{(R_1^{\,n}-1)}{(R_1-1)} - R_1^{\,s} \cdot DS \frac{(R_1^{\,n+3}-1)}{(R_1-1)} \right]$$

$$+ t \left[\sum_{i=1}^{3} CC_i \right] R_1^{\,s+2} \left[\frac{DPF_1}{(1+d)} + \frac{DPF_2}{(1+d)^2} + \cdots + \frac{DPF_n}{(1+d)^n} \right]$$

Where: NPV = Net present value, 1981 base year

$ETCR_i$ = Effective tax credit rate during construction year i

CC_i = Capital Cost during construction year i

R_1 = $(1+g)/(1+d)$

g = General escalation rate

d = Discount rate (varied by trial and error to obtain NPV = 0)

t = Effective tax rate

R_2 = $(1+g)(1+f)/(1+d)$

f = Real fuel escalation

s = Start year for index construction (s=3 for 1983)

n = Project life

F = Annual fuel savings, 1981 dollars

AV = Annual avoided costs, 1981 dollars

DB = Annual value of displaced bagasse, 1981 dollars

OM = Annual operating and maintenance costs, 1981 dollars

DS = Annual value of displaced sugar, 1981 dollars

DPFj = Depreciation factor during year j of project life.

The equation has essentially three components. The first component is the present value of capital costs less tax credits. The second is the present value of after-tax cash flows during the project life. The third is the present value of tax deductions for depreciation. The equation assumes all tax credits and deductions can be taken in the year they arise; there is no carry over from year to year.

The second component reflects incremental revenues and expenditures over the life of the project. This representation of the present value of these cash flows is valid only if R_1 and $R_2 \neq 1$. If $R_2=1$, then the present value of the fuel savings and avoided costs simplifies to n(F+AV), and the present value of displaced bagasse simplifies to (n+3)DB. Similar results obtain for O&M costs and displaced sugar if $R_1=1$.

6.2 ASSUMPTIONS AND RATIONALE

The assumptions on which the analysis is based are documented in this section. They include assumptions about project cash flows and financial parameters. Although the development plan in Section 7 indicates that the solar facility could begin operation during 1985, the economic analysis was done using 1986 as the first operational year.

6.2.1 Project Cash Flows

Table 6-1 summarizes the assumptions used to develop the base-case individual cash flow streams.

TABLE 6-1
BASE-CASE PROJECT CASH FLOW ASSUMPTIONS

ITEM	ASSUMPTION*
General	• Cash flows occur at discrete, yearly intervals only and represent accumulated cash flows throughout the preceeding year.
	• 3-year construction period, beginning first quarter 1983
	• 20-year operating life, beginning first quarter 1986
	• No salvage value (remaining value=cost of removal to restore agriculture).
Capital Costs	• $37,000,000 investment distributed over the three year construction period in the following proportions: 15 percent, 60 percent, and 25 percent
	• 15 percent of costs in each year are ineligible for tax credits
	• 85 percent of costs in each year qualify for solar and investment tax credit
O&M	• $406,000/year
	• Costs escalate at general escalation rate
Displaced Sugar	• Valued at $3,300/acre-year; 42 acres displaced
	• Costs escalate at general escalation rate
Displace Bagasse	• Valued at $20,000/year
	• Costs escalate at fuel escalation rate
Fuel saved	• $28/bbl cost of No. 6 fuel oil
	• 28,800 bbl/year saved
	• Costs escalate at fuel escalation rate
Power Sales Revenues	• Price = Avoided Cost to Maui Electric Company = .85 ($.066253 kWhe)
	• Incremental power sold = 297,000 kWhe

* All dollars are first quarter, 1981

Capital Cost Assumptions. The project capital costs used in the economic analysis are based on the total capital cost displayed in Table 4-4 plus a $3,600,000 allowance for owner's costs. The project capital costs are distributed over the three-year construction period in the following proportions: 15 percent, 60 percent, and 25 percent. Approximately 85 percent of these costs are eligible for the solar and investment tax credits. This percentage equals the percentage of total direct field costs due to the collector, receiver, master control and thermal transport systems. The remainder of the capital costs, approximately 15 percent, are not eligible for tax credits since they are due to the costs of land, site preparation and buildings.

It is assumed that this distribution between costs eligible for tax credits and costs not eligible for tax credits is the same for all three years.

Revenues and Expenditures During Plant Operation. The economic analysis assumes that first-year operation of the solar facility is the same as all other years in the 20-year plant life. Thus, fuel savings, avoided costs paid by Maui Electric Company and O&M costs are incurred during the 20 year operation of the plant, and vary from year to year only as a result of cost escalation. Potential revenues from displaced sugar and bagasse are lost for the 23 years that include plant construction and operation.

6.2.2 Financial Parameters

Table 6-2 summarizes the financial parameters assumed for the base-case economic analysis. These parameters were established in consultation with Amfac.

TABLE 6-2

BASE-CASE FINANCIAL ASSUMPTIONS

ITEM	ASSUMPTION
General	• All tax credits and deductions are taken in first year eligible; no carry-over • 100% equity financing
Tax Credits	• 25 percent Federal • 10 percent State
Tax Rates	• 46 percent Federal • 6 percent State
General Escalation	• 10 percent
Real Fuel Escalation	• 2 percent
Project Hurdle Rate	• 20 percent
Depreciation	• Double-declining balance shifting to straight-line • 14 year tax life

The most uncertain of these assumptions are the escalation rates. Due to this uncertainty, general and real fuel escalation rates are treated parametrically in the economic analysis to ascertain their effect on IRR.

The high project hurdle rate of 20 percent includes an allowance for the risk perceived in the solar technology. This rate is used to establish what portion of the project capital cost Amfac would be willing to consider under a cost-shared program with DOE.

6.3 RESULTS AND CONCLUSIONS

The results of the economic analysis are presented in this section. In the analysis, IRR and hurdle-rate investment are calculated under base-case assumptions and for parametric variations of the base-case. Variations on the following parameters were analyzed:

- Fuel Escalation Rate
- Heliostat Cost
- Fuel Cost
- General Escalation Rate
- Construction Start Year
- Project Life
- Depreciation Method

This section discusses the sensitivity of base-case results to variations in a single parameter. Section 6.4 presents results for "optimistic" cases that consider the coincidence of departures from several base-case assumptions that improve the economic attractiveness of the project.

6.3.1 Results

The figures and table shown on the following pages summarize the essential results of the economic analysis of the Pioneer Mill solar cogeneration facility. As indicated on all three figures, the base-case economic analysis yields a IRR of 4.5 percent, well below the desired 20 percent project hurdle rate. Amfac can achieve a 20 percent IRR if they contribute only 10 percent of the base-case capital cost of the plant. Thus the hurdle-rate investment for the base case is 10 percent of the project capital cost, or $3.7 million.

Figure 6-1 shows the effects of different capital costs on IRR. The base-case capital cost of $37 million reflects an installed collector system cost of $\$416/m^2$. Reducing the installed cost of heliostats to $\$100/m^2$ reduces total capital cost to $21 million and raises the IRR to 7.3 percent. The $3.7 million dollar hurdle-rate investment by Amfac becomes 17 percent of the project capital cost under these circumstances.

A 4 percent real fuel escalation rate would have the same effect raising the IRR to approximately 7.5 percent and the hurdle-rate investment to 17 percent of the project capital cost. The coincidence of low heliostat costs ($\$100/m^2$) and high real fuel escalation rates (4 percent) would produce an IRR of nearly 11 percent, approaching the hurdle rate used for publicly financed projects involving low-risk technology. The corresponding hurdle-rate investment is 30 percent of project capital cost.

The effect of different general escalation rates on the results is summarized in Figure 6-2. The IRR would vary from 3.2 percent to 5.8 percent for general escalation rates ranging from 8 percent to 12 percent. This range corresponds to a hurdle rate investment varying from 8 percent to

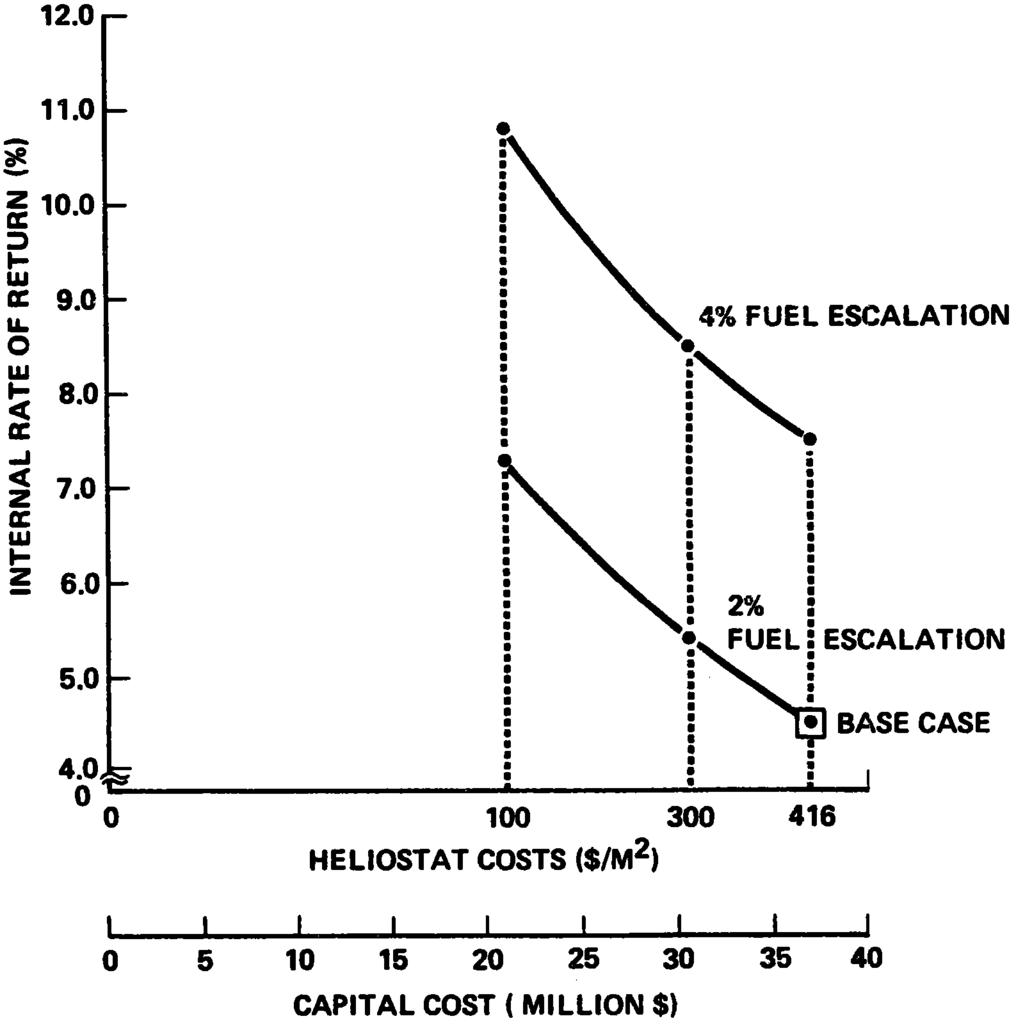


Figure 6-1 IRR VS. CAPITAL COST

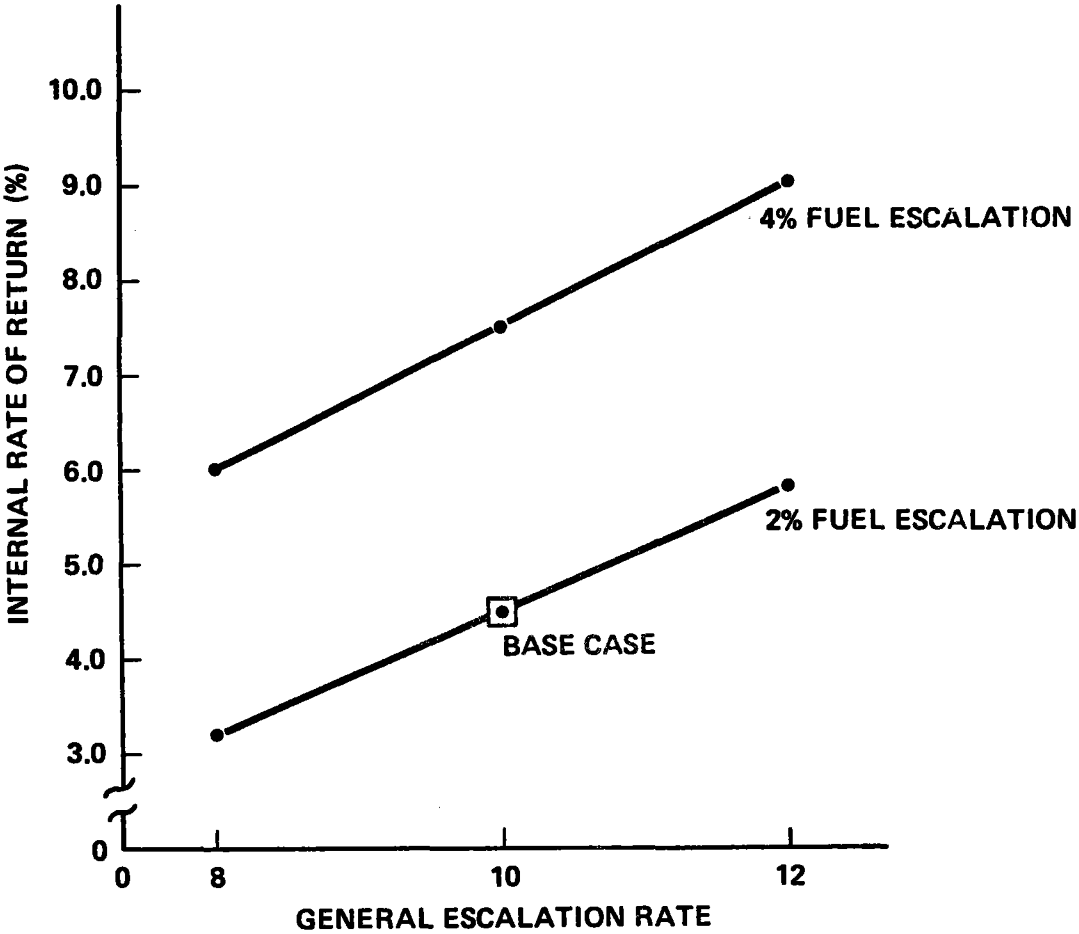


Figure 6-2 IRR VS. GENERAL ESCALATION RATE

12 percent of the project capital cost. At a 4 percent real fuel escalation rate, the IRR varies from 6 percent to 9 percent, with hurdle rate investment varying from 14 percent to 27 percent of the project capital cost.

Figure 6-2 also illustrates the sensitivity of the results to real fuel escalation rates. An increase in the real fuel escalation rate of 2 percentage points, from 2 percent to 4 percent, increases the IRR far more than an increase of 2 percentage points in the general escalation rate. This occurs because the major operating revenues escalate with fuel, at a higher rate than general escalation; whereas, the major operating cost (O&M) escalates only at the general escalation rate.

Amfac currently burns relatively inexpensive No. 6 fuel oil containing a relatively large amount of sulfur. However, other firms are prohibited from using cheap, high sulfur fuels. Thus a parametric analysis is included to convey the profitability of this project when fuel savings are valued above Amfac's fuel costs, as might be the case for a similar plant using a cleaner, more expensive fuel. Figure 6-3 illustrates the effect of different fuel costs on the results. Amfac's fuel costs, in 1981 dollars, are \$28/bbl. If fuel savings are valued at \$40/bbl, then the IRR is 7.7 percent for a 2 percent real fuel escalation rate, and 10.6 percent for a 4 percent real fuel escalation rate. As in the case of \$100/m^2 heliostats and 4 percent fuel escalation, the combination of \$40/bbl fuel and 4 percent fuel escalation produces a rate of return approaching hurdle rates commonly used for publicly funded projects involving proven technology. The hurdle-rate investment assuming \$40/bbl fuel and 4 percent real fuel escalation is 30 percent of the project capital cost.

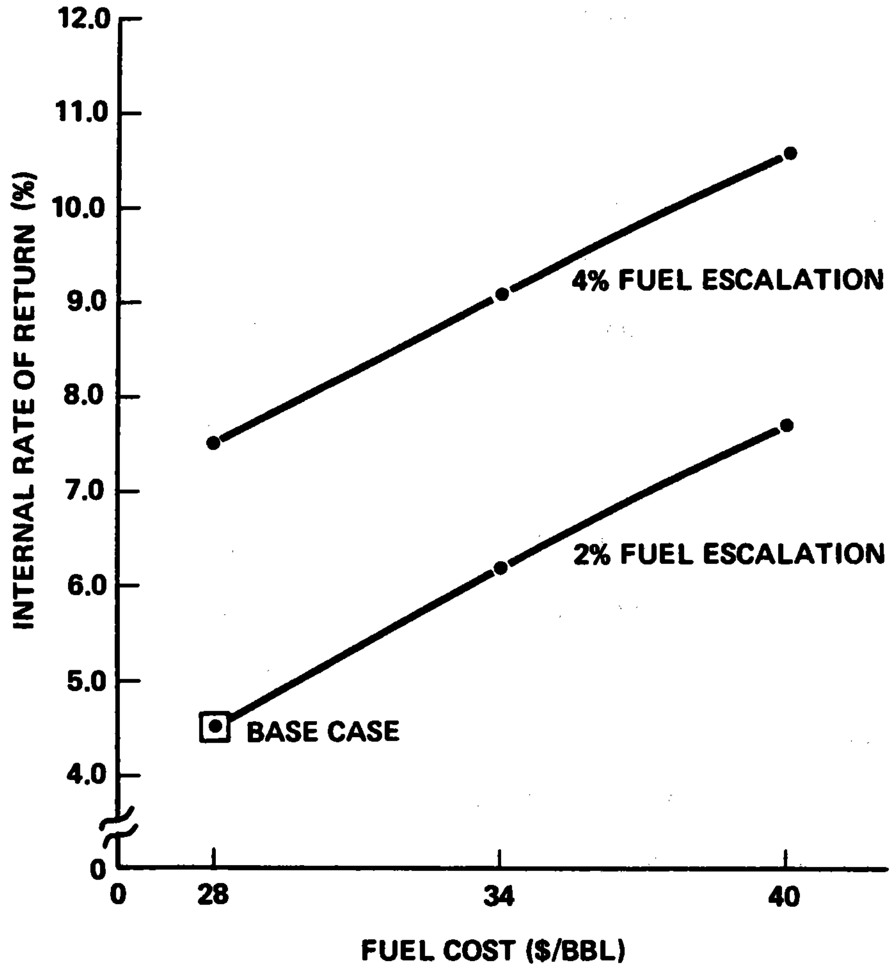


Figure 6-3 IRR VS. FUEL COST

Table 6-3 summarizes other sensitivity analysis results. A two-year delay in the project would increase the base case IRR slightly from 4.5 percent to 4.9 percent. Of particular interest is the effect of using accelerated depreciation methods such as that proposed in H.R. 4646 - the Capital Cost Recovery Act. This legislation would permit a 5-year recovery period for non-automotive machinery and equipment at the following rates:

TABLE 6-3

ADDITIONAL SENSITIVITY ANALYSIS RESULTS

PARAMETER	Base Case Value	Alternate Value	IRR
All	—	Base - Case	4.5
Project Start Year	1983	1985	4.9
Depreciation Method	DDB/SL*	HR 4646	5.6
Project Life	20	25	6.7

*Double-declining balance / straight line

20 percent the first year, followed by 32 percent, 24 percent, 16 percent and then 8 percent in the last year. Table 6-3 shows the result of switching from double-declining balance/ straight line depreciation over 14 years to the 5-year depreciation schedule proposed in H.R. 4646. To simplify the analysis the H.R. 4646 depreciation schedule was applied to the entire project capital cost, not just non-automotive machinery and equipment. Thus, the results only approximate the economic benefits of using accelerated depreciation methods. The effect of increasing the project operating life from 20 to 25 years is also shown in Table 6-3. The five additional years of fuel savings raise the IRR to 6.7 percent.

The solar equipment could easily be designed for 30 years life, without significant additional cost, but that is not consistent with the remaining equipment life for Pioneer Mill or Amfac's current policies.

6.3.2 Conclusions

Under base case assumptions, the proposed project does not meet the 20 percent hurdle rate established by Amfac as its selection criterion. In fact, to obtain this hurdle rate, Amfac would be willing to bear only 10 percent of the base case project cost.

6.4 ECONOMIC SCENARIO

This section briefly summarizes the results of economic analyses using a combination of assumptions that increase the IRR of the project. The reference favorable case includes the following assumptions that differ from the base case:

- Project life is 25 years, not 20
- Fuel escalation is 4 percent, not 2 percent
- Collector system costs are $\$100/m^2$ ($21.2 million project investment) not $\$416/m^2$ ($37 million project investment)

This case results in the following:

- IRR = 13.6 percent
- Hurdle-rate investment = 40 percent of project capital cost

Firms other than Amfac may have fuel costs considerably higher than $28/bbl. Substituting $40/bbl fuel costs in the reference favorable case yields

- IRR = 17 percent
- Hurdle-rate investment = 69 percent of project capital cost

For both fuel costs, using the H.R. 4646 depreciation schedule with the favorable assumptions increases the IRR approximately 1.5 percentage points.

6.5 DISCUSSION OF ECONOMIC RESULTS

The results of the base case economic analysis show only a 4.5 percent IRR for Amfac, or a hurdle rate investment of 10 percent of the total project investment.

The results of the sensitivity analyses showed that the following factors improve the economic attractiveness of the project.

- Lower capital cost of heliostats and other equipment
- Longer project operating lifetime
- Higher fuel oil cost
- Accelerated depreciation methods
- Improved solar facility performance
- Higher fuel escalation rate
- Higher general escalation rate

The economic attractiveness of the project improves dramatically if a combination of these factors are used in the analysis. Under the favorable economic scenario with higher fuel cost included, the IRR approaches the hurdle rate, indicating that similar projects have the potential for private financing under certain conditions. The increase in solar technology maturity that is expected to accompany the development of mass production heliostat manufacturing facilities, capable of achieving the $100/m^2 installed cost, may also boost the confidence of industrial firms and cause a lowering of the required hurdle rate for such projects. The solar cogeneration facility at Pioneer Mill should therefore be viewed in a larger context, as a demonstration of an emerging technology, rather than a project to be evaluated on a purely economic basis.

Two other factors are expected to be important in assessing the viability of this type of project. First, it is of national strategic importance that the U.S. reduce its dependance of imported oil for such a high percentage of its overall energy demand. This project can demonstrate the application of solar central receiver technology with a significant potential of savings of oil and gas fuels in the industrial sector. The inherent simplicity and flexibility of the design is representative of a significant number of existing and future industrial facilities.

The second factor is the possible influence of "creative" financing on the economics of this project. Although our investigation of the possible effects of such techniques as leasing, third party ownership, and debt financing were not within the scope of this study, these techniques have the potential for improving the economic attractiveness, and should be evaluated for similar projects.

SECTION 7

DEVELOPMENT PLAN

The purpose of this plan is to provide a smooth transition from the conceptual design phase of the project to commercial operation.

The phases required to implement the development plan include detailed design, field construction, system checkout and startup, system performance validation, and joint user operation. In this section, each phase is considered for objectives, activities, technical and economic issues, and project management. A project schedule was developed to provide a solar facility for operation by 1985, assuming the notice to proceed is received at the beginning of 1982. This schedule is shown in Figure 7-1. In addition, there is a discussion on the roles of site owner, government and industry.

7.1 ENGINEERING

Under the activity of engineering and project management, data obtained from the conceptual design of the solar cogeneration facility at Pioneer Mill will be developed to give full details of the systems and equipment Wherever possible, existing technology is used to minimize the need for extensive system research experiments. The design information will be used to produce bid specifications for major equipment or subcontracted work. This engineering activity will include optimizing equipment and systems, reviewing available manufacturer's equipment, and finalizing any further development work.

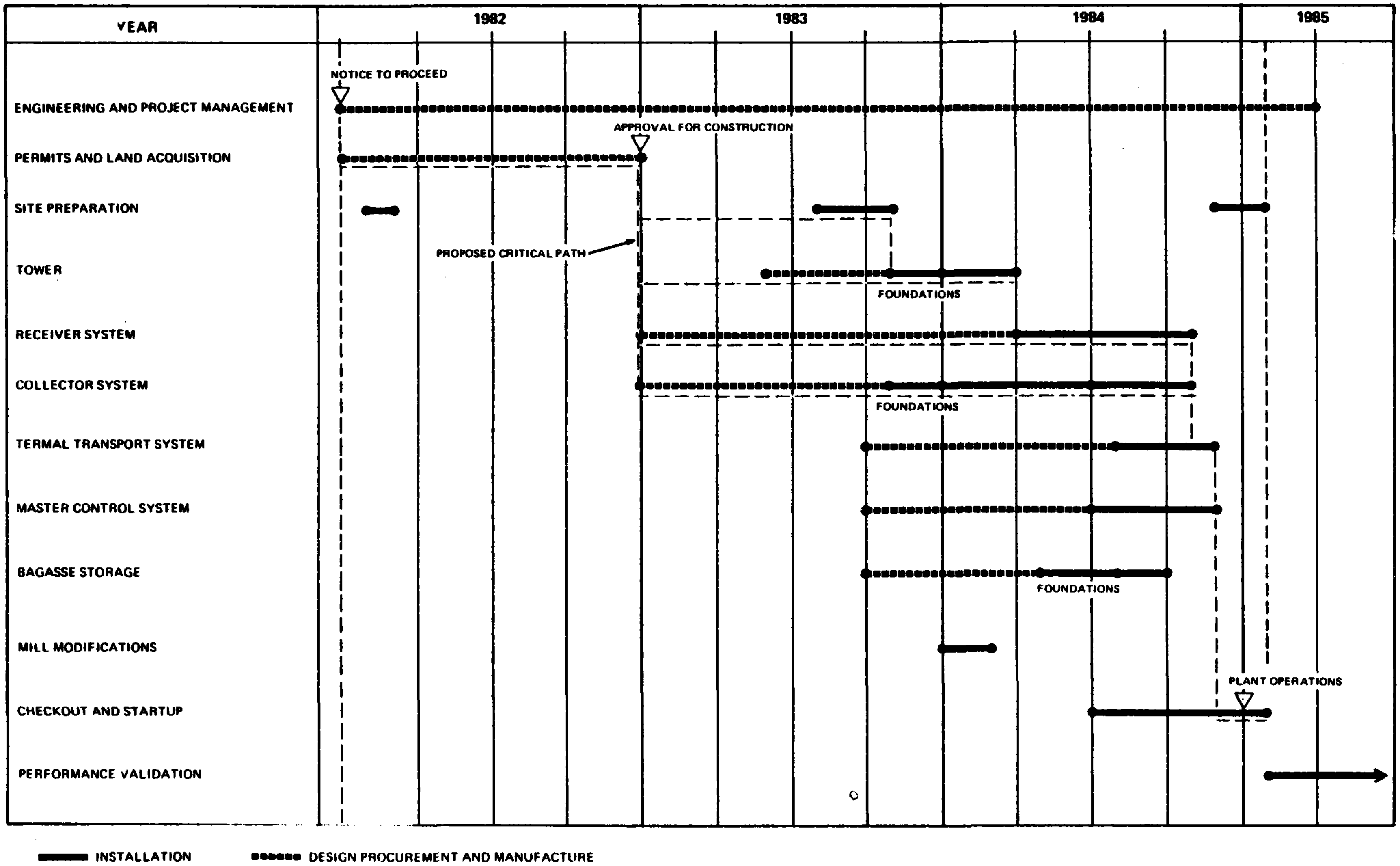


Figure 7-1 PROJECT SCHEDULE

This activity will produce:

- Engineering analysis
- System and equipment specifications
- Piping and instrument diagrams
- System interfaces
- Detailed construction schedules
- Performance and cost analysis of the solar facility

After the purchase orders for the solar equipment have been placed the engineering will be finalized by the incorporation of vendor information. Detailed cost estimates will be completed as engineering proceeds. Engineering support also will be furnished to assist the construction effort.

In addition to the engineering activities, input is required for permits and licenses. Details of the required solar cogeneration facility permits and licenses, including time frames, are given in Table A.2-1 in Appendix A.

Project management procedures will be developed at an early stage of the engineering and will include work scope definition, procedure reviews and approvals, document controls, cost reporting, and project planning and tracking. Detailed costs, cash flows and schedules will be prepared for the project.

Engineering is assumed to begin six months after completion of this conceptual design study of the solar cogeneration facility. Approval of the design by the owner enables the documents for permits and licensing to be filed. Other than the issue of land use, it appears that there will be no major environmental impacts. Therefore, the time required for application review and approval is not considered critical or subject to extension. All designs and specifications will be ready to be issued for bids when approval for construction is received. This is estimated to be 12 months after the initial notice to proceed was obtained. The major subcontractors and vendors will be selected at this point. This is necessary to obtain delivery of the long lead items by the proposed plant operating date.

7.2 CONSTRUCTION

Construction management's objective is to complete the installation and erection of the solar facility so that it meets the planned schedule and is within the budget cost. The conservative approach taken in the baseline conceptual design, by using known technology and off-the-shelf equipment wherever possible, was chosen to achieve these objectives.

Construction activities will include field supervision and coordination, cost and schedule control, contract administration, subcontract direction, technical direction from project engineering and vendors, site safety and security, and compliance with regulatory agencies. Soon after the notice to proceed is obtained, the site will be surveyed and the soils tested.

Site construction will start during the latter period of the design place, after the construction permits and land lease have been acquired. Startup of the solar facility is planned for early 1985, thus construction is scheduled to take 24 months.

7.3 SYSTEMS CHECKOUT AND STARTUP

The objective of this activity is to ensure that the solar facility is in a state of readiness for commercial operation. After verifying that all materials and equipment are in accordance with contract specifications, procedures and documentation will be developed to check the startup, normal, and emergency operating modes of all equipment, interactive components, and complete systems.

System checkout and startup will start about 6 months before the planned startup date of early 1985. During this time the mill personnel will undergo training to be familiar with the new solar systems and their interfaces with the mill facility.

7.4 SYSTEM PERFORMANCE VALIDATION

After the initial operation of the solar cogeneration facility there will be an extended test period. This is a first-of-a-kind demonstration of a solar facility being integrated with an existing commercial process. Therefore, sufficient data will be required to demonstrate that both the mill and the solar systems are operating and performing as designed. Normal operation will include, not only the grinding season when maximum steam and electrical power are required by the mill, but also weekends and off-season when the mill production is stopped and only electrical power is required. The tests will be performed for various times of the day, season, and weather conditions. Transient operational performance tests will cover startup, shutdown, and cloud passage.

Outages will be analyzed and their effect on the mill facility evaluated. Operating and maintenance procedures will be refined to minimize all anticipated outages.

7.5 JOINT AMFAC AND DOE OPERATIONS

The proposed solar cogeneration facility is being developed by an industrial team in response to a government initiative. Thus, for an initial period yet to be determined, there may be a joint ownership of the solar facility that will be retrofitted to Amfac's Pioneer Mill. During the period, the data obtained will be recorded, analyzed, and widely reported. The object will be to demonstrate that a solar facility has the potential for widespread commercial application and to interest other potential users.

At the end of this joint ownership period, after a detailed analysis of the results and an evaluation of the economics, the complete ownership of the solar portion of the cogeneration facility is assumed to be transferred to Amfac.

7.6 SCHEDULE AND MILESTONES

The project schedules and milestones are part of the management procedures. Figure 7-1 shows the schedule of activities and the major milestones. The project is planned to start six months after completion of the conceptual design for the solar cogeneration facility. The facility is scheduled for operation by the beginning of 1985. Thus 36 months are required between initiation of the design phase and full operation. Although it is not essential, startup of the solar facility during the off season period is desirable and was indicated on the schedule.

7.7 ROLES OF OWNER, GOVERNMENT, AND INDUSTRY

For a project designed to demonstrate the commercial feasibility of a new technology, the owner, the government, and industry all play significant roles in a successful project.

Amfac, as site owner/operator must exercise control over the design and operation of the facility. This is essential to maximize their confidence in the project and to justify their portion of project investment. They also must have a reasonable opportunity to realize an acceptable return on their investment, in order to satisfy their corporate policies. They can also offer valuable suggestions on the many factors which can contribute to a successfully operating demonstration project.

Other industrial corporations, both in the sugar industry and in other categories, can help to make the demonstration project as representative of a broad cross section of industrial experience as practical in a single project. After the facility is operating, they can also visit the site to increase their confidence in the technology and the familiarity of their operating personnel with the type of equipment involved. The supplier industries will also be induced to make a reasonable investment in manufacturing facilities, primarily for heliostat production, in order to provide a commercial base for future projects.

The government, both at the federal and state level, will be involved in the project in a variety of ways. Cost-incentives will be necessary, either by direct sharing, or by indirect methods such as tax incentives. The government can also provide valuable technical assistance to private industry through the application of experience gained in the development of this technology.

REFERENCES

2-1 Climates of the States - Hawaii, Climatography of the United States No. 60-51, National Oceanic and Atmospheric Administration, pp. 266-294.

3-1 Phase 2 Test Summary Report - 1 MWt Bench Model Solar Cavity Receiver Steam Generator Build and Test, Martin Marietta Corporation, MCR-76-133 (Issue 3), June 1977.

3-2 Central Receiver Solar Thermal Power System, Phase I: Preliminary Design Report (Volume 4 - Receiver Subsystem), Martin Marietta Corporation, April 1977, SAN/1110-77-2.

3-3 Letter from J. W. Leibenburg and J. E. Grant to J. J. Bartel (on Sandia Laboratories letterhead) dated January 7, 1980. Subject: Tower Costs for Solar Central Towers.

3-4 Second Generation Heliostat Development for Solar Central Receiver Systems, Final Report, February 1981, Northrup Incorporated, Sandia Contract 83-2729E.

3-5 Soil Survey of Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii. U.S. Department of Agriculture, August 1972.

3-6 Solar Repowering/Industrial Retrofit Systems, Category B, Solar Thermal-Enhanced Oil Recovery System, Final Report, Martin Marietta Corporation, July 1980, MCR-80-1353, Contract DE-AC03-79SF10737.

5-1 I. Berman, et. al, "An Interim Structural Design Standard for Solar Energy Applications." Report No. SAND-79-8183, Sandia Laboratories, Livermore, April 1979.

5-2 ANSYS Engineering Analysis System User's Manual. Swanson Analysis Systems, Incorporated, 1974.

5-3 ANSI A58.1-1972. Building Code Requirements for Minimum Design Loads in Building and Other Structures.

5-4 Abrams, M., "The Temperature of Cavity - Type Solar Absorbers with a Circulating Fluid", Journal of Heat Transfer, November 1974, pp. 549-551.

5-5 Central Receiver Solar Thermal Power System, Phase I: Preliminary Design Report (Volume 4 - Receiver Subsystem), Martin Marietta Corporation, April 1977, SAN/1110-77-2.

Appendix A

SYSTEM SPECIFICATION FOR THE PIONEER MILL SOLAR COGENERATION FACILITY

DOE Contract No. DE-AC03-80SF11432

Prepared by

Bechtel Group, Inc.

Amfac Sugar Co.
Foster Wheeler Development Corp.
Northrup, Inc.

Job 14481

Rev. 2
July 1981

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Section 1

GENERAL

1.1 SCOPE

This specification defines the system characteristics, design requirements, and environmental requirements for the addition of a solar central receiver facility to the existing cogeneration plant at Pioneer Mill Company, Ltd., a plantation subsidiary of Amfac Sugar Company.

The level of detail presented in this specification is consistent with the conceptual design phase of an industrial power plant project. Engineering information is developed to the extent necessary to support the conceptual plant cost estimate and the determination of technical and economic feasibility of the project. The listing of required data for the solar cogeneration facility conceptual design is included as Section 5 of this specification.

1.2 SYSTEM DESCRIPTION

A description of the solar cogeneration facility at Pioneer Mill consists of a description of the following:

- Site
- Site facilities
- Collector system
- Receiver system
- Thermal transport system
- Nonsolar energy system

- Master control system
- Specialized equipment
- Modes of operation

The plan for incorporating a solar energy facility into existing Pioneer Mill plant calls for placing a water-steam-cooled solar central receiver in parallel with the existing boilers and displacing the consumption of fuel oil when solar energy is available. Bagasse will be used for energy storage. A schematic diagram of the proposed facility is given in Figure A.1-1.

1.2.1 Site

The plantation at Pioneer Mill is adjacent to the town of Lahaina on the west coast of the island of Maui in Hawaii and occupies 35.5 x 10^6 m^2 (8,776 acres) of land.

The area has a general west-facing slope, which extends from a populated resort area along the beach to the steep foothill slopes of the West Maui Mountains. The plantation altitude varies between 3 m (10 ft) and 590 m (1,925 ft) above sea level. The site coordinates are 20° 53' north latitude and 156° 40' west longitude.

The collector field and receiver tower are located approximately 670 m (2,200 ft) north of the existing cogeneration facility. The collector field area has a southwest-facing slope of approximately 5 percent.

Two distinct soil types are encountered on the sites: Ewa and Wahikuli. The soil in the vicinity of the sugar factory is classified as Ewa silty clay loam. It has a surface layer of dark, reddish-brown silty clay loam about 0.46 m (18 in) thick. The subsoil, about 1.07 m (42 in) thick, is dark-red silty clay loam with a subangular blocky structure. The substratum is coral limestone, sand, or gravelly alluvium. Ewa soil is neutral, with moderate permeability, and its mean temperature is 23C (73F). The corrosion potential for uncoated steel is low.

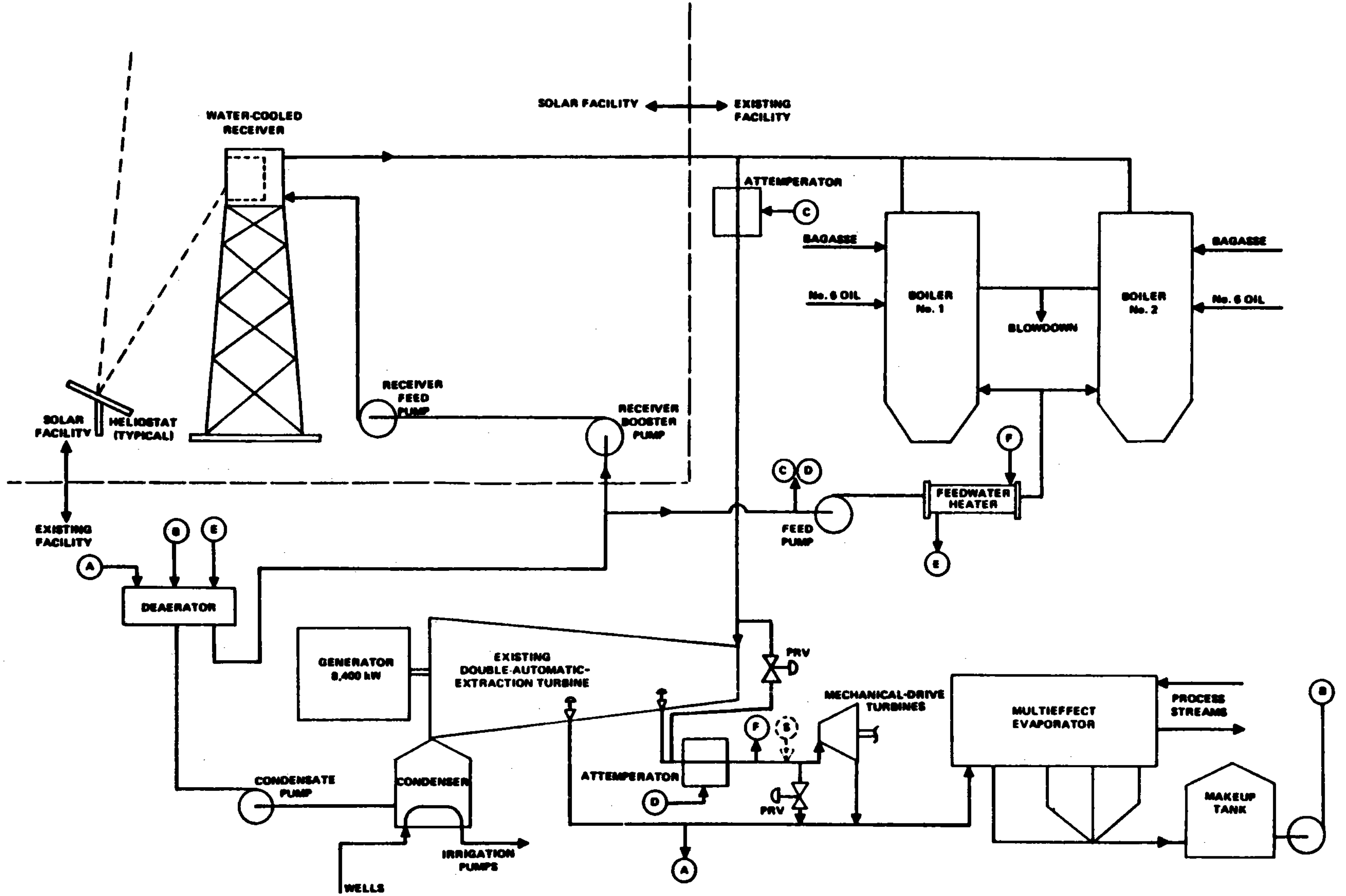


Figure A.1-1 SCHEMATIC DIAGRAM OF THE PROPOSED PIONEER SOLAR COGENERATION FACILITY

Most of the canelands of Pioneer Mill are classified as Wahikuli stony (or very stony) silty clay. The surface layer is dark, reddish-brown silty clay about 0.38 m (15 in) thick. The subsoil, about 0.43 m (17 in) thick, is dark reddish-brown silty clay that has a subangular blocky structure. The substratum is hard basic igneous rock. Wahikuli soil is mildly alkaline, with moderate permeability, and its mean temperature is 24C (75F). The corrosion potential for uncoated steel is low.

Site preparation work for the solar facility includes rough-grading the collector field area and providing improved access roads. Site work for running piping and wiring requires clearing and grading the right-of-way across the cane field and preparing for the pipe-bridge that crosses the diversion channel between the mill and the tower.

1.2.2 Site Facilities

The site facilities of the solar cogeneration facility comprise both the new facilities and the modifications to existing facilities needed to bring about a solar retrofit. They include:

- Operations facilities
- Security facilities
- Storage and maintenance facilities
- Visitors center
- Access roads

1.2.3 Collector System

The collector system collects and concentrates solar radiation on the central receiver during all periods of sufficient insolation, and responds to commands from the master control system for normal focusing, sun tracking, defocusing, heliostat stow operations, and upset operating modes involving emergency defocusing to protect the receiver. The system is designed to be compatible with the receiver and provide energy to the receiver fluid consistent with the input requirements of the plant. The system includes the following:

- Heliostats, including reflective surface, structural support, drive units, control sensors, pedestals, foundations, cabling, and cable array installations
- Electromechanical and electrical controllers, including individual heliostat and heliostat field controllers, control system interface electronics, and power supplies

The heliostats are located in a radial stagger configuration and occupy a 150° circular sector of 360 m (1,180 ft) radius. The field centerline points in a direction approximately 15° east of due north. The sector contains 815 heliostats covering a land area of 0.17 km^2 (42 acres), which gives a packing density of 25 percent.

The collector system design is based on the size and performance characteristics of the ARCO-Northrup II second-generation heliostat. The heliostat contains 12 mirror modules, each of which is 1.22 m x 3.66 m (4 ft x 12 ft), resulting in a total reflective area (allowing for edge molding) of 52.8 m^2 (568 ft^2).

The normal stow position is vertical, but under extreme wind conditions, horizontal stow is required.

The collector system controllers operate the heliostat field in response to plant load conditions, receiver temperature and flow conditions, situations requiring emergency defocus, cloud transients, and safety requirements. The system provides for five modes of field operations as follows:

- Safe course "wake up" — wire walk to stand-by beside the receivers
- Partial track with partial stand-by — controlled receiver heat up
- Tracking — normal solar operation

- Safe course stow – wire walk to stow position
- Special modes – cloud transients, emergency defocus and manual control

The heliostat array controller will provide heliostat status displays and related data acquisition.

The field wiring supplies 115 V ac power to drive each heliostat. The field will consume approximately 2.4 MWhe during a typical clear day.

The control wiring consists of two-wire shielded cable. The wiring layout provides for both simultaneous and individual operation of the portions of the field that are focused on each receiver.

1.2.4 Receiver System

The receiver system permits the incident radiant energy to be transferred from the collector system into the water-steam working fluid. The system consists of an elevated receiver to intercept the radiant flux reflected from the collector system, a tower structure to support the receiver, and valves and controls that regulate the fluid flow, temperature, and pressure in such a manner as to ensure safe and efficient operation.

The receiver is a dual-cavity, natural-circulation steam generator with separate superheater circuitry. It is designed to produce 33 540 kg/hr (73,960 lb/hr) of superheated steam at a pressure of 6.85 MPa (994 psia) and a temperature of 438C (820F), with a thermal output of 26.2 MWt (89.5 x 10^6 Btu/hr). The receiver is fully insulated to reduce thermal losses to the environment. The aperture of each cavity is provided with an insulated door to reduce the receiver cooldown during overnight shutdown periods. The tower includes an elevator and stairs for access. Access to the receiver equipment is provided for inspection and maintenance, and provisions are made for personnel safety.

1.2.5 Thermal Transport System

The thermal transport system supplies water to the receiver system and returns solar steam to the mill facility.

The water is obtained as condensate at 119C (235F) from the mill deaerator and is pumped by transfer pumps to a storage tank which is located at the base of the receiver tower. The 10 cm (4 in) diameter condensate pipeline is 1 190 m (3,900 ft) long. The stored water is supplied to the receiver at 8.45 MPa (1,225 psia) by feed pumps. Solar steam from the receiver system is supplied to the mill facility at 399C (750F) where it is combined with the steam from the mill boilers for use in the main turbine generator. The 15 cm (6 in) diameter steam pipeline is 1 128 m (3,700 ft) long.

The thermal transport system also includes the warmup loop for the receiver system, the emergency steam turbine generator at the receiver tower base, and the mixing station at the mill facility. The mixing station controls the quality of steam that is supplied to the mill.

1.2.6 Master Control System

The master control system coordinates the heliostat array control (HAC), the receiver system controls, the thermal transport system controls, and interfaces with the existing plant controls at the mill. The heliostat array controller is a central computer that provides all field control under normal operating conditions. Receiver controls maintain rated steam exit conditions during normal operation and act to protect the receiver during startup, shutdown, and plant upset conditions. The thermal transport system controls govern the supply of condensate to the tank at the base of the tower, pump feedwater to the receiver, monitor warmup of the steam supply pipe and receiver, control admission of steam to the cogeneration facility, and ensure that emergency electric power is available for the safe shutdown of the solar systems. The master control system senses, monitors, and controls all relevant system parameters necessary to ensure safe and proper operation of the entire integrated cogeneration facility.

1.2.7 Nonsolar Energy System

The nonsolar energy system consists of modifications to the existing oil- and bagasse-fired boilers and ancillary equipment, the existing bagasse storage building, and the bagasse handling equipment. The following existing components in this system must be modified for the solar facility:

- Boiler instrumentation and control panel
- Main steam piping
- Condensate piping

As part of the solar system retrofit, the capacity of the existing bagasse storage building and bagasse handling equipment will be increased. No thermal energy storage is required.

1.2.8 Specialized Equipment

The following specialized equipment has been included as part of the solar cogeneration facility:

- A vehicle for semiautomatic cleaning of the heliostats
- A vehicle for electrical/electronic troubleshooting and repair of the heliostats

1.2.9 Modes of Operation

The solar cogeneration facility is expected to have two steady-state operating modes:

- Solar steam generation mode
- Nonsolar steam generation mode

In the solar steam generation mode, the solar water-steam receiver operates in parallel with the existing boilers. The existing boiler's output is reduced so that the maximum available solar-produced steam is used while the total steam demand is being met. Bagasse is displaced from the existing boilers into storage, and the use of oil is curtailed to the maximum extent possible.

In the nonsolar steam generation mode, during periods when solar-produced steam is unavailable, the existing boilers satisfy the entire steam demand, with bagasse if available. Oil is consumed only when necessary to meet the minimum steam demand.

The solar cogeneration facility is also expected to have the following transitional operating modes:

- Normal solar system startup mode
- Normal solar system shutdown mode
- Emergency solar system shutdown mode

In the normal solar system startup mode, the solar receiver and thermal transport system are heated from cold or warm shutdown conditions to full operations temperature and pressure.

In the normal solar system shutdown mode, the solar receiver and thermal transport systems are transferred from normal steam generation to either a temporary shutdown condition (for cloud passage or overnight outage) or cold shutdown conditions (for longer outages).

In the emergency solar system shutdown mode, solar energy input to the receiver is reduced as fast as possible to meet operational or safety requirements.

1.3 DEFINITION OF TERMS

Annual Capacity Factor, Nonsolar. The annual nonsolar MWh divided by the product of 8,760 hr and the facility or unit rating in MWt.

Annual Capacity Factor, Overall. The annual solar MWh plus the annual nonsolar MWh, divided by the product of 8,760 hr and the facility or unit rating in MWt.

Annual Capacity Factor, Solar. The solar MWh divided by the product of 8,760 hr and the facility or unit rating in MWt.

Bagasse. The cellulose by-product of sugarcane processing.

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

Cogeneration. The combined production of electrical or mechanical energy and useful thermal energy.

Conversion Efficiency, Gross. The gross output provided by a conversion device, divided by the total input power at specified conditions.

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

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

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

Direct Insolation. The nonscattered solar flux, expressed in W/m^2, falling on a surface of given orientation.

Geometric Concentration Ratio. The ratio of the projected area of a reflector system (on a plane normal to the insolation), divided by the receiver aperture area.

Levelized Energy Cost. The cost per unit of energy that, if held constant throughout the life of the system and multiplied by the total system energy output, exactly expresses the after-tax expenses incurred, including return on investment.

Payback Period. A traditional measure of economic viability to investment project. Payback period is defined as the number of years required to accumulate fuel savings that exactly equal the initial capital cost of the system. Payback often does not give an accurate representation of total life-cycle values.

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

Process Heat. The thermal energy used in industrial operations.

Receiver Efficiency. The ratio of thermal power output at the receiver base to solar power incident upon the receiver.

Solar Cogeneration. The combined production of electrical or mechanical energy and useful thermal energy by a solar facility.

Solar Flux. The rate of solar radiation per unit area, expressed in W/m^2.

Solar Fraction, Annual. The ratio of solar energy to the process divided by the total energy consumption, annual average, measured at turbine inlet.

Solar Fraction, Design Point. The ratio of solar energy input to total plant energy input at the design point, measured at turbine inlet.

Storage Capacity. The amount of bagasse that can be delivered from a fully charged storage building, expressed in kilograms (tons).

Thermal Power, Boiler Output. The thermal power input to the working or transport fluids from the boiler, minus stack and miscellaneous losses.

Thermal Power, Receiver Output. The thermal power derived from the receiver; does not include electrical parasitic or downcomer thermal losses.

Section 2

REFERENCES

The equipment, materials, design, and construction of the solar cogeneration plant must comply with all federal, state, and local standards, regulations, codes, laws, and ordinances currently applicable for the specific site and the user. These will include the references listed below. If there is an overlap in, or conflict between, the requirement of these references and the applicable federal, state, county, or municipal codes, laws, or ordinances, that applicable requirement which is the most stringent will take precedence. The revision of these references in effect on September 30, 1980 will be used.

2.1 STANDARDS AND CODES

The standards and codes are as follows:

- ASME Boiler and Pressure Vessel Code
  Section I — Power Boilers
  Section II — Materials Specification
  Section V — Nondestructive Examination
  Section VIII — Unfired Pressure Vessels
  Section IX — Welding and Brazing Qualifications

- ANSI B31.1 – 1977 Power Piping

- Uniform Building Code – 1976 Edition by International Conference of Building Officials

- ANSI A58.1 – 1972 Building Code Requirements for Minimum Design Loads in Buildings and Other Structures

- National Electrical Manufacturers Associations (NEMA) Standards

- Collector Subsystem Requirements Specification A10772, Issue D, Sandia National Laboratories, Livermore, CA

2.2 OTHER PUBLICATIONS AND DOCUMENTS

Other publications and documents are as follows:

- Transactions, American Society of Civil Engineers, Vol. 126, Part II, 1961, "Wind Forces on Structures," ASCE Paper No. 3269
- Manual of Steel Construction, 8th Edition, 1974, American Institute of Steel Construction
- NRC Regulatory Guides 1.60 and 1.61

2.3 PERMITS AND LICENSES REQUIRED

See Table A.2-1.

2.4 APPLICABLE LAWS AND REGULATIONS

The applicable laws and regulations are as follows:

- Pertaining to permits and licenses (See Table A.2-1)
- Crude Oil Windfall Profit Tax Act of 1980. Federal tax credit of 25% (10% general + 15% solar)
- State tax credit regulation (10% allowed)
- Public Utilities Regulatory Policy Act (PURPA)
- State of Hawaii, Title 6, Chapter 74, "Standards for Small Power Production and Cogeneration in the State of Hawaii"

Table A.2-1

SOLAR COGENERATION FACILITY PERMITS AND LICENSES REQUIRED

Federal Authority				
Issue	Pipeline crossing of Kahoma Stream	Receiver tower affecting navigable airspace	Environmental impact, federally funded project	Construction in flood-prone area (Kahoma Stream)
Law	Section 404, FWPCA 33 USC, 1344	49 USC 1304, 1348, 1354, 1431, 1501	National Environmental Policy Act of 1969 (NEPA), PL. 91-190	Chapter X, Title 24, Federal Reg., Federal Insurance Administration
Regulations		14 CFR Part 77	National Council of Environmental Quality Guidelines	
Agency	U. S. Corp of Engineers, Honolulu District, Building 230, Ft. Shafter, HI 96858	Department of Transportation, Federal Aviation Administration, Pacific-Asia Region, P.O. Box 4009, Honolulu, HI 96813	Department of Energy	Department of Public Works, 200 South High Street, Wailuku HI 96793 and U. S. Corp of Engineers, Honolulu District Building 230, Ft. Shafter, HI 96858
Permits	Section 404 permit — $10	Hazard determination — no fee	Environmental impact statement required — no fee	Submit plans to Department of Public Works — no fee
Time frame	30-day comment period, 30-day notice for public hearing (if required). Issued within 120 days.	Not specified	Coterminous with State EIS, I.E., acceptance or rejection within 60 days	Not specified

Table A.2-1 (Cont'd)

SOLAR COGENERATION FACILITY PERMITS AND LICENSES REQUIRED

State Authority				
Issue	Planning for federally funded projects	Use of agricultural district lands	Use of lands in vicinity of designated historic site	Use of state-owned lands
Law	Section 204, Cities and Metro Dev. Act (1966) Title IV. Intergovernmental Cooperation Act (1968)	Chapter 205, HRS	Chapter 6, HRS, Paragraph 6-11	Chapter 343, HRS
Regulations	A-95 procedure manual, State of Hawaii	State Land Use Commission rules, County of Maui, Planning Commission rules		Environmental Quality Commission EIS Regulations
Agency	Department of Planning and Economic Development, 250 S. King Street, Honolulu, HI 96813	State Land Use Commission, Pacific Trade Center, Rm 1795; Maui Planning Commission, 200 S. High Street, Wailuku, HI 96793	Department of Natural Resources, State Parks and Historic Site Division, P.O. Box 621, Honolulu, HI 96809	Maui Planning Commission, 200 South High Street, Wailuku, HI 96793
Permits	1. STD Form 424 2. Clearinghouse form	Application form, $35 fee, seven sets of information	Filing of intention — no fee	Environmental impact statement if agency action. May not apply if applicant action
Time frame	Comments in 20 days. Six steps involved		90 days to action by Department	Acceptance or rejection within 60 days

Table A.2-1 (Cont'd)

SOLAR COGENERATION FACILITY PERMITS AND LICENSES REQUIRED

County Authority			
Issue	Grading of land	Construction within county highways	Outdoor lighting for receiver tower
Law	Chapter 24, Permanent Ordinances, County of Maui, 1971	Per Article 4, Chapter 21, Permanent Ordinances, County of Maui, 1971	Chapter 13, Permanent Ordinances, County of Maui, 1971
Regulation	Ordinance No. 6	Per Article 4, Chapter 21	Ordinance No. 733, National Electric Code
Agency	Department of Public Works, Land Use and Codes Enforcement Division, County of Maui, 200 South High Street, Wailuku, HI 96793	Department of Public Works, Land Use and Codes Enforcement Division, County of Maui, 200 South High Street, Wailuku, HI 96793	Department of Public Works, Land Use and Codes Enforcement Division, County of Maui, 200 South High Street, Wailuku, HI 96793
Permits	Grading permit application fee based on amount of grading	Permit application plans needed - no fee. Performance bond required	Electrical permit fee per ordinances. Set of plans by electrical engineer.
Time frame	45 days for review	14 days for review	1 to 60 months, depending on scope of work

Table A.2-1 (Cont'd)

SOLAR COGENERATION FACILITY PERMITS AND LICENSES REQUIRED

County Authority			
Issue	Building, electrical, and plumbing permits	Construction of driveway onto county highways	Conflict with county general plan (hospital at receiver tower site)
Law	Chapters 12, 13, 14, Permanent Ordinances, County of Maui, 1971	Chapter 21, Article 7, Permanent Ordinances, County of Maui, 1971	Chapter 9, Permanent Ordinances, County of Maui, 1971
Regulations	Ordinances No. 735, 786, 852, 856, Uniform Building Code (1970), National Electric Code (1970), Uniform Plumbing Code (1969)	Ordinance No. 684	Maui County General Plan and Policies, Region 9, Lahaina, Plate 6
Agency	Department of Public Works, Land Use and Enforcement Division, County of Maui, 200 South High Street, Wailuku, HI, 96793	Department of Public Works, Land Use and Enforcement Division County of Maui, 200 South High Street, Wailuku, HI, 96793	Planning Department, 200 South High Street, Wailuku, HI 96793
Permits	Building permit fee based on evaluation. Environmental form (State DOH) coordinated with grading permit	Permit form, two sets of plans	Review of request by director to amend land use map
Time frame	3 to 6 months	30 days for review	30 days Planning Department, 45 days County Council action

Section 3

REQUIREMENTS

The solar cogeneration facility shall be designed to meet the performance requirements stated in this section. This specification is applicable as a design requirement only to the new or modified portions of the solar cogeneration facility. The solar cogeneration design specifications shall make maximum use of completed or ongoing DOE solar R&D activities. The design life of the solar cogeneration facility shall be 20 years.

3.1 SITE

The site for the solar cogeneration facility shall be on land currently owned or leased by Pioneer Mill Co., Ltd., or on land that can be leased from the State of Hawaii. The design should result in minimum impact on the agricultural operations in adjacent areas.

Site preparation shall be limited to rough grading of the heliostat field area. Natural drainage provision shall be maintained.

Access roads with crushed rock surface shall be contructed to the tower and completely around the heliostat field. Security fencing shall be put up to restrict entry into the heliostat field and tower area.

3.2 SITE FACILITIES

All maintenance, storage, and operations facilities shall be integrated with the existing plant facilities. The existing control room shall be expanded to accommodate the solar retrofit, and communication links with a new control room at the base of the solar tower shall be provided. Closed-circuit TV cameras shall be installed to give the operators visual information on systems operations and approaching cloud patterns.

A visitor's center should be considered for location on the hill north of the heliostat field. This center should afford a good view of the center but should be far enough away from the factory and heliostat field so as to prevent interference with operators.

3.3 COLLECTOR SYSTEM

The collector system shall reflect solar radiation into the receiver in a manner that satisfies receiver incident heat flux requirements. In addition, the collector system shall respond to commands from the master control system for emergency defocusing of the reflected energy or to protect the heliostat array against environmental extremes. The heliostats shall be properly positioned for repair or maintenance in response to either master control or manual commands. Heliostat design shall provide for stored or safe position at night, during periodic maintenance, and during adverse weather conditions.

3.2.1 Collector Field

The collector field shall be designed so that 29.8 MWt of radiant solar power will be delivered to the aperture planes at 1 p.m. of an equinox day, with a direct normal insolation value of 950 W/m^2.

The collector field design shall provide the optimum heliostat layout and shall take the following into consideration:

- Heliostat capital cost
- Field wiring cost
- Land availability

- Heliostat performance
- Receiver size
- Receiver tower height
- Shading and blocking
- Atmospheric attenuation
- Sun position
- Piping cost
- Foundation requirements
- Adjacent land use impacts

The collector system shall function as appropriate for all steady-state modes of plant operation. This shall include the capability of controlling the number of heliostats in the tracking mode so as to vary the redirected flux to the receiver between zero and the maximum achievable level with step changes of 7 percent of the total collector field output.

All power and control wiring shall be installed in a manner to prevent damage resulting from environmental conditions, personnel and vehicular activities, rodents, and insects.

3.3.2 Heliostats

Heliostats design shall be consistent with Sandia Specifications A10772, except as noted in Table A.3-1.

3.3.3 Heliostat Control

The heliostat tracking and control shall be accomplished by a three level open loop system. All normal operations shall be provided by a preprogrammed sequence of computer instructions. Manual override and operation cf all control sequences will be available.

Table A.3-1

EXCEPTIONS TO DOE SPECIFICATION A10772, ISSUE D,
COLLECTOR SYSTEM REQUIREMENTS

Section	Exception
General	Change "Subsystem" to "System"
2.1	Delete "Soil and Foundation Investigation Report 5 MW STTF, Sandia Labs"
3.1.2	Delete all
3.2.1 (c&d)	Change 12 m/s (27 mps) operational wind load to 6.7 m/s (15 mph) in three places
3.2.6	Environmental conditions in this specification shall be used in place of Appendix 1
3.2.6.1	Change 12 m/s (27 mph) to 6.7 m/s (15 mph)
Appendix 1	Delete

3.4 RECEIVER SYSTEM

3.4.1 Receiver

Design and Operation. The receiver shall be a dual-cavity-type, natural-circulation steam generator with separate superheat circuitry. It shall be sized to deliver 26.2 MWt (89.5 x 10^6 Btu/hr) to the receiver working fluid (water-steam) at the system design point (1 p.m., equinox). The receiver shall be capable of operating safely and reliably for 20 years with absorbed heat flux levels not exceeding 0.69 MWt/m^2 (220,000 Btu/hr-ft^2) for boiler tubes and 0.55 MWt/m^2 (175,000 Btu/hr-ft^2) for superheater tubes.

The feedwater enters the receiver at 113C (235F). At the system design point, steam shall be generated at the rate of 33 540 kg/hr (73,960 lb/hr) with outlet conditions of 6.85 MPa (994 psia) and 438C (820F). The maximum allowable pressure drop through the superheater shall be 896 kPa (130 psi).

The major components of the receiver shall be a boiler section, a steam drum, and a superheater section. The boiler tubes generate a steam-water mixture from feedwater; the drum separates the saturated steam from the mixture; and the superheater tubes raise the steam temperature to the specified outlet conditions. These three major componenets shall be linked together by a system of downcomers, feeders, headers, risers, and connecting piping. Attemperators shall be provided between the superheater passes for steam temperature control.

The receiver shall be fully insulated to reduce thermal losses to the environment. The aperture of the cavity shall be provided with an insulated door than can be closed to minimize heat loss and resultant cooling of the receiver during overnight shutdown. The entire receiver shall be supported from a structural-steel framework attached to the tower. All structures and supports shall be designed for wind and earthquake loading in accordance with the environmental criteria as listed in Section 4 of the System Specification.

Receiver Working Fluid. The receiver working fluid shall be water-stream. The water treatment system shall maintain the desired quality of feedwater entering the receiver. The maximum limits on critical impurities in the feedwater with 2 percent continuous blowdown are:

- Oxygen 7 ppb
- Silica 100 ppb
- Iron 10 ppb
- Copper 5 ppb
- Hydrazine 20 ppb
- Total hardness Minimum detectable by ASTM D-1126 B or equivalent

The concentration of impurities in the boiler water shall be limited by continuous blowdown from the drum. The recommended maximum limits on critical impurities in the boiler water are:

- Total dissolved solids 300 ppm
- Silica 5 ppm

3.4.2 Tower

The tower shall support the tower piping and the receiver cavities, with the aperture centerline at 76 m (250 ft), and shall satisfy the following criteria:

- Adequate access to the receiver, piping, and valves provided for inspection, maintenance, and repair
- Adequate provisions for crew safety at all times during operation, inspection, maintenance, and repair
- No permanent damage to the tower as a result of the survival wind specified in Section 4 of the System Specification
- A tower design based on the peak ground accelerations of UBC Zone 2, combined with the response spectrum given by NRC

Regulatory Guide 1.60 and the damping values given for the operating basis earthquakes in NRC Regulatory Guide 1.61

- A tower design that blends with the surrounding environment to the maximum extent practical

3.5 THERMAL TRANSPORT SYSTEM

The thermal transport system shall convey condensate from Pioneer Mill to the receiver system condensate holding tank, supply feedwater to the receiver system, convey superheated steam from the receiver system to Pioneer Mill, control the quality of steam during startup, and generate emergency electric power. This system shall incorporate the following features:

- Redundant condensate supply pumps
- Condensate flow control based on the condensate holding tank liquid level
- Condensate line vent and drain provisions
- Redundant receiver feed pumps
- Feedwater flow-modulating capability operating in response to the receiver three-element control signal
- A steam recirculation capability for use during startup and upset transients
- Deaeration capability in the condensate holding tank
- Steam line vent and drain provisions
- Control equipment for steam admission at Pioneer Mill to ensure matching of the steam conditions with the existing boiler

3.6 NONSOLAR ENERGY SYSTEM

The nonsolar energy system is the existing facility modified to accommodate a solar retrofit. Interfaces between this system and the rest of the solar facility shall be at the existing equipment boundaries unless otherwise noted. The design of the solar facility shall minimize operational impacts on the existing facility and shall make maximum use of the normal factory shutdown period for installation of the interfaces with the solar system.

3.7 MASTER CONTROL SYSTEM

The master control system shall coordinate the collector system control, the receiver system controls, and the thermal transport system controls, and interface with the existing facility.

3.7.1 Modes of Operation

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

The collector system controls shall be capable of:

- Relaying time of day and aim point instructions to the heliostats and changing the operating mode to the heliostat as required
- Starting up, shutting down, and stowing the heliostats using preprogrammed automatic sequences compatible with the system condition of the solar facility
- Providing status indication and data-logging capability for the collector system

The receiver system controls shall be capable of:

- Maintaining pressure, temperature, and flow control of the receiver during all normal operating modes
- Detecting problems in the receiver operation and providing an alarm when these problems occur
- Starting up and shutting down the receiver using preprogrammed automatic sequences

- Sending emergency signals to the thermal transport system and collector system to protect the receiver from damage
- Providing receiver status and data logging for the operator

The thermal transport system controls shall be capable of:

- Delivering the working fluid between the receiver and the existing facility during all normal operating modes
- Starting up and shutting down the thermal transport system in conjunction with the receiver system and the existing facility
- Providing system status and data logging for the thermal transport system

3.7.2 Design Criteria

The master control system shall be designed in accordance with the following criteria:

- Design simplicity, requiring:
  - Standard control practices
  - Simple, well-defined interfaces between the master control system and the other facility system controls
- Operational simplicity, requiring:
  - Primary operation to be automatic, with operator override capability
  - Single-console control during both automatic and manual operations
  - Easily read displays
- Design reliability, requiring:
  - Use of proven designs
  - Elimination of single-point failures through redundant elements whenever it is cost-effective to do so

- Operational reliability, requiring:
  - Separation of facility operational controls from data acquisition and evaluation peripheral controls within the master control system (thus permitting each control to function independently)
  - Manual operating of the facility in the event of failure of the master control system (thus requiring independent controls for the other facility systems)
- Cost-effective design, requiring:
  - Selection of off-the-shelf equipment
  - Modularity of the major subsystems of the master control system
  - Generically similar equipment in each major master control system functional element

3.7.3 Interface Requirements

In terms of an overall process control strategy, the solar receiver shall operate in principle as a third fossil-fueled boiler. The solar receiver shall operate at maximum capacity, and the fossil-fueled boilers shall be modulated to make up the remainder of the process load. The fossil boiler control system shall respond to steam distribution demand. There is no restriction of solar receiver output unless fossil-fueled boilers are at minimal output.

3.8 SERVICE LIFE

Equipment shall be designed for a service life of 20 years with no major component replacement required.

3.9 SAFETY

The solar facility design shall include provisions for assuring the safety of crews for inspection, maintenance, and repair of equipment on and in the receiver tower and in the heliostat field. Abort switches and manual override switches shall be located in potentially dangerous areas for the protection of personnel inadvertently placed in hazard. All hot pipes shall have, at minimum, personnel protection insulation.

3.10 RELIABILITY

The addition of the solar steam facility shall not decrease overall plant availability (exclusive of insolation conditions).

3.11 MAINTAINABILITY

The solar steam facility shall be designed to be compatible with existing plant maintenance practices. Easy access for maintenance shall be provided and components such as electronic units, motors, and valves shall be easily serviced and replaced. A minimum of specialized equipment shall be required for plant maintenance.

Section 4

ENVIRONMENTAL CRITERIA

4.1 FACILITY ENVIRONMENTAL DESIGN REQUIREMENTS

The system shall be capable of operating and/or surviving under the temperature, wind, rain, earthquake, hail, and lightning conditions described below.

4.1.1 Temperature

The plant shall be able to operate in an ambient air temperature range from 10C (50F) to 35C (95F). Performance requirements shall be met throughout an ambient air temperature range selected to be consistent with efficient facility operation. The survival range is 7C (45F) to 38C (100F).

4.1.2 Wind

The facility shall be capable of operating with the approximate wind profile shown in Figure A.4-1.

For the calculation of wind speed at other elevations, the following mode is assumed:

$$V_H = V_1 \ (H/H_1)^c$$

where
V_H = wind velocity at height
V_1 = reference wind velocity
H_1 = reference height, 10 m (30 ft)
c = 0.15

Performance requirements shall be met for the most adverse combination of wind and temperature conditions selected to be consistent with efficient facility operation. Wind analysis shall satisfy the requirements of ANSI A58.1-1972.

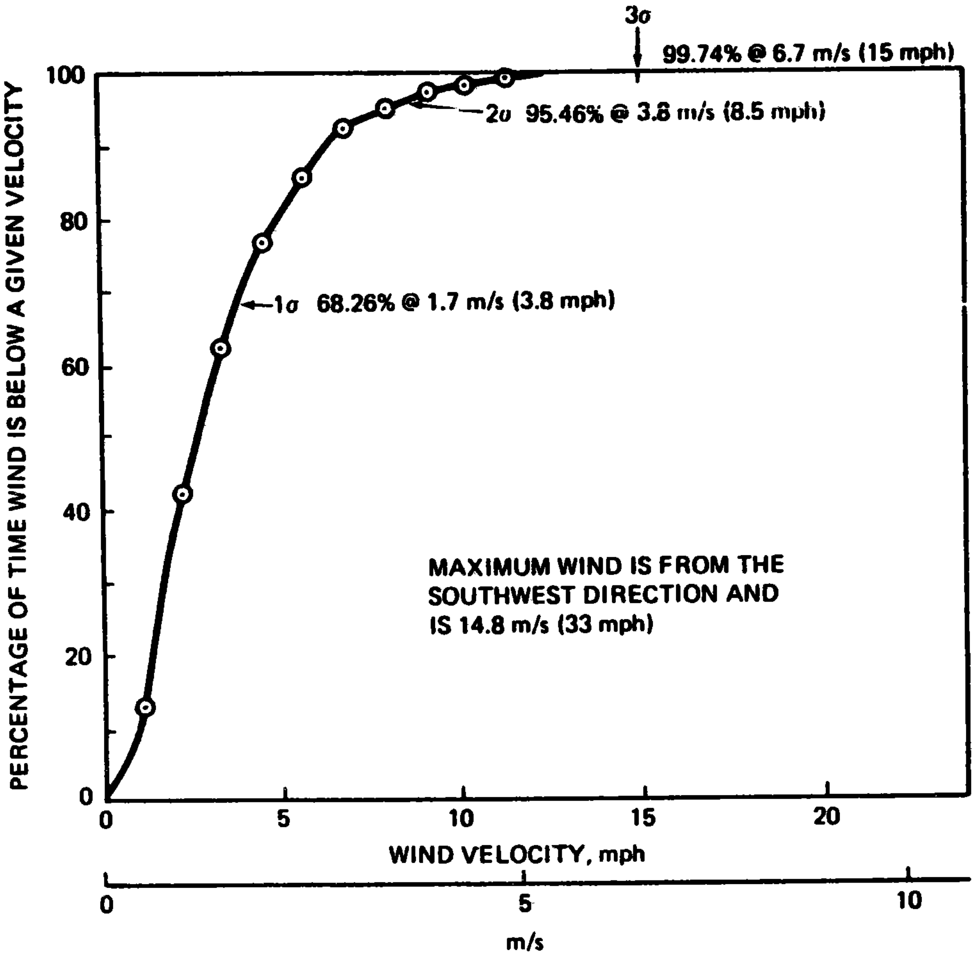


Figure A.4-1 PIONEER MILL WIND PROFILE AT 10-METER ELEVATION SEPTEMBER 1964 TO SEPTEMBER 1968

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

- Wind. The facility shall survive winds with a maximum speed, including gusts of 40 m/s (90 mph), without damage. A local wind vector variation of ± 10° from the horizontal shall be assumed for the survival conditions

- Wind rise rate. A maximum wind rise rate of 0.01 m/s^2 (0.02 mph/min) at 10 m (30 ft) elevation) shall be used in calculating wind loads during stowage and for tower survival.

However, the facility should withstand, without catastrophic failure, a maximum wind of 22 m/s (50 mph) from any direction, for any heliostat orientation, such as might result from unusually rapid wind rise rates, e.g., severe thunderstorm gust fronts.

4.1.3 Rain

The facility shall survive the following rainfall conditions:

- Average annual — 345 mm (13.6 in)
- Maximum 24-hr rate — 152 mm (6 in)

4.1.4 Earthquake

Peak ground accelerations shall be as presented below per applicable UBC zone. This peak ground acceleration is combined with the response spectrum given by NRC Regulation Guide 1.60 and the damping values given for the operating bases earthquake in NRC Regulation Guide 1.61. Zone 2 values shall be used for the baseline design.

The maximum survival ground acceleration for UBC Zone 2 under average or firm conditions is 0.1 g.

4.1.5 Hail

The facility shall be able to survive hail impact up to the limits given below.

	Heliostats in Any Orientation	Heliostats Stowed
Diameter	10 mm (0.75 in)	25 mm (1.0 in)
Specific gravity	0.9	0.9
Terminal velocity	20 m/s (65 fps)	23 m/s (75 fps)

4.1.6 Lightning Considerations

The facility shall be provided with a lightning protection system. Such protection shall be cost-effective with respect to risk of lightning strike.

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

Damage to a heliostat adjacent to a direct lightning strike shall be minimized. The central controller and the local controllers of heliostats adjacent to a direct lightning strike shall be protected, or alternative control methods provided to minimize loss of collector subsystem control.

4.2 ENVIRONMENTAL STANDARDS

4.2.1 Air Quality Control Standards.

The facility pollution emission requirements are shown below.

Particulates	1.0 lb/MBtu
Stack gas capacity	40 percent

It is expected that local air quality will improve, since oil fuel consumption is reduced by the addition of the solar systems.

4.2.2 Water Quality Standards

The retrofitted plant shall not discharge any effluent that adversely affects groundwater quality.

Section 5

DESIGN DATA REQUIREMENTS

This section provides the solar facility technical data, a summary of the main equipment at the existing mill facility, and the solar facility cost data including backup sheets.

5.1 SOLAR FACILITY TECHNICAL DATA

5.1.1 Collector System

- Collector Field

  – Key parameters

Number of heliostats	815
Total reflective area	43 000 m^2 (462,680 ft^2)
Sector width	2.62 rad (150^o)
Radius of circular sector	260 m (1,180 ft)
Area	0.17 km^2 (42 acres)
Axis of symmetry	15^o east of north
Number of rows	24

  – Spacing, distances, and coordinates: Tables A.5-1 and A.5-2 (Reference +Y is north of the tower center, and +X is east of the tower center)

- Heliostats, Northrup second-generation design: Table A.5-3
- Electrical energy consumption : Table A.5-4
- Collector field operating modes: Table A.5-5

Table A.5-1

PIONEER COLLECTOR FIELD PARAMETERS – 76 M (250 FT) TOWER

Row Number	Row Radius m(ft)	Row Length (Arc) m(ft)	Dist. To Next Row m(ft)	Cord Dist. Between Heliostats m(ft)
Tower	-------------	-------------	58.1 (190.5)	
1	58.1 (190.5)	152 (498.8)	10.6 (34.9)	13.4 (43.9)
2	68.7 (225.4)	179.8 (590.1)	10.6 (34.9)	15.8 (52.0)
3	79.3 (260.2)	207.7 (681.3)	10.6 (34.9)	18.3 (60.0)
4	89.9 (295.1)	235.5 (772.6)	10.6 (34.9)	13.4 (43.9)
5	100.6 (330.0)	263.3 (863.8)	10.6 (34.9)	15.0 (49.1)
6	111.2 (364.8)	291.1 (955.1)	10.6 (34.9)	16.5 (54.3)
7	121.8 (399.7)	318.0 (1,046.3)	12.3 (40.3)	18.1 (59.5)
8	134.1 (440.0)	351.1 (1,151.8)	10.6 (34.9)	13.4 (43.9)
9	144.7 (474.8)	378.9 (1,243.1)	10.6 (34.9)	14.4 (47.4)
10	155.3 (509.7)	406.7 (1,334.3)	10.6 (34.9)	15.5 (50.9)
11	170.0 (544.5)	434.6 (1,425.9)	10.6 (34.9)	16.6 (54.4)
12	176.6 (579.4)	462.3 (1,516.8)	18.8 (61.6)	16.6 (57.9)
13	195.4 (641.0)	511.5 (1,678.2)	10.6 (34.9)	13.4 (43.9)
14	206.0 (675.9)	539.3 (1,769.4)	10.6 (34.9)	14.1 (46.3)
15	216.6 (710.7)	567.1 (1,860.7)	10.6 (34.9)	14.8 (48.7)
16	227.2 (745.6)	594.9 (1,951.9)	13.4 (43.9)	15.6 (51.1)
17	240.6 (789.5)	630.0 (2,067.0)	12.1 (39.7)	16.5 (54.1)
18	252.7 (829.2)	661.6 (2,170.8)	27.8 (91.3)	17.3 (56.8)
19	280.6 (920.5)	734.5 (2,409.8)	13.4 (44.1)	13.4 (43.9)
20	294.0 (964.6)	769.6 (2,525.2)	13.4 (44.1)	14.0 (46.0)
21	307.4 (1,008.6)	804.8 (2,640.5)	14.7 (48.1)	14.8 (48.4)
22	322.1 (1,056.7)	843.2 (2,766.4)	20.8 (68.3)	15.4 (50.4)
23	342.9 (1,124.9)	897.6 (2,945.1)	16.5 (54.0)	16.4 (53.7)
24	359.3 (1,178.9)	940.7 (3,086.5)	0 0	17.3 (56.9)

Table A.5-2

PIONEER MILL HELIOSTAT COORDINATES, FT

P. 1

NO.	X	Y	NO.	X	Y	NO.	X	Y	NO.	X	Y
1	-165	95	21	143	174	41	-129	266	61	-74	321
2	-139	131	22	179	137	42	-88	282	62	-26	329
3	-105	159	23	206	92	43	-45	292	63	23	329
4	-66	179	24	221	43	44	-1	295	64	72	322
5	-23	189	25	-225	130	45	43	292	65	119	308
6	21	189	26	-190	178	46	86	282	66	163	287
7	63	180	27	-144	217	47	127	267	67	204	259
8	103	160	28	-90	244	48	165	245	68	240	226
9	137	133	29	-32	258	49	199	218	69	271	188
10	164	98	30	28	259	50	229	186	70	296	146
11	182	58	31	87	245	51	254	150	71	314	100
12	190	14	32	141	219	52	274	110	72	326	52
13	-207	89	33	187	181	53	287	68	73	330	3
14	-181	134	34	223	133	54	294	25	74	-316	182
15	-145	172	35	248	79	55	-297	143	75	-285	227
16	-102	201	36	260	20	56	-273	186	76	-248	267
17	-53	219	37	-256	148	57	-242	224	77	-206	301
18	-2	225	38	-231	184	58	-206	258	78	-159	328
19	50	220	39	-201	216	59	-166	285	79	-109	348
20	99	202	40	-167	244	60	-121	307	80	-56	361

PIONEER MILL HELIOSTAT COORDINATES, FT

P. 2

NO.	X	Y	NO.	X	Y	NO.	X	Y	NO.	X	Y
81	-1	365	101	87	390	121	-21	439	141	-340	332
82	53	361	102	144	373	122	23	439	142	-305	364
83	106	349	103	198	347	123	67	435	143	-267	393
84	156	330	104	247	314	124	110	426	144	-227	417
85	204	303	105	291	274	125	152	413	145	-184	438
86	24[illegible]	269	106	328	228	126	192	396	146	-139	454
87	284	230	107	359	176	127	230	375	147	-93	466
88	314	185	108	381	121	128	267	350	148	-46	473
89	338	136	109	395	63	129	300	322	149	1	475
90	355	84	110	400	4	130	331	290	150	48	472
91	364	31	111	-381	220	131	358	256	151	95	465
92	-360	173	112	-357	257	132	382	219	152	141	453
93	-330	225	113	-330	291	133	402	179	153	186	437
94	-293	272	114	-299	323	134	418	138	154	228	416
95	-250	312	115	-265	351	135	429	96	155	269	392
96	-201	346	116	-229	376	136	437	53	156	306	363
97	-147	372	117	-190	397	137	440	9	157	341	330
98	-90	389	118	-150	414	138	-423	217	158	372	295
99	-31	398	119	-108	427	139	-399	258	159	400	256
100	28	399	120	-65	435	140	-371	296	160	423	215

Table A.5-2 (Cont'd)

PIONEER MILL HELIOSTAT COORDINATES, FT

P. 3

NO.	X	Y	NO.	X	Y	NO.	X	Y	NO.	X	Y
161	443	172	181	267	434	201	-107	534	221	-434	384
162	458	127	182	309	405	202	-53	542	222	-394	425
163	468	80	183	348	373	203	1	545	223	-349	462
164	474	33	184	383	336	204	55	542	224	-302	495
165	-441	255	185	415	296	205	109	533	225	-251	522
166	-414	298	186	442	253	206	162	520	226	-197	545
167	-382	337	187	465	206	207	213	501	227	-142	562
168	-346	374	188	484	160	208	262	477	228	-85	573
169	-307	407	189	497	111	209	308	449	229	-28	579
170	-265	435	190	506	61	210	351	416	230	30	579
171	-221	459	191	510	10	211	391	379	231	88	573
172	-174	479	192	-485	248	212	427	338	232	144	561
173	-125	494	193	-457	296	213	458	294	233	200	544
174	-75	504	194	-426	340	214	485	247	234	253	521
175	-24	509	195	-390	380	215	508	197	235	304	494
176	26	509	196	-350	417	216	525	145	236	351	461
177	77	504	197	-306	450	217	537	92	237	395	423
178	127	494	198	-260	478	218	543	38	238	436	382
179	176	478	199	-211	502	219	-502	290	239	472	337
180	222	459	200	-160	521	220	-470	338	240	503	288

PIONEER MILL HELIOSTAT COORDINATES, FT

P. 4

NO.	X	Y	NO.	X	Y	NO.	X	Y	NO.	X	Y
241	529	236	261	-12	641	281	626	139	301	10	676
242	550	182	262	32	640	282	634	96	302	57	673
243	565	127	263	76	637	283	639	52	303	103	668
244	575	70	264	119	630	284	641	8	304	148	659
245	579	12	265	162	620	285	-597	318	305	193	648
246	-555	321	266	204	608	286	-573	358	306	237	633
247	-532	358	267	245	592	287	-548	396	307	280	615
248	-506	393	268	285	574	288	-519	433	308	321	595
249	-478	427	269	324	553	289	-488	467	309	361	571
250	-448	459	270	361	530	290	-455	500	310	400	545
251	-415	488	271	396	504	291	-420	530	311	436	516
252	-381	516	272	430	475	292	-383	557	312	470	485
253	-344	541	273	462	445	293	-343	582	313	502	452
254	-307	563	274	491	412	294	-303	604	314	532	417
255	-267	583	275	518	378	295	-261	624	315	559	379
256	-227	600	276	543	341	296	-217	640	316	584	340
257	-185	614	277	565	303	297	-173	653	317	606	299
258	-143	625	278	584	264	298	-128	664	318	625	257
259	-100	633	279	601	223	299	-82	671	319	641	213
260	-56	639	280	615	182	300	-36	675	320	654	169

Table A.5-2 (Cont'd)

PIONEER MILL HELIOSTAT COORDINATES, FT   P. 5

NO.	X	Y	NO.	X	Y	NO.	X	Y	NO.	X	Y
321	664	124	341	84	706	361	708	58	381	113	737
322	671	78	342	132	698	362	711	9	382	164	727
323	675	32	343	180	688	363	-658	350	383	213	715
324	-615	355	344	226	674	364	-633	395	384	261	698
325	-590	397	345	272	657	365	-604	437	385	309	679
326	-561	436	346	316	636	366	-573	477	386	354	656
327	-530	474	347	359	613	367	-539	516	387	398	630
328	-496	509	348	400	587	368	-502	551	388	441	601
329	-460	542	349	440	558	369	-463	584	389	481	570
330	-422	572	350	477	527	370	-422	615	390	519	535
331	-382	599	351	512	493	371	-379	642	391	554	499
332	-340	624	352	544	457	372	-334	667	392	587	460
333	-296	646	353	574	419	373	-288	688	393	617	418
334	-251	665	354	602	378	374	-240	706	394	644	375
335	-205	680	355	626	336	375	-191	721	395	669	330
336	-158	693	356	648	292	376	-141	732	396	690	283
337	-110	702	357	666	247	377	-91	740	397	707	235
338	-62	708	358	682	201	378	-40	745	398	722	186
339	-13	711	359	694	154	379	12	745	399	733	137
340	35	710	360	703	106	380	63	743	400	741	86

PIONEER MILL HELIOSTAT COORDINATES, FT   P. 6

NO.	X	Y	NO.	X	Y	NO.	X	Y	NO.	X	Y
401	745	35	421	199	764	441	-732	390	461	237	795
402	-684	395	422	251	748	442	-703	439	462	291	777
403	-655	441	423	302	729	443	-672	486	463	343	755
404	-623	485	424	351	707	444	-637	531	464	394	730
405	-589	526	425	399	681	445	-599	573	465	443	701
406	-551	565	426	445	652	446	-558	613	466	490	669
407	-511	602	427	488	620	447	-515	650	467	535	634
408	-469	635	428	530	586	448	-469	684	468	577	596
409	-424	666	429	568	548	449	-421	714	469	616	555
410	-378	693	430	605	508	450	-371	741	470	653	511
411	-329	718	431	638	465	451	-320	765	471	686	465
412	-279	738	432	668	420	452	-267	785	472	717	417
413	-228	756	433	696	373	453	-212	802	473	744	367
414	-176	770	434	720	325	454	-157	814	474	767	315
415	-123	780	435	740	275	455	-101	823	475	787	262
416	-69	787	436	757	224	456	-44	828	476	803	207
417	-15	789	437	771	171	457	13	829	477	815	152
418	39	789	438	781	118	458	70	826	478	824	96
419	93	784	439	787	64	459	126	820	479	828	39
420	147	776	440	789	10	460	182	809	480	-797	460

Table A.5-2 (Cont'd)

PIONEER MILL HELIOSTAT COORDINATES, FT — P. 7

NO.	X	Y	NO.	X	Y	NO.	X	Y	NO.	X	Y
481	-774	498	501	-41	920	521	727	565	541	-681	683
482	-750	534	502	3	920	522	753	530	542	-648	714
483	-723	569	503	47	919	523	777	493	543	-613	744
484	-695	603	504	91	916	524	800	455	544	-577	773
485	-666	636	505	134	911	525	821	417	545	-540	800
486	-635	667	506	177	903	526	840	377	546	-501	824
487	-602	696	507	220	894	527	857	337	547	-461	847
488	-568	724	508	263	882	528	872	295	548	-420	868
489	-533	751	509	305	869	529	885	253	549	-378	887
490	-497	775	510	346	853	530	896	211	550	-335	904
491	-459	798	511	386	836	531	905	168	551	-292	919
492	-420	819	512	425	816	532	912	125	552	-247	932
493	-381	838	513	464	795	533	917	81	553	-203	943
494	-340	855	514	501	772	534	920	37	554	-157	952
495	-299	870	515	538	747	535	-847	462	555	-112	958
496	-257	884	516	573	721	536	-824	502	556	-66	962
497	-215	895	517	606	693	537	-799	541	557	-20	964
498	-172	904	518	639	663	538	-772	578	558	26	964
499	-129	911	519	670	632	539	-743	615	559	72	962
500	-85	917	520	699	599	540	-713	649	560	118	957

PIONEER MILL HELIOSTAT COORDINATES, FT — P. 8

NO.	X	Y	NO.	X	Y	NO.	X	Y	NO.	X	Y
561	163	951	581	870	416	601	-544	849	621	379	935
562	208	942	582	889	374	602	-503	874	622	423	916
563	253	931	583	906	331	603	-461	897	623	466	894
564	297	918	584	921	288	604	-417	918	624	508	871
565	341	902	585	933	243	605	-373	937	625	549	846
566	383	885	586	944	199	606	-328	954	626	589	819
567	425	866	587	952	153	607	-282	968	627	627	790
568	466	844	588	959	108	608	-235	981	628	664	759
569	506	821	589	963	62	609	-188	991	629	700	726
570	544	796	590	964	16	610	-141	999	630	734	692
571	582	769	591	-873	504	611	-93	1004	631	766	656
572	618	741	592	-848	545	612	-45	1008	632	796	619
573	652	710	593	-821	585	613	3	1009	633	825	580
574	686	678	594	-793	624	614	51	1007	634	852	540
575	717	645	595	-762	661	615	99	1004	635	877	499
576	747	610	596	-729	697	616	147	998	636	895	457
577	775	574	597	-695	731	617	194	990	637	920	413
578	802	536	598	-660	763	618	241	979	638	939	369
579	827	497	599	-623	794	619	288	967	639	955	324
580	849	457	600	-584	822	620	334	952	640	970	278

Table A.5-2 (Cont'd)

PIONEER MILL HELIOSTAT COORDINATES, FT   P. 9

NO.	X	Y	NO.	X	Y	NO.	X	Y	NO.	X	Y
641	982	231	661	-414	972	681	554	900	701	1055	68
642	992	184	662	-367	991	682	596	872	702	1057	17
643	999	136	663	-320	1007	683	637	843	703	-974	563
644	1005	89	664	-271	1021	684	677	811	704	-946	608
645	1008	41	665	-222	1033	685	715	778	705	-916	653
646	964	16	666	-173	1043	686	751	743	706	-884	696
647	-927	506	667	-123	1050	687	786	707	707	-850	737
648	-902	550	668	-72	1054	688	819	668	708	-814	777
649	-875	593	669	-22	1056	689	850	628	709	-776	815
650	-846	634	670	28	1056	690	879	587	710	-736	851
651	-814	673	671	79	1054	691	906	545	711	-694	885
652	-781	711	672	129	1049	692	931	501	712	-651	917
653	-747	748	673	179	1041	693	953	456	713	-607	947
654	-710	783	674	228	1032	694	974	410	714	-561	975
655	-672	816	675	277	1020	695	992	363	715	-514	1001
656	-632	847	676	326	1005	696	1009	315	716	-465	1024
657	-591	876	677	373	989	697	1023	267	717	-416	1045
658	-549	903	678	420	970	698	1034	217	718	-366	1064
659	-505	928	679	466	948	699	1043	168	719	-315	1080
660	-460	951	680	511	925	700	1050	118	720	-263	1094

PIONEER MILL HELIOSTAT COORDINATES, FT   P. 10

NO.	X	Y	NO.	X	Y	NO.	X	Y	NO.	X	Y
721	-210	1105	741	781	810	761	-976	661	781	-25	1179
722	-157	1114	742	818	772	762	-944	707	782	32	1179
723	-104	1120	743	854	732	763	-909	751	783	88	1176
724	-50	1124	744	888	690	764	-872	794	784	144	1170
725	3	1125	745	920	647	765	-833	834	785	200	1162
726	57	1123	746	950	603	766	-792	873	786	255	1151
727	111	1119	747	978	557	767	-750	910	787	309	1138
728	164	1113	748	1003	509	768	-705	945	788	363	1122
729	217	1104	749	1026	461	769	-659	977	789	416	1103
730	269	1092	750	1047	411	770	-612	1008	790	469	1082
731	321	1078	751	1065	361	771	-563	1036	791	520	1058
732	372	1062	752	1081	310	772	-513	1061	792	570	1032
733	422	1043	753	1095	258	773	-462	1085	793	618	1004
734	472	1021	754	1106	205	774	-410	1105	794	665	973
735	520	998	755	1115	152	775	-357	1124	795	711	940
736	567	972	756	1121	99	776	-303	1140	796	755	905
737	613	944	757	1124	45	777	-248	1153	797	798	868
738	657	913	758	1057	17	778	-193	1163	798	838	829
739	700	881	759	-1035	565	779	-137	1171	799	877	788
740	741	846	760	-1007	614	780	-81	1176	800	913	746

Table A.5-2 (Cont'd)

PIONEER MILL HELIOSTAT COORDINATES, FT

NO.	X	Y	NO.	X	Y	NO.	X	Y	NO.	X	Y
801	948	701									
802	980	655									
803	1010	608									
804	1038	559									
805	1064	509									
806	1087	457									
807	1107	405									
808	1125	352									
809	1141	297									
810	1154	243									
811	1164	187									
812	1172	132									
813	1177	76									
814	1179	19									

Table A.5-3

ARCO-NORTHRUP II HELIOSTAT CHARACTERISTICS

• Type	Central pedestal drive mount, dual axis tracking
• Total mirror area	52.76 m^2 (568 ft^2)
• Height	7.75 m (25.38 ft)
• Width	7.44 m (24.41 ft)
• Weight, excluding pedestal	2 260 kg (4,985 lb)

- Mirror modules
  - Mirror surface 1.2 m x 3.66 m (4 ft x 12 ft)
  - Second surface silvered glass
  - Galvannealed sheet steel construction
  - Bond, Dow #4 silicone grease
  - Longitudinal C-web bracing
- Frame structure
  - Four building truss purlins
  - Cross bracing
  - Elevation axis torque tube
- Drive assembly
  - Elevation and azimuth drives
  - Stepper motors
  - Planetary and worm stages for each drive
  - 18,400 reduction ratio
- Pedestal, 0.61 m (2 ft) diameter steel pipe

Table A.5-4

ELECTRICAL ENERGY CONSUMPTION

	Power Input In Watts	Hours Per Day	kWh Per Day
Azimuth Drive			
When motor is operating	200	1.36*	0.272
Standby	85	10.64*	0.904
Off	0	12.00	0
Elevation Drive			
When motor is operating	200	0.68*	0.136
Standby	85	11.32*	0.962
Off	0	12.00	0
Microprocessor			
On	15	12.00	0.180
Off	0	12.00	0
Pedestal Fan			
On	20	24	0.48
Off	0	0	0
TOTAL PER HELIOSTAT PER DAY			2.958
FIELD TOTAL			2 411

* Assumes 240° azimuth motion/day and 120° elevation motion/day.

Table A.5-5

COLLECTOR FIELD OPERATING MODES

Safe course "wake-up":	Wire walk to stand-by beside the receivers (computer/manual)
Partial track; partial stand-by:	Controlled receiver warm-up (computer/manual)
Tracking:	Normal solar operation (computer)
Safe course stow:	Wire walk to stow (computer)
Special modes:	Emergency defocus (computer/manual) Cloud transients (manual/computer) Manual control

5.1.2 Receiver System

- Receiver dimensions

  - Receiver height — 14.63 m (48 ft 0 in)
  - Receiver width — 13.06 m (42 ft 10 in)
  - Receiver depth — 6.86 m (22 ft 6 in)
  - Aperture height — 6.52 m (21 ft 4.5 in)
  - Aperture width — 6.52 m (21 ft 4.5 in)
  - Cavity depth — 4.43 m (14 ft 6.5 in)
  - Angle between aperture normal vectors — 37.5°
  - Height to center line of aperture — 76 m (250 ft)

- Summary of material and estimated weight of the receiver: Table A.5-6

- Characteristics

  - Tube details

Boiler tubes (O.D.)	50.8 mm (2.0 in)
Superheater tubes (O.D.)	31.8 mm (1.25 in)
Headers (O.D.)	219.1 mm (8.625 in)

  - Number of downcomers, feeders, tubes, and risers: Table A.5-7

  - Maximum absorbed heat flux

Boiler section	69.4 W/cm^2 (220,000 Btu/hr ft^2)
Superheater section	55.2 W/cm^2 (175,000 Btu/hr ft^2)

  - Duty

Boiler section	21.43 MWt
Superheater section	4.77 MWt
Receiver system	26.2 MWt

  - Boiler recirculation characteristics: Table A.5-8, Figure A.5-1
  - Superheater performance characteristics: Table A.5-9
  - Energy proportions on the superheater panel: Table A.5-10
  - Superheater temperature profiles: Figure A.5-2

Table A.5-6

SUMMARY OF MATERIAL AND ESTIMATED WEIGHT

OF THE RECEIVER

	Material	Weight, kg x 10^3 (lb x 10^3)	
1. Pressure Parts			
Steam Drum	SA-516 Gr 70	10.0 (22.0)	
Downcomers	SA-106 C	1.8 (4.0)	
Boiler Panels	SA-210 A-1	11.3 (24.9)	
Boiler Headers	SA-106 C	2.0 (4.4)	
Feeders & Risers	SA-210 A-1	1.2 (2.6)	
Superheater Panels	SA-213 TP 316 H	2.1 (4.7)	
Superheater Headers & Piping	SA-335 P-2	1.4 (3.0)	
Miscellaneous Piping	SA-106-C	0.9 (1.9)	
Subtotal Pressure Parts			30.7 (67.5)
2. Cavity Enclosure & Doors			
Casing Plate & Stiffeners	Carbon Steel	21.5 (47.3)	
Insulation	Mineral Wool	6.9 (15.1)	
Lagging	Aluminum	2.7 (6.0)	
Subtotal Enclosure & Doors			31.1 (68.4)
3. Structural Steel	Carbon Steel		37.2 (82.0)
4. Platforms & Ladders	Carbon Steel		9.1 (20.0)
5. Miscellaneous Accessories			13.6 (30.0)
Total Receiver Dry Weight			121.7 (267.9)
Contained Water Weight at 15.6C (60F)			9.4 (20.6)
Total Estimated Weight			131.1 (288.5)

Table A.5-7

SUMMARY OF BOILER CIRCUITRY

Description	No. of Downcomers 168.3 mm O.D. (6.625 in O.D.)	No of Feeders 76.2 mm O.D. (3 in O.D.)	No of Tubes 50.8 mm O.D. (2 in O.D.)	No. of Risers 76.2 mm O.D. (3 in O.D.)
Common Wall	1	2	12	3
Rear Wall East	1	4	45	9
Rear Wall West	1	4	45	9
Side Wall East	1	4	56	9
Side Wall West	1	4	56	9
Total	5	18	214	39

Table A.5-8

BOILER CIRCULATION CHARACTERISTICS AT NOON WINTER SOLSTICE

Circuit Description	Circulating Flow kg/hr(lb/hr)	Velocity Entering m/s (ft/s)	Exit Quality % by Wt.	Steam Generated kg/h (lb/hr)
Common Wall	47 630 (105,000)	1.04 (3.4)	7.1	3 380 (7,460)
Rear Wall East	113 400 (250,000)	0.67 (2.2)	7.9	8 890 (19,600)
Rear Wall West	113 400 (250,000)	0.67 (2.2)	7.9	8 890 (19,600)
Side Wall, East Inboard Panel Outboard Panel	64 410 (142,000) 37 650 (83,000	0.55 (1.8) 0.41 (1.3)	7.5 3.3	4 840 (10,660) 1 240 (2,740)
Side Wall, West Inboard Panel Outboard Panel	64 410 (142,000) 37 650 (83,000)	0.55 (1.8) 0.41 (1.3)	7.5 3.3	4 840 (10,660) 1 240 (2,740)

Total Circulaton Rate = 478,550 kg/hr (1.055 x 10^6 lb/hr)
Steam Generation Rate = 33,320 kg/hr(73,460 lb/hr)

Flux Condition: Noon, Winter Solstice

Overall Quality, % by Wt.=7.0
Overall Circulation Ratio = 14.4:1

Drum Pressure = 7.722 MPa (1120 psia)

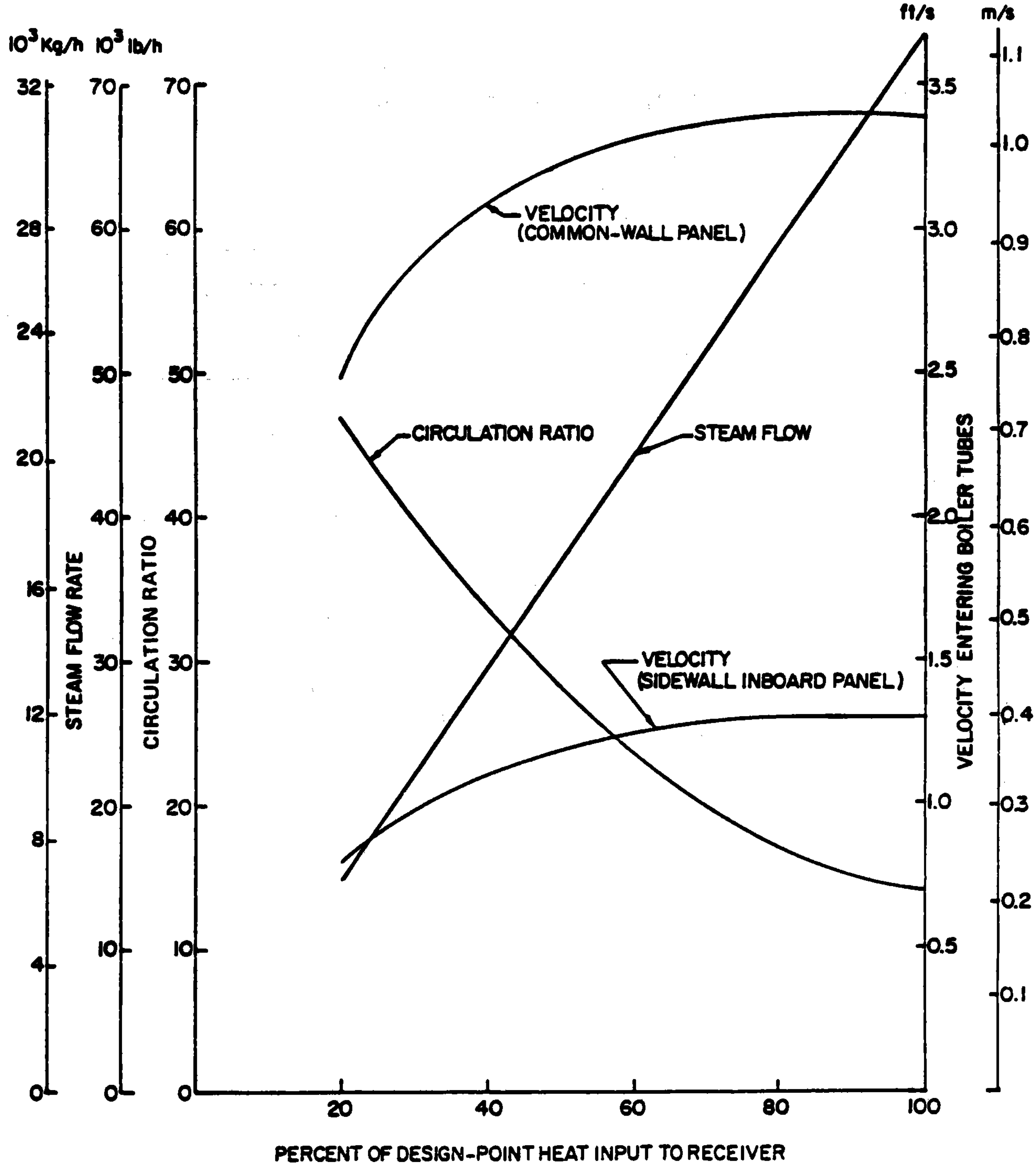


Figure A.5-1 BOILER CIRCULATION CHARACTERISTICS AT DIFFERENT HEAT OUTPUT CONDITIONS

Table A.5-9

SUPERHEATER PERFORMANCE CHARACTERISTICS

AT NOON WINTER SOLSTICE

Superheater Pass No.	Tubes Per Pass	Mass Velocity 10^6kg/hr m^2 (10^6lb/hr ft^2)	H. T. Coefficient W/m^2-C (Btu/hr-ft^2-F)	Pressure Drop (1) kPa (psi)
1	16	4.795 (0.982)	5 390 (950)	159 (23)
2	15	5.117 (1.048)	5 340 (940)	221 (32)
3	17	4.560 (0.934)	4 710 (830)	200 (29)
4	18	4.306 (0.882)	4 490 (790)	193 (28)

(1) interconnecting piping pressure drop not included

Table A.5-10

ENERGY PROPORTIONS ON SUPERHEATER PANELS

Day of Year	Time of Day	% of Energy on Superheater Panels								
		Pass 1		Pass 2		Pass 3		Pass 4		Total
		E	W	E	W	E	W	E	W	
Day 80 (Spring Equinox)	0800	2.0	5.29	1.69	4.56	1.55	3.83	1.15	2.1	22.17
	1200	3.19	3.65	2.61	3.1	2.1	2.62	1.35	1.64	20.26
Day 172 (Summer-Solstice)	1200	3.39.	3.59	2.81	3.08	2.31	2.78	1.46	1.8	21.22
Day 355 (Winter Solstice)	0800	2.02	4.94	1.68	4.19	1.5	3.46	1.03	1.84	20.66
	1000	2.43	4.51	2.0	3.57	1.75	2.94	1.16	1.59	19.95
	1200	2.96	3.6	2.39	3.02	1.95	2.55	1.2	1.51	19.18
	1400	3.44	3.25	2.59	2.87	2.0	2.5	1.12	1.64	19.41

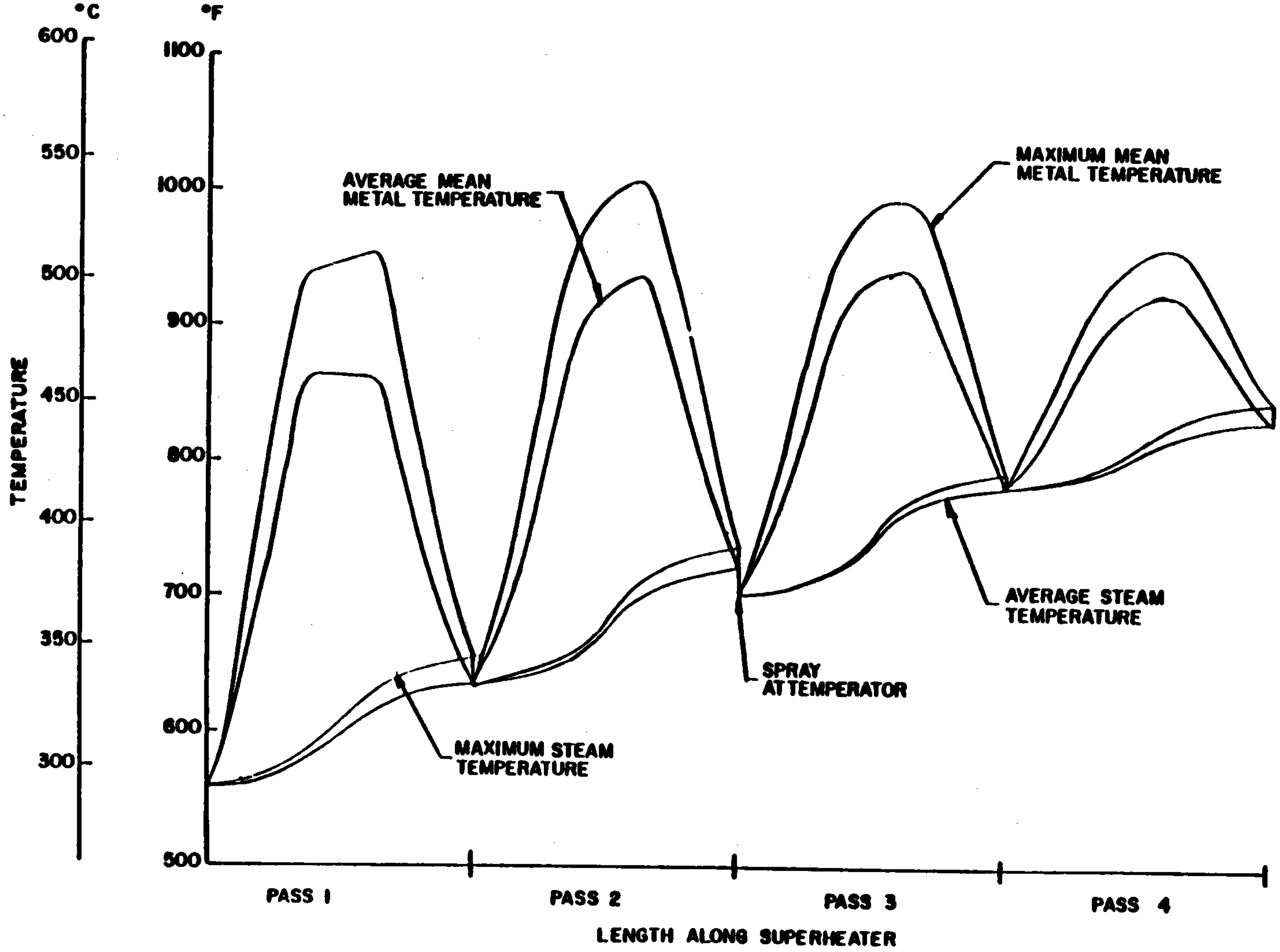


Figure A.5-2 TUBE WALL AND STEAM TEMPERATURES
ALONG THE LENGTH OF SUPERHEATER

- Design Parameters

– Steam temperature at receiver outlet	438C (820F)
– Steam pressure at receiver outlet	6.85 MPa (994 psia)
– Steam flow at receiver outlet	33 500 kg/hr (73,900 lb/hr)
– Drum operating pressure	7.76 MPa (1,125 psia)
– Feedwater temperature at receiver outlet	113C (235F)
– Feedwater pressure at receiver inlet	8.45 MPa (1,225 psia)
– Feedwater flow at receiver inlet	34 220 kg/hr (75,450 lb/hr)

- Incident flux maps, aperture plane, and receiver panels: Appendix G
- Receiver tower

– Type	Steel – 3 support legs
– Tower height	72 m (236 ft)
– Tower and receiver height	86.5 m (284 ft)

– Distance between main structural members

Base	22.9 m (75 ft)
Top	7.6 m (25 ft)

– Primary structural member diameters	0.31 m (12 in) to 0.91 m (36 in)
– Structural member material	Steel pipe
– Design wind speed at 9.14 m (30 ft)	40 m/s (90 mph)
– Seismic load, equivalent lateral force	0.1 g
– Estimated weight of receiver	131 100 kg (288,500 lb)
– Estimated weight of tower	131 500 kg (290,000 lb)
– Estimated weight of tower foundation	102 000 kg (225,000 lb)

5.1.3 <u>Thermal Transport System</u>

Receiver Tower Equipment List. The following major items of equipment are located at the base of the receiver tower.

- Receiver feed pump
  - Quantity: Three, 50% capacity
  - Type: Triplex plunger
  - Rating: .005 m^3/sec (80 gpm) to .0025 m^3/sec (40 gpm) at 905 m (2,970 ft) head
  - General: The pumps will be designed for pumping condensate at 113C (235F) with a discharge pressure of 8.45 MPa (1,225 psia). The pumps will have variable speed electric motor drives and gear boxes to give 250 to 100 rpm; the motor rating will be 75 kW (100 hp).
- Holding tank
  - Quantity: One
  - Type: Vertical, pressurized
  - 3.05 m (10 ft) dia. x 2.29 m (7.5 ft) high
  - General: The 16 m^3 (4,000 gal) tank will be located above the receiver feed pumps on its own support structure. The tank will be designed for 448 kPa (50 psia) and 113C (235F). The tank will be of stainless steel construction, with a stainless steel sparger and heating coil.
- Warmup recirculation pump
  - Quantity: One, 100% capacity
  - Type: Horizontal centrifugal
  - Rating: .005 m^3/sec (80 gpm) at 43 m (140 ft) head
  - General: The pump will be designed for pumping receiver drum water at 273C (525F) with a discharge pressure of 6.93 MPa (1,005 psia). The pump will be electric motor driven with a motor rating of approximately 7.5 kW (10 hp).

- Warmup heater
  - Quantity: One
  - Type: Horizontal shell and tube
  - Rating: 1 084 kW/hr (3.7 x 10^6 Btu/hr), 17 m^2 (183 ft^2) surface area
  - Size: Shell 0.45 m (18 in) dia. x 2.1 m (7 ft) long
  - General: The heater will be designed to raise the temperature of the receiver drum water from 218C (425F) to 288C (550F) in approximately 45 min using steam at 5.86 MPa (865 psia).
- Emergency turbine generator
  - Quantity: One
  - Rating: 500 kW, 3 ϕ, 60 Hz, 480 V
  - General: Turbine will start up on loss of electric power at receiver base. Steam at 4.48 MPa (675 psia) and 343C (650F) will be obtained from the first stage receiver superheater outlet.
- Instrument air package
  - Quantity: One
  - General: Package will include two compressors, each designed for 0.012 standard m^3/s (25 scfm) at 793 kPa (115 psia), two coolers, two dryers, and one receiver tank.

Mill Equipment List. The following major items of equipment are located at the mill.

- Electric steam superheater
  - Quantity: Four
  - Type: Vertical
  - Rating: 400 kWe, 460 V, 3 phase
  - General: Length 4 320 cm (170 in), diameter 46 cm (18 in), weight 1 360 kg (3,000 lb), Incoloy sheath

- Condensate transfer pump
  - Quantity: Three, 50% capacity
  - Type: Horizontal centrifugal
  - Rating: 0.005 m^3/sec (80 gpm) at 26 m (85 ft) head
  - General: The pumps will be designed for pumping condensate at 113C (235F) with a discharge pressure of 545 kPa (79 psia). The pumps will be electric motor driven with a motor rating of approximately 4 kW (5 hp).

Piping Data. The piping design characteristics are as follows:

Description	Material	Diameter cm (in)	Schedule	Length m (ft)	Insulation cm (in)
Main steam	A 335	15 (6)	80	1 130 (3,700)	11.5 (4.5)
Condensate	A 53	10 (4)	40	1 175 (3,900)	3.8 (1.5)
Feedwater	A 53	10 (4)	80	105 (350)	3.8 (1.5)
Emergency steam	A 335	10 (4)	80	105 (350)	6.4 (2.5)

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

Thermal Transport Steam Operating Conditions

- Receiver outlet flow (100%) — 33 500 kg/hr (73,900 lb/hr)
- Pressure at receiver — 6.85 MPa (994 psia)
- Temperature at receiver — 438C (820F)
- Temperature upstream of mixing station — 423C (793F)
- Flow (25%) — 8 385 kg/hr (18,490 lb/hr)

- Pressure at mill — 5.96 MPa (865 psia)
- Temperature at receiver — 438C (820F)
- Temperature at mill — 400C (752F)

5.1.4 Bagasse Storage

New Bagasse House. The new bagasse house is a 25 m x 49 m (80 ft x 160 ft) pre-engineered metal building (Butler type) erected on concrete walls 4.5 m (15 ft) high for protection against bucket loader damage and bagasse stock-piling. The total building height (to eave) is 9.5 m (31 ft). The building capacity is 445 metric tons (490 tons).

Conveyors:

Number	Type	Width m (in)	Length m (ft)	Capacity tonne/hr (ton/hr)	Speed m/min (ft/min)
5	Belt	1.2 (48)	47 (155)	45 (50)	61 (200)
6	Belt(1)	1.2 (48)	47 (155)	45 (50)	61 (200)
7	Belt	1.2 (48)	15 (50)	45 (50)	61 (200)
8	Dry slat	1.8 (72)	21 (68)	45 (50)	Variable
9	Belt	1.2 (48)	88 (290)	45 (50)	61 (200)

(1) With seven pneumatically operated plows.

Closed Circuit Television. There will be two, one at each end of the new bagasse house.

5.2 EXISTING FACILITY DESCRIPTION

5.2.1 Performance

Typical annual performance data for the Pioneer Mill, based on a 10-year average, is as follows:

• Raw sugar produced	47 314 kg (52,155 tons)
• Molasses produced	14 720 kg (16,226 tons)
• Bagasse produced and consumed	112 530 kg (124,042 tons)
• No. 6 fuel oil consumed	9 641 m^3 (60,588 bbl)
• Electric energy	
– Generated	55 332 MWhe
– Factory consumption	18 745 MWhe
– Other consumption (mainly irrigation pumping)	31 838 MWhe
– Sold to Maui Electric	4 750 MWhe

5.2.2 Design Features of the Mill Power Plant Equipment

Existing Turbine

• Type	General Electric, double-automatic extracting/condensing
• Rating	8 400 kWe
• Steam inlet	5.96 MPa (865 psia) 399C (750F)
• High pressure extraction	1.82 MPa (265 psia)
• Low pressure extraction	205 kPa (30 psia)
• Exhaust pressure	7.5 kPa (1.08 psia)

Existing Condenser

• Back pressure	7.5 kPa (1.08 psia)
• Exhaust flow	37 000 kg/hr (81,000 lb/hr)
• Cooling water temperature	24C (75F)
• Surface area	674 m^2 (7,250 ft^2)
• Tubes	1846 at 1.9 cm (0.75 in) O.D., 90-10 copper-nickel

Existing Fossil Boilers

• Number	Two
• Type	Combustion Engineering (VU-40S) dual fuel with bagasse and No. 6 oil
• Superheater outlet	5.96 MPa (865 psia) 404C (760F)
• Feedwater inlet	202C (396F)
• Boiler efficiency	70% with bagasse 90.5% with oil
• Maximum flow (each)	65 800 kg/hr (145,000 lb/hr) – oil 45 400 kg/hr (100,000 lb/hr) – bagasse
• Minimum flow (each)	9 100 kg/hr (20,000 lb/hr) – oil 18 100 kg/hr (40,000 lb/hr) – bagasse
• Oil storage capacity	290 m^3 (1,810 bbl)

Existing Bagasse House

• Capacity	35 000 kg (390 tons) at a bagasse density of 80 kg/m^3 (5 lb/ft^3)
• Dimensions	37.2 m by 22 m (122 ft by 72 ft)
• Number of conveyors	4

5.3 FACILITY COST DATA

The capital cost estimates are based on the conceptual design and engineering information prepared for the study in the form of engineering drawings, outline specifications, and equipment lists. Estimating methods consistent with the conceptual nature of the design information were employed and rely on informal vendor contact as well as extrapolation from current Bechtel information. The cost of equipment for the collector system, the receiver system, and the bagasse storage and conveying system has been obtained from appropriate subcontractors.

5.3.1 Pricing Levels

The estimate is at First Quarter 1981 price and wage levels. No allowance has been made for future escalation. The multiplying factor to convert to mid-1980 dollars is approximately 0.92.

5.3.2 Capital Cost Estimate

The capital cost estimate is composed of field costs, engineering services, contingency, and fee. The largest category, field costs, comprises the direct cost of permanent plant equipment and the indirect cost. The estimate anticipates an engineer-constructor direct-hire operation employing field construction labor forces.

Direct Field Cost. A brief description of the cost code of accounts adopted for this study is listed in section 5.3.5. However, the bases of the cost estimate and cost items covered by different construction disciplines are as follows:

- Civil. Major civil related cost items are for:
  - 0.17 km^2 (42 acre) of site preparation, including clearing and grubbing, rock pile removal, perimeter ditching, rough and fine grading, approximately 1 830 m (6,000 ft) of fencing around the heliostat site, and 3 050 m (10,000 ft) of temporary access road for heavy construction equipment at the site

- Visitors center and tower building
- Heliostat foundations
- Receiving tower and piping supports

The quantities were developed from drawing take-offs, allowances based on discussions with engineering, and comparisons to other projects of a similar nature. Pricing was based on informal vendor contacts for budgetary quotations. However, heliostat foundation construction cost, including drilling and implacement of 0.61 m (24 in) casings, was obtained through two different subcontractors in writing. They are:

- Foundation International, Inc., Kaneohe, Hawaii
- Hawaii Casion, Inc., Kailua, Hawaii

- Equipment. The equipment cost is the summation of the following two types:

  - Direct installed equipment, including all purchased equipment that does not require third-party labor at the construction site for installation or erection. This type of equipment includes receiver feed pump, condensate transfer pump, receiver feed tank, and emergency turbine generator. The cost of this equipment was obtained through informal vendor quotations
  - Subcontracted equipment that requires third party labor for fabrication and installation due to its highly specialized nature. The cost of this equipment and its installation has been obtained through the corresponding subcontractors and is included in the estimate as a subcontract cost. The equipment and subcontractors are:

    Receiver: Foster Wheeler Development Corporation

    Heliostats: Northrup Inc

    New bagasse house: Okahara, Shigeoka and Associates, Inc.

- Piping. The piping required to transport steam and return condensate between the solar energy receiver and the existing cogeneration plant has been estimated based on the piping quantity taken from engineering data. Also included in the cost are all pipe fittings, insulation, valves, pipe anchors, pipe support shoulders, and "A" frames. In order to ensure the inclusion of the intangible piping cost, an allowance for hydro-testing, cleaning, and freight cost has been estimated, based on Bechtel's experience.

- Electrical. Quantities were developed from drawing take-offs, and allowances were based on discussions with engineering and on comparisons to other projects of a similar nature. Pricing was based on recent Bechtel experience, vendor catalogues, and national pricing bulletins.

- Instrumentation. As quantities and descriptions for instrumentation were not available at the time of estimate, an allowance was made based on discussions with engineering and other recent Bechtel experience.

- Construction Labor. The direct hire construction manhours were estimated based on a combination of Bechtel Power Division and Refinery and Chemical Division standard unit manhours, adjusted for recent productivity experience in the State of Hawaii. A wage rate of $21.00 per hour has been estimated for this study and is based on a craft mix appropriate to the type of construction, together with a 5% allowance for casual overtime. Sufficient manual labor to complete the project within the construction schedule is assumed to be available in the project vicinity.

Indirect Field Cost. The indirect field costs are those items of construction cost that cannot be ascribed to direct portions of the facility and thus are accounted separately. They were estimated based on Bechtel experience with similar facilities, resulting in an assessment of 70% of direct labor costs.

The items covered by indirect field costs are as follows:

- Temporary construction facilities: temporary buildings, working areas, roads, parking areas, utility system, and general purpose scaffolding

- Miscellaneous construction services: general job clean-up, maintenance of construction equipment and tools, material handling, and surveying

- Construction equipment and supplies: construction equipment, small tools, consumable supplies, and purchased utilities
- Field office: field labor of craft supervision, engineering, procurement, scheduling, personnel administration, warehousing, first aid, and the costs of operating the field office
- Preliminary check-out and acceptance testing: testing of materials and equipment to insure that components and systems are operable
- Project insurance: public liability, property damage, and builder's risk insurances

Engineering Services. The engineering services include engineering costs and other home office costs. Engineering includes preliminary engineering, optimization studies, specifications, detail engineering, vendor-drawing review, site investigation, and support to vendors. Other home office cost items include procurement and inspection, estimating and scheduling services, quality assurance, acceptance testing, and construction and project management.

The sum of these three categories falls into historically consistent percentages in the range of 10% to 20% of the total field cost, depending on the complexity, design information, and duration of the project. For this study, a figure of 10 percent of field construction costs has been used as typical for a plant that, while new in concept, does not depart radically from basic engineering principles, and is neither complex nor of long duration.

Contingency. Included in the estimate is an allowance for the uncertainty that exists within the conceptual design in quantity, pricing, or productivity and that is under the control of the constructor and within the scope of the project as defined. To cover the cost of this uncertainty, a nominal figure of 15 percent of total field construction and engineering services cost has been included. Costs of this magnitude are expected to be incurred, but they cannot be specifically identified at this stage of the project.

Fee. Fee has been included at 3 percent of total construction cost.

5.3.3 Qualifications

The following are the major qualifications in the estimate:

- The scope of services will be that of a prime contractor responsible to the owner for engineering, procurement, and construction
- Equipment and materials will be procured from U.S. sources, and lead times will be able to support the project schedule without cost penalties
- Sufficient manual and non-manual personnel to complete the project within the construction schedule is assumed to be available in the project vicinity
- Existing water and power sources will be adequate for the project requirements

5.3.4 Owner's Costs

The following costs will be considered owner's cost for the conceptual design study and are not included in the total construction cost estimate:

- Land and land rights and cost of right-of-ways
- Water rights and water allocations
- Recreational areas and landscaping required by agencies
- Consulting services for site studies, if any
- Archeological search for artifacts, if required
- Other environmental studies required for permits
- Public relations activities (both local and regional)
- Costs of obtaining all necessary licenses and permits, including preparation of environmental impact statements
- Dealings with public agencies, long range community relations, etc.

- 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
- Plant consumable supplies and startup costs
- Property taxes and insurance costs on the land and plant during construction
- Sales tax
- Cost of money, AFDC (Allowance for funds during construction).

The owner's cost is estimated to be 10% of total construction cost plus AFDC and is used in Section 6 of the report for the economic analysis.

5.3.5 Code of Accounts

Figure 4-12 depicts a functional schematic showing the cost code account boundaries. The code of accounts adopted for this study and its inclusions are briefly listed as follows:

- 5100: Land and general site preparation
  - Clearing and grubbing
  - Rock pile removal
  - Perimeter ditching
  - Rough and final grading
  - Fencing
  - Access road
  - Lighting
- 5200: Building
  - Building at base of tower
  - Visitors center

- Electrical
- Extension of control room

• <u>5300</u>: Collector system
  - Heliostats
  - Heliostat foundation
  - Heliostat maintenance vehicles
  - Power and control equipment wiring
  - Controls

• <u>5400</u>: Receiver system
  - Receiver
  - Tower with foundation
  - Electrical
  - Instrumentation and controls

• <u>5500</u>: Master control system

• <u>5600</u>: Non-solar energy
  - Bagasse storage building
  - Bagasse handling equipment

• <u>5700</u>: Thermal transport system
  - Piping
  - Piping supports
  - Equipment
  - Electrical
  - Instrumentation and controls

5.3.6 Estimate Tables

The above discussion forms the basis of the estimates contained in the following Tables:

Table A.5-11 Construction Cost Estimate Summary

Table A.5-12 Cost Code of Accounts 5100 – Detail

Table A.5-13 Cost Code of Accounts 5200 – Detail

Table A.5-14 Cost Code of Accounts 5300 – Detail

Table A.5-15 Cost Code of Accounts 5400 – Detail

Table A.5-16 Cost Code of Accounts 5500 – Detail

Table A.5-17 Cost Code of Accounts 5600 – Detail

Table A.5-18 Cost Code of Accounts 5700 – Detail

The construction cost backup sheets follow each cost code of accounts table.

Table A.5-11

CAPITAL COST ESTIMATE SUMMARY
FOR
PIONEER MILL SOLAR COGNERATION PLANT
($ In 1,000s)

Cost Code	Description	Man Hours	Equip. & Mat'l	Labor	Sub-con-tracts	Total
5100	Land and general site prep.	48,100	402	1,010	-	1,412
5200	Buildings	6,500	185	142	-	327
5300	Collector system	16,000	340	336	12,800	13,476
5400	Receiver system	6,700	566	141	3,050	3,757
5500	Master control system	4,800	270	101	-	371
5600	Non-solar energy		-	-	1,900	1,900
5700	Thermal transport system	20,800	2,493	438	250	3,181
Total	direct field cost	102,900	4,256	2,168	18,000	24,424
	Indirect field cost					1,476
Total	field cost					25,900
	Engineering services					2,600
	Contingency					4,300
	Fee					1,000
Total	construction cost					33,800

Price and wage level, first quarter 1981

Table A.5-12
CONSTRUCTION COST ESTIMATE

REV. 2

CLIENT AMFAC SUGAR CO. / D.O.E

TION LAHAINA, MAUI, HAWAII

PROJECT SOLAR CO GEN. PLANT

DESCRIPTION ACCOUNT 5100

LAND & GENERAL SITE PREPARATION

DATE 7/7/81
JOB NO. 14481
MADE BY Y. T. YIM
APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST IN $1,000'S LABOR	SUBCONTRACTS	MATERIALS	TOTALS
		45,000	945		300	1,245
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping					
G	Electrical	3,100	65		102	167
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	48,100	1010		402	1412
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					688
	TOTAL FIELD COSTS					2100
R	Engineering					210
	Design & Engineering					
	Home Office Costs					
	R & D					
V	Contingency					349
W	Fee					81
	TOTAL CONSTRUCTION COST					2740

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

BY [illegible]

DATE 5/12/81

SHEET Summary OF [illegible]

ALL $1,000's

SITE PREP. SUMMARY	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
COST FOREWARDED FROM PP 1 CLEARING, GRUBBING, ROCK REMOVAL, PERIMETER DITCHING & ROUGH GRADING	—				36,580			65 –		65 –
COST FOREWARDED FROM PP 2 FINAL GRADING, FENCING ACCESS ROAD	—				8,838			227 –		227 –
S/T					45,418			292 –		292 –
MAKE ADJUSTMENT					<418>			8 –		8 –
TOTAL					45,000			300 –		300 –

LABOR

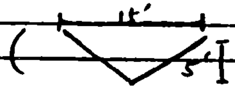
A.5-37

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT
STUDY NO. AND TITLE ______ :

BY W L i C
DATE 5-13-81
SHEET 1 **OF** 2

ALL $1,000's

CIVIL / STRUCTURAL	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
(0) SITE PREPARATION										
CLEARING & GRUBBING	42	AC	100	20	840	21.00		4-		4-
Qty: 42 Acres from R&E B. Lessley,										
Unit MH: 20 MH/Acre see back-up.										
ROCK REMOVAL	25000	CY	1.00	0.5	12500	21.00		25-		25-
Qty: 25,000 CY See Back-up										
Unit MH: 0.5 MH/CY from R&C										
PERIMETER DITCHING	8400	CY	0.25	0.5	4200	21.00		2-		2-
([sketch] x 6000') for drainage										
ROUGH GRADING	136000	CY	0.25	0.14	19040	21.00		34-		34-
Assume 2' average excavation										
42 × 43560 ft² × 2' × 1/27 = 135,520 CY										
SAY: 136,000 CY										
		LABOR			36,580			65-		65-



JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

BY W. - HC

DATE 5-14-81

SHEET 2 OF 2

ALL $1,000's

CIVIL/STRUCTURAL	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
(0) SITE PREPARATION <CONT.>										
FINAL GRADING	205,000	SY	—	.03	6,150	21[00]		—		
42 x 43560 x 1/9 = 203,280 sq yd SAY 205,000 S.Y										
FENCING	6000	LF	10[00]	0.3	1800	21		60		
8 ft high 6000 ft long, chain link.										
ALLOW FOR FENCE FOUNDATION Conc.	55	CY	50.[00]	2.5	138	21[00]		3		
1'⌀ x 3'D = 2.4 CF/ea. Total Post @ 10' ℄ - 6000/10 = 600; 2.4 X 600 X 1/27 = 53.3 CY SAY 55 CY										
Misc Allowance	1	LT	1000	—	—	—		1		
ACCESS ROAD.	250,000	SF	.65	.003	750	21[00]		163		
Qty: 10,000 LF of >8' wide construction Rd Subgrade & subbase only, no asphalt all in cost $0.72/SF. on the top										
LABOR					8838					

A.5-39

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ______: PIONEER MILL SOLAR COGEN. PLANT

BY ______

DATE D.B.S. MAY 20 '81

SHEET 1 OF 2

[illegible]

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
S100 - ELECTRICAL SUMMARY										
AREA LIGHTING (SHEET 2)	1	LT			3100		60	42		
TOTAL S100	1	LT	LABOR		3100		60	42		102

A.5-40

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

BY D.B.S. DATE MAY 19 '81

SHEET 2 OF 2

5100 ELECTRICAL	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
PERIPHERAL LIGHTING:-										
400W HPS FLOODLIGHTS W/P.E CELL	60	EA	420	6	360		25200			
30' STEEL POLES (2 FIXTS/POLE)	30	EA	1100	10	300		33000			
DOUBLE ARMS - FIXTURE MOUNTING	30	EA	50	4	120		1500			
POLE FOUNDATIONS - INCLUDE CONCRETE ANCHOR BOLTS.	30	EA	100	6	180			3000		
(APPROX 4400' PERIMETER 1-POLE & 2-FIXTS 147' O.C)										
4/C #8 D/BURIAL 600V CABLE.	8000	LF	2.50	0.06	480			20000		
4/C #10 600V POLE WIRING (30×30	1000	LF	1.90	0.05	50			1900		
HANDHOLES	30	EA	50	6	180			1500		
GROUNDING	1	LT		-	50			1000		
ARMORED CABLE CONNECTORS.	1	LT		-	30			300		
TRENCHING - EXCAVATION (8000'×2'×2')	1200	CY	-	0.3	360			—		
BACKFILL	1200	CY	-	0.2	240			—		
MISC & ADJUST	1	LT			75		300	150		
OUTDOOR LIGHTING -										
400W HPS FLOODLIGHTS MOUNTED ON TOWER & STRUCTURES.	20	EA	420	6	120			8400		
MOUNTING BRACKETS	20	EA	40	5	100			800		
1" CONDUIT INCL FITTINGS & SUPPORTS.	1000	LF	1.40	0.27	270			1400		
4/C #12 600V CABLE	1000	LF	1.05	0.05	50			1050		
4/C #8 600V D/BURIAL CABLE ALUM. SHEATH	1000	LF	2.50	0.06	60			2500		
TRENCHING - EXCAVATION (1000'×2'×2')	150	CY	-	0.3	45			—		
BACKFILL	150	CY	-	0.2	30			—		
LABOR	1	LT			3100		60000	42000		

A.5-41

Table A.5-13

CONSTRUCTION COST ESTIMATE

REV. 2

CLIENT AMFAC SUGAR/ CO./DOE

DESCRIPTION ACCOUNT 5200

BUILDINGS

TION LAHAINA, MAUI, HAWAII

PROJECT SOLAR/ COGEN/ PLANT

DATE 7/7/81

JOB NO. 14481

MADE BY Y.T. YIM

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST IN $1,000'S LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings	5400	119	—	168	287
E	Machinery & Equipment					
F	Piping					
G	Electrical	1100	23	—	17	40
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	6500	142	—	185	327
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
	Equipment Rental					
	INDIRECT FIELD COSTS					97
	TOTAL FIELD COSTS					424
R	Engineering					43
	Design & Engineering					
	Home Office Costs					
	R & D					
V	Contingency					70
W	Fee					16
	TOTAL CONSTRUCTION COST					553

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______

BECHTEL

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN PLANT

STUDY NO. AND TITLE

BY [illegible]

DATE 5-20-81

SHEET 1 OF

ALL $1,000's

5200 BUILDINGS	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
◦ VISITOR BUILDING (See pp 2)	1600	SF			2300			72		72
◦ CONTROL ROOM EXTENSION TO MILL (See pp 3)	240	SF			300			9		9
◦ TOWER BUILDING ENCLOSURE (See pp 2)	2500	SF			2800			90		90
MAKE ADJUSTMENT								<3>		<3>
TOTAL THIS PAGE	4340	SF	LABOR		5400			168		168

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ______ : PIONEER MILL SOLAR COGEN. PLANT

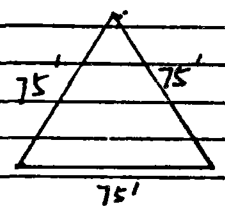
BY W. Liu

DATE 5-20-81

SHEET (2) OF ______

ALL $1,000's

5200 BUILDINGS	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
o VISITOR BLDG. (SEE PP1)	1600	SF			2300			72-		72-
DIMENSION: 40' x 40' x 15' HIGH										
NORMAL REINFORCED CONCRETE BLDG.										
1600 FEET NORTH TO RECEIVER TWR.										
ALL IN COST PER SF. BLDG → $75.00/SF										
WHICH ASSUMING MAT'L → 60%										
LAB → 40%										
o CONTROL ROOM EXTENSION TO MILL (SEE PP3)	240	SF			~~290~~ 300			9		9-
o TOWER BLDG. ENCLOSURE (SEE PP2)	2500	SF			2800			90-		90-
DIMENSION: 75' x 75' x 15' HIGH										
PRE-ENGINEERING BLDG UNDER THE TOWER FOR CONTROL RM. PURPOSE										
ALL-IN COST PER SF BLDG → $60.00/SF										
WHICH ASSUMING MAT'L → 60%										
LAB → 40%										
ADJ.								<1> <2>		<3>
			LABOR		5400	21.00				120-
TOTAL THIS PAGE	4100	SF			5400			160		160-



JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

BY 6/10/81

DATE 1/21/...

SHEET 53 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
C/S										
E200										
CONTROL ROOM EXTENSION TO MILL	240	SF	36 (60 struck)	1.2	290			9.-		9.-
SIZE: 8'x30'x15'H										
PRICE SAME AS TOWER BLDG										
SQ FT = 8x30 = 240 SQFT										
% / $/SF										
MAT'L 60% 36.-										
LABOR 40% 24.-										
Total 100.0 60.-										
LABOR					290					
Total	240	SF			290			9.-		9.-

A.5-45

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ________ : PIONEER MILL SOLAR COGEN. PLANT

BY ________

DATE D.B.S. MAY 20 '81

SHEET 1 OF 4

ALL $1,000's

5200 ELECTRICAL SUMMARY	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
VISITORS CENTER (SHEET 2)	1	4			500		1	6		
CONTROL ROOM AT TOWER (" 3)	1	4			500		2	4		
HELIOSTAT FIELD COMPUTER SHACK (" 4)	1	4			100		2	2		
TOTAL 5200.	1	4 (LABOR)			1100		5	12		17

A.5-46

BECHTEL

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT

STUDY NO. AND TITLE

BY D.B.S.

DATE MAY 19 '81

5200 ELECTRICAL	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
VISITORS CENTER (50' x 30')										
LIGHTING/POWER PANEL	1	EA	600	22	27		600			
SERVICE ENTRANCE & PANEL FEEDER.	1	LT	-	-	50			800		
4' x 4 LAMP RECESSED FLUORESCENT FIX.	30	EA	55	4	120			1650		
BATTERY - EXIT LIGHTS	2	EA	230	6	12			460		
OUTLETS & SWITCHES.	1	LT	-	-	20			300		
EXHIBIT LIGHTING	1	LT	-	-	100			1500		
TELEPHONE OUTLETS	1	LT	-	-	30			200		
3/4" EMT INCL. FITTINGS & SUPPORTS.	350	LF	0.40	0.25	88			140		
1" EMT " " " "	50	LF	0.60	0.27	14			30		
1/C #12 THW WIRE INCL. CONNECTIONS	1400	LF	0.14	0.02	28			196		
MISC. MATERIALS	1	LS			11		400	724		
LABOR	1	LS			500		1000	6000		

A.5-47

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE : PIONEER MILL SOLAR COGEN. PLANT

BY D.B.S. MAY 19 '81

DATE

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
5200 ELECTRICAL										
CONTROL ROOM AT TOWER:- (30'×20'×12')										
LIGHTING/POWER PANEL	1	EA	650	–	36		650	–		
SERVICE ENTRANCE & PANEL FEEDER	1	LT	–	–	50			800		
4'×4 LAMP RECESSED FLUOR. FIXTURES	12	EA	55	4	48			660		
BATTERY EXIT LIGHTS	2	EA	230	6	12			460		
OUTLETS & SWITCHES	1	LT	–	–	15			150		
TELEPHONE OUTLETS	1	LT	–	–	30			200		
WINDOW TYPE AIR CONDITIONER 24,000 BTUH	1	EA	550	–	25		550	–		
3/4" EMT	150	LF	0.40	0.25	38			60		
1" EMT	50	LF	0.62	0.27	14			30		
1/C #12 THW WIRE	700	LF	0.14	0.02	14			98		
MISC. MATERIALS	1	LT		–	80		400	730		
500KW EMERGENCY GENERATOR/STEAM 230/132V. COMPLETE WITH PANEL	1	LT	–				W/MECHANICAL			
MISC MATERIALS	1	LT	–		50		400	500		
ADJUST	1	LT			88		–	312		
LABOR	1	LT			500		2000	4000		

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE .... : PIONEER MILL SOLAR COGEN. PLANT

BY D.B.S.

DATE MAY 19 '81

SHEET 4 OF 4

5200 ELECTRICAL	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
HELIOSTAT FIELD COMPUTER SHACK (HFC)										
WINDOW TYPE AIR CONDITIONER	1	EA	300		12		300			
6000 BTUH.										
OTHER MISC. ELECTRICAL	1	LT	–		88		1700	2000		
LABOR	1	LT			100.		2000	2000		

Table A.5-14
CONSTRUCTION COST ESTIMATE

REV 2

CLIENT AMFAC. SUGAR Co./DOE

TION LAHAINA, MAUI, HAWAII

PROJECT SOLAR CoGEN. PLANT

DESCRIPTION ACCOUNT 5300
COLLECTOR SYSTEM

DATE 7/7/81
JOB NO. 14481
MADE BY Y.T. YIM
APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST IN $1,000's LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	—	—	500	—	500
B	Concrete					
C	Structural Steel					
D	Mobile Equipment	—	—	—	40	40
E	Machinery & Equipment (HELIOSTATS)	S/C	—	12,300	—	12,300
F	Piping					
G	Electrical	16,000	336	—	300	636
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	16,000	336	12,800	340	13,476
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					228
	TOTAL FIELD COSTS					13,704
R	Engineering					1,376
	Design & Engineering					
	Home Office Costs					
	R & D					
V	Contingency					2275
W	Fee					530
	TOTAL CONSTRUCTION COST					17,885

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE

PIONEER MILL SOLAR COGEN PLANT

BY [signature]

DATE 5/20/81

SHEET 1 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
DRILLING, CASING SETTING & CONCRETE										
DRILLING, CASING SETTING & CONCRETE COST INCLUDES FOLLOWING					S/C				500-	500-
• DRILLING 36"Ø x 10' DEEP (815 HOLES)										
• SETTING 24"Ø CASING, FOUNDATION & CONCRETE										
• MOBILIZATION & DEMOBILIZATION OF HEAVY EQUIPMENT.										
S/C COST QUOTED BY FOLLOWING SUB CONTRACTORS										
• HAWAII CASSION INC.										
• FOUND INTER INC										
TOTAL THIS PAGE		LABOR			S/C				500-	500-

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ________ : PIONEER MILL SOLAR COGEN. PLANT

BY [illegible]

DATE 5/20/81

SHEET 1 OF 1

5300

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
• MOBILE EQUIPMENT										
2½ TON WASHING TRUCK	1	EA	30K		—		30 —			30 —
ALLOW $ 30,000										
1 TON MAINTENANCE VAN	1	EA	10K		—		10 —			10 —
ALLOW $ 10,000										
TOTAL THIS PAGE	2	EA	LABOR		—		40 —			40 —

A.5-52

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE Pioneer Mill Solar (Cogen) Plant

BY [illegible]

DATE 5/20/81

SHEET 1 OF

ALL $1,000's

HELIOSTATS	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
815 HELIOSTATS (QUOTED BY NORTHRUP)	815	EA	-	-	S/C				12300	12300
TOTAL THIS PAGE	815	EA	LABOR		S/C				12300	12300

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ________ : PIONEER MILL SOLAR COGEN. PLANT

BY ________

DATE D.B.S. MAY 20 '81

SHEET 1 OF 2

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
5300 ELECTRICAL SUMMARY										
HELIOSTAT ELECTRICAL DISTRIBUTION (SHT #2)	1	LT			16000		9	291		
		LABOR								
TOTAL 5300	1	LT			16000		9	291		300

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT

STUDY NO. AND TITLE

BY

DATE D.B.S. MAY 18 '81

SHEET 2 OF 2

5300 ELECTRICAL	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
HELIOSTAT DISTRIBUTION PANELS	13	EA	650	36	468		8450			
120/240V 3φ 4W. 18 CKT.										
W/ 225A MAIN BREAKER										
4 EA 100A-3P ✓										
3 EA 100A-1P ✓										
MOUNTING MATERIALS	1	LT	–	–	75		550	650		
MISC. & ADJUST								–		
2/C #12 600V. D/B WITH ALUM. SHEATH	47,000	LF	1.10	0.05	2350			51700		
4/C #8 ✓ ✓ ✓ ✓	11,000	LF	2.50	0.06	660			27500		
4/C #2 ✓ ✓ ✓ ✓	4,000	LF	5.90	0.08	320			23600		
4/C #1/0 ✓ ✓ ✓ ✓	6,600	LF	8.95	0.10	660			59070		
3/C #12 ✓ ✓ ✓ ✓	10,000	LF	1.25	0.05	500			12500		
JUNCTION BOXES W/PROOF WITH TERMINALS	13	EA	60.00	10	130			780		
CONDUIT FOR RISERS ETC.	1000	LF	2.50	0.30	300			2500		
ARMORED CABLE CONNECTORS & TERMINATIONS	1	LT	–	–	250			2000		
#2 BARE CU. GROUND WIRE	52000	LF	1.40	0.03	1560			72800		
GROUND WGS	1000	EA	3.50	1.00	1000			3500		
TRENCH EXCAVATION D/B CABLE & GROUND	10,100	CY	–	0.3	3030			–		
68,000 LF × 2' × 2'										
BACKFILL	10,100	CY	–	0.2	2020			–		
MISC. & ADJUST	1	LT			–			485		
#20 AWG. BELDEN #8227 TWIN AXIAL SHLD.	50,100	LF	0.65	*0.05	2505			32565		
(SAME TRENCH AS POWER CABLE)										
#24 AWG 25/C W/SHLD	700	LF	1.50	0.09	63			1050		
CABLE TERMINATIONS	1	LT	–	–	109			300		
*MFR 0.40 PLUS 0.25 FOR SHEATHING IF REQ'D			LABOR							
	1	LT			16000		9000	291000		

A.5-55

PIONEER MILL SOLAR COGENERATION FACILITY

COLLECTOR FIELD COST SUMMARY

(780 Heliostats)

1.	Heliostat Cost F.O.B. Factory	$10,478,052
2.	Control Instrumentation	84,002
3.	Paint	3,900
4.	Field Assembly and Installation	342,424
5.	Temporary Construction Facilities	61,767
6.	Construction Equipment Rental	37,815
7.	Field Overhead	82,182
8.	Contingency	120,472
9.	Shipping (Bakersfield, CA. to Lahaina, Hawaii)	680,527
10.	Fee	823,946
	TOTAL	$12,715,087

ADJUSTED COLLECTOR FIELD COST SUMMARY
(815 Heliostats)

Item	Description	Cost ($1,000s)
1	Heliostat cost	10,478
3	Paint	4
4	Field assembly and installation	342
7	Field overhead	82
9	Shipping	681
		$\frac{815}{780}$ x 11,587
		= 12,107
2	Controls	84
5	Temporary facilities	62
6	Equipment rental	38
		12,291

PIONEER MILL SOLAR COGENERATION FACILITY

(780 Heliostats Installed)

BASIS FOR COST ESTIMATE

1. Heliostat Production Rate - 5000 heliostats per year
2. Plant location - Bakersfield, California
3. Dollars - 1981 (no escalation included)
4. Three-month installation period
5. Three shift operation of assembly facility
6. Day shift installation
7. Heliostats completely assembled and aligned prior to removal from assembly building.
8. Assembly building depreciated to 0 during 3-month assembly.
9. Major assembly fixtures amortized over 10 similar assembly operations (projects)
10. Major assembly and installation equipment rented locally.
11. Pedestals and field wiring installed by others. (Pedestal included in heliostat cost.)

Enclosure III
Exhibit I
Attachment 1
Page 34

CONSTRUCTION COST ESTIMATE

CLIENT Bechtel Group, Inc.

LOCATION Lahaina, Maui, Hawaii

PROJECT Pioneer Solar Co[illegible]

DESCRIPTION Solar Collector Field System

CONT. NO. ______

MADE BY ______

APPROVED ______

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST: LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	~~Machinery & Equipment~~ Heliostats		329,[illegible]	[illegible],527	10,47[illegible],652	11,487,782
F	Piping					
G	Electrical					
H	Instruments				84,002	84,002
J	Painting		13,[illegible]		3,900	17,121
K	Insulation					
	DIRECT FIELD COSTS		34[illegible],424	6[illegible],527	10,565,954	11,58[illegible],905
L	Temporary Construction Facilities				61,767	61,767
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense 24% D.L.		82,18[illegible]			82,182
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental			37,815		37,815
	INDIRECT FIELD COSTS		82,182	37,815	61,767	181,764
	TOTAL FIELD COSTS		42[illegible],6[illegible]	[illegible],342	10,627,721	11,770,669
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 10% (Total Field Costs less Direct Materials)					120,472
W	Fee 7% (Total Field Costs)					823,946
	TOTAL CONSTRUCTION COST					12,715,087

DATE 5/27/81 REVISION NO. 0 REVISION DATE ______ PAGE NO ______

CLIE. Bechtel Group Inc.
LOCATION Lahaina Maui, Hawaii
PROJECT Solar Cogeneration

CONSTRUCTION COSTS

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS ( ) SUB CONTRACT	COSTS ( ) MATERIAL	COSTS ( ) TOTAL
E	Collector Field												11 487,782
E-1	Heliostats (FOB Bakersfield, CA)	780							13,183.40			10,478,052	10 478 052
E-2	Field Assembly Labor	13,650		17.5		16.95	296.63			231 368			231,368
E-3	Installation Labor	5,772		24		16.95				97835			97,835

92

DATE 5/26/81 REVISION NO. 0 REVISION DATE ________ PAGE NO. ____ OF ____

REVISION NO. ________ REVISION DATE ________

CONSTRUCTION COSTS

CLIENT Bechtel

LOCATION Lahaina, Maui, Hawaii

PROJECT Pioneer Solar Cogeneration

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
Q	Equipment Rental												37815
Q-1	Assembly												
	Fork lift	1	3 MO.					1,100			3300		3300
	Paint	2						450			900		900
	Welders - elec.	2						525			1050		1050
	Installation												
	Tractors	2						4275					8550
	Trailers	2						1920					3840
	Cranes 12 TON	2						5775					11550
	Scissor Lift	1						7500					7500
	Pick up truck	1						825					825
	Air comp	1						300					300

DATE ________ REVISION NO. ________ REVISION DATE ________ PAGE NO. ____ OF ____

REVISION NO. ________ REVISION DATE ________

CONSTRU…ION COSTS

CLIENT Bechtel
LOCATION Lahaina, Maui, Hawaii
PROJECT Pioneer Solar Cogeneration

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
H	Control Instrumentation												84,002
H-1	Computer HP 9825 T	2							10,250				20,500
H-2	I/O Expander HP 9878	2							1,875				3750
H-2	Disk Drive HP 9885M	2							[illegible]				10,250
H-3	Serial Interface HP	17							750				12,750
H-5	Line Drivers ARCD	14							813				11,325
H-6	CRT Display HP 2621	1							3,250				3,250
H-7	Plotter Printer	1							6,250				6,250
H-8	Data Logger E-A	1							10,875				10,875
H-9	Voltage Reg. Topaz	2							688				1376
H-10	Real Time Clock	2							750				1,500
H-11	System Program ROM	2							313				626
H-12	Misc. Parts, Plugs, wire, etc	Var.							1500				1,500
J	[illegible]	780		1		16.95			5	13221		3900	17121

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ____ OF ____

REVISION NO. ______ REVISION DATE ______

.NT Bechtel

CONSTRL TION COSTS

LOCATION Lahaina, Maui, Hawaii

PROJECT Pioneer Solar [illegible]

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
1.	Construction Facilities												61767
1-1	Assembly Facility												
	Building 3200 Sq ft	1						5.65/Sq ft			18080		18080
	Foundation 3200 x 4"	39.5	CY					105			4148		4148
	Electrical 3200	3200	S.F					1.83			5856		5856
	Paving (Asphalt) 5600 ft²	57.9	CY					17.00			883		883
1-2	Assembly Equipment												
	Assy Fixtures (Separate)												3500
	Alignment + Centering												1500
	Hoists 2 ton	3							1200			3600	3600
	Small Tools	var.											4000
1-3	Installation Equipment												
	Post Drills	1							5000				5000
	Lifting Frames	2							[illegible]				[illegible]
	Elevator [illegible]	[illegible]							[illegible]				2,000
	Small Tools	var.							[illegible]				4,000
M / N / P	24% of D.L.									242424			122182

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______

REVISION NO. ______ REVISION DATE ______

Table A.5-15
CONSTRUCTION COST ESTIMATE

REV 2

CLIENT AMFAC SUGAR CO/DOE
TION LAHAINA, MAUI, HAWAII
PROJECT SOLAR COGEN. PLANT

DESCRIPTION ACCOUNT 5100
RECEIVER
SYSTEM

DATE 7/7/81
JOB NO. 14481
MADE BY Y.T. YIM
APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST IN $1,000s LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete	5600	118	350	440	908
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment (RECEIVER)	S/C	—	2,700	—	2,700
F	Piping					
G	Electrical	900	19	—	56	75
H	Instruments	200	4	—	70	74
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	6700	141	3050	566	3757
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					96
	TOTAL FIELD COSTS					3853
R	Engineering					387
	Design & Engineering					
	Home Office Costs					
	R & D					
V	Contingency					640
W	Fee					149
	TOTAL CONSTRUCTION COST					5029

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______

BECHTEL

JOB NO. AND TITLE 14481 PIONEER 4KC SOLAR COGEN PLANT

STUDY NO. AND TITLE

BY KDYing

DATE 7/6/81

SHEET SUMMARY OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
RECEIVER TOWER SUMMARY										
RECEIVER TOWER (FROM pp 1)	1	EA			5600		–	440	120	560
TOWER ELEVATOR (FROM pp 10)	1	EA			S/C		–	–	230	230
TOTAL THIS PAGE		LABOR			5600			440	350	790

A.5-65

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT

STUDY NO. AND TITLE

BY NLHC

DATE 7/1/81

SHEET 1 OF

ALL $1,000's

RECEIVER TOWER	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
(0) FOUNDATION (FROM pp 2)					2600		—	20	—	20
(0) STRUCTURAL STEEL PIPE (FROM pp 5)					3000		—	415	115	530
MAKE ADJUSTMENT								5	5	10
TOTAL SUMMARY PAGE		LABOR			5600		—	440	120	562

A.5-66

BECHTEL

JOB NO. AND TITLE 14481 PCS PLANT

STUDY NO. AND TITLE

RECEIVER TOWER

BY WKHC

DATE 7/6/81

SHEET 2 OF

ALL $1,000's

TOWER FOUNDATION SUMMARY	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
FOUNDATION:										
FROM PP3	1500	CY	–		750			–	–	–
FROM PP 4	–	–	–		1870			20	–	20
S/T					2620			20		20
Adj.					<20>			–		–
TOTAL THIS PAGE	1	LT	LABOR		2600			20	–	20

A.5-67

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

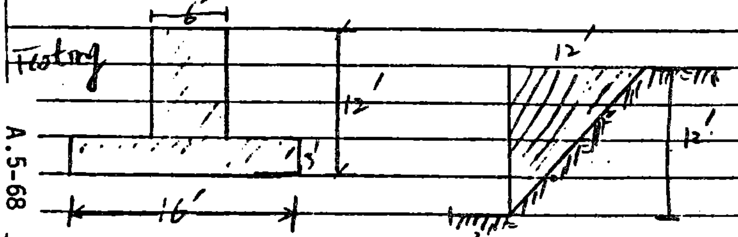
BY WLC

DATE -/-/-

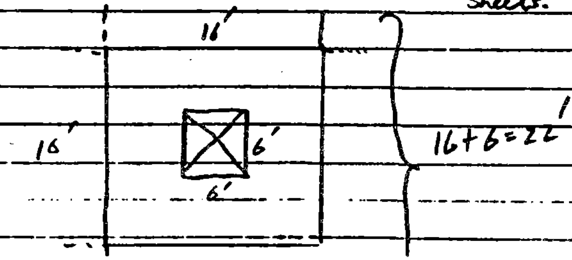
SHEET 3 OF

ALL $1,000's

CIVIL / STRUCTURAL	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
ⓒ RECEIVER SUBSYSTEM										
• STEEL TOWER										
241 ft high. 36"ϕ steel pipe △ structure truss tower, topped up.										
(1) FOUNDATION	1500	CY	-	.5	750			—		—
• EXCAVATION										



Concrete Qty: take off detail shown on the back-up sheets.



	QUANTITY	UNIT	LABOR	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
TOTAL THIS PAGE	1500	CY	-		750			—	—	—

A.5-68

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ______ : PIONEER MILL SOLAR COGEN. PLANT

BY W. C

DATE

SHEET 4 OF

ALL $1,000

CIVIL / STRUCTURAL	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
⑩ RECEIVER SUBSYSTEM (CONT)										
CONCRETE	140	CY	50	1.5	210			7		7
BACKFILL & COMPACTION	1360	CY	–	.25	340			–		–
REBAR FOR R.C. FOUND.	15	TN	450	20	300			7		7
Rebar @ 190#/CY of concrete +10% allowance QTY										
FORMWORK	1200	SF	1.00	.5	600			1		1
4 x (6x6) + ((16x3)x4 = 336 SF + 20% allowance ⇒ 400 SF/EA FOUND										
400 SF x 3 = 1200 SF ÷ 8.6 SF/CY conc.										
Allow for EMBED	2800	lb	2.00	.15	420			6		6
20#/CY → 2800#										
MAKE ADJUSTMENT								⟨1⟩		⟨1⟩
TOTAL THIS PAGE	–	–	–	LABOR	1870			20		20

A.5-69

B&E COST ENGINEERING

CE 11/79

JOB NO. AND TITLE 14481 PIONEER MILL (SOLAR COGEN) PLANT

STUDY NO. AND TITLE

BY WLHC

DATE 7/6/81

SHEET 5 OF

RECEIVER TOWER

ALL $1,000's

TOWER STRUCTURAL STEEL SUMMARY	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
STRUCTURAL STEEL PIPE:										
FROM P.P. 6					1,110			360	–	360
P.P. 7					1,120			–	30	30
P.P. 8					–			–	85	85
P.P. 9					675			52	–	52
SUBTOTAL					2905	–		412	115	527
MAKE ADJUSTMENT					95	–		3	–	3
TOTAL THIS PAGE			LABOR		3000	–		415	115	530

A.5-70

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE : PIONEER MILL SOLAR COGEN. PLANT

BY JV JK

DATE

SHEET 6 OF

ALL $1,000's

CIVIL/STRUCTURAL - Receiver Subsystem	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
b.) STRUCTURAL STEEL - TOWER PORTION										
• Structural Steel -	120	TN	3000	3	360			360		360
Structural pipe supply, and handle										
(includes cutting to length (@ Mill)										
Material price quote provide by the Engineering										
@ $3000/TN										
• FIELD LABOR, ERECT & WELD STRAIGHT SECTIONS										
28' OD - 31 ft long	18	EA	-	20	360					
36' OD - 20 ft long	12	EA	-	24	288					
S/T					648					
ADD ~ 15% FOR PRODUCTIVITY					102					
LOSS FOR WORK @ 50' ~ 250' EL					750					
Ref Job. 13007-500 Solar Hybrid Study Receiver Subsystem Tower section.										
LABOR										
TOTAL THIS PAGE					1,110			360	—	360

A.5-71

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT

STUDY NO AND TITLE

BY

DATE

SHEET 7 OF

ALL $1,000's

C/S — Receiver Subsystem	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
b) <CONT> STEEL - TOWER PORTION										
• CONSTRUCTION SUPPORT										
CREW:										
2 3-OPERATORS; 1-OILERS; 1 2-TEAMSTERS; 2 3-LABORER; 1-FOREMEN } 56 MH/DAY										
TOTAL WELDING MHs From sheet 5. → 750 MH										
Assume 2-3 MAN WELDING CREW										
WELDING WILL TAKE:										
750 ÷ (6×8) ≐ 20 DAYS	1	LT	—	56	1120			—	—	—
• FIELD BOLTED & ERECT 90° JOINTS										
s/c MH 20 MH/EA. MATL $100/EA. 16" OD	12	EA	500	—	—	—			6	6
TOTAL s/c MATL+LAB AT 1500/EA for both 16" & 12" OD pipe 12" OD	48	EA	500	—	—	—			24	24
S/T THIS PAGE										
TOTAL THIS PAGE		LABOR			1,120	—			30	30

A.5-72

JOB NO. AND TITLE 14484

STUDY NO. AND TITLE

PIONEER MILL SOLAR COGEN. PLANT

BY W. C.

DATE 7/6/81

SHEET 8 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
b) STRUCTURAL STEEL TOWER PORTION <CONT.>										
• FIELD ERECTION & BOLDED - 45° JOINT										
16" OD - 27' long	24	EA	$500	—	—	—		—	12 —	12 —
12" OD - 15' long	96	EA	$500	—	—	—		—	48 —	48 —
Use same S/C Material & Unit MH as the previous page. @ $100/EA - MAT; 20MH/EA - LAB; ⇒ $500/EA S/C.										
• X-RAY FOR PIPE WELDING ALLOW $25,000 FOR S/C JOB.	1	LT	[illegible]	—	—	—		—	25 —	25 —
TOTAL THIS PAGE	—	LABOR	—		—		—	—	85 —	85 —

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

BY WCHC

DATE 7/6/81

SHEET 92 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
b) STRUCTURAL STEEL – TOWER PORTION										
TOWER <CONT.>										
• WIDE FLANGE STEEL SUPPORT, MISC AND ELEVATOR TO THE TOP	15	TN	1800	25	375			27		27
ALLOW: 12 TN: Elevator guide rails; 3 TN: for Misc										
• MISC IRON, CHECKER PL, VERTICAL LADDER & CAGE, HANDRAIL, ETC ALLOW @ 10% OF 120 TN SAY 10 TN	10	TN	2500	30	300			25		25
SUBTOTAL TO THIS LINE					675	–		52		52
TOTAL THIS PAGE					675	–		52		52

A.5-74

BECHTEL

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT

STUDY NO. AND TITLE

BY [illegible]

DATE [illegible]

SHEET 10 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
ELEVATOR AT TOWER	1	EA			S/C				230	230
TYPE: GONDOLA										
CAP 1 TON										
LIFT: 240 FT										
FOR COST SEE JOB NO: 13007										
SOLAR HYBRID STUDY										
ADJUST AS FOLLOWS										
JOB NO 13007										
DATE 20, 79										
CAP. 2 TON										
LIFT. 150 ft/min										
VENDOR: OTIS										
COST: $300,000										
$300,000 × $(1.1)^2$ × $(\frac{1}{2})^{.7}$ = $225,000 SAY 230,000										
ESCALATE 2 YRS — CAPACITY ADJUSTMENT										
LABOR	1	EA			S/C				230	230

A.5-75

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE Pioneer Mill Solar Cogen. Plant

BY Y. Y.

DATE 5/18/81

SHEET 1 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
RECEIVER (COST IS FROM FOSTER WHEELER)	1	LT			S/C				2700	2700
Total THIS PAGE (LABOR)	1	LT			S/C				2700	2700

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE

PIONEER MILL SOLAR COGEN. PLANT

BY

DATE D.B.S. MAY 20 '81

SHEET 1 OF 3

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
S400 ELECTRICAL SUMMARY										
TOWER AREA (SHEET 2)		LT			400		37-	5-		42-
" " (" 3)		LT			500		1-	13-		14-
		LABOR								
TOTAL S400	1	LT			900		38-	18-		56-

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ______ : PIONEER MILL SOLAR COGEN. PLANT

BY ______

DATE D.B.S. MAY 18 '81

SHEET 2 OF 3

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
5400. TOWER AREA ELECTRICAL										
500 KVA 3Ø OIL IMMERSED XFR 12470V/ 125-216V W/ 2±2.5% TAPS, STANDARD IMPEDANCE, 3 POLE LOAD BREAK SWITCH 100A, LIGHTNING ARRESTORS, AIR TERML. CHAMBER FOR BUS DUCT TERMNS. AT SEC'Y. BUSHINGS. INSULATED L.V. TERMNL CHAMBER FOR GROUND CONNECTION.	1	EA	13000	-	80		13000	1500		
1500A 3Ø 600V W/PROOF BUS DUCT ALUMN (2+20') W/PROOF - NON SEGREGATED	40	'	110	3.	120		4400	500		
BUS DUCT FITTINGS	1	LT	-	-	30		400			
1500A 3Ø 600V TRANSFER SWITCH W/ N-O, N-C ELECTRICALLY HELD CIRCUIT BREAKERS. COMPLETE WITH CONTROLS, HARDWARE, ENCLOSURES TO ACCEPT 1500A 3Ø BUS DUCT MIN. I.C 22000 AMPS	2	EA	3500	30	60		7000	500		
MISC. MATERIALS	1	LT	-	-	110		200	2000		
DISTRIBUTION CENTER - INDOOR TYPE 120/240V 3Ø, 4W, DEAD FRONT, FLOOR MOUNTED, 22000A,	1	EA	12000				12000	500		
W/ 14 EA 100A - 3P BREAKERS										
4 EA 200A - 3P ✓										
1 EA 200A - 1P ✓										
3 EA 20A - 1P ✓										
1 EA 40A - 2P ✓										
2 EA 15A - 1P ✓										
1 EA SIZE #1 FVNR STARTER			LABOR							
* EXCLUDES FENCING & CIVIL WORK	1	LT			400		37000	5000		42000

A.5-78

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ______ : PIONEER MILL SOLAR COGEN. PLANT

BY ______

DATE D.B.S. MAY 18 '81

SHEET 3 OF 3

5400 TOWER AREA - ELECTRICAL	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
DISTRIBUTION PANEL - TOP OF TOWER.	1	EA	950	-	50		950			
120/240V 3Ø 4W. 24 CKT.										
W/ 200A-3P MAIN BREAKER.										
1 EA 90A-3P BREAKER.										
1 EA 60A-3P ✓										
1 EA 30A-3P										
6 EA 15A-1P										
1 EA 20A-1P.										
MOUNTING MATERIALS	1	LT.	-	-	20			100		
4/C #2 600V CABLE	50	LF	3.00	0.04	2			150		
4/C #8 〃 〃	50	LF	0.90	0.03	2			45		
4/C #4 〃 〃	100	LF	1.90	0.04	4			190		
4/C #4/0 〃 〃	300	LF	8.30	0.06	18			2490		
3/4" RGS. CONDUIT INCL. FITTINGS, SUPPORTS	50	LF	1.00	0.25	13			50		
1¼" 〃 〃 〃 〃	150	LF	1.80	0.29	44			270		
2½" 〃 〃 〃 〃	300	LF	4.50	0.45	135			1350		
3/C #250 MCM D/B 600V W/ALUM. SHEATH	300	LF	14.10	0.18	54			4230		
3/C #10 〃 〃 〃 〃	300	LF	1.50	0.06	18			450		
CABLE TERMINATIONS	1	LT	-	-	30			100		
TRENCH EXCVN. (D/B CABLE) 600'×2'×2'	90	CY	-	0.3	27					
BACKFILL	90	CY	-	0.2	18					
MISC MATERIALS	1	LT			5		50	575		
#2 GROUND WIRE INCL. CONN'S.	2000	LF	1.50	0.03	60			3000		
LABOR	1	LT.			500		1000	13000		14000

A.5-79

BECHTEL

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT

STUDY NO. AND TITLE

BY Y. Yin

DATE 5/21/81

SHEET 1 OF 1

5400

ALL $1,000's

Description	Quantity	Unit	Unit Cost	Manhours Unit	Manhours Total	$/MH	Plant Equipment	Bulk Material	Sub-Cont.	Total
INSTRUMENTATION										
SEE PREVIOUS STUDY FOR INSTRUMENTATION										
LABOR : 400 MH										
MAT'L : $ 132,000										
ASSUME THE SCOPE OF PRESENT STUDY FOR INSTRUMENTATION IS THE SAME AS BEFORE AND DISTRIBUTION FOR DIFFERENT AREA IS AS FOLLOWS.										
MH $										
AREA 5400 200 SAY 70,000										
AREA 5700 200 SAY 70,000										
AREA 5400	1	LT			200			70		70
LABOR	1	LT			200			70		70

A.5-80

<u>CONSTRUCTION COST ESTIMATE</u>

PROJECT: Conceptual Design of a Solar Cogeneration Facility at Pioneer Mills Co., Ltd.

LOCATION: Lahaina, Mau, Hawaii

DESCRIPTION: Receiver System only, not including Support Tower and Tower Downcomer and Riser

A/C NO.	Item & Description	Man Hours	Labor ($)	Estimated Cost ($)		
				Sub-contracts	Materials	Totals
5400	Receiver					
A	Shop Fabrication	12,195	306,200		171,410	477,610
B	Other Shop Cost					175,500
C	Subcontracted Fabrication			191,000		191,000
D	General Accessories				150,000	150,000
E	Home Office Costs	20,850	585,710		61,300	647,010
F	Field Erection	18,000	522,000		200,000	722,000
	Total Shop, Office & Field Costs					2,363,120
G	Contingency (10% of ΣA to F)					236,310
	ΣA to G					2,599,430
H	G&A (6.2% of ΣA to G)					161.160
	ΣA to H					2,760,590
I	Fee (8% of ΣA to H)					220,850
	Total Construction Cost					2,981,440

LOCATION Pioneer Mill Receiver

PROJECT ______ MADE BY FWDC APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5400	Receiver Subsystem												
A	Shop Fabrication												
	1. Drum				2580	26.2				67,600		27,460	95,060
	2. Headers & Downcomers				2230	27.3				60,880		11,450	72,330
	3. Boiler Panels, Risers & Feeders				2990	24.7				73,850		26,300	100,150
	4. S.H. Panels				1365	24.7				33,720		17,050	50,770
	5. S.H. Headers & Piping				745	27.3				20,340		9,590	29,930
	6. Doors & Enclosures				2130	21.4				45,580		76,000	121,580
	7. Hangers				155	27.3				4,230		3,560	7,790
	A/C "A" Total				12,195					306,200		121,410	477,610
B	Other Shop Costs												
	1. Tooling												39,000
	2. Heat Treat												5,000
	3. Manufacturing Develop & Mockup												20,000
	4. Shipping Fixtures												17,500
	5. Freight & Insurance												86,000
	6. Miscellaneous												8,000
	A/C "B" Total												125,500
C	Sub-Contract Fabrication												
	1. Buckstay & Spring Support												28,500
	2. Platforms & Structure Steel												14,400
	3. Support Structure Steel												125,000
	4. Insulating & Sheathing												10,100
	5. Connecting Piping												5,000
	6. Panel/Header Jumpers												5,000
	7. Miscellaneous												3,000
	A/C "C" Total												191,000

A.5-82

DATE ______ REVISION NO. ______ REVISION DATE ______ CODE ______ PAGE NO. ______

LOCATION *Pioneer Mill Receiver*

PROJECT ____________________

MADE BY *FWDC* APVD. ________

A/c NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
D.	General Accessories												
	1. Valves & Fitting												
	2. Controls & Instrumentation											60,000	60,000
	3. Cavity Door Actuators											60,000	60,000
												30,000	30,000
	"A/c "D" Total												150,000
E.	Home office Cost												
	1. Project Management				1,500	39.0				58,500			58,500
	2. Engineering				2500	35.8				89,500			89,500
	3. Design & Drafting				11,100	28.6				317,460			317,460
	4. Mechanical Detailing				4,600	18.3				84,180			84,180
	5. Manufacturing Engineering				400	34.7				13,880			13,880
	6. Welding Engr. QC&QA				250	30.4				7,600			7,600
	7. Contract Administration				300	36.1				10,830			10,830
	8. Estimating				200	18.8				3,760			3,760
	9. Reproduction												5,000
	10. Travel & Living Expense												10,000
	11. Computer												5,000
	12. Contract Reserve												41,300
	A/c "E" Total									585,710			647,010
F.	Field Erection												
	1. Field Labor				18000	29.0				522,200			522,200
	2. Tools & Equip. Rental												75,000
	3. Consumable												30,000
	4. Field Supervision												25,000
	5. Home office Management												20,000
	A/c "E" Total												722,000

DATE ________ REVISION NO. ________ REVISION DATE ________ CODE ________ PAGE NO. ________

Table A.5-16
CONSTRUCTION COST ESTIMATE

REV 2

CLIENT AMFAC SUGAR CO/DOE
[LOCA]TION LAHAINA, MAUI, HAWAII
PROJECT SOLAR COGEN. PLANT

DESCRIPTION ACCOUNT 5500
MASTER CONTROL SYSTEM

DATE 7/7/81
JOB NO. 14481
MADE BY Y.J. YIM
APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST IN $1,000'S LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping					
G	Electrical (E–H)	4800	101	—	270	371
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	4800	101	—	270	371
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
	Equipment Rental					
	INDIRECT FIELD COSTS					69
	TOTAL FIELD COSTS					440
R	Engineering					44
	Design & Engineering					
	Home Office Costs					
	R & D					
V	Contingency					73
W	Fee					17
	TOTAL CONSTRUCTION COST					574

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______

BECHTEL

NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

BY ____ DATE D.B. ~~MAY 20~~ 6-12 '81 SHEET 1 OF 1

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
ELECTRICAL										
CONTROL SYSTEMS (ORDER OF MAGNITUDE)										
LOCATED AT TOWER										
COMPUTERS	2	EA			600		84			
MULTIPLEX UNITS	1	LT			300		20			
MULTIPLEX CABLE & ACCESSORIES	1	LT			700			16		
CLOSED CIRCUIT TV'S INCL WIRING	1	LT			400		5	7		
PUMP CONTROLS	1	LT			200		5			
TOWER DOOR CONTROLS	1	LT			250		5			
INTERCONNECTIONS	1	LT			750		–	15		
MISCELLANEOUS	1	LT			500		1	12		
TOTAL @ TOWER/FIELD	1	LT			3700		120	50		
LOCATED AT MILL										
ADD 64 TO EXISTING PANEL INCL CRT	1	LT			400		60	2		
MULTIPLEX UNITS	1	LT			250		15	5		
MIXING STATION CONTROLS	1	LT			100		5	3		
INTERCONNECTIONS	1	LT			350		–	10		
TOTAL @ MILL	1	LT			1100		80	20		
TOTAL CONTROL SYSTEM DIRECT COST	1	LT			4800		200	70		270
		LABOR			4800	21				101
										371

A.5-85

Table A.5-17
CONSTRUCTION COST ESTIMATE

REV. 2

CLIENT AMFAC SUGAR CO/DOE
[LOCA]TION LAHAINA, MAUI, HAWAII
PROJECT SOLAR COGEN. PLANT

DESCRIPTION ACCOUNT 5600
NON-SOLAR
ENERGY SYSTEM

DATE 7/7/81
JOB NO. 14481
MADE BY V.J. YIM
APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST IN $1,000'S LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings (BAGGAGE STORAGE BLDG)	S/C	—	1900	—	1900
E	Machinery & Equipment					
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	S/C	—	1900	—	1900
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					—
	TOTAL FIELD COSTS					1900
R	Engineering					191
	Design & Engineering					
	Home Office Costs					
	R & D					
V	Contingency					315
W	Fee					73
	TOTAL CONSTRUCTION COST					2479

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______

BECHTEL

JOB NO. AND TITLE 14481 Pioneer Mill Solar Cogen Plant

STUDY NO. AND TITLE

BY V. Ving

DATE 6/11/81

SHEET 1 OF

5600- NON SOLAR ENERGY SYSTEM

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
BAGGASE STORAGE BLDG					S/C				1900-	1900-
(SUBCONTRACT COST QUOTED BY OKAHARA Co.)										
TOTAL THIS PAGE		LABOR			S/C				1900-	1900-

BAGASSE SYSTEM EXPANSION COST ESTIMATE

PIONEER MILL CO. SOLAR
CO-GENERATION STUDY

Item	Description	Estimate($)
1	Clear and grub	1,280
2	Structural excavation and concrete	604,540
3	Pre-engineered building	130,000
4	Conveyors	800,750
5	Electrical and instrumentation	95,600
6	Painting	5,400
7	Service air	4,820
	Subtotal	1,642,390
8	Engineering and taxes	246,360
	Total	1,888,750

MADE BY
EXTENSIONS CHECKED
ADDITIONS CHECKED

ESTIMATE FOR PIONEER MILL
LOCATION

PAGE A OF
DATE 5-19-81

ITEM	QUANTITY	UNIT	UNIT COST	TOTAL	UNIT COST	LABOR	UNIT COST	EQUIPMENT	UNIT COST	MATERIAL	UNIT COST	SUBCONTRACTOR
SUMMARY:												
SHT 1				191996		27172		14220		80174		69450
2				355005		69753				105302		116000
3				71059		10230		1130		26359		22160
PRE-ENG. BLDG	12800	SF		128000							10.00	128000
CLEAR & GRUB	12800	SF		1280							0.10	1280
	3K33/A			133829		107155		15350		211845		338890

MADE BY ______ EXTENSIONS CHECKED ______ ADDITIONS CHECKED ______

ESTIMATE FOR PIONEER HILL

LOCATION ______

PAGE 1 DATE 5-19-81

ITEM	QUANTITY	UNIT	UNIT COST	TOTAL	UNIT COST	LABOR	UNIT COST	EQUIPMENT	UNIT COST	MATERIAL	UNIT COST	SUBCONTRACTOR
FOUNDATION:												
EXCAVATION 1.75	1621	CY		15400	3.00	4003	6.5	10[illegible]				
FINE GRADE	5500	SF		825	0.15	825						
B/F	693	CY		5491	5.00	3475	2.91	2016				
SURPLUS	926	CY		3944	0.35	324	0.98	907	2.93	2713		
CUSHION /	938	TN		12279	2.53	2373	0.81	760	9.75	9146		
BUY PLYFORM	2000	SF		1400					0.70	1400		
LUMBER 3.5	7000	BF		4900					0.70	4900		
ACCESSORIES	4000	SF		600					0.15	600		
CONC 1.1	1019	CY		61140					60.00	61140		
FABRICATE 50%	2000	SF		1740	0.87	1740						
REMAKE 25%	1000	SF		100	0.10	100						
P/S	4000	SF		6000	1.50	6000						
MAKE	4000	SF		800	0.20	800						
POUR	926	CY		6482	7.00	6482						
F/C	5900	SF		1045	0.14	770			0.05	275		
				69450								
REBAR	138900	LB									0.50	69450
				191596		27152		14220		80174		69450

MADE BY
EXTENSIONS CHECKED
ADDITIONS CHECKED

PIONEER MILL

PAGE 2 OF
DATE 5-19-81

ITEM	QUANTITY	UNIT	TOTAL	LABOR UNIT COST	LABOR	EQUIPMENT UNIT COST	EQUIPMENT	MATERIAL UNIT COST	MATERIAL	SUBCONTRACTOR UNIT COST	SUBCONTRACTOR
WALLS											
BUY PLYFORM	19780	SF	9646					0.5	9646		
LUMBER	41340	BF	28930					0.7	28930		
CONC	979	CY	58740					60.00	58740		
ACCESSORIES	27560	SF	4134					0.15	4134		
FAB 50%	3780	SF	11907	3.15	11907						
REMAKE 25%	6890	SF	2094	0.30	2094						
P/S	27560	SF	27560	1.00	27560						
MOVE	27560	SF	4134	0.15	4134						
CONC POUR	890	CY	6230	7.00	6230						
P/R	27560	SF	16260	0.54	14882			0.05	1378		
REBAR	356000	LB	178000							0.50	178000
SHORING	400	LF	4560	4.80	2064			5.??	2496		
			353084		69193				108332		178000

A.5-91

MADE BY
EXTENSIONS CHECKED
ADDITIONS CHECKED

ESTIMATE FOR PIONEER MILL
LOCATION

PAGE 3
DATE 5-19-81

ITEM	QUANTITY	UNIT	TOTAL	UNIT COST	LABOR	UNIT COST	EQUIPMENT	UNIT COST	MATERIAL	UNIT COST	SUBCONTRACTOR
SLAB ON GRADE:											
BASE COARSE 6"	959	TN	4519	2.40	652	0.75	266	9.75	3461		
FINE GRADE	14400	SF	2880	0.14	2016	0.06	864				
VAPOR BARRIER	14400	SF	5040	0.05	720			0.30	4320		
DIKES	100	LF	128	0.32	32			0.96	96		
EDGE FORM	500	LF	1610	2.10	1050			1.12	560		
SCREED	14400	SF	2160	0.10	1440			0.05	720		
CONC.	280	CY	18760	7.00	1960			60.00	16800		
F/C	14400	SF	2592	0.15	2160			0.03	432		
SOIL POISON	14400	SF	2160							0.15	2160
REBAR	40000	LB	20000							0.50	20000
			59859		10230		1130		26339		22160

ISEMOTO
CONTRACTING CO. LTD.
General Contractors

RECEIVED MAY 19 1981

648 Piilani St. P.O. Box 4669 Hilo, Hawaii 96720 Phone 935-7194

BUTLER

May 19, 1981

Okahara/Shigeoka & Associates
200 Kohola St.
Hilo, Hawaii 96720

Re: Bagasse Storage Building

Attention: Wesley Segawa

Dear Wesley:

As per your request, we are submitting our preliminary estimate of One Hundred Thirty Thousand and no/100 Dollars ($130,000.00) for above captioned project.

Our preliminary estimate includes the following:

1. Furnish and erect:
   1 only 80x160x16 Butler RFII 30# LL 15#WL on Owners 2'x15' high concrete wall, 8-20' bays, 4:12 roof slope, 26 ga. pre-finished metal roof and walls, and with the following accessories:
   a. 160 lft gable end trims
   b. 320 lft gutter
   c. 8 only DS
   d. 150 lft continuous ridge vents
   e. 16 only plastic roof skylight
2. A $5,000.00 allowence for any possible doors and windows
3. A $5,000.00 contingency allowence.
4. Bond fees
5. Taxes

We do not include the following:

1. Anchor bolts
2. Concrete, carpentry, plumbing, electrical, conveyor system and/or any other trades other than pre-engineered metal building.

We hope the above quotation will be of help to you in prepairing your preliminary cost estimate.

Please call us for any additional information you may require.

Yours very truly,

Isemoto Contracting Co., Ltd.

by

Toshi Isemoto

HELPING BUILD HAWAII SINCE 1926

KAMAN BEARING AND SUPPLY CORP.
NORTHWEST

BOX 30405 HONOLULU, HI 96820

May 22, 1981

Mr. Mel Tanaka
Okahara - Shigeoka & Associates, Inc.
200 Kohola Street
Hilo, HI 96720

Dear Mel:

In response to your call earlier this month, and confirming our conversation yesterday, we herewith submit our estimated costs for three conveyors each of which to handle 50 TPH of bagasse at 200 FPM. All are truss design and include all mechanical but less supports.

1 ea. 48" x 340' with troughing idlers and cover the first 180 ft. and flat idlers and seven plows (no cover) for the last 160 ft., cat-walk and hand rail full length. (Horizontal)
. . . . $ 92,700.00

1 ea. 48" x 50' with troughing idlers, cat-walk and hand rail full length, no covers. (Horizontal)
. . . . $ 18,900.00

1 ea. 48" x 290' with troughing idlers, cat-walk, hand rail and covers full length. (40 ft vertical rise)
. . . . $ 85,370.00

If you have any further questions on these, please do not hesitate to call.

Yours very truly,

KAMAN BEARING & SUPPLY CORP., N.W.

Wm. N. Ellersick
Regional Sales Manager

RECEIVED MAY 26 1981

WNE-e

ESTIMATE SUMMARY

PROJECT: CONVEYORS

ESTIMATE NO.

SHEET NO.

PREPARED BY: [illegible] DATE: 6/8/81

CHECKED BY: DATE:

MAIN ACCOUNT	DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
			UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
1	Conveyors 5, 6, 7, 9										
	a. Steel		17,665						88,333		105,998
	b. Footings									3700	3700
	c. Belt, Thr… Drive									196,970	196,970
	Lectra Conv … quoted add 15% frt + tax									21,546	[illegible]
2	Conveyor 8									445,316	445,316
3	Conveyor 1. Extension										19,137
											800,746

A.5-95

Pioneer Solar Cogeneration
Feasibility Study Cost Est.
Conveyor #5, #6 & 8 Supports

ESTIMATE NO.
SHEET NO.
PREPARED BY: G S DATE 6-2-81
CHECKED BY: DATE:

COUNT	DESCRIPTION	QUANTITY	MATERIALS UNIT PRICE	MATERIALS AMOUNT	LABOR UNIT M.H.	LABOR TOTAL M.H.	LABOR RATE	LABOR AMOUNT	SUB-CONTRACT UNIT PRICE	SUB-CONTRACT AMOUNT	TOTAL
	Steel Support (Bldg. Interior)										
	Conv. # 5 & 6 755 ea.										
	14 x 755 = 10,570										
	2 x 1782 = 3,564										
	Total 14,134 x 1.5 =	21,201	0.5	10,600.5					2.5	53,003	63,603
	Steel Support (Bldg. Exterior)										
	Conv. # 5 & 8 2057# ea.										
	8 x 2057# x 1.15 =	2366	0.5	1183					2.5	5914	7097
	Conc. Footings										
	0.686 yd³ x 9 pair	6.2 yd³							600	3700	3700
	Roof Penetration (Exist'g Bagasse House)										
	1961 x 3 =	5883	0.50	2941.5					2.50	14,707.5	17,649
	Conv. 5										
	Roof Penetration										
	(Exist'g Bagasse House)										
	1961 x 3 =	5883	0.50	2941.5					2.50	14,707.5	17,649
	Conv. 8										
	TOTAL			17,665						92,033	109,698

Pioneer Solar Co-Generation
Feasibility Study
Conveyor #[illegible]

ESTIMATE NO.
SHEET NO.
PREPARED BY: GS DATE 6-1-81
CHECKED BY: DATE:

COUNT	DESCRIPTION	QUANTITY	MATERIALS UNIT PRICE	MATERIALS AMOUNT	LABOR UNIT M.H.	LABOR TOTAL M.H.	LABOR RATE	LABOR AMOUNT	SUB-CONTRACT UNIT PRICE	SUB-CONTRACT AMOUNT	TOTAL
1	Steel 102,783 x 1.15 =	118,200	.50	59,100					2.50	256958	316,058
2	Railing	250 LF							30.00	7500	7,500
3	Grating	700 ft²							9.00	6300	6,300
4	Head Shaft [illegible] 6 7/16" ϕ x 11'	2442	1.50	3663					3.50	8547	12210
5	Tail Shaft 5 7/16" ϕ x 11'	1738	1.50	2607					3.50	6083	8,690
6	[illegible] 2 x 5 7/16" ϕ x 11 x 2	3476	1.50	5214					3.50	12166	17,380
7	Bearing	8	954	7632	2m x 0.50 x 8hrs x 8	64	45	2880			10,512
8	Rex 2184 Chain	360'	43.2	15,552	4m x 1D x 8hrs	32	45	1440			16,992
9	Falk 2110 Y2 (10,561 x 1.3)		1	14,000							14,000
10	Motor (2872 x 1.3)		1	3800							3,800
11	Coupling	LS								500	500
12	Chain & Guard	LS								2000	2000
13	Additional Catwalks 4307 x 1.15	4954	0.5	2477					2.50	12,383	14,860
14	Sprockets	8	570	4560	2m x 4D x 8hr	64	45	2880			7440
15	Slats 4.48 x 1.2	75	5.38	404	2m x 1hr x 75 slats	150	45	6750			7154
											445,396

[illegible]
FEASIBILITY STUDY COST EST
CONVEYOR #1 EXTENSION - 20'

ESTIMATE NO.
SHEET NO.
PREPARED BY: GS DATE 6-2-81
CHECKED BY: DATE:

COUNT	DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
			UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
	STEEL 4106# x 1.15 =	4722	0.5	2361					2.50	11,805	14,166
	Conveyor Chain	80LF	43.20	3456	2m x 1d x8h	16	45	720			4,196
	Conveyor Slats 2x4 Euchlyptus @ 3'-0" o/c	14	5.38	75	2m x 1d x8	16	45	720			795
											19,137

ESTIMATE SUMMARY

PROJECT: ELECTRICAL & INSTRUMENTATION

ESTIMATE NO.
SHEET NO.
PREPARED BY: [illegible] DATE: 6/8/81
CHECKED BY: DATE:

MAIN ACCOUNT	DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
			UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
1	Building Lights	12,800 SF	-	-					2.00	25,600	25,600
2	Conveyor 5,6,7,9 Drive	4							5,625	22,500	22,500
3	Conveyor 8 Drive	1							12,500	12,500	12,500
4	Pole Relocation	1							10,000	10,000	10,000
5	CCTV w/Focus, Tilt, Pan w/monitor	2							7000	14,000	14,000
6	Zero Speed Switches	5							2000	10,000	10,000
7	LOUDSPEAKER SYSTEM	1							1000	1,000	1,000
	TOTAL										95,600

PROJECT: PAINTING / SERVICE AIR

ESTIMATE NO.
SHEET NO.
PREPARED BY: Nett DATE: 6/8/81
CHECKED BY: DATE:

MAIN ACCOUNT	DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
			UNIT PRICE	AMOUNT	UNIT M.H	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
	PAINTING				3mx5d x8hr	120	45.00	5400			5400
	SERVICE AIR 1"Φ Pipe, A120 Galv +20% Miscell Fittings, & Valves	700LF x1.2									
		840LF	0.671	564	11.25/100LF	94.5	45.00	4253			4817

REV. 2

Table A.5-18

CONSTRUCTION COST ESTIMATE

CLIENT AMFAC SUGAR CO/DOE

TION LAHAINA, MAUI, HAWAII

PROJECT SOLAR COGEN. PLANT

DESCRIPTION ACCOUNT 5700

THERMAL TRANSPORT SYSTEM

DATE 7/7/81

JOB NO. 14481

MADE BY V.J. YIM

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete	1600	33	—	35	68
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	3500	74	—	800	874
F	Piping	9000	190	250	1320	1760
G	Electrical	6500	137	—	268	405
H	Instruments	200	4	—	70	74
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	20,800	438	250	2493	3181
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					298
	TOTAL FIELD COSTS					3479
R	Engineering					349
	Design & Engineering					
	Home Office Costs					
	R & D					
V	Contingency					578
W	Fee					134
	TOTAL CONSTRUCTION COST					4540

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE PIONEER MILL SOLAR CO GEN PLANT

BY V. Yip
DATE 5/15/81
SHEET Summary

5700

ALL $1,000's

PIPE SUPPORT & BRIDGE SUMMARY	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
COST FOREWARDED FROM NEXT PAGE					1550			35-		35-
MAKE ADJUSTMENT					50			-		-
			LABOR							
TOTAL THIS PAGE					1600			35-		35-

A.5-102

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE : PIONEER MILL SOLAR COGEN. PLANT

BY W.L.

DATE 5/20/81

SHEET (10) OF

SUMMARY

ALL $1,000's

5700 PIPE SUPPORT & BRIDGE	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
◦ PIPE SUPPORTS (see pp 11)	1	LT			1250			26		26
THERE ARE TWO TYPES OF PIPE SUPPORTS & TWO TYPES OF PIPE ANCHOR.										
USE CONCRETE CAISSONS FOR FOUNDATION.										
W6x9, or W6x15 FOR COLUMES										
INCLUDES:										
ELEVATED SUPPORT : 63/EA										
HIGH PIPE ANCHOR : 5/EA										
LOW PIPE SUPPORT : 45/EA										
LOW PIPE ANCHOR : 3/EA										
◦ CORRUGATED STEEL PIPE, ϕ_e = 36" PIPE BRIDGE, = 70 FEET LONG 6000 LBS WEIGHT	2	EA.			300			7		7
INCLUDES:										
EXCAVATION & BACKFILL : 150 CY										
ALLOWANCE FOR CONCRETE PAD FOR SUPPORT. & MISC.										
ADJ. MAT'L		LABOR			1550			2		2
TOTAL THIS PAGE					1550			35		35

(See page 12 for detail)

BECHTEL

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT

STUDY NO. AND TITLE

Rev. 1

BY W. Ch

DATE

SHEET 11 OF

ALL $1,000's

CIVIL / STRUCTURAL	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
∘ PIPE SUPPORT										
Elevated Support (HIGH)	63	EA	~280	11	693			18 -		
Low Support	45	EA	100	10	450			5 -		
High Pipe Anchor	5	EA	370	15	75			2 -		
LOW Pipe Anchor	3	EA	150	12	36			.5		
SUB TOTAL	116	EA	-		1254			25.5		25.5
Adj					<4>			.5		.5
		LABOR								
TOTAL THIS PAGE	116	EA			1250			26 -		26 -

A.5-104

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ________ : PIONEER MILL SOLAR COGEN. PLANT

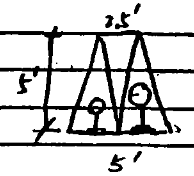
BY W.C.

DATE

SHEET (12) OF

ALL $1,000's

CIVIL/STRUCTURAL	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
CORRUGATED STEEL PIPING										
70' × 50#/LF = 3500#	3500	LB	.60	.02	75			2-		2
Excavation	150	CY	-	.5	75			-		
Backfill @ 70% of excav.	105	CY	-	.25	26			-		
Steel Bridge	5000	lb.	1.00	.02	100			5-		5
70 ft long										
Qty: 5000# from Eng										
Allow $1000.00 for concrete pads. (material + labor)										
(See Back-up for Detail inform. on above items.)										
S/T THIS PAGE					276			7-		7
Adj					24			-		-
TOTAL THIS PAGE		LABOR			300			7-		7-



BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ______ : PIONEER MILL SOLAR COGEN. PLANT

BY Y?Y/?? DATE 5/12/81 SHEET SUMMARY

ALL $1,000's

EQUIPMENT	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
COST FORWARDED FROM PAGE 1	3	EA			75		30			30
" 2	3	EA			300		150			150
" 3	1	EA			25		8			8
" 4	2	EA			50		60			60
" 5	1	EA			1200		65			65
" 6	1	EA			25		18			18
" 7	4	EA			1600		200			200
" 8	1	EA			200		10			10
S/T	16	EA			3,295		541			541
ADD 10% FOR UNIDENTIFIED EQUIPMENT							60			60
MAKE ADJUSTMENT					205		<1>			<1>
ALLOW FOLLOWING:										
ADDITIONAL BULKS 10%										
FREIGHT, HANDLING & STORAGE 25%							200			200
Total 35%										
		LABOR								
TOTAL EQUIPMENT	16	EA			3,500		800			800

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

BY [illegible]
DATE 5/5/81
SHEET 1 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
CONDENSER TRANSFER PUMP (AT MILL)	3	EA	10K	25	75		30-			30-
NUMBER : 3 REQ'D										
TYPE : HORIZONTAL CENTRIF										
RATED : 80 gpm										
LIQUID : CONDENSATE										
SUCTION PRESS: 29 psig										
DISCHARGE PRESS. : 64 psig										
DIFFERENTIAL HEAD : 85 ft										
PUMPING TEMP : 235 °F										
Speed : 3600 rpm										
Bhp : 5 hp										
DRIVE : AC MOTOR 60 Hz										
MANUF : UNITED PUMPS										
COST /EA → PUMP $ 7,000										
MOTOR $ 3,000										
TOTAL $ 10,000										
VENDOR QUOTE 3/24/81										
LABOR : R & C std. 25 MH										
LABOR	3	EA			75		30-			30-

A.5-107

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT

STUDY NO. AND TITLE

BY [illegible]

DATE 5/5/81

SHEET 2 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
RECEIVER FEED PUMP	3	EA	50K	100	300		150-			150-
NUMBER : 3 REQ'D										
TYPE : TRIPLEX PLUNGER										
RATING : 80 ~ 40 gpm										
LIQUID : BOILER FEED WATER										
DIS. PRES. : 1223 psig										
SUCT. PRESS : 19 psig										
Diff. Head, ft : 2930 ft										
PUMPING TEMP. °F : 235										
Speed : 250-100 rpm										
PUMP : 60 Hp										
DRIVE : 100 Hp ELEC. MOTOR										
MANUF. : Union Pump Co.										
COST : VENDOR QUOTE 3/26/81										
PUMP ... $ 32,000										
DC MOTOR										
& CONTROL ... $ 17,000										
TOTAL $ 49,000										
SAY $ 50,000										
LABOR : R & C std. 100MH										
LABOR	3	EA			300		150			150

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

BY Y. Yin

DATE 5/5/81

SHEET 3 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
STARTUP HEATER	1	EA	8K	25	25		8			8
NUMBER : 1										
TYPE : Shell & Tube										
Water : flow 80 gpm										
Inlet Temp. : 425 °F										
Outlet Temp. : 625 °F										
STEAM flow : 7280 lb/hr										
Press : 850 psia										
Duty 3.7×10^6 Btu/hr										
Surface Area : 103 SF										
Shell : ϕ/THICKNESS, IN 12/½ CS										
TUBE : 48 x ¾" ϕ S.S. 96" Long										
Weight : 4000 lbs.										
Cost @ $.075K/SF										
.075 x 103 = $ 8,000										
LABOR R & C Std 25 MH										
LABOR	1	EA			25		8			8

A.5-109

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: Pioneer Mill Solar Cogen. Plant

BY Y.L.M.

DATE 5/5/81

SHEET 4 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
Recirculation Pump	2	EA	30K	25	50		60			60
Number 2										
Type Horizontal Centrifugal										
Rated 80 gpm										
Fluid Boiler Drum Water										
Suc. Press 990 psig										
Disc Press 940 psig										
Diff Head 140 ft.										
Pumping Temp. °F 525°F										
Speed rpm 3600 rpm										
Pump BHp 5.3										
Drive AC Electric Motor 7½ or 10hp										
Efficiency (Pump) % 45										
Material 12 Chrome										
Manufacturer Pacific Pump										
Cost Pump $26000										
Motor $ 400										
Total $26.400										
Say $30000										
Labor R&C std. 25MH										
LABOR	2	EA			50		60			60

A.5-110

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE

PIONEER MILL SOLAR COGEN. PLANT

BY [illegible]
DATE 5/5/81
SHEET 5 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
EMERGENCY TURBINE GEN.	1	EA	65K	1200	1200		65 –			65 –
NUMBER 1										
TYPE SINGLE STAGE, SOLID WHEEL, NON-CONDENSING										
RATING 500 KW										
Steam inlet press 650 psia										
Temp 650 °F										
EXHAUST 14.7 psia										
Steam RATE 28 lb/kW hr										
Manuf. TERRY TURBINE										
COST: VENDOR QUOTE 2/26/81 $60,000										
ADD $2000 for SILENCER										
Total $62,000										
SAY $65,000										
LABOR. R & C Std. 1200 MH										
LABOR	1	EA			1200		65 –			65 –

A.5-111

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

BY Y. Yii

DATE 5/5/81

SHEET 6 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
HOLDING TANK	1	EA		25	25		18-			18-
NUMBER 1										
TYPE VERTICAL										
CAPACITY 4400 GAL										
DIMEN 10'ϕ x 7.5'H										
MATERIAL S.S. 3/8" THICK										
DESIGN PRESS/TEMP. 50 psig/450°F										
Including Stainless Steel										
Sponge and Steam Heating										
Coil. Relief valve &										
With (3" Insulation)										
WEIGHT 6350 lbs.										
Tank @ $1.5/lb $10,000										
Heating Coil, valve etc @ 20% 2,000										
S/T $12,000										
Insulation @ 50% $6,000										
total $18,000										
Labor @ R&C std. 25 MH										
LABOR	1	EA			25		18-			18-

A.5-112

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ______ : PIONEER MILL SOLAR COGEN. PLANT

BY [illegible]
DATE 5/15/81
SHEET 7 OF ____

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
ELECTRIC STEAM SUPERHEATER (AT MILL)	4	EA	50K	400	1600		200-			200-
NUMBER 4										
TYPE VERTICAL MOUNTED										
STEAM PRESS. 900 psia										
POWER 500 KW										
460 VOLTS 3 φ										
DIMENSION 18" OD. x 120"										
OVERALL HEIGHT										
MAKE CHROMALUX										
(EMERSON ELECTRIC										
CO.)										
COST										
HEATER... $ 35,000										
PANEL... $ 15,000										
Total $ 50,000										
Labor @ 15% $7500/$20 = 400 MH										
LABOR	4	Ent			1600		200			200

A.5-113

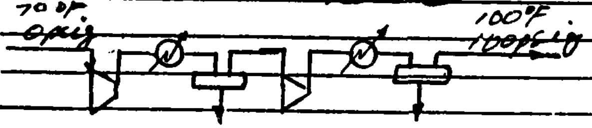
JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT

STUDY NO. AND TITLE

BY [illegible]
DATE 5/5/81
SHEET 8 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
INSTRUMENT AND PLANT AIR PACKAGE	1	EA	10K	200	200		10			10
NUMBER 1										
Includes 2 - 25 SCFM, 100 psig Compressors, 2 Coolers, 2 Dryers and one receiver tank										
Say 10K		LABOR								
	1	EA			200		10			10



Compr. Ratio = 115/15 = 7.7

USE 2 stage $(7.7)^{1/2}$ = 2.73/stage

$T_2 = T_1(R)^{n-1/n} = (530)(2.73)^{.4/1.4} = 689°R$

= 229°F

N_0 = 25×60/379 ≐ 4 moles/hr

hp = $N_0 \times C_p \times \Delta T$ / 2450 × eff

= (4)(9)(229−100)/2450 × .85 = 2.23 hp

Say 3 hp/stage

2 stage compressor @ 3 hp/stage @ $500/hp = $3,000

DRIVER $2,000

Cooler & Knockout Drum $3,000

Total $8,000

A.5-114

BECHTEL

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT

STUDY NO. AND TITLE

BY [illegible]

DATE 5/15/81

SHEET Summary

ALL $1,000's

PIPING	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
FROM PIPING SUMMARY (NEXT PAGE)	15000 LF				8853			1150-	248-	1398-
Allow { Unidentified Bulks @ 5% / Freight, Storage etc @ 10% / Total 15% }								170-		170-
MAKE ADJUSTMENT					147			—	2	2-
TOTAL PIPING					9,000			1320-	250-	1570-

LABOR

A.5-115

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT

STUDY NO. AND TITLE

BY Lh. 1

DATE 5/12/81

SHEET SUMMARY OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
THERMAL TRANSPORT SYSTEM										
SUMMARY (INCL. PIP'G. & INS.)										
					PIPE MH'S / INS. MH'S					
RECEIVER TO OFFPLOT AREA SUMMARY OF SHT. 1,2,3	4750	LF			2376 / 881			223.0	56.0	
VA'S	39	EA.								
RECEIVER OFFPLOT TO MILL AREA SUMMARY OF SHT. 4,5	9950	LF			5120 / 2268			298.0	168.0	
NO VA'S	-	-								
AT THE MILL SUMMARY OF SHT. 6,7,8	1200	LF			1359 / 334			634.0	24.0	
VA'S	41	EA.								
* PLEASE NOTE ADD FACTOR FOR JOB SITE IN HAWAII										
INSULATION	9250	LF			3483				248.0	
PIPING	15100	LF	LABOR		8853			1155.0		
DIRECT COST SUMMARY THERMAL TRANSPORT SYS PIP'G/INS. (U.S.A.		JOB LOCATION)						1155.0	248.0	

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE : PIONEER MILL SOLAR COGEN. PLANT

BY LA

DATE 5/13/81

SHEET Summary shts 1,2,3 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
THERMAL TRANSPORT SYSTEM										
SUMMARY OF SECTION FROM RECEIVER										
TO OFFPLOT AREA										
ALL PIPE (FITT. ALLOW. INCL.) SHT. 1	4750	LF			1557			48.0		
VL'S SHT. 2	39	EA.			140			111.0		
SUBTOTAL					1697			159.0		
MISC. 40% OF S/T					679			64.0		
INCLUDES FRT. 5%										
HDLG. 5%										
CLEANING 10%										
TESTING 10%										
X-RAY 10%										
40%										
TOTAL PIPING THIS AREA					2376			223.0		
TOTAL PIPE INSULATION SHT. 3	2150	LF			881				56.0	
LABOR					3257 MHS					
TOTAL THIS SECTION								223.0	56.0	

A.5-117

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE : PIONEER MILL SOLAR COGEN. PLANT

BY LA

DATE 5/12/81

SHEET 1 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
THERMAL TRANSPORT SYSTEM										
FROM RECEIVER TO OFF PLOT (RECEIVER 240' HIGH ON TOWER)										
PLUS P.W. EXTENDS 2000' FURTHER TO VISITOR BLDG. PLNG.										
MAIN STM - A335-P11 Sch. 80 PIPE 6"	350	LF	52-	.92	322			18.2		
FITT. ALLOW. INCL. IN UNITS EXCL. VALVES *										
EMER. STM - A335-P11 Sch. 80 PIPE 4"	350	LF	28-	.75	197			9.8		
*										
CONDENSATE A53 Sch. 40 PIPE 4"	100	LF	10-	.61	61			1.0		
*										
FEEDWATER A53 Sch. 80 PIPE 4"	350	LF	13-	.61	213			4.5		
*										
POTABLE WATER A106 Sch. 80 PIPE 2"	2200	LF	4-	.15	330			8.8		
(2000' TO VISITOR BLDG. 200' TO BLDG. BELOW TOWER FOR M/R) *										
AIR (ALLOW.) A106 Sch. 80 PIPE 2"/SMALLER	400	LF	4-	.31	124			1.6		
SMALL PIPING 2 & SMALLER ASSUME A106 Sch. 80	1000	LF	4-	.31	310			4.0		
(NOT DEFINED)										
ADJ.								.1		
		LABOR			1557 MH.					
	4750	LF						49.0		

A.5-118

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

BY [initials]
DATE 5/12/81
SHEET 2 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
FROM RECEIVER TO OFF PLOT										
VALVES ASSUME ALL CS EXCEPT AS NOTED *					ASSUME					
USED 1300# 1250# GATES 4" (B.F) MANUAL	1	EA.	6000	3.1	3			6.0		
2½" MOTOR	3	EA.	6200	5.4	16			18.6		
CHECK'S 4" (B.F.) MANUAL	1	EA	4700	3.1	3			4.7		
2½" (B.F.)	3	EA.	3400	2.4	7			10.2		
USED 1000 1000# GATES 2" (WARM UP) MOTOR	1	EA.	4600	2.9	3			4.6		
2" " MANUAL	4	EA.	2000	1.3	5			8.0		
2" " PNEU.	4	EA.	4600	2.9	12			18.4		
* CHECK'S 4" (EMER. STM.) 4800 X 2.1	1	EA.	10200	7.4	7			10.2		
* 4" (EMER. STM.)	1	EA.	10200	7.4	8			10.2		
2" (WARM UP)	2	EA.	2000	1.3	3			4.0		
RELIEF 2" (HEATER)	1	EA.	2500	1.5	2			2.5		
50#/10# GATES (USE 150#) 4" (COMP.) MANUAL	4	EA.	700	1.7	12			2.8		
2" (RECIRC.) "	3	EA.	500	.5	2			1.5		
2" (HLDG. TK) "	3	EA.	500	.5	2			1.5		
(100#) 1" (COMP. AIR) "	4	EA.	300	.3	1			1.2		
CHECK 4" (COMP.)	1	EA.	600	1.7	2			.6		
2" (HLDG. TK)	1	EA.	400	.5	1			.4		
RELIEF 2" (HLDG. TK.)	1	EA.	1000	1.5	1			1.0		
ALLOW. FOR DR. & VENT VA'S	1	LOT		—	50			5.0		
LABOR					140 MHS.			2.4 >		
	31 EA.							111.0		

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ______ : PIONEER MILL SOLAR COGEN. PLANT

BY [illegible]

DATE 5/12/81

SHEET 3 OF ____

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
FROM RECEIVER TO OFF PLOT 0-240' High										
INSULATION (PIPE)			[illegible]							
CALSIUM SILICATE w/ ALUM. WEATHER PROOF JACKET										
MAIN STM. 6" x 4" THK -	350	LF	S/C 32.70	.47	165				11.5	
ADD'L. FOR HIGH WORK			L 20.00	.53	185				7.0	
EMER. STM 4" x 2½" THK -	350	LF	S/C 15.85	.15	52				5.5	
ADD'L FOR HIGH WORK			L 9.50	.17	59				3.3	
CONDENSATE 4" x 2" THK -	100	LF	S/C 13.10	.15	15				1.3	
ADD'L. FOR HIGH WORK			L 7.90	.17	17				.8	
FEEDWATER 4" x 2" THK. -	350	LF	S/C 13.10	.15	52				4.6	
ADD'L. FOR HIGH WORK			L 7.90	.17	59				2.8	
UNDRAINED 3" DEAERATOR 2" x 1½" THK. NO HIGH WORK	1000	LF	S/C 4.80	.13	130				9.8	
ASSUME NO VA'S INSULATED										
PREVIOUS EST. DID NOT INSULATE VA'S.										
SUB-TOTAL					734				46.6	
MISC. FRT. & GUIDES (20% OF S/T)					147				9.4	
			LABOR		881 MHS					
	2150	LF							56.0	

A.5-120

BECHTEL

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT

STUDY NO. AND TITLE

BY L. A

DATE 5/13/81 SUMMARY OF SHT. 4,5

SHEET ____ OF ____

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
THERMAL TRANSPORT SYSTEM										
SUMMARY OF SECTION FROM RECEIVER OFFPLOT										
TO MILL AREA										
ALL PIPE (FITT. ALLOW. INCL.) SHT. 4	9950	LF			3657			213.0		
NO V/S.	—				—			—		
SUBTOTAL					3657			213.0		
MISC. 40% OF S/T					1463			85.0		
INCLUDES SEE SHT. SUMM. OF SHT. 1,2,3										
TOTAL PIPING THIS AREA					5120			298.0		
TOTAL PIPE INSULATION SHT. 5	6100	LF			2268				168.0	
INS.	6100	LF							168.0	
		LABOR			7388					
TOTAL THIS SECTION PIPG.	9950	LF						298.0		

A.5-121

JOB NO. AND TITLE 14481 : PIONEER MILL SOLAR COGEN. PLANT

STUDY NO. AND TITLE

BY LJM

DATE 5/12/81

SHEET 4 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
THERMAL TRANSPORT SYSTEM										
RECEIVER OFFPLOT TO MILL (LOW SLEEPER 2' / HIGH RACK 12' } ASSUME 49 SUPP. / 63 SUPP.)										
U'GROUND CULVERT PIPE BY CIVIL										
MAIN STEAM - A335-P11 Sch 80 PIPE 6" SLEEPER	1525	LF	53-	.44	671			79.3		
(FIT ALLOW. INCL. IN UNITS EXCL. VA'S *) RACK	1525	LF	52	.55	839			79.3		
CONDENSATE A53 Sch. 40 PIPE 4" SLEEPER	1525	LF	10-	.29	442			15.3		
* RACK	1525	LF	10-	.36	549			15.3		
POTABLE WATER A106 Sch. 80 PIPE 2" SLEEPER	1525	LF	4-	.15	229			6.1		
RACK	1525	LF	4-	.28	427			6.1		
EXPANSION LOOPS (ALLOWED FOR IN LGTH'S)	—		—		—			—		
LOW LEVEL SUPPORTS (BY CIVIL)	—		—		—			—		
ELEVATED (RACK) SUPPORTS (BY CIVIL)	—		—		—			—		
SLIDING GUIDES (ON SUPPORTS) ALLOW.	1	LOT	—	—	300			7.0		
(4) DRAIN LOOPS (FROM STM. LINE TO COND. LINE) INCLUDES DR. POT, VALVES, STRS, TRAPS, LEVEL CHAMBERS, INSTRUMENTATION (2) EA, SMALL PIPING	1	LOT	—	—	200			5.0		
ADJ.								<4.7>		
LABOR					3657 MHS					
	9950	LF						213.0		

A.5-122

BECHTEL

JOB NO. AND TITLE 14481 PIONEER MILL SOLAR COGEN. PLANT

STUDY NO. AND TITLE ______ :

BY L.M

DATE 5/12/81

SHEET 5 OF ___

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
THERMAL TRANSPORT SYSTEM										
RECEIVER OFFPLOT TO MILL (LOW ON SLEEPER 2' ELEV'D. ON RACK 12')										
INSULATION – CALSIUM SILICATE w/ ALUM. WEATHER PROOF JACKET										
MAIN STEAM – 6" x 4" thk.	3050	LF	$/LF 32.70	.47	1433				99.7	
CONDENSATE – 4" x 3" thk.	3050	LF	$/LF 13.10	.15	457				40.0	
SUB-TOTAL	6100	LF			1890				139.7	
MISC. FRT & GUIDES (20% of S/T)					378				27.9	
ADJ.									.4	
			LABOR		2268 MHS					
	6100	LF							168.0	

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE : PIONEER MILL SOLAR COGEN. PLANT

BY LA

DATE 5/13/81

SUMMARY SHT 6,7,8

SHEET ____ OF ____

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
THERMAL TRANSPORT SYSTEM										
SUMMARY OF SECTION AT THE MILL										
ALL PIPE (FITT. ALLOW. INCL.) SHT. 6	1200	LF			852			26.0		
VA'S SHT. 7	41	EA.			117			427.0		
SUB-TOTAL					969			453.0		
MISC. 40% OF S/T					388			181.0		
TOTAL PIPING THIS AREA					1357			634.0		
TOTAL PIPE INSULATION	1000	LF			334				24.0	
		LABOR			1691 MHS					
TOTAL THIS SECTION								634.0	24.0	

A.5-124

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ....: PIONEER MILL SOLAR COGEN. PLANT

BY La.J

DATE 5/12/81

SHEET 6 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
THERMAL TRANSPORT SYSTEM										
AT the MILL										
MAIN STEAM - A335-P11 sch. 80 PIPE 6"	200	LF	52-	1.03	206			10.4		
FITT. ALLOW. INCL. IN UNITS EXCL. VA'S. *										
DUMP STEAM - A335-P11 - Sch 80 PIPE 6" ASSUMED	200	LF	52-	1.03	206			10.4		
*										
CONDENSATE A53 Sch. 40 PIPE 4"	400	LF	10-	.63	252			4.0		
*										
ATTEMPERATOR WATER A106 sch. 80 PIPE 2"	200	LF	4-	.47	94			.8		
*										
POTABLE WATER A106 Sch. 80 PIPE 2" ASSUME TO TIE-IN	200	LF	4-	.47	94			.8		
ADJ.								<.4>		
		LABOR			852 MHS					
	1200	LF						26.0		

A.5-125

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

BY L. ?

DATE 5/12/81

SHEET 7 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
THERMAL TRANSPORT SYSTEM										
AT THE MILL										
VALVES ASSUME ALL CS EXCEPT AS NOTED *				*	Assume					
* 1250# GATES 6" (MAIN STM) MANUAL	9	EA	26000	5.1	46			234.0		
* 6" DITTO MOTOR	1	EA	30,000	11.5	12			30.0		
* ASSUME 6" (DUMP STM) MANUAL	3	EA	26000	5.1	15			78.0		
1" (DUMP WTL)	4	EA	1400	.6	3			5.6		
* CHECKS 6" (DUMP STM) CS 5600 T2.12	3	EA	19400	5.1	15			58.2		
1" (DUMP WTR.)	2	EA	1300	.6	1			2.6		
50#/100#/265# GATES ASSUME 6" (DUMP STM.) MANUAL	3	EA	1200	2.2	7			3.6		
4" (COND.) MOTOR	1	EA	2200	3.8	4			2.2		
4" (COND.) MANUAL	4	EA	700	1.7	7			2.8		
1½" (COND.) MOTOR	3	EA	1900	.4	1			5.7		
1" (COND.) MANUAL	3	EA	300	.3	1			.9		
CHECKS ASSUME 6" (DUMP STM) MANUAL	2	EA	1000	2.2	4			2.0		
1½" (COND.)	3	EA	300	.4	1			.9		
ADJ.								.5		
		LABOR			117 MHS					
	41	EA.						427.0		

A.5-126

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE PIONEER MILL SOLAR COGEN. PLANT

BY LAL

DATE 5/12/81

SHEET 8 OF

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
THERMAL TRANSPORT SYSTEM										
AT THE MILL										
INSULATION - CALSIUM SILICATE w/ ALUM. WEATHERPROOF JACKET										
MAIN STM. 6" x 4" thk	200	LF	S/C 32.70	.47	94				6.5	
DUMP STM. 6" x 4" thk ASSUME	200	LF	S/C 32.73	.47	94				6.5	
CONDENSATE 4" x 2" thk	400	LF	S/C 13.10	.15	60				5.2	
ATTEMPERATOR WATER 2" x 1" thk	200	LF	S/C 8.80	.15	30				1.8	
SUB-TOTAL	1000	LF			278				20.0	
MISC. FRT & GUIDES (20% OF S/C)					56				4.0	
LABOR					334 MHS					
	1000	LF							24.0	

A.5-127

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE : PIONEER MILL SOLAR COGEN. PLANT

BY

DATE D.B.S. MAY 20 '81

SHEET 1 OF 4

ALL $1,000's

5700 - ELECTRICAL SUMMARY	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
MILL AREA. (SHEET 2)	1	LT			700		149	5		
✓ ✓ (✓ 3)	1	LT			4700		–	58		
✓ ✓ (✓ 4)	1	LT			1100		6	50		
TOTAL 5700	1	LT (LABOR)			6500		155	113		

ZAR

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE ______ : PIONEER MILL SOLAR COGEN. PLANT

BY D.B.S. MAY 18 '81

DATE

5700 - MILL AREA - ELECTRICAL	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
2.2 MVA 3∅ OIL IMMERSED XFR.	1	EA	25000	–	140		25000			
12.470V/480-277V. WITH 2±2.5% TAPS										
STANDARD IMPEDANCE, AIR TERMINAL										
CHAMBER FOR 3000A BUS DUCT TERMN.										
AT SECY. BUSHING & INSULATED L.V. TERML.										
CHAMBER FOR GRD. CONN. STANDARD ACCESS.										
DISTRIBUTION CENTER 480V. 3∅ 4W.	1	EA	12200		80		12200			
W/ 4 EA 700A 3P CCT BREAKERS										
1 EA 50A-3P " "										
1 EA 50A-3P " " SPACE										
2 EA SIZE #1 FVNR STARTERS										
ENTRANCE FOR 3000A 600V INCOMING BUS										
RATE OF RISE & OVERCURRENT RELAYS										
OUTDOOR ENCLOSURE										
3000A 3∅ 600V W/PROOF BUS	20	℄	180	4	80		3600			
DUCT, NON SEGREGATED, ALUMINUM.										
BUS DUCT FITTINGS	1	LT	–	–	30		400			
13.8KV. METAL CLAD SWITCHGEAR	1	EA	107,000		310		107000			
WITH 1 EA 1200A-3P INCOMING CCT. BREAKER										
2 EA 1200A-3P FEEDER " "										
(3/3) RATE OF RISE & OVERCURRENT RELAYS										
2 EA 200/5 CT, 1 EA 50/5 CT										
MISC. MATERIALS	1	LT.			60		1800	5000		
LABOR										
EXCLUDES FENCING	1	LT			700		149000	5000		

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

BY D.B.S.

DATE MAY 18 '81

SHEET 3 OF 4

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
5700 ELECTRICAL										
12.47KV TRANSMISSION LINE 3Ø (2800 LF)										
50' WOOD POLES, TREATED & RODENT PROTECTED BASES.	28	EA	1150	30	840			32200		
SUPPORT ARMS	28	EA	60	10	840			1680		
INSULATORS	84	EA	10	4	336			840		
ARMOR RODS	84	EA	7	3	252			588		
#6 ACSR (2800 x 3) + 10%	9300	LF	0.20	0.04	372			1860		
1/2" STRANDED STEEL WIRE (MESSENGER)	3100	LF	1.10	0.05	155			3410		
CLAMPS FOR MESSENGER @ POLES	28	EA	4.50	1.0	28			126		
STRAIN RELIEF CLAMPS CABLE TO MESSENGER	1600	EA	3.50	0.5	800			5600		
GROUND RODS	28	EA	15.00	4	112			420		
GROUND WIRE INCL. CONNECTORS										
TRANSITION OVERHEAD LINE TO 13.8KV SWITCHGEAR ✓ ✓ ✓ ✓ TO DISC SWITCH.	1	LT			240			4000		
POLE FOUNDATION EXCAVATION 28 x 1½ CY.	42	CY	-	0.4	17			—		
CONTROL CABLES (SUPPORTED BY MESSENGER) BELDEN #8227 (TOWER TO MILL BLDG.) 3 x 3000 LF	9000	LF	0.65	0.05	450			5850		
MISC. MATERIALS	1	LT			98			1426		
LABOR	1	LT			4700			58000		

A.5-130

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE: PIONEER MILL SOLAR COGEN. PLANT

BY D.B.S.
DATE MAY 10 81

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
5700 MILL AREA - ELECTRICAL										
ELECTRIC HEATERS 500KVA 460V 3Ø	4	EA	—	—	—		WITH MECHANICAL			
SIMILAR TO CHROMALOX GCH-108 LT.										
CONTROL SYSTEMS (AMP)	4	EA	1500		250		6000	—		
MISC MATERIALS.	1	LT	—		120			4000		
3/C #4/0 15KV. D/B CABLE, ALUM SHEATH, SHD	100	LF	21.00	0.19	19			2100		
3/C #1/0 ✓ ✓ ✓ ✓ ✓	50	LF	9.50	0.13	7			475		
15KV. TERMINATIONS	12	EA	30	6	72			360		
15KV. CONNECTORS	12	EA	70	4	48			840		
TRENCH EXCAVATION 450'x2'x2'	70	CY	-	0.3	21			—		
BACKFILL	70	CY	-	0.2	14			—		
3/C 750 MCM 600V D/B CABLE, ALUM SHEATH.	1200	LF	33.00	0.25	300			39600		
TERMINATIONS	24	EA	12.50	4.0	96			300		
CONNECTORS	24	EA	60	4.0	96			1440		
MISC. MATERIALS	1	LT	—	—	57			885		
LABOR	1	LT			1,100		6000	50000		

A.5-131

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE : PIONEER MILL SOLAR COGEN. PLANT

BY [illegible]

DATE 5/21/81

SHEET 1 OF

5-700

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
INSTRUMENTATION)										
SEE AREA 5400 (INSTRUMENTATION)	1	LT			200			70		70
LABOR	147				200			70		70

A.5-132

BECHTEL

JOB NO. AND TITLE 14481

STUDY NO. AND TITLE

PIONEER MILL SOLAR COGEN. PLANT

BY

DATE

SHEET ____ OF ____

ALL $1,000's

	QUANTITY	UNIT	UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	PLANT EQUIPMENT	BULK MATERIAL	SUB-CONT.	TOTAL
INSTRUMENTATION										
MAT'L ··· 35% of Piping MAT'L										
LABOR ··· 38 MH / $1,000										
FOR DETAIL OF THIS, SEE BACKUP										
PIPING MAT'L = $1,320,000 (See PIPING)										
MAT'L INSTRU = 1320,000 x 0.35 = $ 460,000										
MH = 38 x 460 = 12,000 MH										
INSTRUMENTATION	1	LOT			12,000			460		460
LABOR					12,000			460		460

A.5-133

O&M COST ESTIMATE
(dollars per year)

• Operation			
– Personnel[1]		228,800	
(1) 3 operators, 8 hours/day, 365 days/year; $20 per hour +30% for supervision and administration			
– Consumables			
Collector system	5,700		
Receiver system	3,000		
Thermal system	5,000		
Other systems	1,000		
		14,700	
			243,500
• Maintenance materials			
– Spares			
Collector system	44,730		
Receiver system	21,000		
Thermal system	8,800		
Other systems	5,000		
		79,530	
– Repair materials		1,000	
– Other costs[2]		9,300	
(2) Includes lights, vehicle fuel, water, site upkeep			89,800
• Maintenance labor			
– Scheduled			
Collector system	6,900		
Receiver system	29,100		
Thermal system	1,500		
Other systems	2,000		
		39,500	

– Unscheduled			
Collector system	2,500		
Receiver system	29,200		
Thermal system	1,500		
Other systems	0		
		33,200	
			72,700
			406,000

COLLECTOR SYSTEM

OPERATIONS AND MAINTENANCE WORKSHEET

OM 110 Operating Personnel

Description

Operating Engineer - Full time engineer - Should be assigned to field operations. In addition to solar collector, receiver, tower and energy transport systems may also be his responsibility.

(2) Operating Technicians - Full time - Similar duties as described above and also provide field coverage during weekends, holidays, illness and vacations.

COLLECTOR SYSTEM

OPERATIONS AND MAINTENANCE WORKSHEET

OM 120 Operating Consumables

Description	Quantity per Year	Unit Cost	Total Direct Cost	G&A	Overhead	Total
Electrical Power*	842,742 KWH					
Deionizing chemicals**	104 gal.	1.50	156			
Water***	175,000 gal	¢41/1000 gal (will be 60¢ 1982)	74			
Helio Drive O.L.	312 gal	10.00	3,120			
Misc. (Mag. Tapes, chart paper, disks, etc.)	Varies		2,400			
			5740			

* 2.96 KWH/Helio/day x 780 helios x 365 days

** based on 2 resin beds (caustic & HCL); 6 washes per year; 30,000 gal./wash; 3 day wash period

*** 34 gal./helio/wash x 780 helio x 6 wash plus 10% waste

COLLECTOR SYSTEM

OPERATION AND MAINTENANCE WORKSHEET

OM 212 Collector Equipment

Part Description	Failure Rate per year/part	Failures	Avg. Cost Per Unit	Direct Cost	G&A	Overhead	Total
Mirror Modules	.2%*	19	$ 200	$3,800			
Rack Structure (half)	.1%**	2	937	1,874			
Drive Units	.1%	1	6,750	6,750			
Motors	.2%**	4	125	500			
Limit Switches	.2%***	13	31	403			
Cables and Connectors	.2%****	16	25	400			
Controller	1.05%	9	563	5,067			
Surface Corrosion	10.0%	78	16	1,248			
TOTAL				$20,042			

* 12 per Heliostat

** 2 per Heliostat

*** 8 per Heliostat

**** 10 per Heliostat

COLLECTOR SYSTEM

OPERATIONS AND MAINTENANCE WORKSHEET

OM 212 Collector Equipment (Continued)

Due to the significant impact of a failure of key pieces of field control instrumentation, it is cost effective to maintain complete resource units regardless of low failure rates.

1 HP 9825 calculator	$10,250
1 HP 9878 I/O Expander	1,875
1 HP 9885 Disc Drive	5,125
2 HP Serial Interface	1,500
1 Real Time Clock	375
1 Topaz Voltage regulation	688
2 Line Drivers	1,626
1 CRT Display	3,250
TOTAL	$24,689
	20,042
	44,731

COLLECTOR SYSTEM

OPERATION AND MAINTENANCE WORKSHEET

OM 230 Other

Description	Initial Cost	Annual Cost 15% over 20 yrs.	G & A	Overhead	Total
Deionizer (2 bed) (10,000 gal. day)	14,000	2,240			

COLLECTOR SYSTEM

OPERATIONS AND MAINTENANCE WORKSHEET

OM 310 Scheduled Maintenance

Description	Hours per Year	Unit Cost	Direct Cost	G&A	Overhead	Total
Mirror Washing*	281	17.00	4,777			
Drive Lubrication**	78	16.95	1,322			
Deionizer Recharge	48	16.95	814			
			6913			

* 2 man crew x .03 hr/wash/helio x 780 helio x 6 wash = 280.8 manhour/yr

** based on recommended oil change at 10 yr. intervals

5.4 ECONOMIC DATA

The economic assumptions and data used, as well as the calculations of the levelized busbar energy cost, are given in Section 6 of this report.

5.5 SIMULATION MODELS

5.5.1 Insolation Model

The solar model for direct normal insolation is described in Appendix C.

5.5.2 Facility Performance Model

The performance model used in evaluating the facility performance is given in Appendix E.

5.5.3 Facility Economic Model

The model used in determining the facility economics is given in Section 6.

Appendix B

SITE INSOLATION MEASUREMENT PROGRAM

Prior insolation measurements in the vicinity of Pioneer Mill are insufficient for the insolation model needed to determine the annual performance of the solar cogeneration facility. Available measurements include 6 to 8 years of data from the "wig wag" instrument used at Pioneer Mill for determining irrigation requirements. Approximately 1 year of global radiation data from a pyranometer at the Lahaina Recreation Center is also available. To provide added data for the insolation model, an insolation measurement station was placed in operation in October 1980.

The station was installed by Professor Paul Ekern of the University of Hawaii Natural Energy Institute. In addition to taking "wig wag" instrument readings, the station records pyranometer measurements of total global radiation and direct normal insolation measurements from an Eppley normal incidence pyrheliometer (NIP).

These instruments, installed on the grounds of the Pioneer Mill offices, have provided insolation measurements since October 1980. (Calibration and mounting problems were experienced during the first 2 weeks.) This appendix presents tabulations of integrated hourly NIP measurements through May 1981 and pencharts of instantaneous NIP measurements for 3 weeks in November-December 1980. Every major division on the penchart time scale represents one half hour. Penchart time is not synchronized with local time. The penchart vertical scale measures 0 to 10 millivolts. Corresponding insolation values (in W/m^2) are obtained by dividing the penchart reading (in millivolts) by 0.00892. The tabulated NIP insolation values are converted from cal/cm^2 to W/m^2 by multiplying by 11.6222.

PIONEER MILL DIRECT STATION 50 HOURLY SOLAR RADIATION - CAL./SQ. CM

HOUR / DAY	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	TOTAL
21080	*****	*****	*****	*****	*****	69.0	75.2	80.3	78.0	74.6	69.0	49.8	15.3	0.0	0.0	*****
31080	0.0	0.0	20.9	63.9	74.1	78.0	70.7	30.5	2.8	1.1	1.1	1.1	0.6	0.0	0.0	344.9
41080	0.0	0.0	23.7	66.2	74.1	71.2	53.1	12.4	1.1	1.1	1.1	1.1	0.6	0.0	0.0	305.9
51080	0.0	0.0	53.1	71.2	72.4	63.9	31.1	5.1	1.1	1.1	1.1	0.6	0.0	0.0	0.0	300.8
61080	0.0	0.0	49.2	68.4	68.4	57.7	17.5	1.1	0.6	0.6	0.6	1.1	0.6	0.0	0.0	265.7
71080	0.0	0.0	20.9	43.5	69.0	52.0	11.9	76.3	58.2	68.4	65.0	41.8	10.2	0.0	0.0	517.3
81080	0.0	0.0	18.1	54.3	74.1	49.8	11.3	1.1	1.1	20.9	37.3	43.5	19.2	0.0	0.0	330.8
91080	0.0	0.0	3.4	55.4	68.4	73.5	75.2	75.8	76.9	70.7	66.2	56.0	20.9	0.0	0.0	642.3
101080	0.0	0.0	0.0	17.0	25.4	18.7	40.7	44.7	37.9	52.6	29.4	48.1	17.5	0.0	0.0	331.9
111080	0.0	0.0	4.5	35.6	20.4	57.7	75.8	75.8	69.0	65.6	60.5	55.4	20.9	0.0	0.0	541.1
121080	0.0	0.0	8.5	2.3	22.1	42.4	31.1	56.5	76.9	75.2	70.1	54.3	18.7	0.0	0.0	458.0
131080	0.0	0.0	10.2	19.8	31.7	35.1	62.2	49.8	61.6	8.5	18.1	0.6	0.0	0.0	0.0	297.4
141080	0.0	0.0	40.1	59.9	67.8	77.5	78.6	73.5	75.2	74.1	67.3	50.9	18.7	0.0	0.0	683.6
151080	0.0	0.0	43.0	65.0	67.8	62.8	76.3	62.8	72.9	61.6	59.4	39.6	9.0	0.0	0.0	620.2
161080	0.0	0.0	5.7	18.7	69.5	53.7	25.4	71.2	68.4	61.1	70.7	57.1	20.9	0.0	0.0	522.4
171080	0.0	0.0	9.0	56.5	65.6	74.1	78.0	79.2	78.0	75.2	69.0	53.1	19.2	0.0	0.0	657.0
181080	0.0	0.0	43.0	67.8	75.2	78.6	80.3	80.3	78.0	75.8	70.1	52.0	20.9	0.0	0.0	722.0
191080	0.0	0.0	43.0	68.4	74.1	78.6	79.7	78.6	75.8	75.2	68.4	45.2	13.6	0.0	0.0	700.5
201080	0.0	0.0	43.0	36.2	73.5	78.0	74.1	27.1	33.9	9.6	67.8	56.0	18.1	0.0	0.0	517.3
211080	0.0	0.0	1.7	56.5	74.6	75.2	47.5	22.6	32.2	72.9	66.7	53.7	15.3	0.0	0.0	519.0
221080	0.0	0.0	35.1	65.0	68.4	77.5	79.7	72.4	62.8	49.2	37.9	33.4	13.6	0.0	0.0	594.8
231080	0.0	0.0	26.6	69.0	76.3	79.7	81.4	80.3	79.7	75.8	69.0	57.7	14.1	0.0	0.0	709.6
241080	0.0	0.0	0.0	17.0	45.8	40.7	14.1	1.1	45.8	74.1	69.0	53.7	11.3	0.0	0.0	372.6
251080	0.0	0.0	0.0	0.0	2.3	2.8	24.9	44.7	78.6	75.8	67.3	44.1	12.4	0.0	0.0	352.8
261080	0.0	0.0	18.7	37.9	63.9	36.2	48.6	41.8	75.2	73.5	64.5	33.9	7.9	0.0	0.0	502.1
271080	0.0	0.0	9.6	39.0	43.5	49.8	46.9	66.7	32.2	60.5	65.6	46.4	10.7	0.0	0.0	471.0
281080	0.0	0.0	41.8	69.5	75.8	80.3	80.9	80.9	65.0	63.9	68.4	54.8	13.0	0.0	0.0	694.3
291080	0.0	0.0	43.5	70.7	76.9	80.3	81.4	81.4	79.7	76.9	71.2	55.4	14.1	0.0	0.0	731.6
301080	0.0	0.0	1.1	41.8	71.2	50.9	53.1	47.5	67.8	54.3	60.5	53.7	11.9	0.0	0.0	513.9
311080	0.0	0.0	2.8	59.4	62.8	35.1	5.1	37.3	70.1	54.3	65.6	54.8	11.3	0.0	0.0	458.5
AVERAGE	0.0	0.0	21.4	48.1	60.5	59.3	53.7	52.0	54.6	53.5	53.3	41.6	12.7	0.0	0.0	506.2
MAXIMUM	0.0	0.0	53.1	71.2	76.9	80.3	81.4	81.4	79.7	76.9	71.2	57.7	20.9	0.0	0.0	731.6
MINIMUM	0.0	0.0	0.0	0.0	2.3	2.8	5.1	1.1	0.6	0.6	0.6	0.6	0.0	0.0	0.0	265.7

PIONEER MILL DIRECT STATION 50 HOURLY SOLAR RADIATION - CAL./SQ. CM

HOUR DAY	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	TOTAL
11180	0.0	0.0	31.7	66.2	46.9	28.3	1.1	45.2	28.3	32.8	58.8	54.3	11.3	0.0	0.0	404.8
21180	0.0	0.0	38.4	66.7	76.3	79.2	78.6	81.4	77.5	58.2	66.2	54.3	9.6	0.0	0.0	686.4
31180	0.0	0.0	37.9	68.4	74.6	79.2	80.9	78.6	76.9	71.2	64.5	50.9	7.4	0.0	0.0	690.4
41180	0.0	0.0	7.9	20.9	65.6	59.4	70.7	67.8	69.0	64.5	55.4	39.6	4.5	0.0	0.0	525.3
51180	0.0	0.0	32.8	64.5	71.2	78.0	79.2	78.0	78.0	74.6	67.3	52.0	5.1	0.0	0.0	680.7
61180	0.0	0.0	0.6	6.8	56.5	77.5	24.9	75.8	76.3	75.2	69.0	55.4	7.4	0.0	0.0	525.3
71180	0.0	0.0	24.9	58.8	72.9	76.3	24.9	69.5	66.2	70.1	61.1	40.7	3.4	0.0	0.0	568.8
81180	0.0	0.0	1.1	23.2	7.4	25.4	56.5	44.7	39.6	44.1	59.9	49.2	4.0	0.0	0.0	355.1
91180	0.0	0.0	6.2	20.4	48.6	59.4	59.9	50.3	23.2	35.1	26.6	26.0	1.7	0.0	0.0	357.3
101180	0.0	0.0	10.7	26.0	45.8	57.7	63.9	58.2	35.1	62.2	36.8	6.8	0.0	0.0	0.0	403.1
111180	0.0	0.0	15.8	58.8	66.7	74.1	76.9	73.5	73.5	70.7	62.2	39.0	2.8	0.0	0.0	614.0
121180	0.0	0.0	21.5	57.1	59.4	75.2	77.5	76.9	76.3	72.4	60.5	38.4	2.8	0.0	0.0	618.0
131180	0.0	0.0	22.6	64.5	73.5	78.0	79.2	78.6	75.8	74.1	67.3	50.3	2.8	0.0	0.0	666.6
141180	0.0	0.0	24.3	60.5	71.8	79.7	82.0	80.9	77.5	75.2	68.4	49.2	1.7	0.0	0.0	671.1
151180	0.0	0.0	0.6	28.3	46.9	27.7	28.3	28.3	26.6	9.0	0.6	1.7	0.0	0.0	0.0	197.9
161180	0.0	0.0	6.2	44.1	69.0	79.2	81.4	80.9	79.2	75.2	67.8	49.8	1.7	0.0	0.0	634.4
171180	0.0	0.0	15.8	63.3	72.9	76.3	78.6	79.7	78.6	75.2	68.4	54.3	1.7	0.0	0.0	664.9
181180	0.0	0.0	17.5	65.6	74.1	78.6	79.2	79.7	78.0	71.8	66.7	16.4	0.0	0.0	0.0	627.6
191180	0.0	0.0	19.8	65.6	72.4	79.7	80.9	80.9	79.7	76.3	67.8	52.0	2.3	0.6	0.0	677.9
201180	0.0	0.6	21.5	63.3	67.3	69.5	69.0	75.2	73.5	70.7	58.8	43.0	2.3	0.0	0.0	614.6
211180	0.0	0.0	8.5	59.4	64.5	69.5	79.2	78.0	75.8	60.5	40.1	36.8	2.3	0.0	0.0	574.4
221180	0.0	0.0	11.3	30.0	53.1	68.4	56.0	67.3	73.5	66.2	55.4	32.2	2.3	0.0	0.0	515.6
231180	0.0	0.0	13.0	60.5	69.5	74.1	53.7	44.7	73.5	72.4	65.0	45.8	2.8	0.0	0.0	575.0
241180	0.0	0.0	20.9	61.1	31.1	71.2	76.9	71.2	48.6	58.2	63.9	48.6	3.4	0.0	0.0	555.2
251180	0.0	0.0	20.9	63.3	72.9	76.9	76.3	64.5	49.8	71.2	9.6	6.8	2.8	0.0	0.0	515.1
261180	0.0	0.0	1.1	18.7	57.7	75.2	78.0	78.0	76.3	60.5	45.2	4.0	2.3	0.0	0.0	497.0
271180	0.0	0.0	19.8	61.1	71.2	76.9	79.2	79.7	72.9	64.5	62.8	30.0	1.1	0.0	0.0	619.1
281180	0.0	0.0	19.8	64.5	74.1	78.0	80.3	79.7	78.6	74.6	67.3	49.2	4.0	0.0	0.0	670.0
291180	0.0	0.0	20.9	65.6	74.1	78.6	81.4	82.0	79.7	75.8	68.4	31.1	1.1	0.6	0.0	659.3
301180	0.0	0.0	20.4	63.3	74.1	79.2	82.0	80.9	79.7	76.3	69.5	53.7	4.5	0.0	0.0	683.6
AVERAGE	0.0	0.0	17.2	51.3	62.7	69.5	67.2	70.3	66.6	64.6	56.7	38.7	3.3	0.0	0.0	568.3
MAXIMUM	0.0	0.6	38.4	68.4	76.3	79.7	82.0	82.0	79.7	76.3	69.5	55.4	11.3	0.6	0.0	690.4
MINIMUM	0.0	0.0	0.6	6.8	7.4	25.4	1.1	28.3	23.2	9.0	0.6	1.7	0.0	0.0	0.0	197.9

PIONEER MILL DIRECT STATION 50 HOURLY SOLAR RADIATION - CAL./SQ. CM

HOUR DAY	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	TOTAL
11280	0.0	0.0	18.7	63.9	73.5	77.5	24.9	79.7	48.1	44.1	68.4	54.8	4.5	0.0	0.0	558.0
21280	0.0	0.6	19.8	69.0	77.5	82.0	84.8	84.8	83.7	79.7	73.5	59.4	5.1	0.0	0.0	719.8
31280	0.0	0.0	18.1	68.4	76.3	82.0	83.7	83.1	82.0	78.0	67.8	51.5	4.0	0.0	0.0	694.9
41280	0.0	0.0	15.8	63.3	74.1	79.2	80.3	65.0	74.1	17.0	0.0	0.6	0.6	0.0	0.0	469.8
51280	0.0	0.0	0.6	2.8	1.1	1.1	3.4	2.8	2.3	0.6	1.7	0.0	0.0	0.0	0.0	16.4
61280	0.0	0.0	0.6	0.6	1.1	16.4	53.7	50.9	45.2	30.0	1.7	0.6	0.0	0.0	0.0	200.7
71280	0.0	0.0	9.6	37.3	66.7	74.6	78.0	58.8	74.1	47.5	65.6	50.9	5.1	0.0	0.0	568.2
81280	0.0	0.6	13.0	58.2	70.1	74.6	76.3	72.9	72.4	67.3	64.5	47.5	4.5	0.0	0.0	621.9
91280	0.0	0.0	12.4	59.9	70.7	75.8	76.9	76.9	51.5	17.0	41.3	40.1	4.0	0.0	0.0	526.4
101280	0.0	0.0	13.0	63.3	72.9	77.5	78.6	79.2	78.6	75.2	68.4	51.5	5.1	0.0	0.0	663.2
111280	0.0	0.0	11.3	59.9	10.7	15.8	78.0	78.6	78.0	75.2	68.4	53.1	5.7	0.0	0.0	534.9
121280	0.0	0.0	11.3	62.8	65.0	62.8	79.7	78.0	79.2	57.1	34.5	32.2	5.7	0.0	0.0	568.2
131280	0.0	0.0	0.0	5.1	32.2	75.8	79.2	80.3	79.7	76.3	69.5	55.4	6.8	0.0	0.0	560.3
141280	0.0	0.0	0.0	0.0	0.6	8.5	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4
151280	0.0	0.0	4.0	43.0	43.0	52.0	50.9	61.6	10.2	0.6	0.0	0.0	0.6	0.0	0.0	265.7
161280	0.0	0.0	9.0	62.8	72.9	76.9	79.7	46.9	52.6	74.1	68.4	54.3	7.9	0.0	0.0	605.5
171280	0.0	0.0	8.5	63.3	72.4	70.7	59.4	76.3	77.5	53.7	57.1	49.2	4.5	0.0	0.0	592.5
191280	0.0	0.0	0.0	20.9	8.5	0.6	0.6	1.7	0.6	1.7	13.0	15.8	2.3	0.0	0.0	65.6
201280	0.0	0.0	8.5	63.3	74.1	79.2	35.6	58.8	58.2	49.8	46.4	41.3	0.0	0.0	0.0	515.1
211280	0.0	0.0	1.7	18.1	15.3	0.6	2.3	9.0	8.5	4.5	1.1	0.0	0.0	0.0	0.0	61.1
221280	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	6.2	3.4	6.2	1.1	0.0	0.0	19.8
231280	0.0	0.0	0.0	11.3	22.6	23.7	46.4	43.5	74.6	59.4	52.6	24.9	6.8	0.0	0.0	365.8
241280	0.0	0.0	0.0	0.6	0.6	0.6	2.8	4.0	1.1	11.9	26.0	4.0	1.1	0.0	0.0	52.6
251280	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6	0.0	0.0	0.6	0.0	0.0	0.0	0.0	1.7
261280	0.0	0.0	4.5	49.8	56.5	65.6	50.3	74.6	64.5	19.2	54.8	32.8	4.0	0.0	0.0	476.6
271280	0.0	0.0	0.0	0.0	1.7	1.1	0.6	0.6	0.6	0.6	1.7	26.6	9.6	0.0	0.0	43.0
281280	0.0	0.0	0.0	0.0	0.6	30.0	6.2	0.6	20.9	15.8	0.6	0.0	1.7	0.0	0.0	76.3
291280	0.0	0.6	2.3	53.7	67.3	74.6	79.2	79.7	62.8	23.7	15.3	26.0	2.3	0.0	0.0	487.4
301280	0.0	0.0	3.4	63.3	73.5	47.5	78.0	63.3	64.5	72.9	13.6	8.5	11.9	0.0	0.0	500.4
311280	0.0	0.0	4.0	58.2	69.0	62.2	79.7	80.3	79.2	76.9	71.2	59.4	14.1	0.0	0.0	654.2
AVERAGE	0.0	0.1	6.3	37.4	42.3	46.3	48.4	49.8	47.6	37.9	35.0	28.2	4.0	0.0	0.0	383.3
MAXIMUM	0.0	0.6	19.8	69.0	77.5	82.0	84.8	84.8	83.7	79.7	73.5	59.4	14.1	0.0	0.0	719.8
MINIMUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7

PIONEER MILL DIRECT STATION 50 HOURLY SOLAR RADIATION - CAL./SQ. CM

HOUR DAY	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	TOTAL
1 181	0.0	0.0	2.8	57.7	70.1	75.8	79.7	80.9	72.9	50.9	64.5	50.3	11.9	0.0	0.0	617.4
2 181	0.0	0.0	2.3	61.6	73.5	79.7	81.4	56.5	49.2	76.3	70.7	57.1	13.0	0.0	0.0	621.4
3 181	0.0	0.0	0.0	34.5	34.5	50.3	37.3	33.9	62.2	3.4	0.0	0.0	0.0	0.0	0.0	256.1
4 181	0.0	0.0	0.6	58.8	71.2	76.3	75.8	75.2	74.1	71.2	64.5	50.9	11.3	0.0	0.0	629.9
5 181	0.0	0.0	0.6	38.4	58.8	74.1	76.9	77.5	76.3	75.8	69.0	56.5	14.7	0.0	0.0	618.5
6 181	0.0	0.0	0.6	58.2	72.4	77.5	80.9	82.0	80.9	77.5	72.4	61.6	17.0	0.0	0.0	680.7
7 181	0.0	0.0	0.6	58.2	72.4	76.9	78.6	79.2	75.2	59.9	70.1	59.4	7.4	0.0	0.0	637.8
8 181	0.0	0.0	0.0	41.8	18.1	60.5	79.7	80.3	79.7	76.3	71.2	59.9	18.1	0.0	0.0	585.8
9 181	0.0	0.0	0.6	59.9	74.1	80.3	82.0	82.0	80.9	78.6	73.5	62.2	19.2	0.0	0.0	693.2
10 181	0.0	0.0	0.6	63.3	76.3	81.4	83.7	84.2	83.7	80.9	75.8	65.6	22.1	0.0	0.0	717.5
11 181	0.0	0.0	0.6	58.2	71.8	78.0	70.1	35.6	30.0	18.7	18.7	35.6	0.6	0.0	0.0	417.8
12 181	0.0	0.0	0.6	62.2	74.6	79.2	82.0	82.5	82.0	80.3	71.2	36.2	20.9	0.0	0.0	671.7
13 181	0.0	1.1	0.6	60.5	70.7	79.2	81.4	82.0	69.0	58.2	73.5	62.2	22.1	0.0	0.0	660.4
14 181	0.0	0.0	0.6	59.9	72.9	79.2	81.4	81.4	82.0	78.0	53.7	62.2	22.1	0.0	0.0	673.4
15 181	0.0	0.0	0.6	60.5	73.5	79.7	82.0	82.5	81.4	79.2	74.6	63.3	22.6	0.0	0.0	700.0
16 181	0.0	0.0	0.0	6.8	24.9	22.1	46.9	66.2	74.6	49.2	1.7	4.0	3.4	0.0	0.0	299.7
17 181	0.0	0.0	0.0	3.4	36.2	70.1	76.9	75.2	76.9	75.8	67.3	56.5	18.7	0.0	0.0	556.9
18 181	0.0	0.0	0.6	43.0	64.5	71.8	74.1	75.2	70.1	66.2	59.4	48.1	13.6	0.0	0.0	586.3
19 181	0.0	0.0	0.0	2.3	9.0	46.4	62.2	0.6	0.6	1.7	6.2	41.8	4.0	0.0	0.0	174.7
20 181	0.0	0.0	0.6	24.3	34.5	24.9	35.1	30.0	32.2	62.2	65.6	51.5	15.8	0.0	0.0	376.6
21 181	0.0	0.0	0.6	46.9	68.4	70.7	52.0	65.0	75.8	68.4	66.7	41.3	0.6	0.0	0.0	556.4
22 181	0.0	0.0	0.6	31.7	63.9	71.2	76.3	72.4	48.6	72.9	66.7	44.7	22.6	0.0	0.0	571.6
23 181	0.0	0.0	0.6	47.5	68.4	75.2	78.6	78.0	77.5	75.2	69.5	59.4	23.2	0.0	0.0	653.0
24 181	0.0	0.0	0.0	45.8	70.1	76.3	79.7	79.2	75.2	78.0	72.9	61.1	23.7	0.0	0.0	662.1
25 181	0.0	0.0	0.6	49.8	72.4	79.2	81.4	82.0	79.2	67.3	54.8	56.5	20.9	0.0	0.0	644.0
26 181	0.0	0.0	1.1	43.0	70.7	77.5	80.9	82.5	82.0	80.3	75.2	65.6	27.7	0.0	0.0	686.4
27 181	0.0	0.0	0.6	14.7	1.1	9.6	35.1	62.8	74.6	69.0	64.5	37.3	6.2	0.0	0.0	375.4
28 181	0.0	0.0	0.6	49.8	70.1	76.9	79.7	80.9	79.7	76.3	71.2	60.5	24.9	0.0	0.0	670.6
29 181	0.0	0.0	0.6	0.6	70.1	75.8	79.2	75.8	76.3	37.3	24.9	1.1	0.0	0.0	0.0	441.6
30 181	0.0	0.0	0.6	48.1	69.0	76.3	79.2	80.9	80.3	78.0	71.8	59.4	24.3	0.0	0.0	667.7
31 181	0.0	0.0	0.0	50.3	70.1	75.2	78.6	70.1	44.1	34.5	68.4	50.9	0.6	0.0	0.0	542.8
AVERAGE	0.0	0.0	0.6	43.3	59.6	68.6	72.5	70.1	68.6	63.1	59.0	49.1	14.6	0.0	0.0	569.3
MAXIMUM	0.0	1.1	2.8	63.3	76.3	81.4	83.7	84.2	83.7	80.9	75.8	65.6	27.7	0.0	0.0	717.5
MINIMUM	0.0	0.0	0.0	0.6	1.1	9.6	35.1	0.6	0.6	1.7	0.0	0.0	0.0	0.0	0.0	174.7

PIONEER MILL DIRECT STATION 50 HOURLY SOLAR RADIATION - CAL./SQ. CM

HOUR DAY	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	TOTAL
1 281	0.0	0.0	0.0	0.6	38.4	26.0	58.2	61.1	33.4	16.4	37.3	35.6	23.2	0.0	0.0	330.2
2 281	0.0	0.0	0.6	23.2	73.5	77.5	80.3	80.9	80.3	78.6	74.6	65.0	32.8	0.0	0.0	667.2
3 281	0.0	0.0	0.6	2.8	43.0	27.1	41.3	66.2	79.7	69.5	54.3	63.3	33.4	0.0	0.0	481.2
4 281	0.0	0.0	1.1	53.7	48.1	31.1	53.7	70.7	51.5	77.5	74.1	65.6	33.9	0.0	0.0	560.9
5 281	0.0	0.0	0.0	0.0	0.0	2.3	0.6	1.1	0.6	11.3	55.4	27.1	2.3	0.0	0.0	100.6
6 281	0.0	0.0	1.1	62.2	75.2	80.9	83.1	83.1	82.5	80.3	75.2	65.6	36.8	0.0	0.0	726.0
7 281	0.0	0.0	1.7	59.4	69.0	78.6	80.3	61.1	69.5	71.2	46.4	50.9	21.5	0.0	0.0	609.5
8 281	0.0	0.0	0.0	0.0	0.0	20.4	24.9	2.8	6.2	56.5	31.7	7.9	17.0	0.0	0.0	167.4
9 281	0.0	0.0	1.1	53.7	15.8	26.0	71.8	63.3	28.8	4.5	0.6	2.3	0.0	0.0	0.0	268.0
10 281	0.0	0.0	0.0	9.6	11.3	71.2	81.4	82.0	75.2	80.3	63.9	16.4	7.4	0.0	0.0	498.7
11 281	0.0	0.0	0.0	0.0	13.6	24.9	0.0	0.0	4.0	9.6	6.8	1.1	0.6	0.0	0.0	60.5
12 281	0.0	0.0	0.6	11.9	10.2	74.1	72.4	72.9	70.7	56.0	71.8	1.1	0.6	0.6	0.0	442.7
13 281	0.0	0.0	0.0	13.0	66.2	78.0	67.8	79.7	82.0	80.9	76.3	68.4	46.9	0.6	0.0	659.8
14 281	0.0	0.0	1.1	57.1	66.2	76.3	75.2	42.4	0.6	0.6	0.6	45.8	12.4	0.0	0.0	378.3
15 281	0.0	0.0	0.6	48.1	66.2	58.2	19.2	2.3	2.8	60.5	73.5	62.2	28.3	0.0	0.0	421.8
16 281	0.0	0.0	0.6	57.7	70.1	74.6	57.7	80.3	78.6	75.2	71.8	62.8	36.2	0.0	0.0	665.5
17 281	0.0	0.0	0.6	56.0	72.4	78.0	80.9	80.3	78.6	76.3	72.4	55.4	18.1	0.6	0.0	669.4
18 281	0.0	0.0	0.6	49.2	69.5	74.1	76.3	72.4	80.9	80.3	76.9	69.0	48.1	1.7	0.0	698.8
19 281	0.0	0.0	0.6	48.1	28.3	62.2	41.8	19.8	72.4	65.6	8.5	30.0	33.4	2.3	0.0	412.7
20 281	0.0	0.0	5.7	58.2	72.4	30.5	20.9	25.4	1.1	40.1	48.1	36.8	26.6	0.6	0.0	366.4
21 281	0.0	0.0	1.1	4.5	67.3	78.6	76.3	82.5	82.0	80.3	72.9	68.4	37.3	1.7	0.0	653.0
22 281	0.0	0.0	0.0	54.8	48.1	67.3	76.9	81.4	82.0	79.7	76.3	69.5	49.8	4.5	0.0	690.4
23 281	0.0	0.0	9.6	66.7	70.1	78.0	83.1	84.2	82.5	80.9	76.9	69.0	50.3	6.8	0.0	758.2
24 281	0.0	0.0	1.1	17.5	33.9	46.9	64.5	67.3	70.1	72.9	67.8	57.7	41.8	4.0	0.0	545.6
25 281	0.0	0.0	2.8	24.3	27.1	11.9	1.7	67.8	80.3	77.5	72.9	63.3	43.0	3.4	0.0	476.1
26 281	0.0	0.0	0.0	18.1	28.3	4.0	4.0	2.8	52.6	70.7	52.6	45.8	25.4	0.0	0.6	304.7
27 281	0.0	0.0	0.0	32.2	26.0	52.6	63.9	69.5	69.0	70.1	63.3	51.5	17.5	1.1	0.0	516.8
28 281	0.0	0.0	0.0	0.6	19.2	62.8	70.1	74.1	76.3	74.6	70.7	64.5	47.5	6.2	0.0	566.5
AVERAGE	0.0	0.0	1.1	31.5	43.9	52.6	54.6	56.3	56.2	60.6	56.2	47.2	27.6	1.2	0.0	489.2
MAXIMUM	0.0	0.0	9.6	66.7	75.2	80.9	83.1	84.2	82.5	80.9	76.9	69.5	50.3	6.8	0.6	758.2
MINIMUM	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.6	0.6	0.6	1.1	0.0	0.0	0.0	60.5

PIONEER MILL DIRECT STATION 50 HOURLY SOLAR RADIATION - CAL./SQ. CM

HOUR DAY	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	TOTAL
1 381	0.0	0.0	3.4	61.6	72.4	78.6	80.3	80.9	79.7	78.6	73.5	66.7	49.2	6.2	0.0	731.1
2 381	0.0	0.0	18.1	1.1	0.0	62.8	81.4	78.0	74.6	75.8	72.9	63.9	36.2	0.0	0.0	564.8
3 381	0.0	0.0	7.9	5.1	60.5	79.7	81.4	73.5	66.2	59.4	12.4	54.8	30.0	0.0	0.0	530.9
4 381	0.0	0.0	33.4	65.6	73.5	61.1	80.3	80.9	78.0	75.8	70.7	59.4	29.4	0.0	0.0	707.9
5 381	0.0	0.0	32.8	66.2	76.3	79.7	75.8	82.0	75.2	75.2	64.5	57.1	26.0	0.0	0.0	710.7
6 381	0.0	0.0	40.7	55.4	60.5	77.5	75.8	74.6	37.9	9.0	56.5	59.9	28.3	0.0	0.0	576.1
7 381	0.0	0.0	39.0	60.5	72.4	79.7	81.4	82.0	80.3	75.8	70.1	60.5	32.2	0.0	0.0	733.9
8 381	0.0	0.0	18.7	67.8	76.3	80.9	82.0	80.9	79.7	75.8	69.5	40.7	28.3	0.0	0.0	700.5
9 381	0.0	0.0	26.6	66.7	76.3	80.3	67.3	15.3	35.6	36.2	31.7	35.1	17.0	0.0	0.0	487.9
10 381	0.0	0.0	40.7	39.6	72.4	77.5	80.3	81.4	79.7	76.9	71.2	59.9	27.7	0.0	0.0	707.3
11 381	0.0	0.0	43.5	69.0	76.3	79.2	79.7	79.2	79.2	49.2	23.2	54.3	29.4	0.0	0.0	662.1
12 381	0.0	0.0	27.1	59.9	74.1	76.3	78.6	79.2	65.0	63.3	64.5	54.8	27.1	0.0	0.0	670.0
13 381	0.0	0.0	24.9	24.3	58.8	60.5	66.2	65.6	62.8	54.8	54.3	57.1	30.0	0.0	0.0	559.2
14 381	0.0	0.0	49.8	68.4	76.9	78.6	80.9	58.2	70.1	76.9	72.9	62.8	32.2	0.0	0.0	727.7
15 381	0.0	0.0	14.7	48.6	43.5	72.9	59.4	56.0	49.2	62.8	29.4	17.5	0.6	0.0	0.0	454.6
16 381	0.0	0.0	0.0	0.6	4.0	47.5	73.5	75.2	76.9	76.9	70.7	58.2	30.0	0.0	0.0	513.4
17 381	0.0	0.0	41.3	63.3	70.1	79.7	76.3	76.3	80.3	57.1	62.2	58.8	31.1	0.0	0.0	696.6
18 381	0.0	0.0	44.1	63.3	65.0	71.8	60.5	70.1	80.3	80.3	58.8	57.1	38.4	0.0	0.0	689.6
19 381	0.0	0.0	57.1	69.0	78.0	48.1	66.7	66.7	78.0	78.6	73.5	65.6	33.4	0.6	0.0	715.2
20 381	0.0	0.6	57.7	54.8	74.6	78.6	82.0	82.5	72.4	75.8	69.0	66.7	35.6	0.0	0.0	750.3
21 381	0.0	0.6	56.5	69.5	76.3	76.9	43.5	33.4	73.5	71.2	54.8	12.4	22.6	0.0	0.0	591.4
22 381	0.0	2.3	57.7	70.1	76.9	79.2	6.8	14.1	64.5	69.5	35.6	60.5	29.4	0.0	0.0	566.5
23 381	0.0	3.4	39.6	67.3	74.1	52.0	72.4	64.5	71.2	76.9	69.5	61.1	27.1	1.1	0.0	680.2
24 381	0.0	1.7	41.6	52.6	71.8	69.0	57.1	51.5	75.2	75.2	63.9	52.0	22.1	0.6	0.0	634.4
25 381	0.0	0.0	0.6	34.5	58.2	62.8	42.4	70.1	79.2	76.9	63.9	53.1	11.9	0.6	0.0	554.1
26 381	0.0	0.0	33.4	53.1	66.2	64.5	24.9	21.5	53.1	69.5	66.2	54.8	17.0	0.6	0.0	524.7
27 381	0.0	0.0	9.0	24.9	72.4	76.9	76.9	74.6	71.8	72.9	67.3	40.1	17.5	0.0	0.0	604.4
28 381	0.0	1.1	50.3	23.7	31.7	59.4	76.3	79.7	22.1	19.2	1.1	27.7	14.1	0.0	0.0	406.5
29 381	0.0	0.0	2.8	0.6	35.6	35.6	78.0	82.0	80.3	77.5	74.1	65.0	33.4	0.6	0.0	565.4
30 381	0.0	0.0	2.3	0.0	24.3	72.9	79.2	81.4	73.5	16.4	20.9	65.0	30.5	0.0	0.0	466.5
31 381	0.0	0.6	29.4	48.1	40.7	38.4	72.9	76.9	79.2	79.7	76.3	66.2	36.2	0.0	0.0	644.6
AVERAGE	0.0	0.3	30.5	46.9	61.0	69.0	69.0	67.4	69.2	65.1	56.9	53.8	27.5	0.3	0.0	617.0
MAXIMUM	0.0	3.4	57.7	70.1	78.0	80.9	82.0	82.5	80.3	80.3	76.3	66.7	49.2	6.2	0.0	750.3
MINIMUM	0.0	0.0	0.0	0.0	0.0	35.6	6.8	14.1	22.1	9.0	1.1	12.4	0.6	0.0	0.0	406.5

PIONEER MILL DIRECT STATION 50 HOURLY SOLAR RADIATION - CAL./SQ. CM

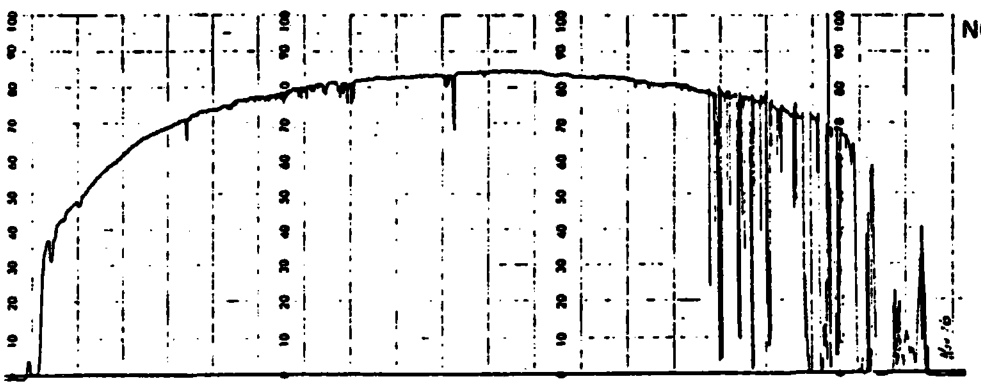
HOUR DAY	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	TOTAL
1 481	0.0	0.0	23.2	40.7	56.0	71.2	71.8	74.1	64.5	44.7	54.8	58.8	32.8	0.0	0.0	592.5
2 481	0.0	0.0	11.3	5.1	7.4	11.9	38.4	66.2	72.4	71.8	65.0	56.5	29.4	0.0	0.0	435.4
3 481	0.0	0.6	44.1	65.6	72.4	74.6	71.8	74.6	69.0	68.4	42.4	43.0	23.2	0.0	0.0	649.6
4 481	0.0	0.0	34.5	65.0	75.8	78.6	80.9	81.4	78.0	76.3	96.1	61.1	33.9	0.0	0.0	761.6
5 481	0.0	9.0	59.9	71.8	78.6	80.9	82.5	82.5	81.4	79.2	52.6	22.1	22.1	0.0	0.0	722.6
6 481	0.0	9.0	6.2	61.1	74.6	76.9	75.8	77.5	76.3	72.9	69.5	59.4	31.7	0.0	0.0	690.9
7 481	0.0	9.0	56.5	57.7	71.2	71.2	71.2	77.5	74.6	39.0	54.8	41.3	21.5	0.0	0.0	645.7
8 481	0.0	10.2	55.4	63.9	65.6	75.2	76.9	80.9	80.3	78.6	72.9	63.3	41.8	0.6	0.0	765.6
9 481	0.0	10.2	58.2	69.5	76.3	74.6	55.4	67.8	62.2	17.5	0.6	0.0	0.6	0.6	0.0	493.6
10 481	0.0	12.4	56.0	44.7	64.5	60.5	65.0	69.0	56.0	31.1	34.5	24.3	2.8	0.0	0.0	520.7
11 481	0.0	8.5	54.3	70.7	76.9	71.2	80.3	78.0	81.4	75.2	74.1	61.1	42.4	0.6	0.0	774.6
12 481	0.0	8.5	54.3	70.7	76.9	71.2	80.3	78.0	81.4	75.2	74.1	61.1	42.4	0.6	0.0	774.6
13 481	0.0	14.7	54.8	47.5	72.4	65.0	70.1	53.1	22.1	42.4	57.1	57.1	41.8	0.6	0.0	598.8
14 481	0.0	6.2	20.4	20.9	19.8	38.4	27.1	15.8	15.8	7.9	2.3	0.6	0.0	0.0	0.0	175.3
15 481	0.0	0.6	25.4	54.8	37.3	29.4	15.8	0.6	48.1	64.5	71.8	61.6	38.4	0.6	0.0	448.9
16 481	0.0	13.6	59.4	69.0	74.6	71.2	62.2	42.4	44.1	58.8	68.4	22.1	27.7	0.6	0.0	614.0
17 481	0.0	13.6	54.8	67.3	63.3	71.2	69.0	53.7	62.8	58.8	63.9	59.4	4.5	0.6	0.0	642.9
18 481	0.0	0.6	1.1	31.1	9.6	14.7	56.5	78.6	78.6	76.3	70.7	59.9	39.0	1.1	0.0	517.9
19 481	0.0	7.4	55.4	66.7	71.2	74.6	76.3	75.8	75.8	71.2	53.1	52.0	30.5	1.1	0.0	711.3
20 481	0.0	4.0	55.4	62.8	69.5	69.5	71.8	46.9	51.5	67.3	45.8	38.4	28.3	0.6	0.0	611.8
21 481	0.0	2.8	23.7	58.8	69.5	41.8	23.2	19.8	69.5	56.0	57.7	36.2	16.4	0.6	0.0	476.1
22 481	0.0	13.6	56.5	61.6	71.8	74.6	74.6	73.5	76.3	70.7	46.9	36.8	33.4	0.6	0.0	690.9
23 481	0.0	0.0	48.6	50.9	14.7	30.5	63.9	69.0	65.6	72.9	71.8	57.7	13.0	1.1	0.0	559.7
24 481	0.0	12.4	57.7	72.9	65.6	76.9	81.4	80.9	79.2	78.0	67.8	40.1	37.3	0.6	0.0	750.8
25 481	0.0	20.4	62.8	69.5	77.5	80.3	79.2	75.2	79.2	76.3	64.5	59.4	36.8	0.6	0.0	781.4
26 481	0.0	4.0	61.6	71.8	69.0	62.8	53.7	82.0	79.2	76.9	73.5	63.3	35.6	0.6	0.0	733.9
27 481	0.0	4.0	2.8	37.3	70.1	49.8	48.1	30.0	12.4	5.1	15.3	25.4	11.3	0.0	0.0	311.5
28 481	0.0	15.3	59.9	59.9	63.3	76.3	59.9	65.0	52.6	6.2	12.4	50.9	18.7	0.0	0.0	540.5
29 481	0.0	0.6	0.0	9.0	2.8	4.0	0.6	0.6	12.4	0.0	0.6	0.6	1.7	0.0	0.0	32.8
30 481	0.0	12.4	26.0	33.9	32.8	46.9	10.7	53.1	74.1	64.5	65.6	54.8	10.2	0.0	0.0	485.1
AVERAGE	0.0	7.4	41.3	54.4	58.4	59.9	59.8	60.8	62.6	56.1	53.4	44.3	25.0	0.4	0.0	583.7
MAXIMUM	0.0	20.4	62.8	72.9	78.6	80.9	82.5	82.5	81.4	79.2	96.1	63.3	42.4	1.1	0.0	781.4
MINIMUM	0.0	0.0	0.0	5.1	2.8	4.0	0.6	0.6	12.4	0.0	0.6	0.0	0.0	0.0	0.0	32.8

PIONEER MILL DIRECT STATION 50 HOURLY SOLAR RADIATION - CAL./SQ. CM

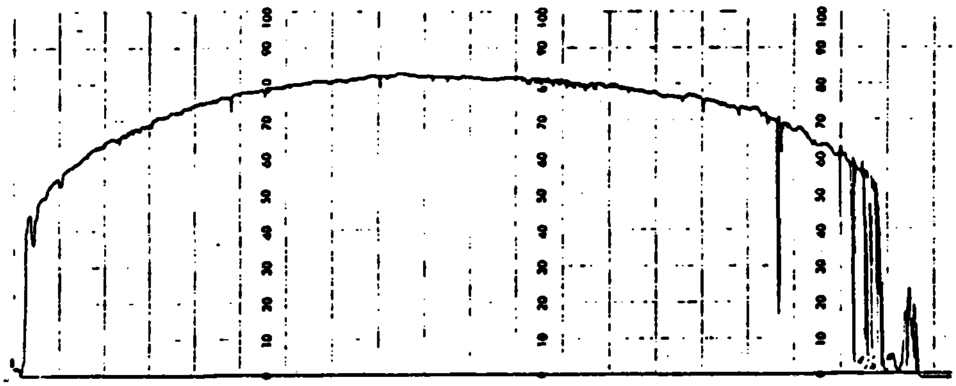
HOUR DAY	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	TOTAL
1 581	0.0	6.8	46.4	60.5	66.2	77.5	78.0	76.3	74.1	67.6	70.1	63.9	30.0	0.6	0.0	718.1
2 581	0.0	13.6	61.6	68.4	78.0	80.3	74.1	80.3	70.7	74.1	67.3	62.2	23.7	0.0	0.0	754.2
3 581	0.0	23.7	12.4	36.2	61.1	35.6	43.0	62.2	58.8	43.0	70.1	53.1	22.6	0.6	0.0	522.4
4 581	0.0	25.4	51.5	71.2	76.3	74.1	76.3	71.8	78.6	75.6	70.1	13.6	0.0	0.0	0.0	684.7
5 581	0.0	24.9	58.2	69.0	73.5	76.3	77.5	56.5	37.3	57.7	68.4	55.4	15.8	0.0	0.0	670.6
6 581	0.0	2.3	24.3	24.9	63.3	55.4	44.1	32.8	0.6	9.0	2.3	14.1	0.6	0.0	0.0	273.7
7 581	0.0	25.4	59.4	49.2	27.7	74.1	41.8	46.4	71.2	38.4	39.6	52.6	1.7	0.0	0.0	527.5
8 581	0.0	23.7	57.7	65.0	71.2	66.7	65.0	50.9	43.5	61.1	42.4	14.7	2.8	0.0	0.0	564.8
9 581	0.0	7.4	35.1	58.2	72.4	33.4	19.8	43.0	40.7	33.4	41.3	53.7	10.2	0.6	0.0	448.9
10 581	0.0	18.1	43.0	66.7	74.1	76.3	77.5	74.1	74.1	72.4	67.8	52.0	11.3	0.6	0.0	707.9
11 581	0.0	1.7	6.5	33.4	60.5	65.0	64.5	53.1	65.0	56.0	62.8	53.7	18.7	0.6	0.0	543.3
12 581	0.0	0.0	4.5	44.7	13.0	2.8	4.5	2.3	28.8	9.6	2.3	1.7	11.9	0.0	0.0	126.1
13 581	0.0	10.4	54.8	26.6	45.2	71.2	35.1	40.1	50.3	55.4	53.1	39.6	11.3	0.0	0.0	499.2
14 581	0.0	0.0	29.4	56.5	60.5	64.5	69.5	63.3	63.9	66.2	57.1	46.4	15.8	0.0	0.0	593.1
15 581	0.0	0.0	33.4	56.0	23.2	42.4	34.5	41.3	67.8	68.4	40.1	15.3	18.1	0.0	0.0	440.4
16 581	0.0	0.0	10.4	26.0	56.0	15.8	52.6	59.9	70.1	71.8	61.1	58.8	19.8	0.0	0.0	506.3
17 581	0.0	0.0	24.3	66.4	48.1	76.3	59.9	76.9	75.8	74.6	69.5	56.5	7.9	0.0	0.0	638.3
18 581	0.0	0.6	0.6	0.6	1.1	1.7	17.0	61.6	2.3	40.7	64.5	57.7	17.5	0.0	0.0	265.7
19 581	0.0	0.6	52.6	65.6	73.5	49.8	24.9	49.8	35.1	64.5	56.0	26.0	6.2	0.0	0.0	504.3
20 581	0.0	0.0	0.6	7.9	24.3	6.8	31.7	76.3	76.9	73.5	70.1	57.1	20.9	0.0	0.0	446.1
21 581	0.0	13.6	56.5	53.7	17.5	12.4	53.1	78.6	39.0	58.2	57.1	58.2	22.1	0.6	0.0	520.7
22 581	0.0	1.7	39.6	63.9	30.0	57.7	70.7	75.2	77.5	63.9	71.8	50.3	18.1	0.0	0.0	620.2
23 581	0.0	0.0	0.6	22.6	27.7	28.3	15.8	59.4	73.5	56.0	65.0	57.7	20.4	0.0	0.0	426.9
24 581	0.0	12.4	56.8	56.8	75.8	45.8	72.4	80.3	79.7	76.3	71.2	52.6	23.2	0.6	0.0	707.9
25 581	0.0	12.4	44.7	54.3	50.3	45.8	58.8	26.0	63.3	62.2	33.9	1.7	0.6	0.0	0.0	454.0
26 581	0.0	18.1	59.4	63.3	72.9	76.9	72.9	78.0	75.2	77.5	72.4	31.7	23.2	0.0	0.0	721.4
27 581	0.0	14.7	61.6	36.2	76.3	56.0	74.1	65.6	4.0	16.4	37.3	2.3	0.6	0.6	0.0	445.5
28 581	0.0	0.0	0.0	0.6	10.2	8.5	17.0	16.4	48.6	77.5	72.4	44.7	26.0	0.6	0.0	322.3
29 581	0.0	4.5	50.3	71.2	71.8	76.9	65.6	36.2	56.0	58.2	32.2	24.9	17.0	0.6	0.0	565.4
30 581	0.0	7.9	61.6	67.3	65.0	74.6	69.5	65.0	71.2	49.2	11.3	28.8	2.3	0.0	0.0	573.9
31 581	0.0	0.0	22.1	37.3	61.1	49.2	45.2	20.4	52.6	54.8	27.1	18.7	19.2	0.6	0.0	408.2
AVERAGE	0.0	8.9	36.4	47.9	52.5	50.9	51.8	55.5	55.7	56.9	52.5	39.3	14.2	0.2	0.0	522.7
MAXIMUM	0.0	25.4	61.6	71.2	78.0	80.3	78.0	80.3	79.7	77.5	72.4	63.9	30.0	0.6	0.0	754.2
MINIMUM	0.0	0.0	0.0	0.6	1.1	1.7	4.5	2.3	0.6	9.0	2.3	1.7	0.0	0.0	0.0	126.1

INSOLATION (W/m²) – LAHAINA PYRHELIOMETER
NOVEMBER 16-22, 1980

TIME	SUNDAY NOV 16	MONDAY NOV 17	TUESDAY NOV 18	WEDNESDAY NOV 19	THURSDAY NOV 20	FRIDAY NOV 21	SATURDAY NOV 22
8:00	72.3	183.1	203.6	229.9	249.6	78.8	131.4
9:00	512.3	735.6	761.8	761.8	735.6	689.6	348.1
10:00	801.3	847.2	860.4	840.6	781.6	748.7	617.4
11:00	919.5	886.6	912.9	926.0	807.8	807.8	794.7
12:00	945.8	912.9	919.5	939.0	801.2	919.5	650.2
1:00	939.2	926.0	926.0	939.0	673.5	906.3	781.6
2.00	919.5	912.9	906.3	926.0	853.8	880.0	853.8
3:00	873.5	873.5	834.1	886.6	820.9	702.7	768.4
4:00	788.1	794.7	775.0	788.1	683.0	466.3	643.6
5:00	578	630.5	190.5	604.0	499.0	426.9	374.4
6:00	19.7	19.7	0	26.3	263.0	26.3	26.3



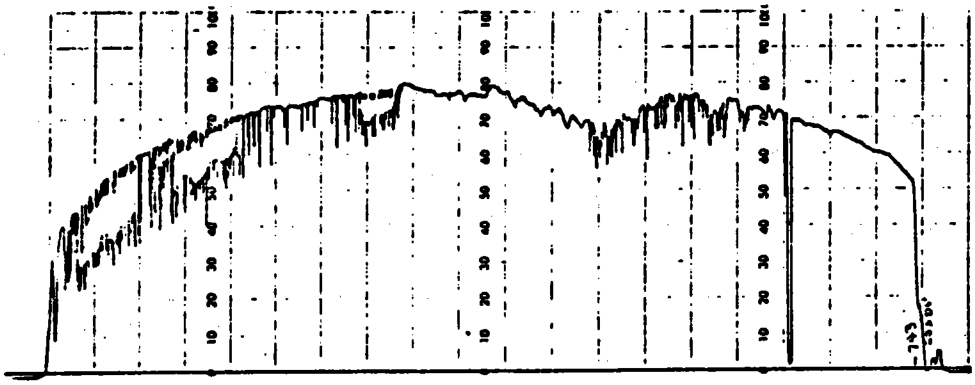
NOV. 16



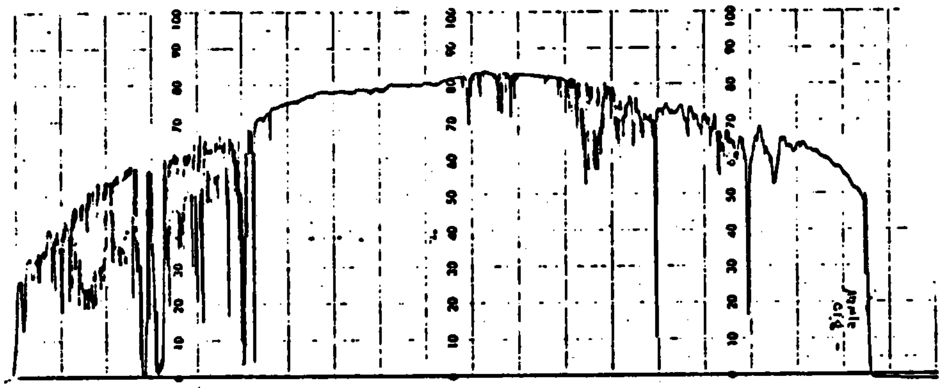
NOV. 17

NOV. 18

NOV. 19



NOV. 20



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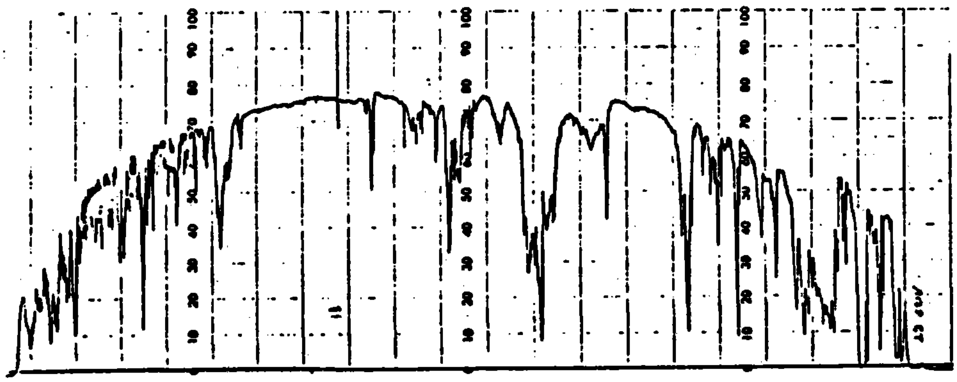
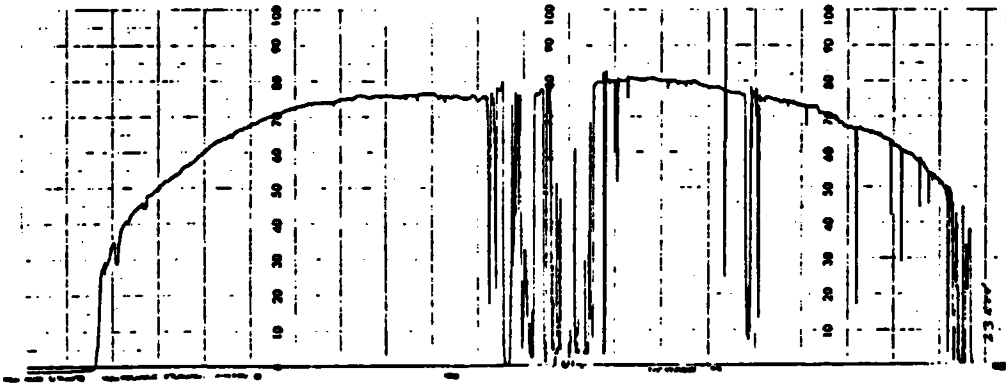


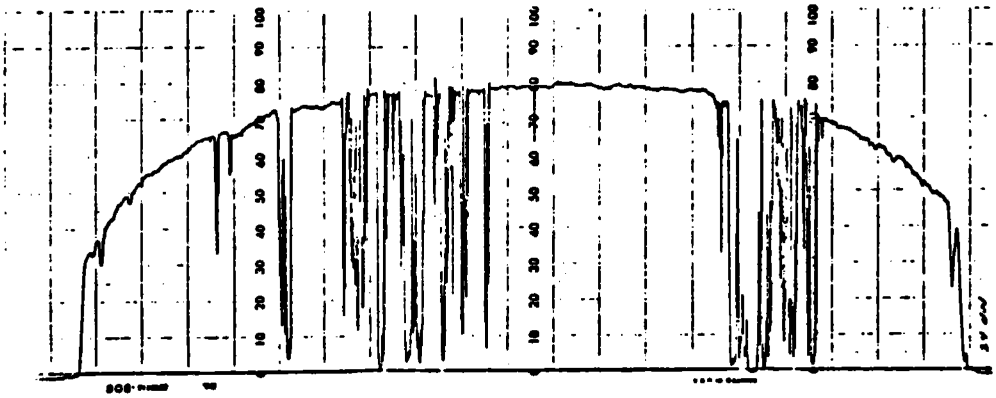
NOV. 22

INSOLATION (W/m^2) – LAHAINA PYRHELIOMETER
NOVEMBER 23-29, 1980

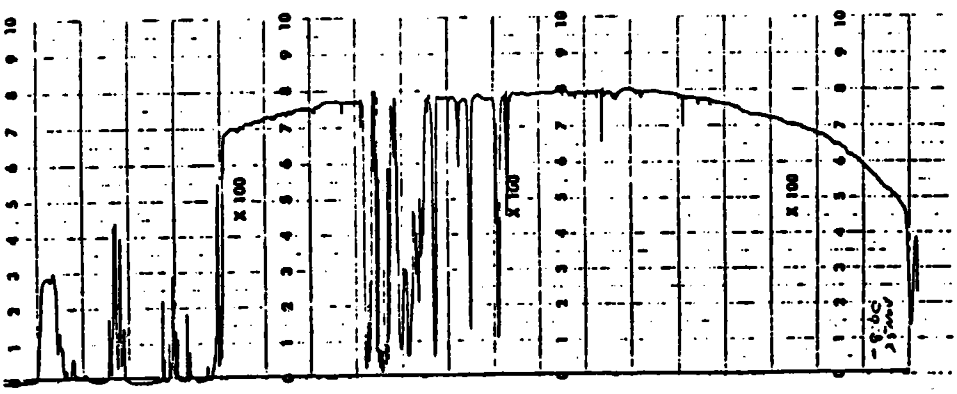
TIME	SUNDAY NOV 23	MONDAY NOV 24	TUESDAY NOV 25	WEDNESDAY NOV 26	THURSDAY NOV 27	FRIDAY NOV 28	SATURDAY NOV 29
8:00	151.1	.	243.0	13.1	229.9	229.9	243.0
9:00	702.7	709.3	735.6	216.7	709.3	748.7	761.8
10:00	807.9	361.2	847.2	669.9	827.5	860.4	860.4
11:00	860.4	827.5	893.2	873.5	893.2	906.3	913.0
12:00	623.9	893.2	886.6	906.3	919.5	932.6	945.7
1:00	518.8	827.5	748.7	906.3	926.0	926.0	952.3
2:00	853.8	564.8	577.9	886.6	847.2	912.9	926.0
3:00	840.6	676.5	827.5	702.7	748.7	866.9	880.0
4:00	755.3	742.2	111.6	525.4	729.0	781.5	794.7
5:00	532.0	564.8	78.8	45.9	348.0	571.4	361.2
6:00	32.8	39.4	32.8	26.3	13.1	45.9	13.1



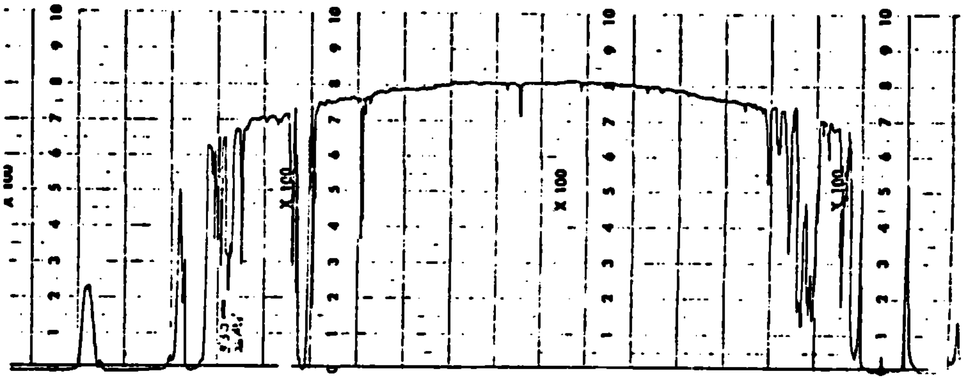
NOV. 23



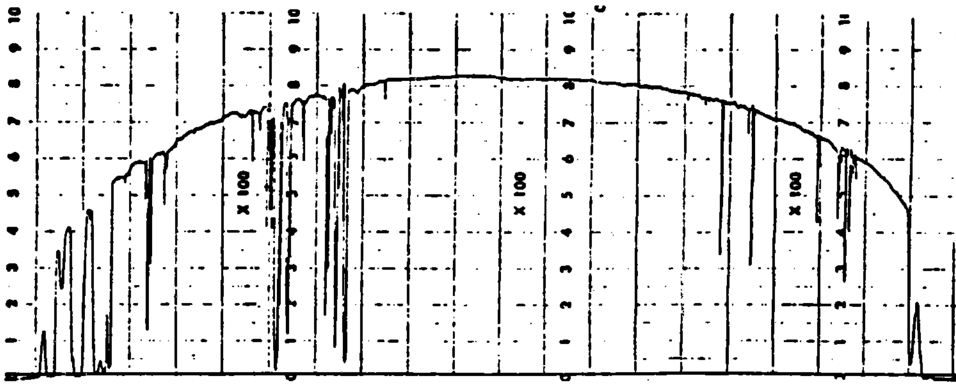
NOV. 24



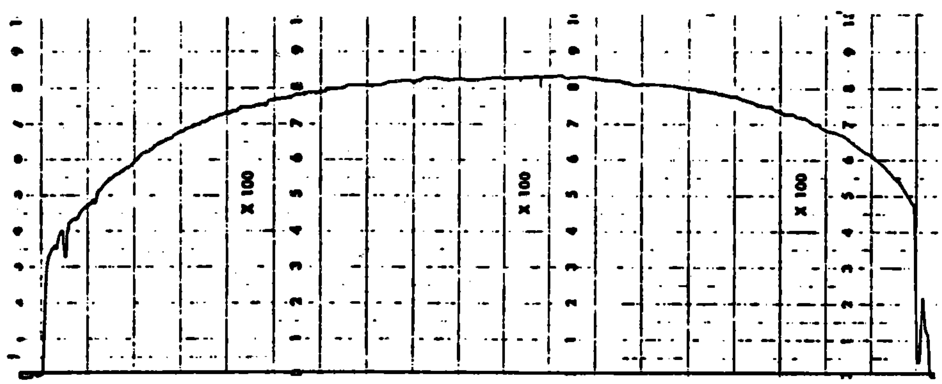
NOV. 25



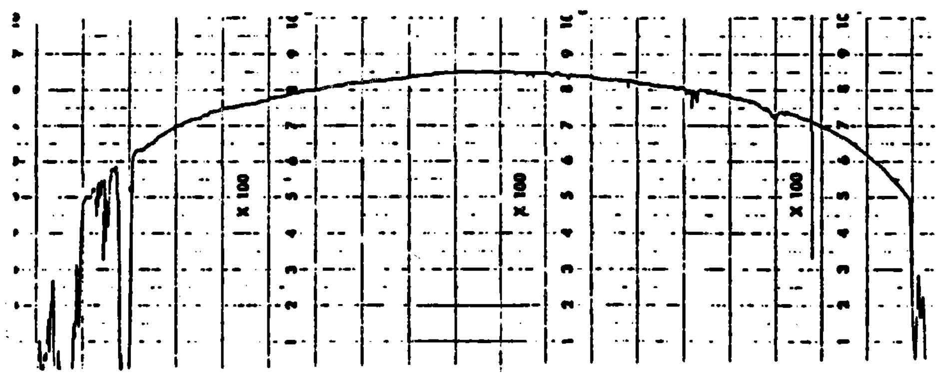
NOV. 26



NOV. 27



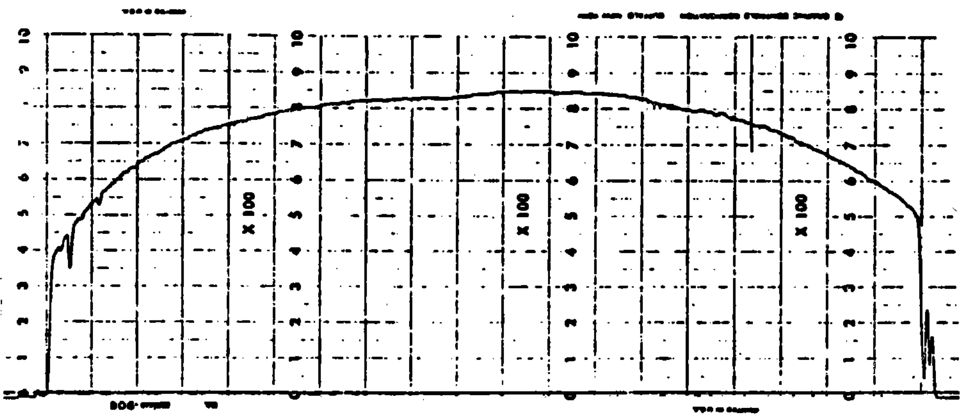
NOV. 28

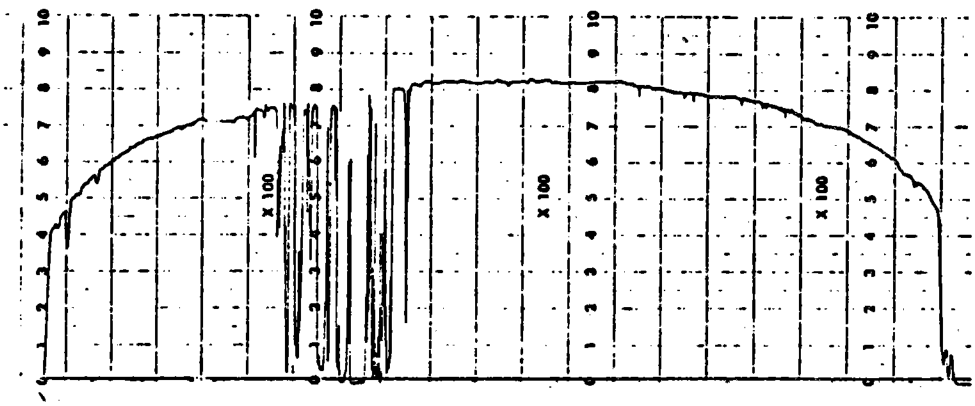


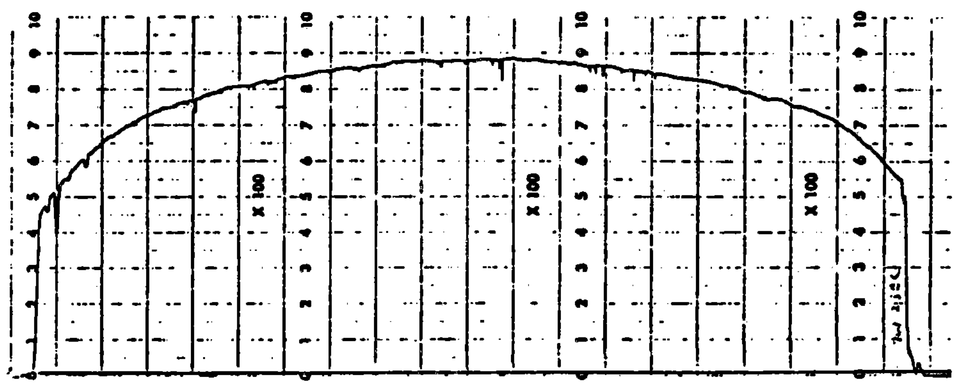
NOV. 29

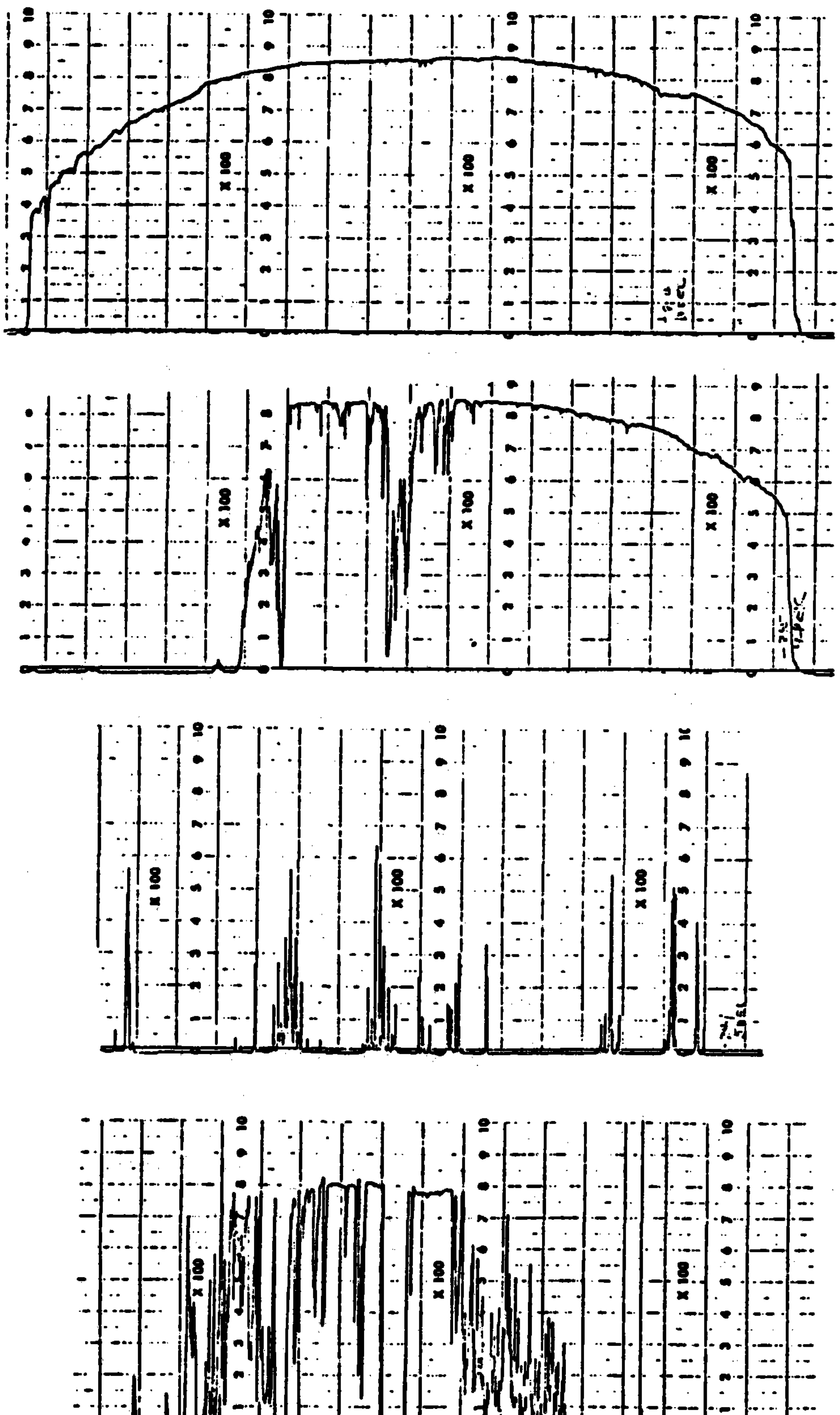
INSOLATION (W/m²) – LAHAINA PYRHELIOMETER
NOVEMBER 30 – DECEMBER 6, 1980

TIME	SUNDAY NOV 30	MONDAY DEC 1	TUESDAY DEC 2	WEDNESDAY DEC 3	THURSDAY DEC 4	FRIDAY DEC 5	SATURDAY DEC 6
8:00	236.4	217.6	229.9	210.2	183.9	6.6	6.6
9:00	735.6	742.1	801.2	794.7	735.6	32.8	6.6
10:00	860.4	853.8	899.8	886.6	860.4	13.1	13.1
11:00	919.5	899.8	952.3	952.3	919.5	13.1	190.5
12:00	952.3	919.5	985.1	972.0	932.6	39.4	623.9
1:00	939.2	926.0	985.1	965.4	755.3	32.8	591.1
2:00	926.0	558.2	972.0	952.3	860.4	26.3	525.4
3:00	886.6	512.2	926.0	906.3	197.0	6.6	348.1
4:00	807.8	794.7	853.8	788.1	0	19.7	19.7
5:00	623.9	637.1	689.6	597.6	6.6	0	6.6
6:00	52.5	52.5	59.1	46.0	6.6	0	0









Appendix C

SITE INSOLATION MODEL

This Appendix describes the solar model for direct normal insolation at Pioneer Mill. It was first used in the Task 2 comparison of annual performance for the two candidate heliostat field sites and later modified to improve correspondence with the site measurements tabulated in Appendix B. The insolation model is based upon the ASHRAE clear sky model for direct normal insolation with modifications to make it applicable to Hawaii and Pioneer Mill.

The ASHRAE model for direct insolation is given by the equation

$$I_{DN} = \frac{A\ (CN)}{\exp\ (B/\sin E)}$$

where

A = apparent solar irradiation at air mass = 0

B = atmospheric extinction coefficient

E = solar elevation (angle of sun vector above horizon)

CN = clearness number

The normal seasonal variation of the coefficients A and B due to changes in the dust and water content of the atmosphere were assumed to be representatives of the continental United States but not representative of Hawaii.

Professor Ekern and others at the University of Hawaii Natural Energy Institute agreed that for Pioneer Mill, it would be more accurate to assume no seasonal variation in turbidity of the atmosphere. The model was therefore modified to give the following relationship:

$$I_{DN} = \frac{I_0 \ (CN)}{\exp. \ (.142/\sin E)}$$

where

I_0 = solar irradiation above the earth's atmosphere (varies only with distance from the sun).

The value of 0.8251 was then assigned to the clearness number in order to make the resulting direct normal incidence insolation value calculated for November agree with the peak mid-day measurements at Pioneer Mill taken during November of 1980, (953 W/m^2).

The resulting model was used to calculate clear sky insolation for the 15th day of each month. These insolation values were used, as input to the computer program STEAEC, to calculate typical clear sky performance of the Task 2 candidate heliostat fields. The estimates of actual annual performance for each heliostat field was obtained by multiplying monthly clear sky performance by weather factors for each month of the year.

The weather factors were formulated by taking the ratio of existing global radiation measurements, recorded at Lahaina, to global radiation values calculated from the ASHRAE global model (also modified to remove seasonal variations in the atmosphere). These weather factors are tabulated in Table 3-5, in the main body of this report. The resulting estimate of annual average daily direct normal insolation was 7.4 $kWh/m^2/day$.

The insolation model was reevaluated after 5 months of site measurements had been gathered in preparation for the performance analysis of the conceptual design. It was found that the calculation of weather factors based on the comparison of the global model with the global site data did not result in a good correlation with the observed weather factors for 5 months of direct data. In clear months, the weather factors were found to agree closely for direct and global data. But during relatively cloudy months, the weather factor for direct data was lower than that for global data. This result was expected, and a better method of predicting weather factors for direct insolation was developed.

The three sets of solar data that were available and useful in updating the insolation model were:

- Global insolation data by month for 48 years collected at the Makiki station near the University of Hawaii campus by the Hawaiian Sugar Planter's Association.
- Direct normal and global hourly integrated data from Holmes Hall at the University of Hawaii near Honolulu, covering the period from January 1979 through March 1981.
- Direct normal and global hourly integrated data from Amfac's measuring station near the Pioneer Mill Offices, covering the period from October 1980 through March 1981.

Comparison of the global and direct data for Holmes Hall and Pioneer Mill showed that the diffuse fraction at Holmes Hall averaged 29.5 percent while Pioneer Mill averaged 20 percent over the same 6 month time period.

This leads to the conclusion that the direct insolation at Pioneer Mill is higher than Holmes Hall, and the direct measurements confirm this, although there is significant day to day variation.

Using the Makiki long term monthly data as a baseline, monthly direct insolation valves were estimated for both Holmes Hall and Pioneer Mill using the devised diffuse fractions above. The clear day totals for each month were also estimated using the ASHRAE model. The actual direct data from the two sites was then compared to these estimates. The results are shown in Figure C-1.

Reasonably good agreement was found between the measured data and the solar model. The clear sky data from Pioneer Mill and Holmes Hall are very close, with Holmes Hall appearing to have slightly higher values. This difference may be due to the location of the Pioneer Mill instruments, however, which is blocked by the mill buildings for the last hour of the day for particular solar declinations.

The average data shows good agreement with the model although the variations from month to month are significant. It was concluded that the solar model was sufficient for this study. The annual weather factor was calculated to be 0.74, with only a small variation from month to month. The revised estimate of annual average direct insolation was found to be 6.85 kWh/m^2/day.

Significant uncertainty remains about the summer insolation characteristics. Measurements are being continued by Amfac but were not available for this report.

The 1979-1980 Holmes Hall data shows lower than predicted clear day data. Whether this same phenomenon exists at Pioneer Mill is unknown. The model based on long-term average data does not have this characteristic. The long-term Makiki data also shows 20 to 30 year cycles in annual insolation, and the 1970's are within the lower quartile of the data.

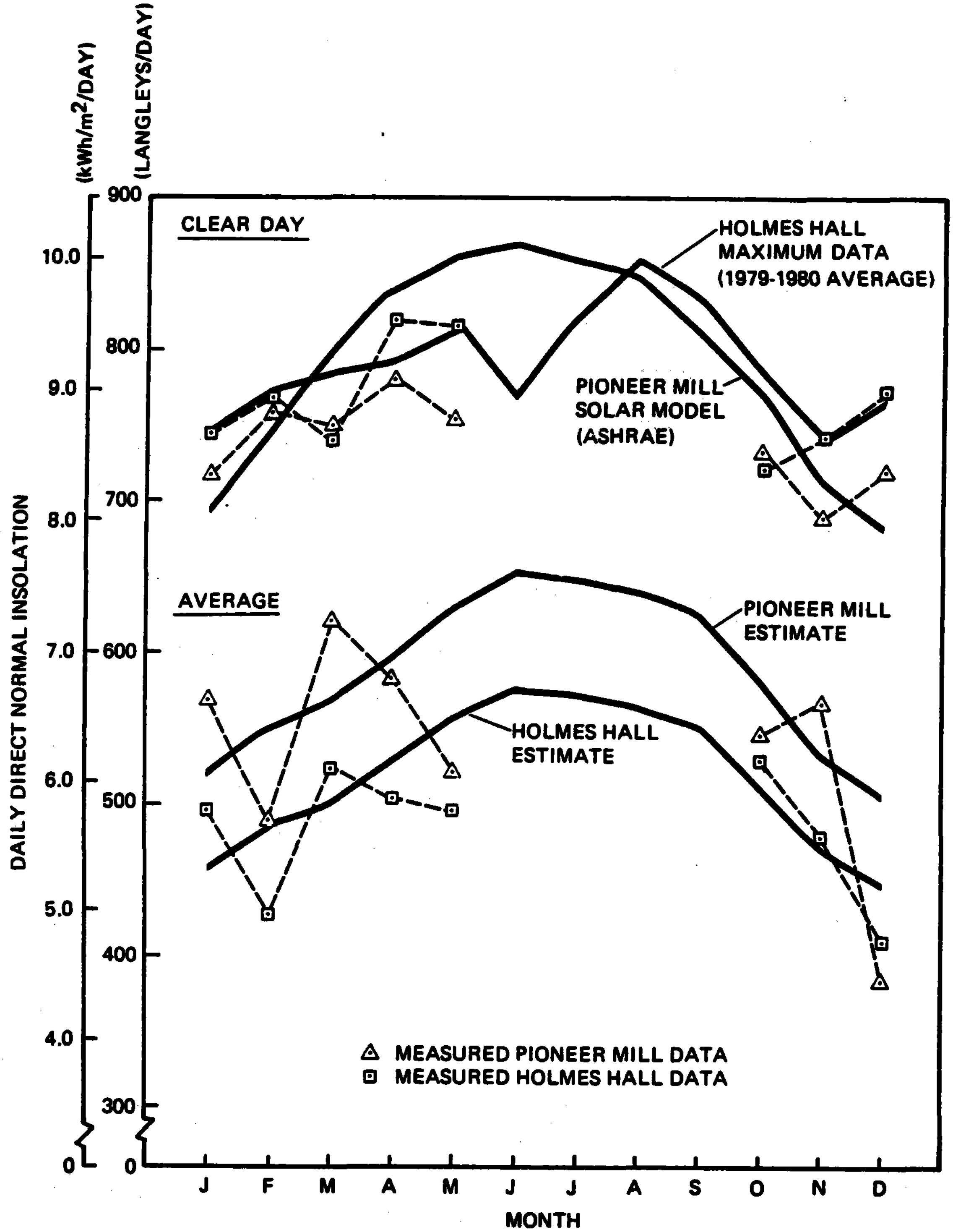


Figure C-1 DIRECT INSOLATION COMPARISON

It was thought at the beginning for the study that a correllation between the "wig-wag" instrument readings and direct normal insolation could be developed. It was later found that the wig-wag characteristics are much closer to global instruments and no correllation with direct data was possible.

APPENDIX D

TYPICAL UTILITY POWER PURCHASE AGREEMENT

This appendix contains an example of an agreement between a sugar mill – Hawaiian Commercial and Sugar Company – and the Maui Electric Company, for the sale of electric power to the utility. Although not specific to Pioneer Mill, it is the most recent such contract negotiated on Maui. A new contract for Pioneer Mill is not necessary as a result of the solar retrofit, since no capacity addition is involved and little additional power is generated. The contract on the following pages is considered by Amfac to be representative of future agreements for the sugar mills.

The sales price for electric power in the contract is tied to the Maui Electric average fuel cost per kwh for the preceeding quarter. Table D-1 presents some recent values for this quantity. It is assumed the displaced fuel will be from the diesel units if they are operating, since they have the highest incremental fuel cost to the utility. Additional information on the Maui Electric Company System is presented in Appendix F.

Table D-1

MAUI ELECTRIC COMPANY FUEL COST DATA

	Year Ending 12/31/80		4-month Period Ending 4/30/81	
	Fuel Oil	Diesel	Fuel Oil	Diesel
BBL Oil Consumed	467,749	358,798	137,615	170,840
Avg. Oil Cost/BBL	$ 23.38	$ 35.28	$ 28.06	$ 40.45
Cost/kWh Generated	$0.0502	$0.0568	$0.0598	$0.0644

POWER PURCHASE AGREEMENT

BETWEEN

MECO AND

ALEXANDER & BALDWIN, INC. DBA

HAWAIIAN COMMERCIAL & SUGAR COMPANY

THIS CONTRACT, made this 31st day of July, 1980, by and between Alexander & Baldwin, Inc., a Hawaii corporation, doing business as Hawaiian Commercial & Sugar Company (hereinafter called "Seller"), and Maui Electric Company, Limited, a Hawaii corporation (hereinafter called "MECO"),

W I T N E S S E T H T H A T:

WHEREAS, Seller is engaged in the business of growing sugar cane and in the manufacture of sugar and molasses, and in connection therewith owns and operates power plants for the manufacture of electric power primarily from non-fossil fuel sources for use in its own facilities and practices; and

WHEREAS, it is the policy of the State of Hawaii and of the United States Congress to encourage increased capacity for and use of non-fossil fuels in order to reduce dependence upon fuel imports for the generation of electricity; and

WHEREAS, electric power can be produced and its electricity generating capacity can be increased and a portion thereof made available by Seller in excess of its own needs; and

WHEREAS, Seller is willing to sell such electric energy and to make such generating capacity available to

MECO, and MECO is willing to purchase such electric energy and to make payments to secure availability of such generating capacity.

NOW THEREFORE, in consideration of the premises and the respective promises herein of the parties hereto, it is mutually agreed as follows:

I. DEFINITIONS

A. Firm Energy. The term "Firm Energy" as used herein means the scheduled amounts of energy in kilowatt hours (kwh) which Seller has agreed to deliver to MECO under MECO Dispatch and MECO has agreed to purchase from Seller within agreed upon time periods, all as set forth in Section II.A. hereof and elsewhere herein.

B. Firm Capacity. The term "Firm Capacity" as used herein means the scheduled amounts of capacity in kilowatts which Seller has agreed to make available to MECO under MECO Dispatch within particular weeks, or portions thereof, and which MECO has agreed to purchase.

C. Unscheduled Energy. The term "Unscheduled Energy" as used herein means the unscheduled amounts of energy in kilowatt hours (kwh) which Seller can make available and has agreed to deliver to MECO, and MECO has agreed to accept.

D. Emergency Energy. The term "Emergency Energy" as used herein means energy requested by MECO and delivered to MECO by Seller as a direct result of a request by MECO of Emergency Capacity (which energy shall be measured by the Emergency Capacity provided as a result of such request multiplied by the hours over which such Emergency Capacity is provided) or a request by MECO for Firm Energy deliveries above and beyond 105% of the weekly Firm Energy agreed to, as set forth in Section II.A. It is expressly agreed that increased energy deliveries approved and agreed to by MECO pursuant to Sections II.A.2., II.A.3., and III.A.2.c. hereof shall not be considered Emergency Energy.

E. Emergency Capacity. The term "Emergency Capacity" as used herein means capacity requested by and made available to MECO under MECO Dispatch by Seller, above and beyond the Firm Capacity agreed to, as set forth in Section II.B.

F. Electric Power. The term "Electric Power" as used herein means both capacity and energy.

G. Contract Week. The term "Contract Week" as used herein means the time period beginning 0000 Sunday and ending 2400 the following Saturday during the term of this Contract.

H. Calendar Month. The term "Calendar Month" as used herein means the period commencing on the first day of any month and terminating on the last day of the same month.

I. Calendar Quarter. The term "Calendar Quarter" as used herein means the three-month period commencing on January 1, April 1, July 1, or October 1 of any Calendar Year.

J. Calendar Year. The term "Calendar Year" as used herein means the period commencing on January 1 of any year and terminating on December 31 of the same year.

K. MECO Dispatch. The term "MECO Dispatch" as used herein means MECO's absolute and sole right, during any Contract Week, through supervisory equipment or otherwise, to control within the limits of sound engineering practices, both Firm and Emergency Energy and Capacity offered by Seller and accepted by MECO pursuant to this Agreement.

L. Shutdown Period. The term "Shutdown Period" as used herein means the consecutive eight-week period consisting of weeks two through nine, inclusive, of each Calendar Year.

M. Shutdown Weeks. The term "Shutdown Weeks" as used herein means the period of up to four consecutive weeks during each Shutdown Period which shall be agreed upon by Seller and MECO for the annual maintenance of Seller's power plant.

N. Power Factor. The term "Power Factor" as used herein means the ratio of the active power (kw) to apparent power (kva) at which Seller has agreed to deliver energy to MECO, as set forth in Section II.E.1. hereof.

O. On-Peak is the period beginning 0700 and ending 2100 hours daily, seven days a week.

P. Off-Peak is the period beginning 2100 hours and ending 0700 hours on the following day, seven days a week.

Q. Avoided Cost means "avoided cost" as defined by the Public Utility Regulatory Policies Act of 1978 and the regulations issued thereunder, or such equivalent term established by any new federal or state law or regulation, taking into account the factors affecting rates for purchases of electric energy or capacity or both from a qualifying facility by an electric utility thereunder.

R. PUC means the Public Utilities Commission of the State of Hawaii.

II. SELLER'S OBLIGATIONS

A. Obligations to Deliver Firm Energy

1. Seller shall furnish MECO with Firm Energy (kwh) under MECO Dispatch each week in the amount scheduled, as shown in Attachment I, or as otherwise agreed to under the provisions of this Contract.

2. Seller shall use its reasonable best efforts to deliver in each Contract Week at least 95% of the designated weekly Firm Energy amount. Except as provided in Section III.A.2.c. hereof, should there be a failure to deliver at least 95% of the Firm Energy commitment in any week, and such failure is not excused by the operation of Section VIII.A. hereof, the shortfall will be made up by Seller in the following eight (8) Contract Weeks by delivering Firm Energy in excess of 100% of the designated weekly Firm Energy amount for these weeks at such reasonable times and in such reasonable amounts for each Contract Week to be agreed to by Seller and MECO not less than three (3) days in advance of such Contract Week. Any failure to make up such shortfall shall result in a reduction in the number of kilowatt hours paid for by MECO. Such reduction shall be accomplished by deducting from the number of kilowatt hours actually delivered an amount equal to the number of kilowatt hours of shortfall below the 95% level.

3. Seller may request authority to increase the weekly Firm Energy deliveries by up to 15% above those shown in Attachment I for any particular Contract Week after Contract Week 44 of 1982 by delivering to MECO a written request to do so which is received by MECO no later than the Monday immediately preceding the first day of such Contract

Week. MECO shall thereafter approve or disapprove such request, or approve some lesser amount than stated in Seller's written request, by written response received by Seller at least four (4) days prior to the first day of such Contract Week. MECO shall not disapprove such request, nor approve some lesser amount than stated in Seller's request, unless (i) the MECO system is unable to reasonably accept such additional amounts of Firm Energy during such Contract Weeks, and/or (ii) the cost of such additional amounts of Firm Energy would exceed the cost to MECO of the energy that would be displaced by such amounts. If MECO fails to so respond to Seller's request at least four (4) days prior to the first day of such Contract Week, then such request shall be deemed automatically approved. Such agreed-upon increases in Firm Energy shall be paid for at the same rates as the originally agreed amounts of Firm Energy for such Contract Week and shall have no effect on Firm Capacity amounts.

B. Obligation to Guarantee Firm Capacity

1. Seller shall make available to MECO Firm Capacity (kw) under MECO Dispatch in the amounts and for the number of days shown in Attachment I herein on a 24-hour basis, or as otherwise agreed to under the provisions of this Contract.

2. Unless excused by reason of any event or circumstances described in Section VIII hereof, the failure by Seller to deliver the committed amount of Firm Capacity to MECO will result in a reduction in the amount paid to Seller by MECO in each instance where the capacity deficiency exists for more than two (2) continuous hours. In each such case the reduction in payment shall be $0.08 per kw for each full hour, including the two (2) hour grace period, that the deficiency exists.

3. Seller may request authority to increase the Firm Capacity provided under this Contract from Seller's generating facilities existing as of November 1, 1982 for the remaining years of the Contract by giving MECO written notice of its desire to do so at least three (3) months prior to the Calendar Year in which the increase is to be effective. MECO shall approve or disapprove such request prior to the Calendar Year in which the increase is to be effective. MECO shall approve such request unless the MECO system is unable to reasonably accept such increased capacity offered. If MECO approves the request, the capacity amounts shown in Attachment I shall be increased and made available by Seller as approved by MECO, effective as of the first day of the immediately following Calendar Year, and the additional kw shall be paid for at the Avoided Cost for MECO for such additional Firm Capacity at such time of notification, or at a rate otherwise agreed upon by the parties.

4. Seller shall have the right to decrease the Firm Capacity provided under this Contract under the following conditions:

a. Such right to reduce may be exercised only once during the term of this Contract, and shall be exercised by giving written notice of such decrease to MECO not less than three (3) years prior to the effective date of such decrease; PROVIDED, however, that such notice shall not be given prior to December 31, 1982.

b. The maximum Firm Capacity which Seller is obligated to commit to MECO under this Contract may not be reduced below six (6) megawatts.

c. As of a date three years prior to the effective date of such decrease, the Firm Capacity Charge payments payable by MECO hereunder as set forth in Section III.B.1. hereof shall be reduced by computing the payments as though the Firm Capacity reduction already were in effect. Seller shall continue to supply the originally agreed upon Firm Capacity during the three-year notification period, notwithstanding the reductions in the Firm Capacity Charge payments.

C. Obligation to Supply Emergency Capacity

Seller shall have no obligation to deliver Emergency Capacity, but shall make every effort to fulfill MECO's request without materially affecting Seller's operations, including but not restricted to factory operations, irrigation requirements and fuel supply.

D. Unscheduled Energy.

1. Seller shall have no obligation to offer Unscheduled Energy to MECO.

2. All energy, with the exception of Emergency Energy, supplied by Seller to MECO hereunder prior to Contract Week 45 of 1982 shall be Unscheduled Energy.

E. Power Factor and Rate of Energy Delivery

1. In satisfying all energy or capacity contracted for herein, Seller will provide reactive in proportion to real power in the range .85 lagging to 1.0 (unity) power factor.

2. It is understood that changes in the rate of energy delivery in excess of that provided under Section II.E.3. hereof under normal operating conditions may cause MECO to start or stop generating units due to resulting frequency excursion. Should such changes in the rate of energy delivery occur, Seller agrees to pay MECO, in addition to any other damages to which MECO may be entitled pursuant to Section XI.A. hereof, all out-of-pocket expenses of

starting and stopping its generating units; provided, however, that such out-of-pocket expenses shall be limited to the cost of fuel and manpower, if any, incurred by MECO over and above the fuel and manpower costs incurred by MECO during normal plant operations.

3. Unless otherwise requested by MECO, the rate of delivery of electric energy shall vary no more than plus or minus 500 kw from the rate established by MECO Dispatch. Rate of change of energy delivery shall not exceed 100 kw per minute unless a higher rate of changes is requested by MECO or caused by a MECO system disturbance.

F. Obligation to Maximize Cogenerated Energy

Seller shall make every reasonable effort to optimize, on a cost-benefit basis, cogenerated energy and biomass energy for delivery to MECO by: a) improving the thermal efficiencies by such techniques as greater use of vapors for processing, bagasse drying with flue gas; and b) optimizing the biomass availability and utilization by densifying and storing bagasse, growing and processing more cane recovering additional biomass from trash and use of other noncane biomass.

G. Seller's Shutdown Weeks

Notwithstanding any provision of this Contract to the contrary, Seller shall have the right during the Shutdown Period to shut down its power plant for up to the four consecutive Shutdown Weeks, in connection with the maintenance or repair of any plantation facility or for the convenience of its agricultural practices. The specific Shutdown Weeks shall be mutually agreed upon between Seller and MECO no later than the immediately preceding November 15. Seller shall have no obligation to deliver energy or capacity during the Shutdown Weeks.

III. MECO'S OBLIGATIONS

A. Energy Rates

1. Determination of Rates.

The rates for purchases of energy hereunder by MECO in any Calendar Quarter during the term of this Contract shall be determined for each Calendar Quarter by reference to MECO's average fuel cost per net kilowatt hour for the preceding computation period.

As used herein:

i) "MECO's average fuel cost per net kwh" means the average fuel cost incurred by MECO for fossil fuel generation, per net kilowatt hour, as reflected by MECO's recorded costs. MECO fossil fuel generation shall include, but not be limited to, all energy produced by bottoming cycle or combined cycle units to the extent that such generation is owned by MECO.

ii) "preceding computation period" means the three-month period preceding the Calendar Quarter for which the rate is being determined, lagged by one month. The following is a schedule of computation periods:

For energy purchased by MECO in the following Calendar Quarter:	Average fuel cost per net kwh shall be computed from the following preceding computation period:
January 1 through March 31	-- September 1 through November 30
April 1 through June 30	-- December 1 through February 28 c
July 1 through September 30	-- March 1 through May 31
October 1 through December 31	-- June 1 through August 31

Energy rates shall be determined prior to each Calendar Quarter, or as soon as possible thereafter, and shall be effective throughout such Calendar Quarter.

2. Firm Energy

a. Subject to the provisions of this Contract, MECO will pay Seller for Firm Energy delivered to MECO beginning from Contract Week 45 of 1982 through the termination of this Contract at rates to be determined for each Calendar Quarter as follows:

OFF-PEAK (per kwh):	.9 x MECO's average fuel cost per net kwh for the preceding computation period.
ON-PEAK (per kwh):	1.0 x MECO's average fuel cost per net kwh for the preceding computation period.

b. If by reason of any event or circumstances which would excuse Seller from liability under Section VIII.A. of this Contract, Seller is unable to fulfill agreed-upon deliveries of Firm Energy in any Contract Week, Seller shall be paid at the Firm Energy rate per kilowatt hour for any Firm Energy actually delivered, with no shortfall penalty.

c. If by reason of MECO Dispatch, Seller is unable to fulfill agreed-upon deliveries of Firm Energy in any Contract Week, Seller shall have the right to make up the shortfall in the following eight (8) Contract Weeks by delivering energy in excess of 100% of the agreed-upon weekly Firm Energy amount for these weeks at reasonable times and in reasonable amounts; PROVIDED, that such deliveries shall be made during On-Peak hours, and PROVIDED, FURTHER, that Seller shall notify MECO in advance of any such deliveries that such deliveries are for the purpose of shortfall make up pursuant to this paragraph. Seller shall incur no shortfall penalty for failure to make up any shortfall caused by MECO

Dispatch, and shall be paid at the Firm Energy rate per kilowatt hour for any energy actually delivered pursuant to this paragraph.

3. Energy Purchased Prior to Contract Week 45 of 1982, and Unscheduled Energy Thereafter.

Subject to the provisions of the Contract, MECO will pay to Seller for Unscheduled Energy purchased by MECO from Seller during the term of this Contract at rates to be determined for each Calendar Quarter as follows:

OFF-PEAK (per kwh):	.7 x MECO's average fuel cost per net kwh for the preceding computation period
ON-PEAK (per kwh):	.85 x MECO's average fuel cost per net kwh for the preceding computation period

MECO shall accept any Unscheduled Energy offered to MECO by Seller unless (i) the MECO system is unable to reasonably accept such additional amounts of Unscheduled Energy at any given time, and/or (ii) the cost of such Unscheduled Energy would exceed the cost to MECO of the energy that would be displaced by such amounts.

4. Emergency Energy. MECO will pay Seller for Emergency Energy delivered to MECO during the term of this Contract at a rate (per kwh) to be determined for each Calendar Quarter as follows:

3.0 x MECO's average fuel cost per net kwh for the preceding computation period.

B. Capacity Charges

1. Firm Capacity Charge. As compensation for Seller's commitment of the scheduled amounts (including both maximum and minimum amounts) of Firm Capacity under MECO Dispatch as described herein, and in Attachment I, MECO will pay Seller during the term of this Contract a Firm Capacity Charge of

$1.28 per kilowatt per week for the maximum Firm Capacity committed in that week. The Firm Capacity Charge payment shall be made each month for twelve months of each year, including the Shutdown Weeks, the payment for which shall be computed on the basis of the scheduled Firm Capacity of the week preceding the Shutdown Weeks. Such Firm Capacity Charge shall not be subject to adjustment by reason of a utilization by MECO of a capacity that varies from the scheduled amount of Firm Capacity; provided, however, that the Firm Capacity Charge payments hereunder may be reduced as provided in this Contract. Unless otherwise mutually agreed to, as provided for in this Contract, the maximum and minimum Firm Capacity committed shall be as shown in Attachment I herein.

C. Hawaii General Excise Tax.

MECO shall not be liable for payment of the applicable Hawaii General Excise Tax levied and assessed against Seller as a result of this Contract. The rates and charges in this Section III shall not be adjusted by reason of any subsequent increase or reduction of the applicable Hawaii General Excise Tax.

IV. INTERCONNECTION FACILITIES AND CHARGE

A. MECO will construct, own, operate and maintain all facilities required to interconnect the MECO system with the Seller's system up to the point of delivery at 69-kv. The interconnection facilities will include lines, equipment and controls equivalent to those which MECO would provide for comparable generation installed by MECO. The facilities shall be designed and constructed by a licensed Hawaii contractor mutually acceptable to Seller and MECO based on bids received. Bids will be based on design specifications provided by MECO, and the facilities must be approved by MECO and Seller, which approvals shall not be unreasonably withheld. MECO will finance construction, own, operate and maintain the facilities. For financing construction, owning, maintaining and operating such operating facilities, MECO will discount the Firm Capacity Charge payments made pursuant to Section III.B.1. hereof by the following amount per month for each month of the term of the Contract commencing November 1, 1982 and ending October 31, 1992: one and seven-tenths percent (1.7%) of the total costs of the interconnection facilities, including but not limited to design and engineering costs, construction costs, and administrative costs, as recorded on MECO's books according to the Uniform System of Accounts and approved by Seller, which approval shall not be unreasonably withheld. If the Firm Capacity Charge payments are insufficient to cover such monthly interconnection cost charge, any remaining balance may be deducted by MECO from the monthly energy payments under Section III.A. hereof. It is understood that the facilities are and shall remain the property of MECO for its use as described, including service to other customers. Upon termination or expiration of this Contract, MECO shall have the obligation to remove any and all of its facilities from the interconnection site and to restore the land to even grade. If Seller terminates this Contract prior to October 31, 1992 pursuant to Section XI.B. hereof, or if MECO terminates this Contract prior to October 31, 1992 pursuant to Section XI.A. hereof, then Seller shall pay to MECO on demand any and all costs incurred by MECO in removing its facilities from the interconnection site and restoring the land to even grade. If Seller terminates this Contract prior to October 31, 1992 pursuant to Section XI.A. hereof, or if this Contract terminates for any reason after

October 31, 1992, then MECO shall bear all costs incurred by MECO in removing its facilities from the interconnection site and restoring the land to even grade.

B. The above-mentioned interconnection facilities charge is based on completion of the interconnection facilities on or before March 1, 1982. Should completion of the facilities be delayed past March 1, 1982 by any action or inaction on the part of Seller, then any additional costs caused by such delay shall be paid for by Seller.

C. The cables, circuit breakers, protective relays, equipment, and apparatus (including transformers) on the Seller's side of the point of interconnection shall be constructed, owned, operated, and maintained by Seller at Seller's expense. MECO shall have the right to specify type of protective relaying equipment (which equipment shall be mutually agreeable to the parties) and the settings that affect the reliability and safety of operation of the MECO and Seller's interconnected systems.

D. Seller shall, within the time periods stated below, grant and convey unto MECO, its successors and assigns, the following:

1. Within thirty (30) days after this Contract becomes effective, a perpetual right and easement to build, construct, rebuild, reconstruct, repair, maintain and operate the power lines necessary to connect Seller and MECO, and to use such poles, wires, guys and other appliances and equipment as may be necessary for the transmission and distribution of electricity to be used for light and power and/or communications and control circuits, including the right to trim and keep trimmed any trees in the way of its poles, wires, guys and other appliances and equipment, and including also the right of entry upon the premises for the construction,

maintenance, repair and operation of the lines and equipment in efficient use and condition over, upon, across, through and under those mutually agreed upon areas on Seller's land.

Such grant of easement shall be substantially in the form attached hereto as Attachment II.

Seller shall, at its own expense, obtain all consents and approvals necessary for such grant of easement, and shall use its best efforts in obtaining such consents and approvals. MECO shall cooperate with Seller in seeking such approvals as reasonably requested by Seller, provided MECO is reimbursed for any costs and expenses incurred thereby.

2. Within thirty (30) days after this Contract becomes effective, Seller shall submit an application for subdivision approval for the mutually agreed upon site on Seller's land for the interconnection facilities, and upon such approval shall promptly grant to Seller a lease of a such mutually agreed upon site on Seller's land for the interconnection facilities. Said lease shall be for a term equivalent to the term of this Contract, including any extensions thereof, subject to earlier termination upon the earlier termination of this Contract. Lease rent shall be one dollar ($1.00) per year. Said lease shall grant MECO the right to construct, reconstruct, maintain, repair, operate and remove the interconnection facilities and appurtenances upon the leased land, and to conduct all activities incidental thereto. Said lease shall further expressly provide that (i) the interconnection facilities are and shall remain the sole property of MECO; (ii) MECO shall have the obligation to remove any and all of its facilities from the interconnection site and restore the land to even grade

upon termination or expiration of said lease; (iii) MECO shall pay all real property taxes applicable thereto, if any; (iv) MECO shall use and maintain the land and facilities in a safe and operating manner; (v) MECO shall indemnify and defend A&B from and against all claims, costs (including attorneys' fees), damages and injuries arising out of the use or occupancy of the premises by MECO unless such are proximately caused by the negligence of Seller, its officers, employees or agents, while acting within the scope of their employment; (vi) MECO shall insure with such coverage, in such manner and to such limits, as Seller may reasonably require from time to time consistent with then prudent practice in the State of Hawaii for the protection of lessors; and (vii) shall contain other mutually agreed upon provisions consistent with Seller's current land leasing policies and practices. Said lease shall further provide that if MECO terminates the lease prior to October 31, 1992, pursuant to Section XI.A. of this Contract or because of breach of the lease by Seller, or if Seller terminates the lease pursuant to Section XI.B. of this Contract, then in any such event Seller shall pay to MECO on demand any and all costs incurred by MECO in removing its facilities from the interconnection site and restoring the land to even grade. Said lease shall further provide that if Seller terminates the lease prior to October 31, 1992 pursuant to Section XI.A. of this Contract or because of breach of the lease by MECO, or if this Contract terminates for any reason after October 31, 1992, then in any such event MECO shall bear any and all costs incurred by MECO in removing its facilities from the interconnection site and restoring the land to even grade.

Seller shall, at its own expense, obtain all necessary consents and approvals for such lease, including but not limited to any necessary subdivision approvals, and shall use its best efforts in obtaining such consents and approvals. MECO shall cooperate with Seller in seeking such approvals as reasonably requested by Seller, provided MECO is reimbursed by Seller for any costs and expenses incurred thereby.

V. PURCHASE OF POWER BY SELLER

All electric power supplied to Seller by MECO at the interconnection point shall be billed on an applicable rate schedule in effect, except that the maximum measured demand during the Shutdown Weeks will be excluded in the calculation of the billing demand for all other periods. The Seller may not change the rate schedule under which Seller takes this service from MECO until at least 12 months after the previous rate change.

MECO further agrees to enter into curtailable or interruptible contracts with Seller, provided Seller's operations allow for such curtailment or interruption. Such contracts shall be in accordance with general conditions filed with the PUC, and the contracts shall be subject to PUC approval. Such contracts shall include provisions allowing the Seller to provide MECO additional Firm Capacity and Firm Energy in lieu of curtailment at the option of Seller, which additional Firm Capacity shall be provided without charge to MECO, where MECO's system can reasonably accept such additional capacity in lieu of curtailment.

VI. PAYMENTS

The amount to be paid by MECO to Seller shall be determined monthly for each calendar month in accordance with the provisions of this Contract. MECO will prepare and furnish Seller a statement by the 20th of each calendar month showing in reasonable detail the meter readings and rates applied. MECO further agrees to make payment by the 20th of each calendar month.

Seller agrees to pay MECO for power delivered to Seller in accordance with the filed applicable tariffs.

VII. METERING

All electric energy to be delivered hereunder shall be what is commonly called 3-phase, 60 cycle (Hertz) alternating current, and shall be delivered and metered at Seller's Substation at an electromotive force of 69-kv with a maximum variation of plus or minus 10%. All revenue-metering equipment shall be owned and operated by MECO in a metering compartment provided by MECO in MECO's Substation. Metering shall be accomplished by individual systems measuring energy from Seller to MECO, and from MECO to Seller. MECO shall, at least once each Calendar Year during the term hereof, test and adjust, in the presence of Seller's representative, all revenue-metering equipment in conformity with General Order No. 7 of the Public Utilities Commission (PUC). Adjustment in the billing for meter inaccuracy will also be made in conformity with General Order No. 7.

VIII. INTERRUPTION OF SERVICE

A. Commencing with the first day of the term hereof, if Seller shall be wholly or partially prevented from delivering the electric energy or capacity contracted for herein, or if the service thereof shall be interrupted, by reason of or through strikes which directly affect Seller's production of electricity or provision of capacity, riot, fire, flood, invasion, insurrection, lava flow or volcanic activity, tidal wave, civil commotion, accident, the order of any court, judge or civil authority, any act of God or the public enemy, or any other similar or dissimilar cause reasonably beyond its exclusive control and not attributable to its neglect, then and in any such event, Seller shall not be obligated to deliver said electric energy or capacity hereunder during such period and shall not be liable for any damage or loss resulting from such interruption or suspension. During any period in which Seller shall be properly relieved from the obligations hereunder, MECO shall likewise be relieved from paying the Firm Capacity charges it pays Seller hereunder, prorated to reflect the duration of any such period. In any such event or events, the party or parties suffering such interruption or suspension shall be prompt and diligent in removing the cause thereof. It is further understood that Seller will not be relieved of its obligations under this Contract because of inability to obtain bagasse so long as fuel oil supplies are or can be made available. In order to minimize the possibility of interruption, Seller agrees to keep reasonable fuel oil reserves and a reasonable inventory of spare parts on hand at all times, and to burn fuel oil whenever necessary to fulfill its commitments hereunder.

B. If MECO shall be prevented from receiving, using and applying the electric energy contracted for herein, or if the service is interrupted, by reason of or through strikes, riots, fire, floods, invasion, insurrection, lava flow, or volcanic activity, tidal wave, civil commotion, accident, the order of any court, judge or civil authority, any act of God, or the public enemy, or any other similar or dissimilar cause reasonably beyond its exclusive control and not attributable to its neglect, then and in any such events, MECO shall not be obligated or liable to take or pay for any energy during such periods, but shall continue to pay Firm Capacity charges to Seller as required hereunder.

IX. PRIVITY

Any other term, covenant or provision herein contained to the contrary notwithstanding, this contract is not intended and shall not be construed in any manner so as to benefit any third party; nor is it intended nor shall it be construed in a manner such as to place Seller in privity with any parties who might have a contract to purchase electric energy from MECO; nor is it intended nor shall it be construed in any manner so as to impose a duty upon Seller to supply electric energy to the public or any portion of the public or to any private person or parties not a party to this contract, or to supply electric energy to any particular locality or district in the County of Maui.

X. APPROVALS

A. This Contract shall not become effective or be in any way binding upon the parties hereto or create any obligation of either party to the other unless and until the PUC has, by appropriate decision and order satisfactory to MECO and Seller, given its approval of this Contract and in such approval has authorized the terms of rates and charges to be paid by MECO to Seller hereunder to be included in MECO's Fuel Adjustment computation for the term of this Contract, and has determined that such charges are reasonable for rate making purposes. It is expressly agreed that the rates and charges to be paid by MECO to Seller hereunder shall become effective only upon such PUC approval, and shall not be retroactively applied.

B. The parties agree this Contract may be changed or modified in such manner only as mutually acceptable to the parties as the PUC may from time to time direct in the exercise of its jurisdiction.

C. Seller agrees to cooperate at its own expense as may reasonably be requested by MECO in connection with MECO's application to the PUC for the aforesaid approval MECO agrees to use its best efforts to obtain the aforesaid approval as soon as reasonably possible.

D. Seller shall be solely responsible for obtaining all other governmental approvals which may be necessary in order to carry out its responsibilities under this Contract.

XI. DAMAGES AND SPECIAL TERMINATION RIGHTS

A. Except for the specific penalty clauses of II.A.2, II.B.2 and II.E.2, and except for the provisions of Section VIII on Interruption of Service, neither party shall be liable to the other party for any loss, cost, damage or expense resulting from a failure to perform any of its obligations hereunder occasioned by any cause not within its control through the exercise of reasonable diligence and care. In the event that the failure to observe the obligations imposed herein is substantial or continuous or frequent so as to create an unreasonable burden upon the other party, then such other party, at its option, may terminate this contract by giving written notice of its intention to terminate to the other party. The party giving notice to terminate may set the termination date at any date not less than 36 months from the date of said notice. During such period between the notice of termination, the obligations of this Contract shall continue in full force and effect for all purposes, including the right to collect damages resulting from one party's failure to perform.

B. If, upon initial approval of this Contract, the PUC requires any changes or modifications of this Contract not acceptable to Seller, Seller shall have the right to terminate this Contract upon written notification to MECO within two (2) weeks of the PUC order. If, at any time following initial approval of this Contract, the PUC requires any changes or modifications of this Contract not acceptable to Seller, Seller shall have the right to terminate this Contract by giving MECO 36 months prior written notice.

XII. ASSIGNMENT

This Agreement shall not be assigned by either party without the prior written consent of the other party, which consent shall not be unreasonably withheld; provided that Seller shall have the right to assign this Contract without the consent of MECO to a corporation which shall succeed to substantially all of the business being conducted by Hawaiian Commercial & Sugar Company as of the effective date of this Contract; provided, further, that MECO shall have the right to assign this Contract, without the consent of Seller, to Bishop Trust Company, Limited as Trustee under

Indenture of Mortgage and Deed of Trust dated March 1, 1948, as amended.

XIII. ARBITRATION

If at any time during the term of this Agreement or after termination thereof, any dispute, difference or question shall arise between the parties hereto with respect to the provisions, construction, meaning or effect of this contract or anything herein contained or the rights or limitations of the parties under this contract, every such dispute, difference or question shall, at the desire of any party, be submitted to and determined by a board of three arbitrators, as follows: The party desiring to have the matter in dispute submitted to arbitration shall give the other party written notice of such desire and shall name one of the arbitrators in such notice. Within ten days after the receipt of such notice, the other party shall name a second arbitrator, and in case of failure so to do the party who has already named an arbitrator may have the second arbitrator selected or appointed by a judge of the Circuit Court, Second Circuit, State of Hawaii, and the two arbitrators so appointed by either manner shall select and appoint a third arbitrator, and in the event the two arbitrators so appointed shall fail to appoint the third arbitrator within ten days after the naming of the second arbitrator, either party may have the third arbitrator selected or appointed by one of said judges, and the three arbitrators so appointed shall thereupon proceed to determine the matter in question, disagreement or difference, and the decision of any two of them shall be final, conclusive and binding upon all parties, all as provided in Chapter 658, Hawaii Revised Statutes, as the same may be amended, and judgment may be entered upon any such decision by the Circuit Court as provided in said statute. In all cases or arbitration each of the parties hereto shall pay the expense of its own attorneys' and witnesses' fees, and all other expenses of such arbitration shall be divided equally between the parties.

XIV. TRAINING STANDARDS

Seller shall maintain and operate its power plant in accordance with sound engineering practice designed to achieve the highest practicable reliability considering its function as a source of power for MECO. All Seller's employees operating the plant shall have received training in accordance with reasonable mutually agreed standards established by MECO for its employees in comparable positions. Seller's operation and maintenance schedules shall be established to provide adequate staffing by qualified personnel at all times.

XV. TERM OF CONTRACT

This contract, unless terminated under the provisions of Section XI herein, shall commence on upon approval by the PUC, and continue in effect through October 31, 1992, and from year-to-year thereafter; subject to termination on not less than three (3) years' written notice by either party, which notice shall not be given earlier than October 30, 1989.

IN WITNESS WHEREOF, the undersigned have caused these presents to be executed as of the day and year first above written.

ALEXANDER & BALDWIN, INC. dba
HAWAIIAN COMMERCIAL & SUGAR COMPANY

By ______________________
Its Executive Vice President - Agriculture

By ______________________
Its Secretary

MAUI ELECTRIC COMPANY, LIMITED

By ______________________
Its President

By ______________________
Its Vice President

ATTACHMENT I

Contract Amounts of Firm Energy and Firm Capacity are as follows:

Calendar Year(s)*	Contract Weeks (of Each Calendar Year)*	Firm Capacity in MW Min.	Firm Capacity in MW Max.	Firm Energy in MWH Per Week	Hrs/ Day	Days/ Week	Hrs/ Week	Outp Fact
1982	45-52	4	6	180	5	6	30	100
1983	1-5	4	6	150	5	6	30	83
1983	6-9	0	0	0	0	0	0	0
1983	10-15	4	6	705	24	7	168	70
1983	16-44	0	10	1175	24	7	168	70
1983	45-52	4	12	360	5	6	30	100
1984-1992	1-5	4	12	360	5	6	30	100
1984-1992	6-9	0	0	0	0	0	0	0
1984-1992	10-15	4	12	1400	24	7	168	69
1984-1992	16-44	0	12	1400	24	7	168	69
1984-1991	45-52	4	12	360	5	6	30	10(

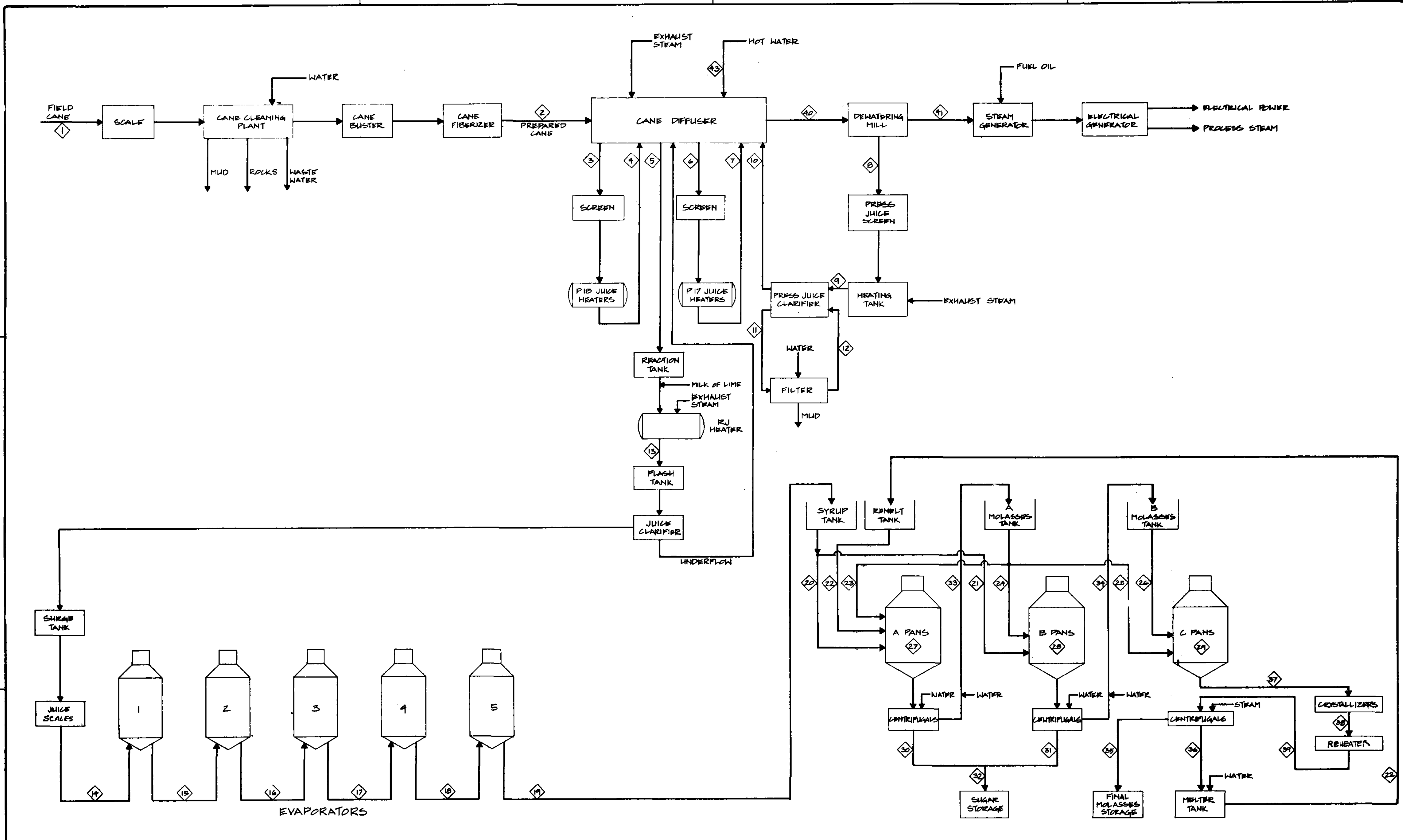
If the Contract continues in effect from year-to-year after 1992, the amounts shown for Firm Energy and Firm Capacity for Contract Year 1991 shall apply.

* "-" denotes "through"

Appendix E

PIONEER MILL PERFORMANCE SIMULATION RESULTS

A performance analysis of the existing facility was performed by Okahara, Shigeoka and Associates under Amfac's direction. Figure E-1, the sugar factory process flow diagram, provides the basic performance data on the sugar processing. These data served as input to the performance simulation of the solar retrofit. Figure E-2 shows the results, for the steam and condensate flows, of the simulation run for the solar design point. Figures E-3 and E-4, the energy flow diagrams, give a simplified picture of the solar cogeneration facility operation for 5 different operating modes. The remainder of this appendix includes sample printouts of weekly simulation using average weather grinding season and off season operation. This and other similar information was used to develop the performance data presented in Sections 4.5 and 4.6 of the main report.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
TEMPERATURE, °F	80	80	150	185	150	150	160	150	205	183	160±	160±	215	205	233	202	192	176	142	140	140	140	140	140	140	140	160	160	160
FLOW, LB/HR	303,530	231,760	244,660	244,660	244,660	244,660	244,660	141,800	151,900	153,900	54,000	54,000	244,660	240,100	182,100	142,300	101,500	73,600	44,700	32,000	12,700	7,000	7,650	8,800	1,300	13,350	36,500	18,400	11,900
PURITY, %	—	—	85.95	85.95	85.95	85.95	85.95	72.34	72.34	72.34	72.34	72.34	85.95	85.95	85.95	85.95	85.95	85.95	85.95	85.95	85.95	81.67	62.14	62.14	62.14	55.21	81.00	73.91	66.00
SOLIDS, %	—	—	12.60	12.60	12.60	12.60	12.60	—	—	—	—	—	12.60	12.60	16.82	21.26	29.82	[illegible]	67.14	67.14	67.74	68.10	75.0	75.0	75.0	75.0	93.43	94.50	95.12

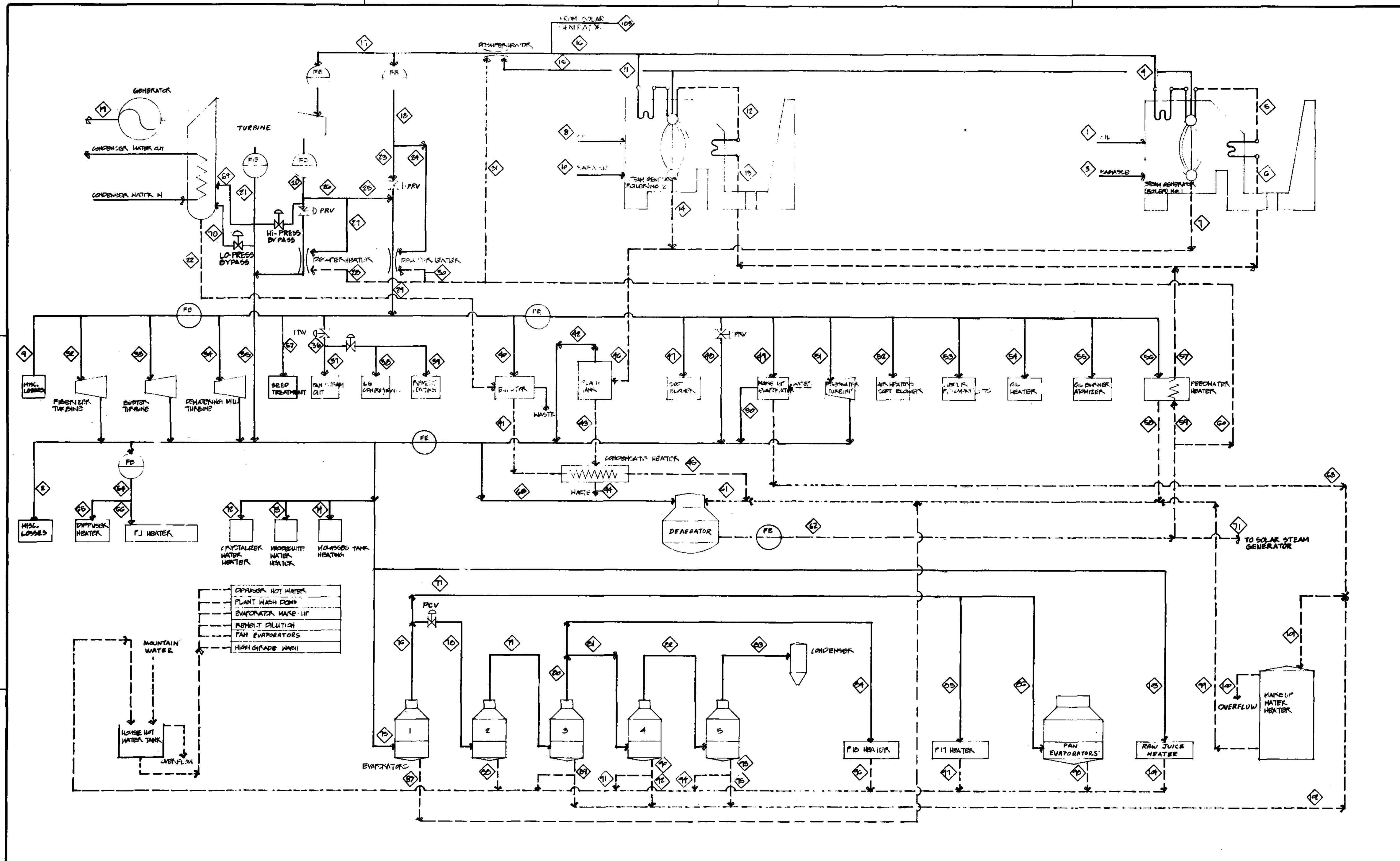
	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
TEMPERATURE, °F	100	100	100	140	140	95	120	160	110	120	150	150	NOT	146	180	204
FLOW, LB/HR	16,400	7,360	23,760	17,750	13,350	7,200	4,820	11,900	11,900	—	209,300	67,520	USED	65,200	72,000	252,100
PURITY, %	99.36	99.36	99.36	62.14	55.21	37.83	81.67	56.00	56.00	56.00	—	—		0	0	85.95
SOLID, %	99.80	99.80	99.80	75.0	75.0	90.07	99.0	95.12	95.12	95.12	—	—		0	0	12.00

Okahara, Shigeoka & Associates Inc.
• CIVIL • STRUCTURAL • MECHANICAL • SANITARY • ELECTRICAL •

SOLAR CO-GENERATION FACILITY
@ PIONEER MILL COMPANY
SUGAR FACTORY PROCESS FLOW DIAGRAM
PIONEER MILL COMPANY LTD. - LAHAINA MAUI HAWAII

SHEET NO. B-1

Figure E-1 SUGAR FACTORY PROCESS FLOW DIAGRAM



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
TEMPERATURE, °F	220	246	80	760	532	–	532	220	500	80	760	532	–	532	532	760	750	750	–	500	275	101	750	675	500	500	500	246	246	246	246	500	500	500	246
PRESSURE, PSIG	–	13	–	875	890	–	890	–	250	–	675	890	–	890	890	875	850	850	–	250	13	28" HgA	850	250	250	250	250	–	13	–	–	250	250	250	13
FLOW, LB/HR	0	4500	21,500	60050	63200	63,200	3000	0	2000	21500	60050	63200	63200	3000	300	120,100	168900	0	8000	68000	95400	5600	0	0	68000	68000	0	0	68000	0	100	0	17000	17000	95,400

	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
TEMPERATURE, °F	500	482	470	470	500	–	246	246	–	–	537	500	500	500	500	500	500	500	500	500	500	396	406	246	246	–	246	406	246	246	246	500	246	–	–
PRESSURE, PSIG	250	160	100	100	250	–	13	13	13	–	925	250	250	250	250	250	250	250	250	250	250	950	250	950	950	–	–	250	13	13	13	250	13	–	–
FLOW, LB/HR	2700	2000	400	300	400	6000	2000	4000	4000	6000	6000	1000	0	0	0	0	1000	1400	100	1500	22400	126400	22400	126400	100	167900	176400	0	13300	3200	10100	1500	8500	0	0

	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
TEMPERATURE, °F	246	246	246	246	246	232	232	215	201	190	190	173	134	190	232	232	246	215	201	190	190	170	173	173	173	190	232	232	165	165	–	–	246	246	760
PRESSURE, PSIG	–	13	13	13	13	7	7	1	6.0" HgA	11.0" HgA	11.0" HgA	12.0" HgA	25" HgA	11" HgA	7	7	13	1.0	6.0" HgA	11" HgA	11" HgA	11" HgA	17" HgA	17" HgA	17" HgA	11" HgA	7	7	–	–	–	–	13	13	875
FLOW, LB/HR	49,900	1300	100	1900	84,500	70000	39000	35300	39,800	40800	26800	27900	29100	14000	2700	32000	84500	35300	39800	26[illegible]	11600	15200	27900	0	0	14000	2700	32000	55000	0	55000	55000	17,300	17300	48400

GRINDING SEASON W/ SOLAR (AVERAGE DAY IN MARCH – TUESDAY 1pm TO 2pm) 8 MWe GENERATION

Okahara, Shigeoka & Associates Inc.

SOLAR CO-GENERATION FACILITY @ PIONEER MILL COMPANY
STEAM & CONDENSATE FLOW DIAGRAM

SHEET NO. 13-2

Figure E-2 STEAM AND CONDENSATE FLOW DIAGRAM

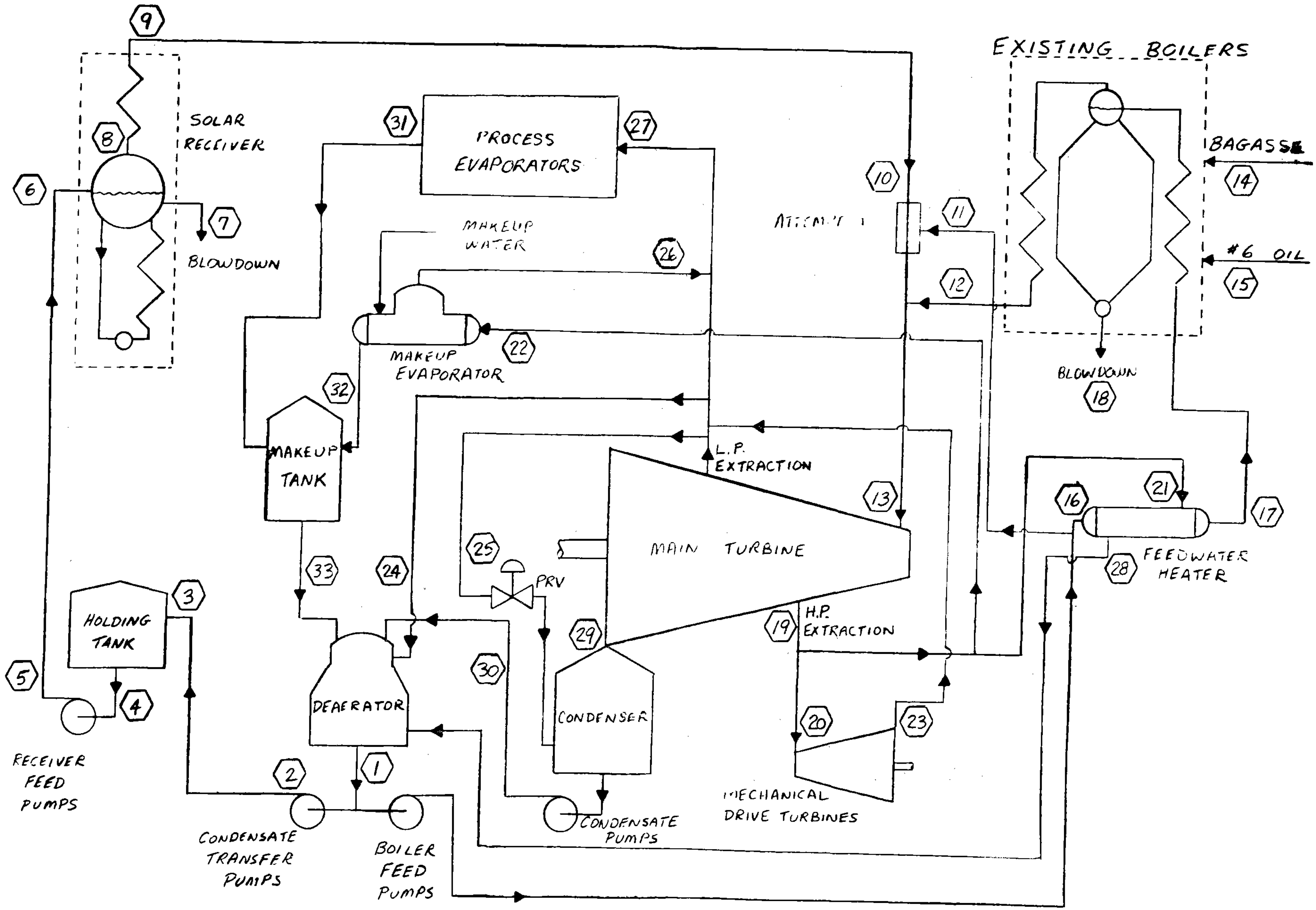


Figure E-3 ENERGY FLOW DIAGRAM

	⟨1⟩	⟨2⟩	⟨3⟩	⟨4⟩	⟨5⟩	⟨6⟩	⟨7⟩	⟨8⟩	⟨9⟩	⟨10⟩	⟨11⟩	⟨12⟩	⟨13⟩	⟨14⟩	⟨15⟩
	SOLAR MODE - FACTORY OPERATION -														
FLOW	76.4	34.2	34.2	34.2	34.2	34.2	0.7	33.5	33.5	33.5	0.9	40.5	74.9	△1	0
PRESS.	0.19	0.55	0.11	0.17	8.55	7.75	7.75	7.75	6.85	5.96	6.5	5.96	5.96	N/A	—
TEMP.	119	119	113	113	113	113	293	293	438	423	113	399	399	N/A	—
	SOLAR MODE - FACTORY OPERATION -														
FLOW	76.8	8.6	8.6	8.6	8.6	8.6	0.2	8.4	8.4	8.4	0	69.6	78.0	△2	0
PRESS.	0.19	0.30	0.11	0.17	8.20	6.09	6.09	6.09	6.03	5.96	—	5.96	5.96	N/A	—
TEMP.	119	119	113	113	113	113	277	277	438	400	—	399	399	N/A	—
	SOLAR MODE - WEEKEND OPERATION -														
FLOW	43.5	34.2	34.2	34.2	34.2	34.2	0.7	33.5	33.5	33.5	0.9	9.1	43.5	0	△3
PRESS.	0.19	0.55	0.11	0.17	8.55	7.75	7.75	7.75	6.85	5.96	6.5	5.96	5.96	N/A	—
TEMP.	119	119	113	113	113	113	293	293	438	423	113	399	399	N/A	104
	NONSOLAR MODE - FACTORY OPERATION														
FLOW	82.4	0	0	0	0	0	0	0	0	0	0	79.9	79.9	△4	0
PRESS.	0.19	—	—	—	—	—	—	—	—	—	—	5.96	5.96	N/A	—
TEMP.	119	—	—	—	—	—	—	—	—	—	—	399	399	N/A	—
	NONSOLAR MODE - OFF-SEASON OPERATION														
FLOW	37.1	0	0	0	0	0	0	0	0	0	0	35.7	35.7	0	△5
PRESS.	0.19	—	—	—	—	—	—	—	—	—	—	5.96	5.96	N/A	—
TEMP.	119	—	—	—	—	—	—	—	—	—	—	399	399	N/A	104

UNITS

FLOW - 1000 kg/h

PRESS. - MPa

TEMP. - °C

NOTE SOME AUXILIARY FLOWS IN EXISTING FACILITY ARE NOT INCLUDED.

⟨16⟩	⟨17⟩	⟨18⟩	⟨19⟩	⟨20⟩	⟨21⟩	⟨22⟩	⟨23⟩	⟨24⟩	⟨25⟩	⟨26⟩	⟨27⟩	⟨28⟩	⟨29⟩	⟨30⟩	⟨31⟩	⟨32⟩	⟨33⟩

SOLAR DESIGN POINT

41.3	41.3	0.8	28.5	15.4	7.9	0	15.4	4.5	0	0	54.7	7.9	2.8	3.0	62.7	0	62.7
6.65	6.65	6.24	1.83	1.83	1.83	–	0.19	0.19	–	–	0.19	1.83	0.008	0.19	0.19	–	0.19
113	202	278	260	260	260	–	135	135	–	–	135	208	38	40	–	–	101

25% OF DESIGN SOLAR FLOW

68.2	68.2	1.4	33.1	15.4	12.7	0	15.4	3.1	0	0	54.7	12.7	2.3	2.5	62.7	0	62.7
6.65	6.65	6.24	1.83	1.83	1.83	–	0.19	0.19	–	–	0.19	1.83	0.008	0.19	0.19	–	0.19
113	202	278	260	260	260	–	135	135	–	–	135	208	38	40	–	–	101

100% OF DESIGN SOLAR FLOW

9.3	9.3	0.2	2.3	0	2.3	0	0	5.0	6.6	0	0	2.3	29.0	36.0	0	0	4.2
6.65	6.65	6.24	1.83	–	1.83	–	–	0.19	0.19	–	–	1.83	0.008	0.19	–	–	0.19
113	202	278	260	–	260	–	–	135	135	–	–	208	38	40	–	–	74

82.4	82.4	2.7	35.5	15.4	14.6	0	15.4	3.0	0	0	54.7	14.6	2.1	2.3	63.0	0	63.0
6.65	6.65	6.24	1.83	1.83	1.83	–	0.19	0.19	–	–	0.19	1.83	0.008	0.19	0.19	–	0.19
113	202	278	260	260	260	–	135	135	–	–	135	208	38	40	–	–	101

37.1	37.1	1.4	15.8	0	6.8	4.2	0	2.4	0	3.0	0	6.8	20.0	22.2	0	4.2	4.2
6.65	6.65	6.24	1.83	–	1.83	1.83	–	0.19	–	0.19	–	1.83	0.008	0.19	–	1.83	0.19
113	202	278	260	–	260	260	–	135	–	135	–	208	38	40	–	208	74

△1 14300 KG/HR (15.8 TON/HR)
△2 24600 KG/HR (27.2 TON/HR)
△3 0.56 m^3/HR (3.5 BBL/HR)
△4 28700 KG/HR (31.6 TON/HR)
△5 2.16 m^3/HR (13.6 BBL/HR)

Figure E-4 ENERGY FLOW DIAGRAM

SOLAR -- OFF SEASON -- PIONEER MILL FACTORY STEAM BALANCE
(TYPICAL WEEK IN JANUARY - AVERAGE DAY - PROCESS LOSS RATE IS 3.5%)

DAY	HOUR	BOILER STEAM	SOLAR STEAM	SOLAR DECMT	THROTTLE STEAM	EXTRACTION HI-PR	EXTRACTION LO-PR	DA FLOW	CNDNSNG FLOW	BYPASS HI-PR	BYPASS LO-PR	PRV FLOW	MAKEUP WATER	FD-WTR HEATER	GENRTR OUTPUT (MW)	ENERGY GENERTED (MWH)	FUEL RATE (B/HR)	OIL ACCUM (BBL)	BAGASSE RATE (T/HR)	BAGASSE ACCUM (TON)
					(ALL FLOWS ARE IN KLB/HR)															
SUN	0- 1A	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	5.000	13.1	13.1	0.00	0.00
	1- 2	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	10.000	13.1	26.2	0.00	0.00
	2- 3	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	15.000	13.1	39.4	0.00	0.00
	3- 4	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	20.000	13.1	52.5	0.00	0.00
	4- 5	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	25.000	13.1	65.6	0.00	0.00
	5- 6	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	30.000	13.1	78.7	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	35.000	13.1	91.9	0.00	0.00
	7- 8	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	40.000	13.1	105.0	0.00	0.00
	8- 9	57.0	17.0	0.0	74.2	27.6	0.0	6.0	49.5	0.0	0.0	0.0	8.1	11.2	5.000	45.000	9.8	114.8	0.00	0.00
	9-10	71.9	35.4	0.0	107.6	31.2	12.7	9.7	63.6	0.0	12.5	0.0	8.7	13.8	8.000	53.000	12.4	127.2	0.00	0.00
	10-11	61.0	45.3	0.0	106.4	29.9	12.6	10.1	64.0	0.0	12.5	0.0	9.0	11.9	8.000	61.000	10.5	137.7	0.00	0.00
	11-12	58.9	49.7	0.0	108.7	29.4	18.8	10.5	60.5	0.0	18.2	0.0	9.1	11.5	8.000	69.000	10.1	147.8	0.00	0.00
	12- 1P	54.0	51.8	0.0	106.0	28.7	13.5	10.4	63.7	0.0	13.2	0.0	9.2	10.7	8.000	77.000	9.3	157.1	0.00	0.00
	1- 2	53.2	52.3	0.0	105.7	28.7	13.1	10.4	64.0	0.0	12.8	0.0	9.2	10.5	8.000	85.000	9.2	166.3	0.00	0.00
	2- 3	55.5	51.1	0.0	106.8	28.8	15.3	10.4	62.6	0.0	14.8	0.0	9.1	10.9	8.000	93.000	9.6	175.9	0.00	0.00
	3- 4	59.4	46.9	0.0	106.4	29.3	13.5	10.2	63.6	0.0	13.0	0.0	9.0	11.6	8.000	101.000	10.2	186.1	0.00	0.00
	4- 5	72.2	35.6	0.0	108.1	31.3	13.7	9.8	63.0	0.0	13.4	0.0	8.7	13.9	8.000	109.000	12.4	198.5	0.00	0.00
	5- 6	61.8	12.8	0.0	74.8	28.6	0.0	5.8	49.4	0.0	0.0	0.0	8.0	12.0	5.000	114.000	10.6	209.2	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	119.000	13.1	222.3	0.00	0.00
	7- 8	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	124.000	13.1	235.4	0.00	0.00
	8- 9	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	129.000	13.1	248.5	0.00	0.00
	9-10	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	134.000	13.1	261.7	0.00	0.00
	10-11	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	139.000	13.1	274.8	0.00	0.00
	11-12	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	144.000	13.1	287.9	0.00	0.00
MON	0- 1A	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	149.000	13.1	301.0	0.00	0.00
	1- 2	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	154.000	13.1	314.1	0.00	0.00
	2- 3	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	159.000	13.1	327.3	0.00	0.00
	3- 4	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	164.000	13.1	340.4	0.00	0.00
	4- 5	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	169.000	13.1	353.5	0.00	0.00
	5- 6	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	174.000	13.1	366.6	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	179.000	13.1	379.8	0.00	0.00
	7- 8	78.7	0.0	0.0	79.0	34.8	0.0	5.4	48.9	0.0	0.0	0.0	9.3	15.0	5.000	184.000	13.6	393.3	0.00	0.00
	8- 9	59.7	17.0	0.0	76.9	32.1	0.0	6.1	49.4	0.0	0.0	0.0	9.8	11.7	5.000	189.000	10.3	403.6	0.00	0.00
	9-10	75.8	35.4	0.0	111.5	35.7	13.9	9.9	62.0	0.0	15.0	0.0	10.4	14.5	8.000	197.000	13.1	416.7	0.00	0.00
	10-11	64.0	45.3	0.0	109.5	34.1	11.9	10.3	63.4	0.0	13.2	0.0	10.7	12.4	8.000	205.000	11.0	427.7	0.00	0.00
	11-12	59.1	49.7	0.0	108.9	33.4	12.0	10.4	63.6	0.0	13.3	0.0	10.8	11.6	8.000	213.000	10.2	437.9	0.00	0.00
	12- 1P	59.4	51.8	0.0	111.4	33.6	17.5	10.7	60.3	0.0	18.6	0.0	10.9	11.6	8.000	221.000	10.2	448.1	0.00	0.00
	1- 2	57.9	52.3	0.0	110.4	33.1	16.0	10.6	61.3	0.0	17.0	0.0	10.9	11.3	8.000	229.000	10.0	458.1	0.00	0.00
	2- 3	60.9	51.1	0.0	112.2	33.6	19.3	10.7	59.2	0.0	20.2	0.0	10.8	11.9	8.000	237.000	10.5	468.6	0.00	0.00
	3- 4	59.4	46.9	0.0	106.4	29.3	13.5	10.2	63.6	0.0	13.0	0.0	9.0	11.6	8.000	245.000	10.2	478.8	0.00	0.00
	4- 5	72.2	35.6	0.0	108.1	31.3	13.7	9.8	63.0	0.0	13.4	0.0	8.7	13.9	8.000	253.000	12.4	491.2	0.00	0.00
	5- 6	61.8	12.8	0.0	74.8	28.6	0.0	5.8	49.4	0.0	0.0	0.0	8.0	12.0	5.000	258.000	10.6	501.9	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	263.000	13.1	515.0	0.00	0.00
	7- 8	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	268.000	13.1	528.1	0.00	0.00
	8- 9	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	273.000	13.1	541.2	0.00	0.00
	9-10	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	278.000	13.1	554.4	0.00	0.00
	10-11	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	283.000	13.1	567.5	0.00	0.00
	11-12	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	288.000	13.1	580.6	0.00	0.00

SOLAR -- OFF SEASON -- PIONEER MILL FACTORY STEAM BALANCE
(TYPICAL WEEK IN JANUARY - AVERAGE DAY - PROCESS LOSS RATE IS 3.5%)

DAY	HOUR	BOILER STEAM	SOLAR STEAM	SOLAR DECMT	THROTTLE STEAM	EXTRACTION HI-PR	EXTRACTION LO-PR	DA FLOW	CNDNSNG FLOW	BYPASS HI-PR	BYPASS LO-PR	PRV FLOW	MAKEUP WATER	FD-WTR HEATER	GENRTR OUTPUT (MW)	ENERGY GENERTED (MWH)	FUEL RATE (B/HR)	OIL ACCUM (BBL)	BAGASSE RATE (T/HR)	BAGASSE ACCUM (TON)
					(ALL FLOWS ARE IN KLB/HR)															
TUE	0- 1A	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	293.000	13.1	593.7	0.00	0.00
	1- 2	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	298.000	13.1	606.8	0.00	0.00
	2- 3	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	303.000	13.1	620.0	0.00	0.00
	3- 4	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	308.000	13.1	633.1	0.00	0.00
	4- 5	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	313.000	13.1	646.2	0.00	0.00
	5- 6	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	318.000	13.1	659.3	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	323.000	13.1	672.5	0.00	0.00
	7- 8	78.7	0.0	0.0	79.0	34.8	0.0	5.4	48.9	0.0	0.0	0.0	9.3	15.0	5.000	328.000	13.6	686.0	0.00	0.00
	8- 9	59.7	17.0	0.0	76.9	32.1	0.0	6.1	49.4	0.0	0.0	0.0	9.8	11.7	5.000	333.000	10.3	696.3	0.00	0.00
	9-10	75.8	35.4	0.0	111.5	35.7	13.9	9.9	62.0	0.0	15.0	0.0	10.4	14.5	8.000	341.000	13.1	709.4	0.00	0.00
	10-11	64.0	45.3	0.0	109.5	34.1	11.9	10.3	63.4	0.0	13.2	0.0	10.7	12.4	8.000	349.000	11.0	720.4	0.00	0.00
	11-12	59.1	49.7	0.0	108.9	33.4	12.0	10.4	63.6	0.0	13.3	0.0	10.8	11.6	8.000	357.000	10.2	730.6	0.00	0.00
	12- 1P	59.4	51.8	0.0	111.4	33.6	17.5	10.7	60.3	0.0	18.6	0.0	10.9	11.6	8.000	365.000	10.2	740.8	0.00	0.00
	1- 2	57.9	52.3	0.0	110.4	33.1	16.0	10.6	61.3	0.0	17.0	0.0	10.9	11.3	8.000	373.000	10.0	750.8	0.00	0.00
	2- 3	60.9	51.1	0.0	112.2	33.6	19.3	10.7	59.2	0.0	20.2	0.0	10.8	11.9	8.000	381.000	10.5	761.3	0.00	0.00
	3- 4	59.4	46.9	0.0	106.4	29.3	13.5	10.2	63.6	0.0	13.0	0.0	9.0	11.6	8.000	389.000	10.2	771.5	0.00	0.00
	4- 5	72.2	35.6	0.0	108.1	31.3	13.7	9.8	63.0	0.0	13.4	0.0	8.7	13.9	8.000	397.000	12.4	783.9	0.00	0.00
	5- 6	61.8	12.8	0.0	74.8	28.6	0.0	5.8	49.4	0.0	0.0	0.0	8.0	12.0	5.000	402.000	10.6	794.6	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	407.000	13.1	807.7	0.00	0.00
	7- 8	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	412.000	13.1	820.8	0.00	0.00
	8- 9	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	417.000	13.1	833.9	0.00	0.00
	9-10	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	422.000	13.1	847.1	0.00	0.00
	10-11	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	427.000	13.1	860.2	0.00	0.00
	11-12	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	432.000	13.1	873.3	0.00	0.00
WED	0- 1A	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	437.000	13.1	886.4	0.00	0.00
	1- 2	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	442.000	13.1	899.5	0.00	0.00
	2- 3	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	447.000	13.1	912.7	0.00	0.00
	3- 4	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	452.000	13.1	925.8	0.00	0.00
	4- 5	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	457.000	13.1	938.9	0.00	0.00
	5- 6	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	462.000	13.1	952.0	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	467.000	13.1	965.2	0.00	0.00
	7- 8	78.7	0.0	0.0	79.0	34.8	0.0	5.4	48.9	0.0	0.0	0.0	9.3	15.0	5.000	472.000	13.6	978.7	0.00	0.00
	8- 9	59.7	17.0	0.0	76.9	32.1	0.0	6.1	49.4	0.0	0.0	0.0	9.8	11.7	5.000	477.000	10.3	989.0	0.00	0.00
	9-10	75.8	35.4	0.0	111.5	35.7	13.9	9.9	62.0	0.0	15.0	0.0	10.4	14.5	8.000	485.000	13.1	1002.1	0.00	0.00
	10-11	64.0	45.3	0.0	109.5	34.1	11.9	10.3	63.4	0.0	13.2	0.0	10.7	12.4	8.000	493.000	11.0	1013.1	0.00	0.00
	11-12	59.1	49.7	0.0	108.9	33.4	12.0	10.4	63.6	0.0	13.3	0.0	10.8	11.6	8.000	501.000	10.2	1023.3	0.00	0.00
	12- 1P	59.4	51.8	0.0	111.4	33.6	17.5	10.7	60.3	0.0	18.6	0.0	10.9	11.6	8.000	509.000	10.2	1033.5	0.00	0.00
	1- 2	57.9	52.3	0.0	110.4	33.1	16.0	10.6	61.3	0.0	17.0	0.0	10.9	11.3	8.000	517.000	10.0	1043.5	0.00	0.00
	2- 3	60.9	51.1	0.0	112.2	33.6	19.3	10.7	59.2	0.0	20.2	0.0	10.8	11.9	8.000	525.000	10.5	1054.0	0.00	0.00
	3- 4	59.4	46.9	0.0	106.4	29.3	13.5	10.2	63.6	0.0	13.0	0.0	9.0	11.6	8.000	533.000	10.2	1064.2	0.00	0.00
	4- 5	72.2	35.6	0.0	108.1	31.3	13.7	9.8	63.0	0.0	13.4	0.0	8.7	13.9	8.000	541.000	12.4	1076.6	0.00	0.00
	5- 6	61.8	12.8	0.0	74.8	28.6	0.0	5.8	49.4	0.0	0.0	0.0	8.0	12.0	5.000	546.000	10.6	1087.3	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	551.000	13.1	1100.4	0.00	0.00
	7- 8	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	556.000	13.1	1113.5	0.00	0.00
	8- 9	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	561.000	13.1	1126.6	0.00	0.00
	9-10	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	566.000	13.1	1139.8	0.00	0.00
	10-11	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	571.000	13.1	1152.9	0.00	0.00
	11-12	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	576.000	13.1	1166.0	0.00	0.00

SOLAR -- OFF SEASON -- PIONEER MILL FACTORY STEAM BALANCE
(TYPICAL WEEK IN JANUARY - AVERAGE DAY - PROCESS LOSS RATE IS 3.5%)

DAY	HOUR	BOILER STEAM	SOLAR STEAM	SOLAR DECMT	THROTTLE STEAM	EXTRACTION HI-PR	EXTRACTION LO-PR	DA FLOW	CNDNSNG FLOW	BYPASS HI-PR	BYPASS LO-PR	PRV FLOW	MAKEUP WATER	FD-WTR HEATER	GENRTR OUTPUT (MW)	ENERGY GENERTED (MWH)	FUEL RATE (B/HR)	OIL ACCUM (BBL)	BAGASSE RATE (T/HR)	BAGASSE ACCUM (TON)
					(ALL FLOWS ARE IN KLB/HR)															
THU	0- 1A	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	581.000	13.1	1179.1	0.00	0.00
	1- 2	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	586.000	13.1	1192.2	0.00	0.00
	2- 3	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	591.000	13.1	1205.4	0.00	0.00
	3- 4	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	596.000	13.1	1218.5	0.00	0.00
	4- 5	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	601.000	13.1	1231.6	0.00	0.00
	5- 6	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	606.000	13.1	1244.7	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	611.000	13.1	1257.9	0.00	0.00
	7- 8	78.7	0.0	0.0	79.0	34.8	0.0	5.4	48.9	0.0	0.0	0.0	9.3	15.0	5.000	616.000	13.6	1271.4	0.00	0.00
	8- 9	59.7	17.0	0.0	76.9	32.1	0.0	6.1	49.4	0.0	0.0	0.0	9.8	11.7	5.000	621.000	10.3	1281.7	0.00	0.00
	9-10	75.8	35.4	0.0	111.5	35.7	13.9	9.9	62.0	0.0	15.0	0.0	10.4	14.5	8.000	629.000	13.1	1294.8	0.00	0.00
	10-11	64.0	45.3	0.0	109.5	34.1	11.9	10.3	63.4	0.0	13.2	0.0	10.7	12.4	8.000	637.000	11.0	1305.8	0.00	0.00
	11-12	59.1	49.7	0.0	108.9	33.4	12.0	10.4	63.6	0.0	13.3	0.0	10.8	11.6	8.000	645.000	10.2	1316.0	0.00	0.00
	12- 1P	59.4	51.8	0.0	111.4	33.6	17.5	10.7	60.3	0.0	18.6	0.0	10.9	11.6	8.000	653.000	10.2	1326.2	0.00	0.00
	1- 2	57.9	52.3	0.0	110.4	33.1	16.0	10.6	61.3	0.0	17.0	0.0	10.9	11.3	8.000	661.000	10.0	1336.2	0.00	0.00
	2- 3	60.9	51.1	0.0	112.2	33.6	19.3	10.7	59.2	0.0	20.2	0.0	10.8	11.9	8.000	669.000	10.5	1346.7	0.00	0.00
	3- 4	59.4	46.9	0.0	106.4	29.3	13.5	10.2	63.6	0.0	13.0	0.0	9.0	11.6	8.000	677.000	10.2	1356.9	0.00	0.00
	4- 5	72.2	35.6	0.0	108.1	31.3	13.7	9.8	63.0	0.0	13.4	0.0	8.7	13.9	8.000	685.000	12.4	1369.3	0.00	0.00
	5- 6	61.8	12.8	0.0	74.8	28.6	0.0	5.8	49.4	0.0	0.0	0.0	8.0	12.0	5.000	690.000	10.6	1380.0	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	695.000	13.1	1393.1	0.00	0.00
	7- 8	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	700.000	13.1	1406.2	0.00	0.00
	8- 9	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	705.000	13.1	1419.3	0.00	0.00
	9-10	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	710.000	13.1	1432.5	0.00	0.00
	10-11	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	715.000	13.1	1445.6	0.00	0.00
	11-12	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	720.000	13.1	1458.7	0.00	0.00
FRI	0- 1A	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	725.000	13.1	1471.8	0.00	0.00
	1- 2	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	730.000	13.1	1484.9	0.00	0.00
	2- 3	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	735.000	13.1	1498.1	0.00	0.00
	3- 4	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	740.000	13.1	1511.2	0.00	0.00
	4- 5	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	745.000	13.1	1524.3	0.00	0.00
	5- 6	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	750.000	13.1	1537.4	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	755.000	13.1	1550.5	0.00	0.00
	7- 8	78.7	0.0	0.0	79.0	34.8	0.0	5.4	48.9	0.0	0.0	0.0	9.3	15.0	5.000	760.000	13.6	1564.1	0.00	0.00
	8- 9	59.7	17.0	0.0	76.9	32.1	0.0	6.1	49.4	0.0	0.0	0.0	9.8	11.7	5.000	765.000	10.3	1574.4	0.00	0.00
	9-10	75.8	35.4	0.0	111.5	35.7	13.9	9.9	62.0	0.0	15.0	0.0	10.4	14.5	8.000	773.000	13.1	1587.5	0.00	0.00
	10-11	64.0	45.3	0.0	109.5	34.1	11.9	10.3	63.4	0.0	13.2	0.0	10.7	12.4	8.000	781.000	11.0	1598.5	0.00	0.00
	11-12	59.1	49.7	0.0	108.9	33.4	12.0	10.4	63.6	0.0	13.3	0.0	10.8	11.6	8.000	789.000	10.2	1608.7	0.00	0.00
	12- 1P	59.4	51.8	0.0	111.4	33.6	17.5	10.7	60.3	0.0	18.6	0.0	10.9	11.6	8.000	797.000	10.2	1618.9	0.00	0.00
	1- 2	57.9	52.3	0.0	110.4	33.1	16.0	10.6	61.3	0.0	17.0	0.0	10.9	11.3	8.000	805.000	10.0	1628.9	0.00	0.00
	2- 3	60.9	51.1	0.0	112.2	33.6	19.3	10.7	59.2	0.0	20.2	0.0	10.8	11.9	8.000	813.000	10.5	1639.4	0.00	0.00
	3- 4	59.4	46.9	0.0	106.4	29.3	13.5	10.2	63.6	0.0	13.0	0.0	9.0	11.6	8.000	821.000	10.2	1649.6	0.00	0.00
	4- 5	72.2	35.6	0.0	108.1	31.3	13.7	9.8	63.0	0.0	13.4	0.0	8.7	13.9	8.000	829.000	12.4	1662.0	0.00	0.00
	5- 6	61.8	12.8	0.0	74.8	28.6	0.0	5.8	[illegible]	0.0	0.0	0.0	8.0	12.0	5.000	834.000	10.6	1672.7	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	839.000	13.1	1685.8	0.00	0.00
	7- 8	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	844.000	13.1	1698.9	0.00	0.00
	8- 9	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	849.000	13.1	1712.0	0.00	0.00
	9-10	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	854.000	13.1	1725.2	0.00	0.00
	10-11	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	859.000	13.1	1738.3	0.00	0.00
	11-12	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	864.000	13.1	1751.4	0.00	0.00

SOLAR -- OFF SEASON -- PIONEER MILL FACTORY STEAM BALANCE
(TYPICAL WEEK IN JANUARY - AVERAGE DAY - PROCESS LOSS RATE IS 3.5%)

DAY	HOUR	BOILER STEAM	SOLAR STEAM	SOLAR DECMT	THROTTLE STEAM	EXTRACTION HI-PR	EXTRACTION LO-PR	DA FLOW	CNDNSNG FLOW	BYPASS HI-PR	BYPASS LO-PR	PRV FLOW	MAKEUP WATER	FD-WTR HEATER	GENRTR OUTPUT (MW)	ENERGY GENERTED (MWH)	FUEL OIL RATE (B/HR)	FUEL OIL ACCUM (BBL)	BAGASSE RATE (T/HR)	BAGASSE ACCUM (TON)
					(ALL FLOWS ARE IN KLB/HR)															
SAT	0- 1A	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	869.000	13.1	1764.5	0.00	0.00
	1- 2	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	874.000	13.1	1777.6	0.00	0.00
	2- 3	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	879.000	13.1	1790.8	0.00	0.00
	3- 4	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	884.000	13.1	1803.9	0.00	0.00
	4- 5	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	889.000	13.1	1817.0	0.00	0.00
	5- 6	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	894.000	13.1	1830.1	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	899.000	13.1	1843.2	0.00	0.00
	7- 8	78.7	0.0	0.0	79.0	34.8	0.0	5.4	48.9	0.0	0.0	0.0	9.3	15.0	5.000	904.000	13.6	1856.8	0.00	0.00
	8- 9	59.7	17.0	0.0	76.9	32.1	0.0	6.1	49.4	0.0	0.0	0.0	9.8	11.7	5.000	909.000	10.3	1867.1	0.00	0.00
	9-10	75.8	35.4	0.0	111.5	35.7	13.9	9.9	62.0	0.0	15.0	0.0	10.4	14.5	8.000	917.000	13.1	1880.2	0.00	0.00
	10-11	64.0	45.3	0.0	109.5	34.1	11.9	10.3	63.4	0.0	13.2	0.0	10.7	12.4	8.000	925.000	11.0	1891.2	0.00	0.00
	11-12	59.1	49.7	0.0	108.9	33.4	12.0	10.4	63.6	0.0	13.3	0.0	10.8	11.6	8.000	933.000	10.2	1901.4	0.00	0.00
	12- 1P	59.4	51.8	0.0	111.4	33.6	17.5	10.7	60.3	0.0	18.6	0.0	10.9	11.6	8.000	941.000	10.2	1911.6	0.00	0.00
	1- 2	57.9	52.3	0.0	110.4	33.1	16.0	10.6	61.3	0.0	17.0	0.0	10.9	11.3	8.000	949.000	10.0	1921.6	0.00	0.00
	2- 3	60.9	51.1	0.0	112.2	33.6	19.3	10.7	59.2	0.0	20.2	0.0	10.8	11.9	8.000	957.000	10.5	1932.1	0.00	0.00
	3- 4	59.4	46.9	0.0	106.4	29.3	13.5	10.2	63.6	0.0	13.0	0.0	9.0	11.6	8.000	965.000	10.2	1942.3	0.00	0.00
	4- 5	72.2	35.6	0.0	108.1	31.3	13.7	9.8	63.0	0.0	13.4	0.0	8.7	13.9	8.000	973.000	12.4	1954.7	0.00	0.00
	5- 6	61.8	12.8	0.0	74.8	28.6	0.0	5.8	49.4	0.0	0.0	0.0	8.0	12.0	5.000	978.000	10.6	1965.4	0.00	0.00
	6- 7	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	983.000	13.1	1978.5	0.00	0.00
	7- 8	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	988.000	13.1	1991.6	0.00	0.00
	8- 9	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	993.000	13.1	2004.7	0.00	0.00
	9-10	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	998.000	13.1	2017.9	0.00	0.00
	10-11	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	1003.000	13.1	2031.0	0.00	0.00
	11-12	76.1	0.0	0.0	76.3	30.7	0.0	5.3	49.0	0.0	0.0	0.0	7.6	14.6	5.000	1008.000	13.1	2044.1	0.00	0.00

SOLAR -- GRINDING SEASON -- PIONEER MILL FACTORY STEAM BALANCE PROGRAM
(TYPICAL WEEK IN MARCH - AVERAGE DAYS - PROCESS LOSS RATE IS 3.5%)

(ALL FLOWS ARE IN KLB/HR)

DAY	HOUR	BOILER STEAM	SOLAR STEAM	SOLAR DECMT	THROTTLE STEAM	EXTRACTION HI-PR	EXTRACTION LO-PR	DA FLOW	CNDNSNG FLOW	BYPASS HI-PR	BYPASS LO-PR	PRV FLOW	MAKEUP WATER	FD-WTR HEATER	GENRTR OUTPUT (MW)	ENERGY GENERTED (MWH)	FUEL RATE (B/HR)	OIL ACCUM (BBL)	BAGASSE RATE (T/HR)	BAGASSE ACCUM (TON)
SUN	0- 1A	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	5.000	0.0	0.0	12.64	158.18
	1- 2	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	10.000	0.0	0.0	12.64	145.54
	2- 3	70.5	0.0	0 0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	15.000	0.0	0.0	12.64	132.90
	3- 4	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	20.000	0.0	0.0	12.64	120.25
	4- 5	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	25.000	0.0	0.0	12.64	107.61
	5- 6	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	30.000	0.0	0.0	12.64	94.97
	6- 7	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	35.000	0.0	0.0	12.64	82.33
	7- 8	62.7	6.9	0.0	69.8	18.0	4.3	5.3	47.5	0.0	0.0	0.0	0.0	12.2	5.000	40.000	0.0	0.0	11.23	71.10
	8- 9	40.8	26.1	0.0	67.0	14.0	5.1	6.0	47.9	0.0	0.0	0.0	0.0	8.3	5.000	45.000	0.0	0.0	7.29	63.82
	9-10	64.7	37.0	0.0	101.9	18.5	22.7	9.5	60.6	0.0	14.2	0.0	0.0	12.6	8,000	53.000	0.0	0.0	11.60	52.22
	10-11	56.0	42.3	0.0	98.5	16.9	17.6	9.5	64.0	0.0	9.1	0.0	0.0	11.0	8.000	61.000	0.0	0.0	10.03	42.19
	11-12	55.0	45.5	0.0	100.7	16.7	23.2	9.8	60.7	0.0	14.4	0.0	0.0	10.8	8.000	69.000	0.0	0.0	9.84	32.35
	12- 1P	49.8	47.7	0.0	97.7	15.6	18.1	9.7	64.0	0.0	9.2	0.0	0.0	9.9	8.000	77.000	0.0	0.0	8.91	23.44
	1- 2	49.2	48.4	0.0	97.7	15.5	18.2	9.8	63.9	0.0	9.3	0.0	0.0	9.8	8.000	85.000	0.0	0.0	8.79	14.65
	2- 3	50.6	47.5	0.0	98.2	15.6	19.4	9.8	63.3	0.0	10.2	0.0	0.0	10.0	8.000	93.000	0.0	0.0	9.05	5.60
	3- 4	53.1	44.9	0.0	98.1	16.3	17.8	9.6	64.0	0.0	9.2	0.0	0.0	10.5	8.000	101.000	3.8	3.8	5.60	0.00
	4- 5	59.4	39.3	0.0	98.9	17.4	17.5	9.4	64.0	0.0	9.0	0.0	0.0	11.6	8.000	109.000	10.2	14.0	0.00	0.00
	5- 6	42.8	24.3	0.0	67.2	14.2	5.2	6.0	47.8	0.0	0.0	0.0	0.0	8.7	5.000	114.000	7.4	21.4	0.00	0.00
	6- 7	65.9	4.1	0.0	70.2	18.6	4.2	5.2	47.4	0.0	0.0	0.0	0.0	12.8	5.000	119.000	11.3	32.7	0.00	0.00
	7- 8	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	124.000	12.1	44.9	0.00	0.00
	8- 9	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	129.000	12.1	57.0	0.00	0.00
	9-10	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	134.000	12.1	69.2	0.00	0.00
	10-11	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	139.000	12.1	81.3	0.00	0.00
	11-12	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	144.000	12.1	93.5	0.00	0.00
MON	0- 1A	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	149.000	12.1	105.6	0.00	0.00
	1- 2	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	154.000	12.1	117.7	0.00	0.00
	2- 3	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	159.000	12.1	129.9	0.00	0.00
	3- 4	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	164.000	12.1	142.0	0.00	0.00
	4- 5	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	169.000	12.1	154.2	0.00	0.00
	5- 6	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	174.000	12.1	166.3	0.00	0.00
	6- 7	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	179.000	12.1	178.5	0.00	0.00
	7- 8	64.1	6.9	0.0	71.2	19.8	4.3	5.3	47.1	0.0	0.0	0.0	0.0	12.4	5.000	184.000	11.0	189.5	0.00	0.00
	8- 9	42.2	26.1	0.0	68.4	15.6	5.3	6.1	47.4	0.0	0.0	0.0	0.0	8.6	5.000	189.000	7.3	196.8	0.00	0.00
	9-10	63.4	37.0	0.0	100.6	19.7	17.4	9.3	63.5	0.0	8.9	0.0	0.0	12.3	8.000	197.000	10.9	207.7	0.00	0.00
	10-11	57.0	42.3	0.0	99.5	18.5	17.1	9.5	64.0	0.0	8.3	0.0	0.0	11.2	8.000	205.000	9.8	217.5	0.00	0.00
	11-12	53.9	45.5	0.0	99.6	18.0	18.1	9.7	63.5	0.0	9.3	0.0	0.0	10.6	8.000	213.000	9.3	226.8	0.00	0.00
	12- 1P	52.9	47.7	0.0	100.8	17.8	21.4	9.9	61.5	0.0	12.4	0.0	0.0	10.5	8.000	221.000	9.1	236.0	0.00	0.00
	1- 2	51.1	48.4	0.0	99.7	17.4	19.6	9.8	62.7	0.0	10.6	0.0	0.0	10.1	8.000	229.000	8.8	244.8	0.00	0.00
	2- 3	53.2	47.5	0.0	100.8	17.6	21.8	9.9	61.4	0.0	12.6	0.0	0.0	10.5	8.000	237.000	9.2	253.9	0.00	0.00
	3- 4	122.7	44.9	0.0	168.0	66.9	95.1	8.3	6.0	0.0	0.0	0.0	0.0	22.8	8.000	245.000	0.0	253.9	21.97	8.41
	4- 5	129.1	39.3	0.0	168.9	68.2	94.9	8.1	5.8	0.0	0.0	0.0	0.0	24.0	8.000	253.000	0.0	253.9	23.13	15.67
	5- 6	146.3	24.3	0.0	171.1	71.4	94.2	7.5	5.5	0.0	0.0	0.0	0.0	27.0	8.000	261.000	0.0	253.9	26.24	19.81
	6- 7	169.4	4.1	0.0	174.1	75.7	93.3	6.7	5.1	0.0	0.0	0.0	0.0	31.1	8.000	269.000	0.0	253.9	30.44	19.76
	7- 8	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	277.000	0.0	253.9	31.27	18.87
	8- 9	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	285.000	0.0	253.9	31.27	17.98
	9-10	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	293.000	0.0	253.9	31.27	17.09
	10-11	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	301.000	0.0	253.9	31.27	16.20
	11-12	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	309.000	0.0	253.9	31.27	15.31

SOLAR -- GRINDING SEASON -- PIONEER MILL FACTORY STEAM BALANCE PROGRAM
(TYPICAL WEEK IN MARCH - AVERAGE DAYS - PROCESS LOSS RATE IS 3.5%)

(ALL FLOWS ARE IN KLB/HR)

DAY	HOUR	BOILER STEAM	SOLAR STEAM	SOLAR DECMT	THROTTLE STEAM	EXTRACTION HI-PR	EXTRACTION LO-PR	DA FLOW	CNDNSNG FLOW	BYPASS HI-PR	BYPASS LO-PR	PRV FLOW	MAKEUP WATER	FD-WTR HEATER	GENRTR OUTPUT (MW)	ENERGY GENERTED (MWH)	FUEL RATE (B/HR)	OIL ACCUM (BBL)	BAGASSE RATE (T/HR)	BAGASSE ACCUM (TON)
TUE	0- 1A	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	317.000	0.0	253.9	31.27	14.43
	1- 2	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	325.000	0.0	253.9	31.27	13.54
	2- 3	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	333.000	0.0	253.9	31.27	12.65
	3- 4	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	341.000	0.0	253.9	31.27	11.76
	4- 5	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	349.000	0.0	253.9	31.27	10.87
	5- 6	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	357.000	0.0	253.9	31.27	9.98
	6- 7	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	365.000	0.0	253.9	31.27	9.10
	7- 8	167.6	6.9	0.0	175.1	76.8	93.7	6.9	4.7	0.0	0.0	0.0	0.0	30.8	8.000	373.000	0.0	253.9	30.11	9.37
	8- 9	145.7	26.1	0.0	172.3	72.8	94.3	7.6	5.2	0.0	0.0	0.0	0.0	26.9	8.000	381.000	0.0	253.9	26.13	13.62
	9-10	133.2	37.0	0.0	170.6	70.4	94.8	8.0	5.4	0.0	0.0	0.0	0.0	24.7	8.000	389.000	0.0	253.9	23.87	20.13
	10-11	127.1	42.3	0.0	169.9	69.4	95.0	8.2	5.5	0.0	0.0	0.0	0.0	23.6	8.000	397.000	0.0	253.9	22.77	27.75
	11-12	123.4	45.5	0.0	169.4	68.6	95.3	8.4	5.5	0.0	0.0	0.0	0.0	23.0	8.000	405.000	0.0	253.9	22.10	36.03
	12- 1P	120.9	47.7	0.0	169.0	68.2	95.3	8.4	5.6	0.0	0.0	0.0	0.0	22.5	8.000	413.000	0.0	253.9	21.65	44.77
	1- 2	120.1	48.4	0.0	168.9	68.0	95.4	8.5	5.6	0.0	0.0	0.0	0.0	22.4	8.000	421.000	0.0	253.9	21.50	53.65
	2- 3	121.2	47.5	0.0	169.1	68.3	95.1	8.4	5.7	0.0	0.0	0.0	0.0	22.6	8.000	429.000	0.0	253.9	21.70	62.33
	3- 4	122.7	44.9	0.0	168.1	66.9	95.1	8.3	6.0	0.0	0.0	0.0	0.0	22.8	8.000	437.000	0.0	253.9	21.97	70.74
	4- 5	129.1	39.3	0.0	168.9	68.2	94.9	8.1	5.8	0.0	0.0	0.0	0.0	24.0	8.000	445.000	0.0	253.9	23.13	78.00
	5- 6	146.3	24.3	0.0	171.1	71.4	94.2	7.5	5.5	0.0	0.0	0.0	0.0	27.0	8.000	453.000	0.0	253.9	26.24	82.14
	6- 7	169.4	4.1	0.0	174.1	75.7	93.3	6.7	5.1	0.0	0.0	0.0	0.0	31.1	8.000	461.000	0.0	253.9	30.44	82.09
	7- 8	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	469.000	0.0	253.9	31.27	81.20
	8- 9	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	477.000	0.0	253.9	31.27	80.31
	9-10	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	485.000	0.0	253.9	31.27	79.42
	10-11	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	493.000	0.0	253.9	31.27	78.54
	11-12	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	501.000	0.0	253.9	31.27	77.65
WED	0- 1A	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	509.000	0.0	253.9	31.27	76.76
	1- 2	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	517.000	0.0	253.9	31.27	75.87
	2- 3	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	525.000	0.0	253.9	31.27	74.98
	3- 4	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	533.000	0.0	253.9	31.27	74.09
	4- 5	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	541.000	0.0	253.9	31.27	73.21
	5- 6	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	549.000	0.0	253.9	31.27	72.32
	6- 7	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	557.000	0.0	253.9	31.27	71.43
	7- 8	167.6	6.9	0.0	175.1	76.8	93.7	6.9	4.7	0.0	0.0	0.0	0.0	30.8	8.000	565.000	0.0	253.9	30.11	71.70
	8- 9	145.7	26.1	0.0	172.3	72.8	94.3	7.6	5.2	0.0	0.0	0.0	0.0	26.9	8.000	573.000	0.0	253.9	26.13	75.95
	9-10	133.2	37.0	0.0	170.6	70.4	94.8	8.0	5.4	0.0	0.0	0.0	0.0	24.7	8.000	581.000	0.0	253.9	23.87	82.47
	10-11	127.1	42.3	0.0	169.9	69.4	95.0	8.2	5.5	0.0	0.0	0.0	0.0	23.6	8.000	589.000	0.0	253.9	22.77	90.08
	11-12	123.4	45.5	0.0	169.4	68.6	95.3	8.4	5.5	0.0	0.0	0.0	0.0	23.0	8.000	597.000	0.0	253.9	22.10	98.37
	12- 1P	120.9	47.7	0.0	169.0	68.2	95.3	8.4	5.6	0.0	0.0	0.0	0.0	22.5	8.000	605.000	0.0	253.9	21.65	107.10
	1- 2	120.1	48.4	0.0	169.0	68.0	95.4	8.5	5.6	0.0	0.0	0.0	0.0	22.4	8.000	613.000	0.0	253.9	21.50	115.98
	2- 3	121.2	47.5	0.0	169.1	68.3	95.1	8.4	5.7	0.0	0.0	0.0	0.0	22.6	8.000	621.000	0.0	253.9	21.70	124.67
	3- 4	122.7	44.9	0.0	168.1	66.9	95.1	8.3	6.0	0.0	0.0	0.0	0.0	22.8	8.000	629.000	0.0	253.9	21.97	133.08
	4- 5	129.1	39.3	0.0	168.9	68.2	94.9	8.1	5.8	0.0	0.0	0.0	0.0	24.0	8.000	637.000	0.0	253.9	23.13	140.33
	5- 6	146.3	24.3	0.0	171.1	71.4	94.2	7.5	5.5	0.0	0.0	0.0	0.0	27.0	8.000	645.000	0.0	253.9	26.24	144.47
	6- 7	169.4	4.1	0.0	174.1	75.7	93.3	6.7	5.1	0.0	0.0	0.0	0.0	31.1	8.000	653.000	0.0	253.9	30.44	144.42
	7- 8	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	661.000	0.0	253.9	31.27	143.53
	8- 9	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	669.000	0.0	253.9	31.27	142.64
	9-10	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	677.000	0.0	253.9	31.27	141.76
	10-11	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	685.000	0.0	253.9	31.27	140.87
	11-12	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	693.000	0.0	253.9	31.27	139.98

SOLAR -- GRINDING SEASON -- PIONEER MILL FACTORY STEAM BALANCE PROGRAM
(TYPICAL WEEK IN MARCH - AVERAGE DAYS - PROCESS LOSS RATE IS 3.5%)

(ALL FLOWS ARE IN KLB/HR)

DAY	HOUR	BOILER STEAM	SOLAR STEAM	SOLAR DECMT	THROTTLE STEAM	EXTRACTION HI-PR	EXTRACTION LO-PR	DA FLOW	CNDNSNG FLOW	BYPASS HI-PR	BYPASS LO-PR	PRV FLOW	MAKEUP WATER	FD-WTR HEATER	GENRTR OUTPUT (MW)	ENERGY GENERTED (MWH)	FUEL RATE (B/HR)	OIL ACCUM (BBL)	BAGASSE RATE (T/HR)	BAGASSE ACCUM (TON)
THU	0- 1A	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	701.000	0.0	253.9	31.27	139.09
	1- 2	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	709.000	0.0	253.9	31.27	138.20
	2- 3	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	717.000	0.0	253.9	31.27	137.31
	3- 4	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	725.000	0.0	253.9	31.27	136.43
	4- 5	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	733.000	0.0	253.9	31.27	135.54
	5- 6	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	741.000	0.0	253.9	31.27	134.65
	6- 7	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	749.000	0.0	253.9	31.27	133.76
	7- 8	167.6	6.9	0.0	175.1	76.8	93.7	6.9	4.7	0.0	0.0	0.0	0.0	30.8	8.000	757.000	0.0	253.9	30.11	134.04
	8- 9	145.7	26.1	0.0	172.3	72.8	94.3	7.6	5.2	0.0	0.0	0.0	0.0	26.9	8.000	765.000	0.0	253.9	26.13	138.29
	9-10	133.2	37.0	0.0	170.6	70.4	94.8	8.0	5.4	0.0	0.0	0.0	0.0	24.7	8.000	773.000	0.0	253.9	23.87	144.80
	10-11	127.1	42.3	0.0	169.9	69.4	95.0	8.2	5.5	0.0	0.0	0.0	0.0	23.6	8.000	781.000	0.0	253.9	22.77	152.42
	11-12	123.4	45.5	0.0	169.4	68.6	95.3	8.4	5.5	0.0	0.0	0.0	0.0	23.0	8.000	789.000	0.0	253.9	22.10	160.70
	12- 1P	120.9	47.7	0.0	169.0	68.2	95.3	8.4	5.6	0.0	0.0	0.0	0.0	22.5	8.000	797.000	0.0	253.9	21.65	169.44
	1- 2	120.1	48.4	0.0	169.0	68.0	95.4	8.5	5.6	0.0	0.0	0.0	0.0	22.4	8.000	805.000	0.0	253.9	21.50	178.32
	2- 3	121.2	47.5	0.0	169.1	68.3	95.1	8.4	5.7	0.0	0.0	0.0	0.0	22.6	8.000	813.000	0.0	253.9	21.70	187.00
	3- 4	122.7	44.9	0.0	168.1	66.9	95.1	8.3	6.0	0.0	0.0	0.0	0.0	22.8	8.000	821.000	0.0	253.9	21.97	195.41
	4- 5	129.1	39.3	0.0	168.9	68.2	94.9	8.1	5.8	0.0	0.0	0.0	0.0	24.0	8.000	829.000	0.0	253.9	23.13	202.67
	5- 6	146.3	24.3	0.0	171.1	71.4	94.2	7.5	5.5	0.0	0.0	0.0	0.0	27.0	8.000	837.000	0.0	253.9	26.24	206.81
	6- 7	169.4	4.1	0.0	174.1	75.7	93.3	6.7	5.1	0.0	0.0	0.0	0.0	31.1	8.000	845.000	0.0	253.9	30.44	206.75
	7- 8	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	853.000	0.0	253.9	31.27	205.87
	8- 9	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	861.000	0.0	253.9	31.27	204.98
	9-10	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	869.000	0.0	253.9	31.27	204.09
	10-11	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	877.000	0.0	253.9	31.27	203.20
	11-12	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	885.000	0.0	253.9	31.27	202.31
FRI	0- 1A	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	893.000	0.0	253.9	31.27	201.42
	1- 2	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	901.000	0.0	253.9	31.27	200.54
	2- 3	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	909.000	0.0	253.9	31.27	199.65
	3- 4	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	917.000	0.0	253.9	31.27	198.76
	4- 5	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	925.000	0.0	253.9	31.27	197.87
	5- 6	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	933.000	0.0	253.9	31.27	196.98
	6- 7	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	941.000	0.0	253.9	31.27	196.09
	7- 8	167.6	6.9	0.0	175.1	76.8	93.7	6.9	4.7	0.0	0.0	0.0	0.0	30.8	8.000	949.000	0.0	253.9	30.11	196.37
	8- 9	145.7	26.1	0.0	172.3	72.8	94.3	7.6	5.2	0.0	0.0	0.0	0.0	26.9	8.000	957.000	0.0	253.9	26.13	200.62
	9-10	133.2	37.0	0.0	170.6	70.4	94.8	8.0	5.4	0.0	0.0	0.0	0.0	24.7	8.000	965.000	0.0	253.9	23.87	207.13
	10-11	127.1	42.3	0.0	169.9	69.4	95.0	8.2	5.5	0.0	0.0	0.0	0.0	23.6	8.000	973.000	0.0	253.9	22.77	214.75
	11-12	123.4	45.5	0.0	169.4	68.6	95.3	8.4	5.5	0.0	0.0	0.0	0.0	23.0	8.000	981.000	0.0	253.9	22.10	223.03
	12- 1P	120.9	47.7	0.0	169.0	68.2	95.3	8.4	5.6	0.0	0.0	0.0	0.0	22.5	8.000	989.000	0.0	253.9	21.65	231.77
	1- 2	120.1	48.4	0.0	169.0	68.0	95.4	8.5	5.6	0.0	0.0	0.0	0.0	22.4	8.000	997.000	0.0	253.9	21.50	240.65
	2- 3	121.2	47.5	0.0	169.1	68.3	95.1	8.4	5.7	0.0	0.0	0.0	0.0	22.6	8.000	1005.000	0.0	253.9	21.70	249.33
	3- 4	122.7	44.9	0.0	168.1	66.9	95.1	8.3	6.0	0.0	0.0	0.0	0.0	22.8	8.000	1013.000	0.0	253.9	21.97	257.74
	4- 5	129.1	39.3	0.0	168.9	68.2	94.9	8.1	5.8	0.0	0.0	0.0	0.0	24.0	8.000	1021.000	0.0	253.9	23.13	265.00
	5- 6	146.3	24.3	0.0	171.1	71.4	94.2	7.5	5.5	0.0	0.0	0.0	0.0	27.0	8.000	1029.000	0.0	253.9	26.24	269.14
	6- 7	169.4	4.1	0.0	174.1	75.7	93.3	6.7	5.1	0.0	0.0	0.0	0.0	31.1	8.000	1037.000	0.0	253.9	30.44	269.09
	7- 8	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	1045.000	0.0	253.9	31.27	268.20
	8- 9	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	1053.000	0.0	253.9	31.27	267.31
	9-10	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	1061.000	0.0	253.9	31.27	266.42
	10-11	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	1069.000	0.0	253.9	31.27	265.53
	11-12	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	1077.000	0.0	253.9	31.27	264.65

SOLAR -- GRINDING SEASON -- PIONEER MILL FACTORY STEAM BALANCE PROGRAM
(TYPICAL WEEK IN MARCH - AVERAGE DAYS - PROCESS LOSS RATE IS 3.5%)

DAY	HOUR	BOILER STEAM	SOLAR STEAM	SOLAR DECNT	THROTTLE STEAM	EXTRACTION HI-PR	EXTRACTION LO-PR	DA FLOW	CNDNSNG FLOW	BYPASS HI-PR	BYPASS LO-PR	PRV FLOW	MAKEUP WATER	FD-WTR HEATER	GENRTR OUTPUT (MW)	ENERGY GENERTED (MWH)	FUEL RATE (B/HR)	OIL ACCUM (BBL)	BAGASSE RATE (T/HR)	BAGASSE ACCUM (TON)
					(ALL FLOWS ARE IN KLB/HR)															
SAT	0- 1A	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	1085.000	0.0	253.9	31.27	263.76
	1- 2	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	1093.000	0.0	253.9	31.27	262.87
	2- 3	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	1101.000	0.0	253.9	31.27	261.98
	3- 4	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	1109.000	0.0	253.9	31.27	261.09
	4- 5	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	1117.000	0.0	253.9	31.27	260.20
	5- 6	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	1125.000	0.0	253.9	31.27	259.32
	6- 7	174.0	0.0	0.0	174.7	76.4	93.3	6.5	5.0	0.0	0.0	0.0	0.0	32.0	8.000	1133.000	0.0	253.9	31.27	258.43
	7- 8	167.6	6.9	0.0	175.1	76.8	93.7	6.9	4.7	0.0	0.0	0.0	0.0	30.8	8.000	1141.000	0.0	253.9	30.11	258.70
	8- 9	145.7	26.1	0.0	172.3	72.8	94.3	7.6	5.2	0.0	0.0	0.0	0.0	26.9	8.000	1149.000	0.0	253.9	26.13	262.95
	9-10	133.2	37.0	0.0	170.6	70.4	94.8	8.0	5.4	0.0	0.0	0.0	0.0	24.7	8.000	1157.000	0.0	253.9	23.87	269.47
	10-11	127.1	42.3	0.0	169.9	69.4	95.0	8.2	5.5	0.0	0.0	0.0	0.0	23.6	8.000	1165.000	0.0	253.9	22.77	277.08
	11-12	123.4	45.5	0.0	169.4	68.6	95.3	8.4	5.5	0.0	0.0	0.0	0.0	23.0	8.000	1173.000	0.0	253.9	22.10	285.37
	12- 1P	120.9	47.7	0.0	169.0	68.2	95.3	8.4	5.6	0.0	0.0	0.0	0.0	22.5	8.000	1181.000	0.0	253.9	21.65	294.10
	1- 2	120.1	48.4	0.0	169.0	68.0	95.4	8.5	5.6	0.0	0.0	0.0	0.0	22.4	8.000	1189.000	0.0	253.9	21.50	302.98
	2- 3	121.2	47.5	0.0	169.1	68.3	95.1	8.4	5.7	0.0	0.0	0.0	0.0	22.6	8.000	1197.000	0.0	253.9	21.70	311.67
	3- 4	122.7	44.9	0.0	168.0	66.9	95.1	8.3	6.0	0.0	0.0	0.0	0.0	22.8	8.000	1205.000	0.0	253.9	21.97	289.69
	4- 5	107.8	39.3	0.0	147.5	64.3	47.7	8.9	35.6	0.0	0.0	0.0	0.0	20.2	8.000	1213.000	0.0	253.9	19.43	270.26
	5- 6	95.9	24.3	0.0	120.5	62.0	44.6	5.9	13.9	0.0	0.0	0.0	0.0	18.1	5.000	1218.000	0.0	253.9	17.26	253.00
	6- 7	85.6	4.1	0.0	90.0	25.1	39.9	4.5	25.0	0.0	0.0	0.0	0.0	16.3	5.000	1223.000	0.0	253.9	15.38	237.62
	7- 8	90.3	0.0	0.0	90.6	25.9	39.8	4.4	24.9	0.0	0.0	0.0	0.0	17.1	5.000	1228.000	0.0	253.9	16.24	221.39
	8- 9	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	1233.000	0.0	253.9	12.64	208.74
	9-10	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	1238.000	0.0	253.9	12.64	196.10
	10-11	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	1243.000	0.0	253.9	12.64	183.46
	11-12	70.5	0.0	0.0	70.7	19.3	4.1	5.0	47.3	0.0	0.0	0.0	0.0	13.6	5.000	1248.000	0.0	253.9	12.64	170.82

Appendix F

MAUI ELECTRIC COMPANY INTERFACE DATA

Maui Electric Company operates the isolated grid on the island of Maui. Most of its generating capacity, tabulated in Table F-1, is located in the central area. Pioneer Mill has the only generating capacity in west Maui. It is linked to the Maui electric system by two parallel transmission lines that traverse the West Maui Mountains. When these lines are out of service, which occurs occasionally as a result of windstorms, Pioneer Mill must isolate from the grid because it cannot carry the west Maui load.

Table F-1

MAUI ELECTRIC CO. INSTALLED CAPACITY

Units	Rating, kW	Totals, kW
Diesel		
Units 1 to 3	2,750	8,250
Units 4 to 7	5,600	22,400
Units 8 and 9	6,160	12,320
Units 10 and 11	12,500	25,000
Subtotal		67,970
Steam		
Units 1 and 2	6,000	12,000
Unit 3	12,000	12,000
Unit 4	13,000	13,000
Subtotal		37,000
Total system installed capacity		104,970
System momentary peak expected for 1980 (approximate)		90,000

Maui Electric Company regularly requests power from Pioneer Mill and the other two sugar plantations on the island. During 1980, they paid between 39.3-61.3 mills/kWh for power on demand and a rate of 8 mills/kWh lower for unregulated power. This rate is expected to increase significantly because the Maui Electric units are totally oil-fired and new EPA regulations will soon force them to burn low-sulfur oil at a premium over the current oil costs.

The projected load growth for the west Maui area is given in Table F-2. Any excess power generated by Pioneer Mill can be easily absorbed by the Maui electric system.

Table F-2

PROJECTED ELECTRIC LOAD GROWTH ON MAUI

Year	West Maui Peak, MW	MECo System Peak, MW
1980	29.8	89.7
1981	31.1	93.6
1982	32.0	96.5
1983	33.1	99.6
1984	34.1	102.7
1985	35.2	105.9
1986	36.2	109.2
1987	37.4	112.6
1988	38.5	116.1
1989	39.7	119.7
1990	41.0	123.4
1991	42.2	127.2
1992	43.5	131.1
1993	44.9	135.2
1994	46.3	139.4
1995	47.7	143.7
1996	49.2	148.2
1997	50.7	152.8
1998	52.3	157.5
1999	53.9	162.4

Note: The line loss is 1.8% of the west Maui peak load for a 24-hour period.

Typical weekly load variations for the Maui electric system are presented in Table F-3. Figures F-1 through F-5 show examples of the daily load curve at different times of year.

Table F-3

MAUI ELECTRIC COMPANY
TYPICAL WEEKLY LOAD PROFILES

Date	Day	Daily Minimum, MWe (3-5 a.m.)	Morning Peak, MWe (10-11 a.m.)	Evening Peak, MWe (6-8 p.m.)
4/6/80	Sun	33	55	64.5
4/7/80	Mon	31.5	69	74
4/8/80	Tues	33	68	75.5
4/9/80	Wed	32.5	67	76
4/10/80	Thurs	31	68	75
4/11/80	Fri	33.5	68.5	73
4/12/80	Sat	34	60.5	65.5
8/3/80	Sun	37	61	70
8/4/80	Mon	36.5	73	75.5
8/5/80	Tues	37	73	80.5
8/6/80	Wed	37	74	78
8/7/80	Thurs	38	74	79.5
8/8/80	Fri	38.5	76	81.5
8/9/80	Sat	38.5	68	74
12/24/80	Wed	40	78	84
12/25/80	Thurs	39.5	67.5	71.5
12/26/80	Fri	36	71.5	87
12/27/80	Sat	38	69.5	82.5
12/28/80	Sun	37.5	68	80
12/29/80	Mon	37.5	76.5	89
12/30/80	Tues	38.5	78	87.5
12/31/80	Wed	38.5	76	87.5

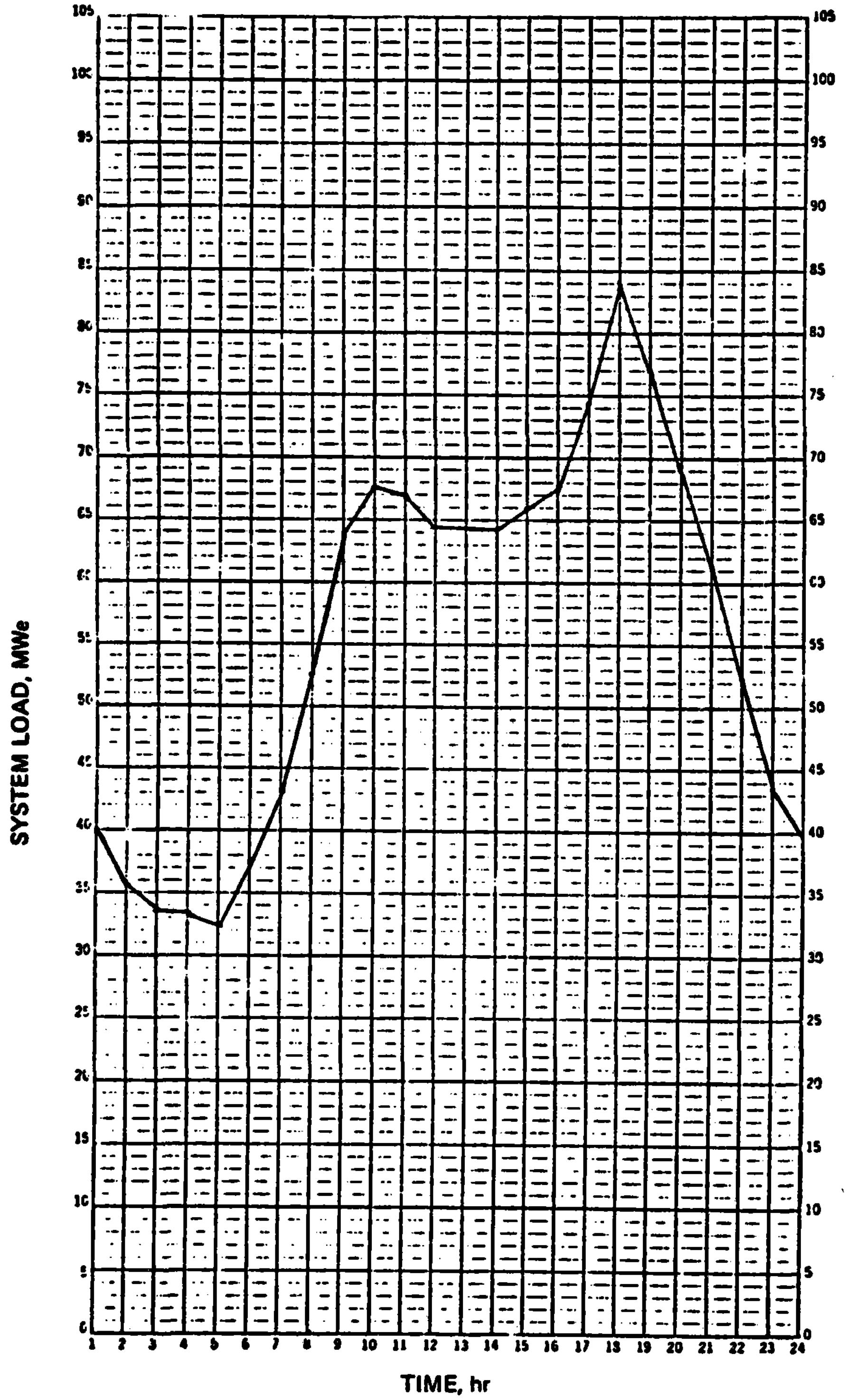


Figure F-1 TYPICAL MAUI ELECTRIC DAILY LOAD PATTERN, 27 DEC 79

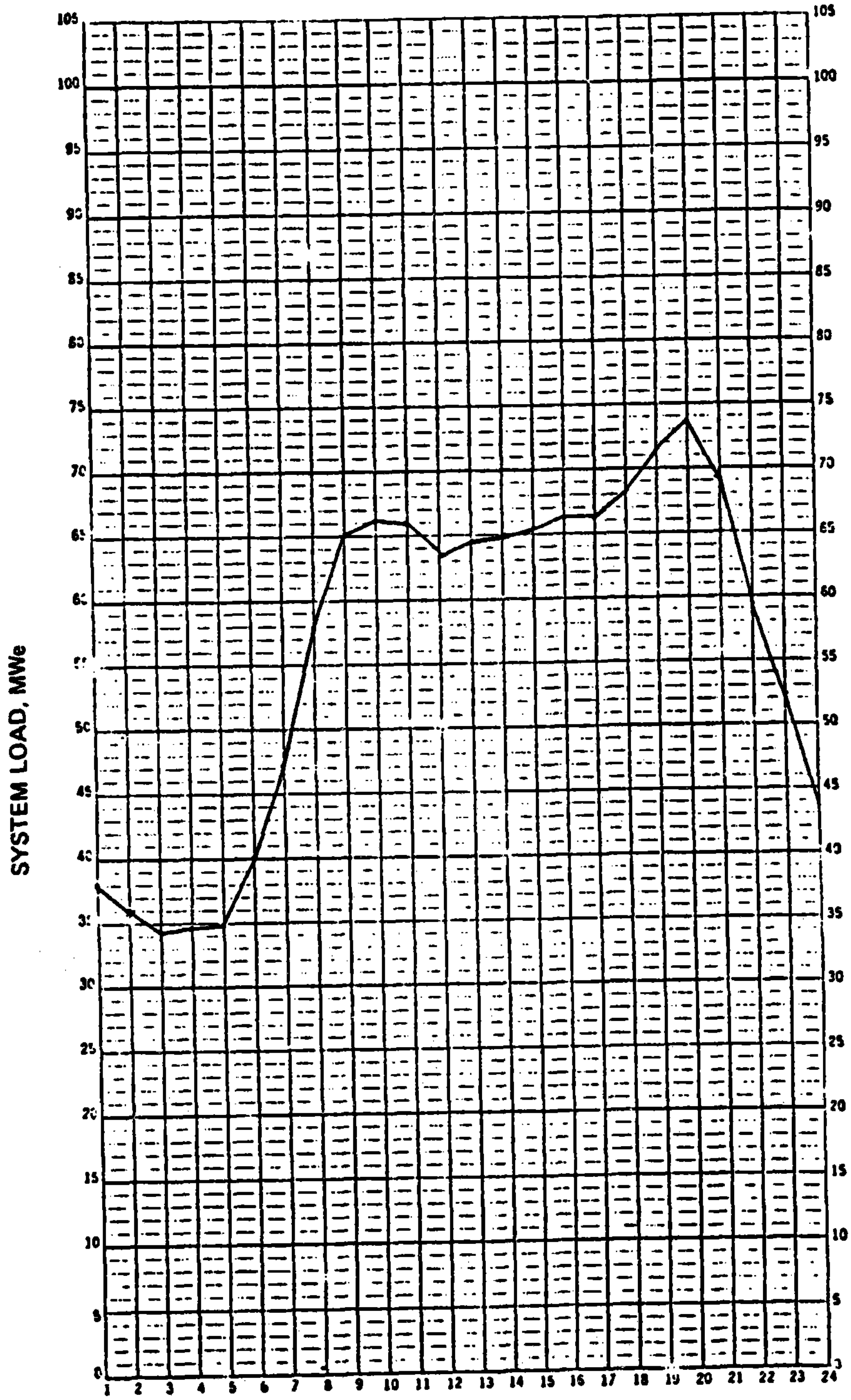


Figure F-2 TYPICAL MAUI ELECTRIC DAILY LOAD PATTERN, 17 APR 80

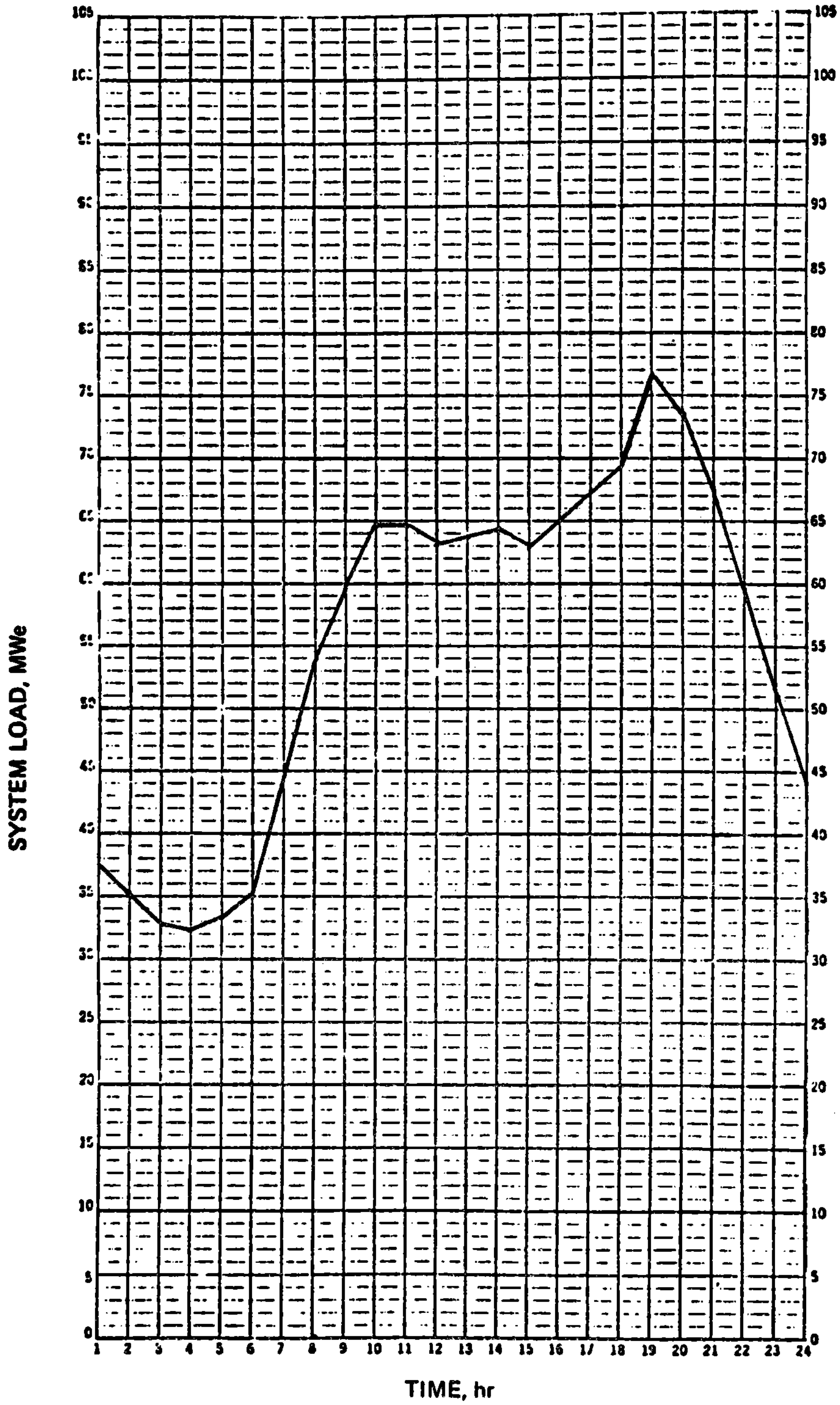


Figure F-3 TYPICAL MAUI ELECTRIC DAILY LOAD PATTERN, 19 DEC 79

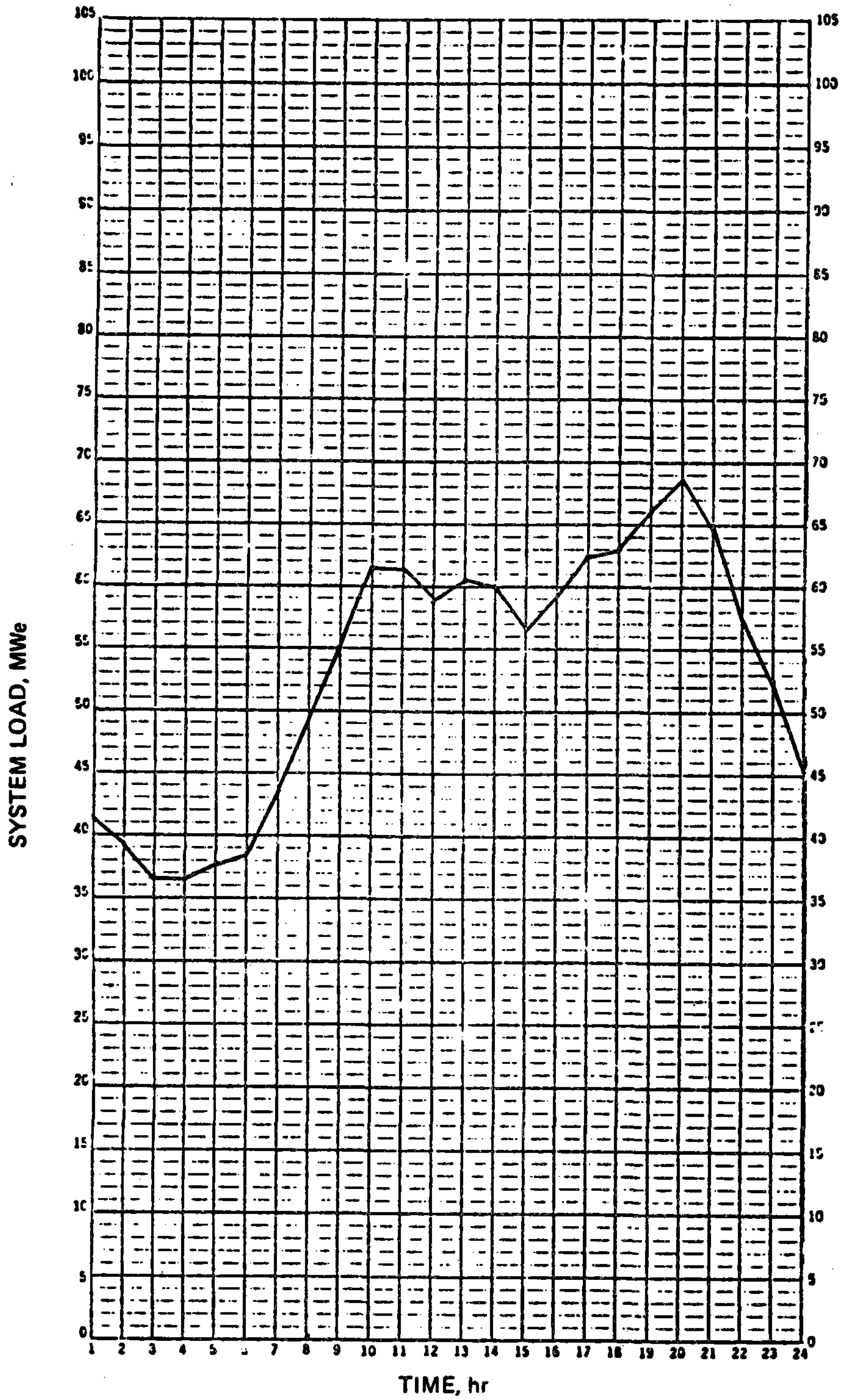


Figure F-4 TYPICAL MAUI ELECTRIC DAILY LOAD PATTERN, 14 JUNE 80

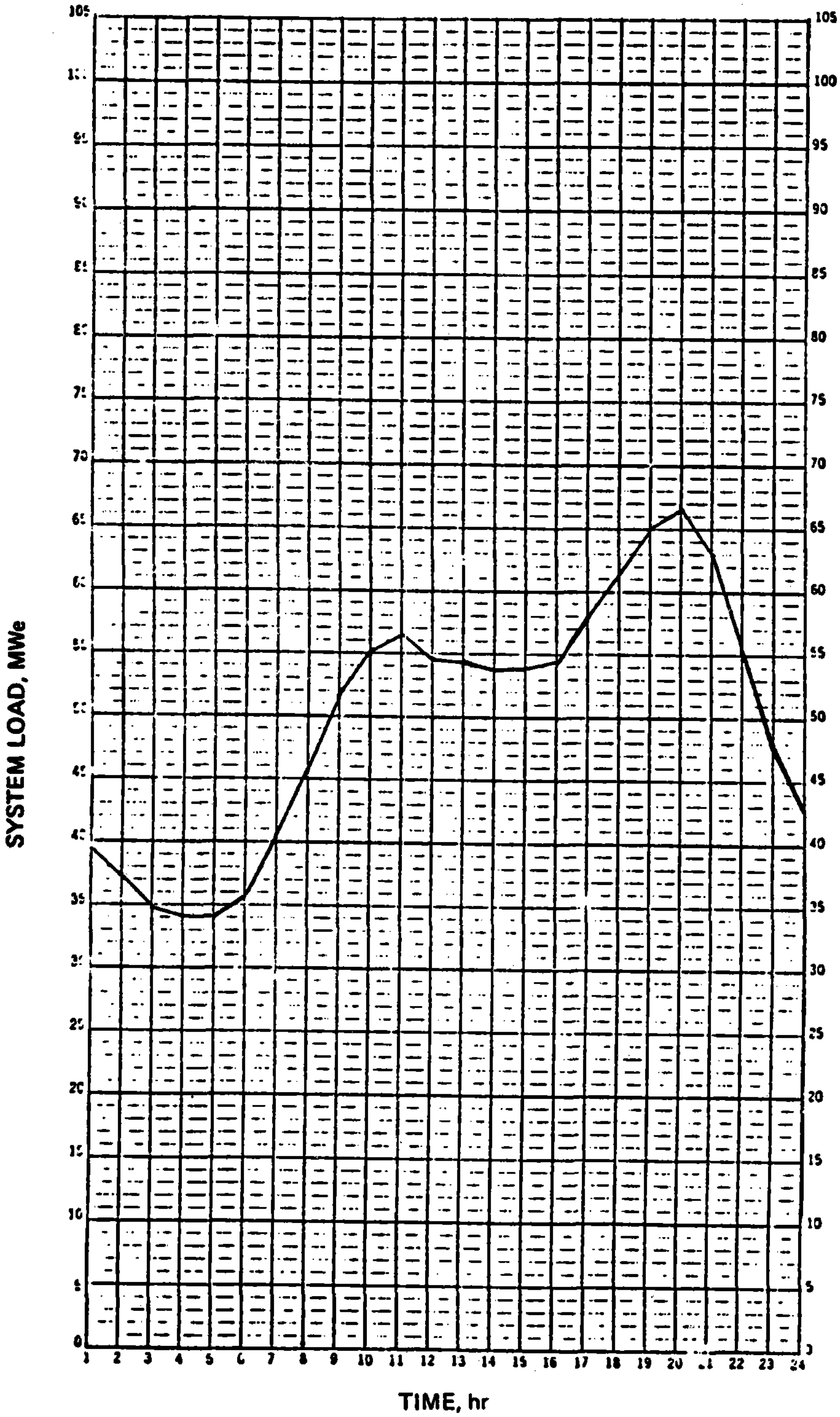


Figure F-5 TYPICAL MAUI ELECTRIC DAILY LOAD PATTERN, 4 MAY 80

Table G-1

KEY TO FLUX MAPS

Day	Time	Page East Cavity	Page West Cavity
80	8 am	G-3	G-4
	10 am	G-5	G-6
	12 noon	G-7	G-8
	2 pm	G-9	G-10
	4 pm	G-11	G-12
172	8 am	G-13	G-14
	10 am	G-15	G-16
	12 noon	G-17	G-18
	2 pm	G-19	G-20
	4 pm	G-21	G-22
355	8 am	G-23	G-24
	10 am	G-25	G-26
	12 noon	G-27	G-28
	2 pm	G-29	G-30
	4 pm	G-31	G-32

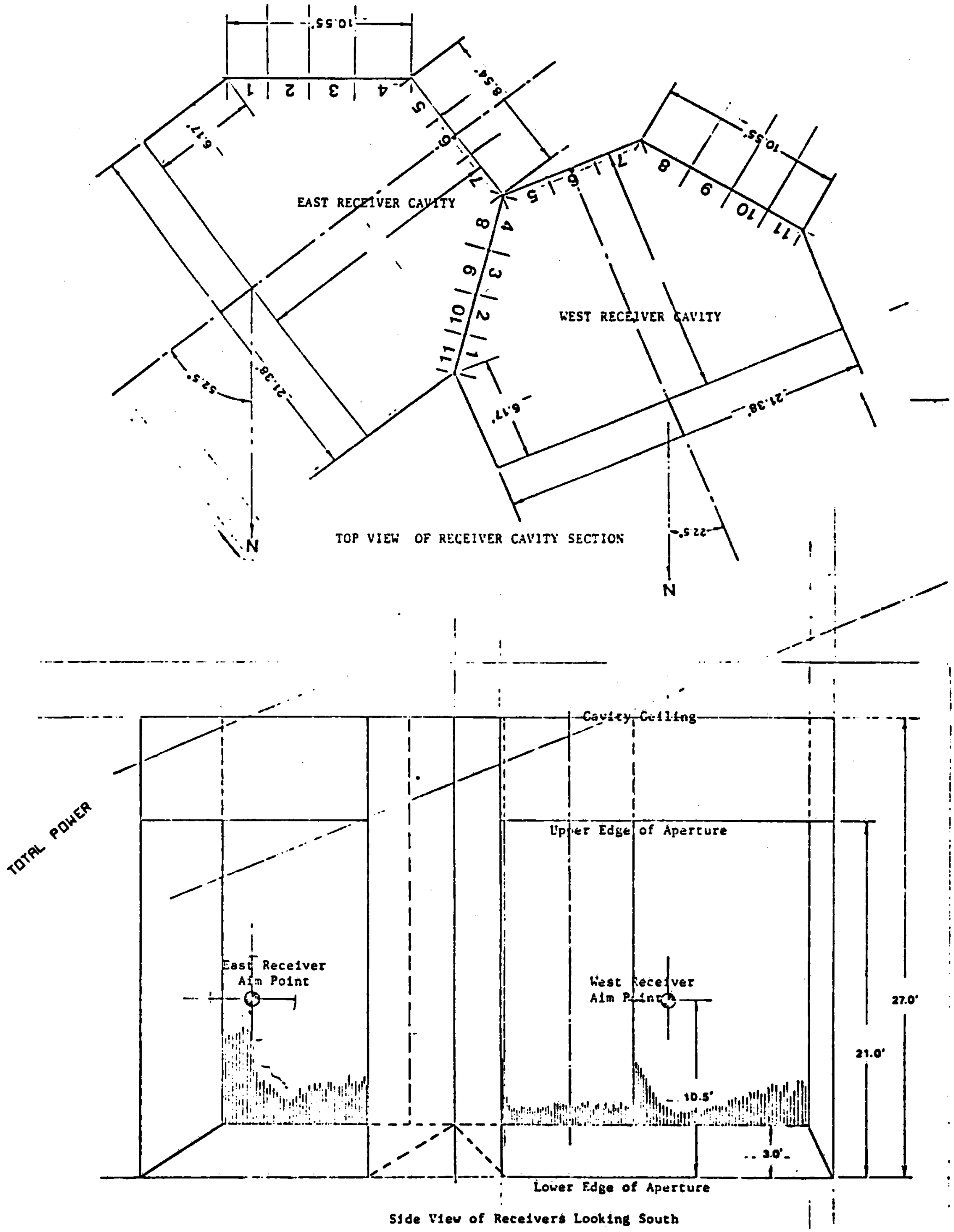


Figure G-1 DIMENSIONS SKETCH FOR INTERPRETATION OF FLUX MAPS

EAST RECEIVER:

TARGET PLANE FLUX -KW/M2

15	1	3	7	12	17	19	17	12	7	3	1
12	3	10	19	33	47	53	47	33	19	9	3
9	7	19	41	77	113	129	113	77	42	19	7
6	12	33	77	147	225	260	225	148	77	33	12
3	17	47	113	225	351	410	352	225	113	47	17
0	19	53	129	260	410	481	411	261	130	53	19
-3	17	47	113	225	352	411	353	226	114	47	17
-6	12	33	77	148	226	261	226	149	77	33	12
-9	7	19	42	77	113	130	114	77	42	19	7
-12	3	9	19	33	47	53	47	33	19	9	3
-15	1	3	7	12	17	19	17	12	7	3	1
	-15	-12	-9	-6	-3	0	3	6	9	12	15

10.1M [33FT] (horizontal)

10.1M [33FT] (vertical)

TOTAL POWER = 6863.23

DAY - 60.00

TIME = 8.00

AZ = 76.64

ELEV = 27.95

JE

TOTAL ENERGY = 8261.59

DAY - 63.00

TIME = 8.00

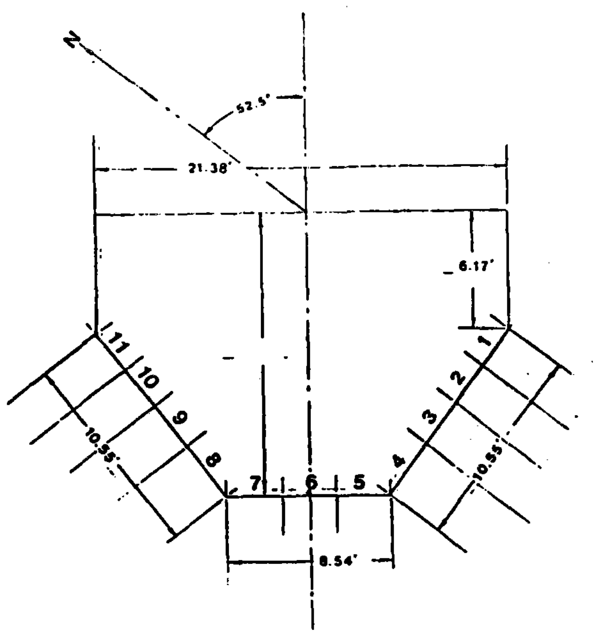
EAST RECEIVER FLUX, kW/m²

DAY

TIME

POWER

Distance Above Aperture Centerline, ft.	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	23	35	48	64	94	109	114	91	71	50	29
12	42	63	85	105	151	182	189	157	134	100	61
9	62	92	120	144	206	244	256	219	198	152	97
6	75	109	140	162	222	272	285	251	235	187	123
3	75	108	136	152	205	250	260	232	225	183	124
0	63	89	109	119	156	189	193	173	172	144	99
-3	44	61	74	78	99	118	117	104	106	90	63
-6	26	36	42	43	53	62	59	52	53	46	32
Panel No.	11	10	9	8	7	6	5	4	3	2	1



WEST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	1	3	5	6	5	3	1	0	0
12	0	2	6	14	25	31	25	14	6	2	0
9	1	6	21	57	100	135	100	57	21	6	1
6	3	14	57	169	351	457	352	170	57	14	3
3	5	25	100	351	800	1007	803	353	109	25	5
0	6	31	135	456	1005	1505	1002	459	136	31	6
-3	5	25	100	351	801	1000	804	354	109	26	5
-6	3	14	57	170	352	458	353	171	57	14	3
-9	1	6	21	57	100	135	109	57	21	6	1
-12	0	2	6	14	25	31	25	14	6	2	0
-15	0	0	1	3	5	6	5	3	1	0	0

10.1M [33FT] (horizontal)

10.1M [33FT] (vertical)

TOTAL POWER = 14151.22

DAY - 63.00

TIME = 8.00

AZ = 78.64

ELEV = 27.95

JB

WEST RECEIVER FLUX, kW/m²

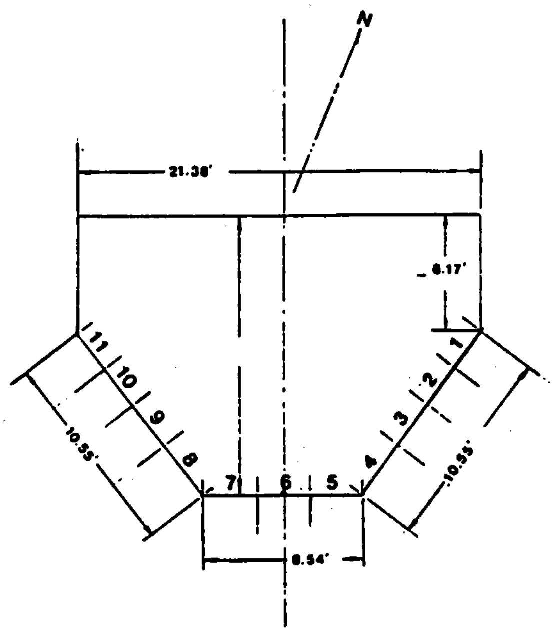
DAY - 63.00

TIME = 8.00

TOTAL POWER = 13733.22

Distance Above Aperture Centerline, Ft.

	10.55				8.54			10.55			
	2.84	2.30	2.84	3.17	2.88	2.78	2.88	3.17	2.84	2.30	2.34
15	13	24	42	69	92	94	102	71	60	38	15
12	42	74	116	160	212	227	231	186	170	122	53
9	99	155	242	291	389	441	455	395	350	238	111
6	131	224	317	356	512	601	621	560	519	362	181
3	134	225	309	355	464	546	558	507	493	359	189
0	99	162	216	236	297	448	341	307	306	230	126
-3	54	96	110	115	139	159	146	130	130	100	56
-6	23	35	42	42	48	52	46	41	39	30	17
Panel No.	11	10	9	8	7	6	5	4	3	2	1



EAST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	1	2	4	8	12	13	12	8	4	2	1
12	2	5	13	27	42	48	42	27	13	5	2
9	4	13	36	78	128	161	128	78	37	13	4
6	8	27	78	180	311	378	312	180	78	27	8
3	12	42	128	312	573	716	574	313	128	43	12
0	13	48	152	379	716	985	718	381	152	58	13
-3	12	42	128	313	576	719	577	314	129	43	12
-6	8	27	79	181	314	381	314	162	73	27	8
-9	4	13	37	79	129	153	128	79	37	13	4
-12	2	5	13	27	43	58	43	27	13	5	2
-15	1	2	4	8	12	13	12	8	4	2	1

10.1M [33FT] (horizontal)

10.1M [33FT] (vertical)

TOTAL POWER = 12013.47

DAY - 80.00

TIME = 10.00

AZ = 58.70

ELEV = 54.10

JB

EAST RECEIVER FLUX, kW/m²

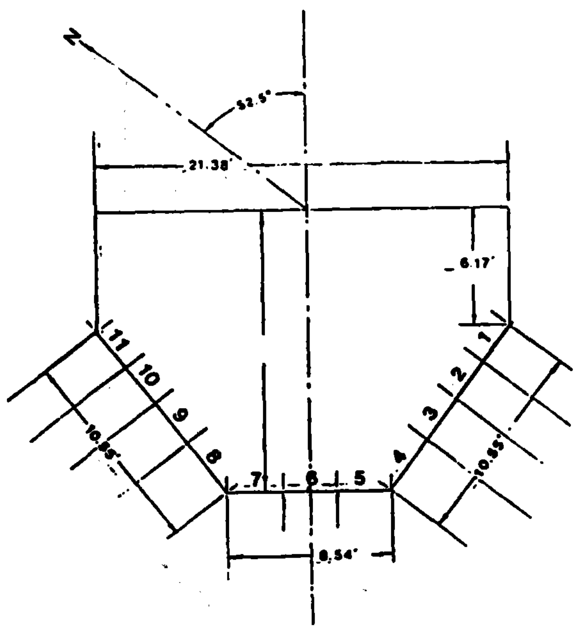
DAY - 80.00

TIME = 10.00

TOTAL POWER = 11471.37

	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	20	34	54	81	120	142	144	117	75	45	21
12	47	79	117	154	218	260	263	204	166	112	56
9	92	134	188	230	314	375	282	314	267	186	101
6	109	174	234	274	368	438	446	380	338	245	142
3	112	174	227	257	336	399	402	349	324	246	149
0	89	136	173	189	240	281	277	241	233	183	114
-3	56	83	104	109	135	155	149	128	127	102	65
-6	28	43	49	50	61	68	62	53	54	44	10
Panel No.	11	10	9	8	7	6	5	4	3	2	1

Distance Above Aperture Centerline, Ft.



WEST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	1	2	4	5	4	2	1	0	0
12	0	1	5	13	24	29	24	13	5	1	0
9	1	5	19	55	108	136	108	55	19	5	1
6	2	13	55	172	366	481	366	172	55	13	2
3	4	24	108	366	868	1204	870	367	108	24	4
0	5	29	136	481	1205	1717	1207	483	136	29	5
-3	4	24	108	367	871	1208	872	368	108	24	4
-6	2	13	55	173	368	483	368	173	56	13	2
-9	1	5	19	55	108	137	108	56	19	5	1
-12	0	1	5	13	24	29	24	13	5	1	0
-15	0	0	1	2	4	5	4	2	1	0	0

10.1M [33FT] (horizontal) — 10.1M [33FT] (vertical)

TOTAL POWER = 15079.52

DAY - 80.00

TIME = 10.00

AZ = 58.70

ELEV = 54.18

JB

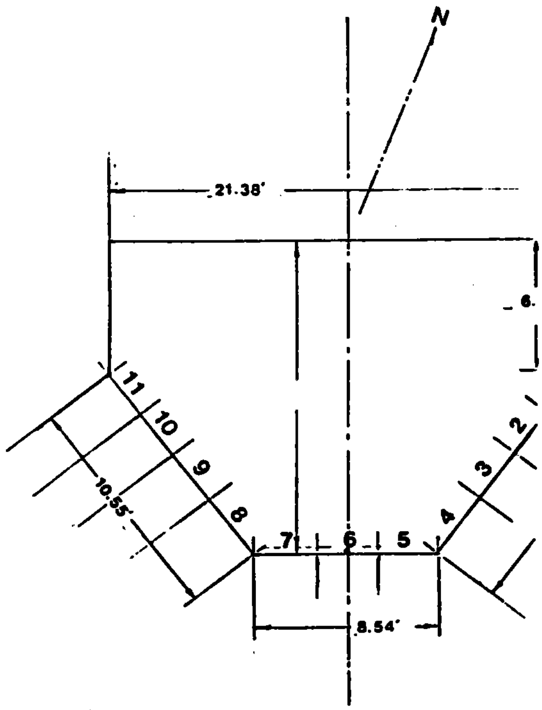
WEST RECEIVER FLUX, kW/m²

DAY - 80.00

TIME = 10.00

TOTAL POWER = 14666.50

Distance Above Aperture Centerline, Ft.	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	9	18	37	76	105	96	115	75	63	41	16
12	38	74	125	182	233	237	245	193	178	132	56
9	96	180	274	346	444	485	478	402	350	241	113
6	150	273	393	465	591	660	649	560	506	352	179
3	153	270	376	422	528	597	576	504	478	346	187
0	109	186	251	269	327	370	350	307	300	225	126
-3	56	92	120	123	145	163	149	131	131	101	58
-6	21	34	42	41	48	52	46	40	41	32	19
Panel No.	11	10	9	8	7	6	5	4	3	2	1



EAST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	2	4	6	7	6	4	2	0	0
12	0	2	7	18	30	37	30	18	7	2	0
9	2	7	25	65	119	146	119	65	25	7	2
6	4	18	65	181	356	454	356	181	65	18	4
3	6	30	119	356	776	1043	777	357	119	31	6
0	7	37	146	456	1045	1440	1046	457	147	37	7
-3	6	31	119	357	779	1048	780	358	119	31	6
-6	4	18	65	182	358	458	358	182	66	18	4
-9	2	7	25	66	119	147	120	66	25	7	2
-12	0	2	7	18	31	37	31	18	7	2	0
-15	0	0	2	4	6	7	6	4	2	0	0

10.1M [33FT] (horizontal)

10.1M [33FT] (vertical)

TOTAL POWER = 14232.00

DAY - 80.00

TIME = 12.00

AZ = 0.01

ELEV = 69.44

JB

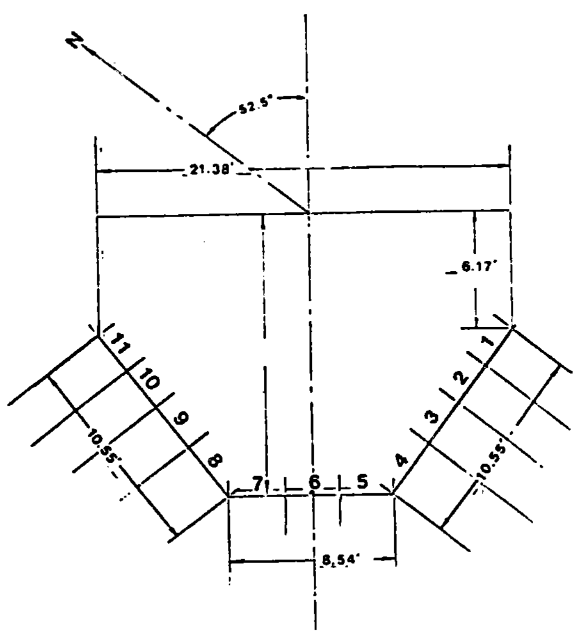
EAST RECEIVER FLUX, kW/m²

DAY - 82.22

TIME = 12.22

TOTAL POWER = 13926.22

Distance Above Aperture Centerline, Ft.	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	11	24	48	87	121	152	159	97	69	37	14
12	39	77	133	186	249	305	305	215	174	109	45
9	87	163	252	314	414	481	473	375	301	192	92
6	134	233	341	405	526	604	593	489	413	277	145
3	141	242	334	376	478	548	529	445	401	284	157
0	106	177	235	254	315	358	337	287	271	201	115
-3	58	94	122	127	152	171	157	135	132	101	59
-6	24	38	47	47	56	61	55	47	47	37	22
Panel No.	11	10	9	8	7	6	5	4	3	2	1



WEST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	1	3	5	6	5	3	1	0	0
12	0	2	6	15	27	33	27	15	6	2	0
9	1	6	22	60	114	142	114	60	22	6	1
6	3	15	60	178	364	471	364	178	360	15	3
3	5	27	114	365	825	1119	825	365	114	27	5
0	6	33	142	473	1122	1557	1122	473	142	33	6
-3	5	27	114	366	829	1125	828	366	114	27	5
-6	3	15	61	179	367	475	366	179	61	15	3
-9	1	6	22	61	115	143	115	61	22	6	1
-12	0	2	6	15	27	33	27	15	6	2	0
-15	0	0	1	3	5	6	5	3	1	0	0

10.1M [33FT] (horizontal); 10.1M [33FT] (vertical)

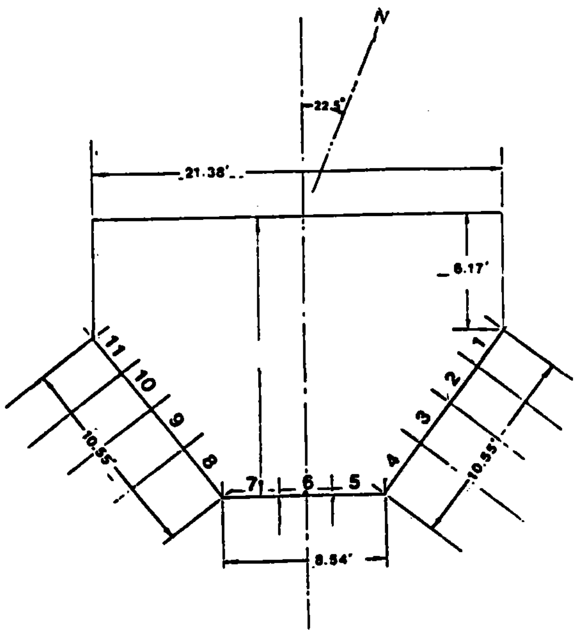
TOTAL POWER = 14674.00
DAY - 80.00
TIME = 12.00
AZ = 0.01
ELEV = 69.43

JB

WEST RECEIVER FLUX, kW/m²

DAY 80
TIME 12:00
POWER 14219 KW

Distance Above Aperture Centerline, Ft.	10.55				8.54			10.55			
	2.34	2.39	2.84	3.17	2.88	2.78	2.88	3.17	2.84	2.39	2.34
15	8	16	55	78	112	99	115	83	64	44	22
12	33	73	129	191	242	210	244	193	167	123	63
9	75	195	300	369	450	465	442	357	307	219	118
6	105	303	433	493	593	623	577	471	415	293	166
3	98	295	405	444	527	563	514	427	393	291	169
0	65	199	266	280	329	357	324	274	262	200	120
-3	31	96	125	127	198	163	149	128	127	100	62
-6	10	34	43	43	50	55	51	44	46	37	23
Panel No.	11	10	9	8	7	6	5	4	3	2	1



EAST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	1	2	3	4	3	2	1	0	0
12	0	1	4	11	21	26	21	11	4	1	0
9	1	4	17	52	103	131	103	51	17	4	1
6	2	11	52	168	368	489	368	168	52	11	2
3	3	21	103	368	911	1250	911	368	103	21	3
0	4	26	132	490	1292	1809	1291	490	132	26	4
-3	3	21	104	369	914	1254	913	369	104	21	3
-6	2	11	52	169	370	491	370	169	52	11	2
-9	1	4	17	52	104	132	104	52	17	4	1
-12	0	1	4	11	21	27	21	11	4	1	0
-15	0	0	1	2	3	4	3	2	1	0	0

10.1M [33FT] (width); 10.1M [33FT] (height)

TOTAL POWER = 15541.84

DAY - 80.00

TIME = 14.00

AZ = -58.80

ELEV = 54.22

JB

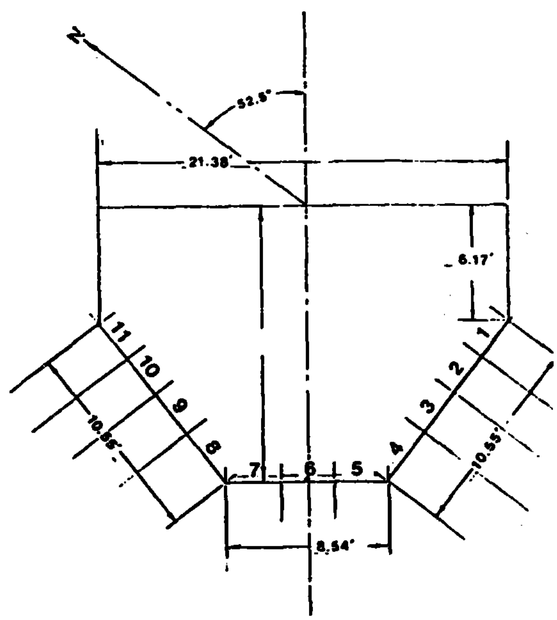
EAST RECEIVER FLUX, kW/m²

TOTAL POWER = 15226.51

DAY - 80.00

TIME = 14.00

Distance Above Aperture Centerline, Ft.	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	5	13	38	90	113	148	165	88.1	62	33	12
12	26	62	129	196	248	212	316	207	162	100	40
9	80	172	291	377	410	539	519	396	302	185	85
6	143	288	403	527	660	728	687	546	441	282	140
3	157	299	434	491	600	662	611	492	433	294	154
0	111	203	283	306	367	405	367	306	282	201	111
-3	52	93	126	131	154	171	155	132	127	95	54
-6	17	30	39.3	40	46	51	47	41	41	32	19
Panel No.	11	10	9	8	7	6	5	4	3	2	1



WEST RECEIVER 1

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	1	2	5	8	9	8	5	2	1	0
12	1	3	9	21	35	41	35	21	9	3	1
9	2	9	29	71	124	150	124	71	29	9	2
6	5	21	71	184	346	433	345	183	71	21	5
3	8	35	124	347	700	904	699	345	124	35	8
0	9	42	151	435	907	1186	904	433	151	41	9
-3	8	35	125	348	703	907	701	347	124	35	8
-6	5	21	71	185	348	436	347	184	71	21	5
-9	2	9	30	71	125	152	125	71	29	9	2
-12	1	3	9	21	35	42	35	21	9	3	1
-15	0	1	2	5	8	9	8	5	2	1	0

10.1M (33FT) (horizontal and vertical extent)

TOTAL POWER = 13385.08

DAY - 80.00

TIME = 14.00

AZ =-58.80

ELEV = 54.22

JB

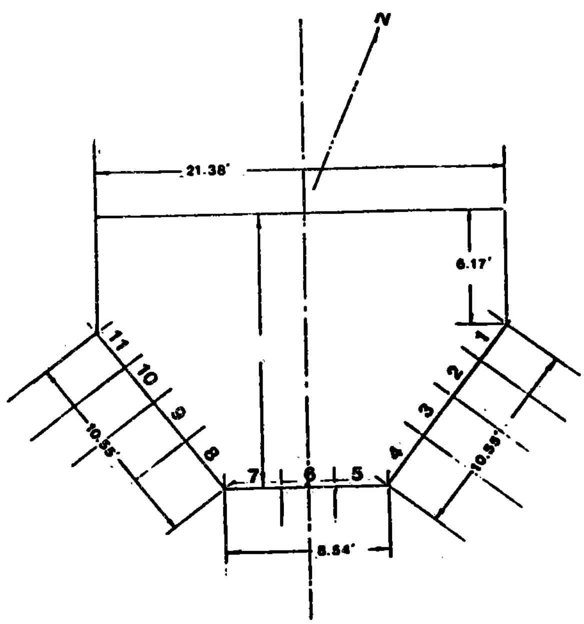
WEST RECEIVER FLUX, kW/m²

TOTAL POWER = 12841.59

DAY - 82.02

TIME = 14.22

Distance Above Aperture Centerline, Ft.	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	7	19	40	78	112	105	110	85	64	46	28
12	37	80	136	191	239	235	224	175	144	106	65
9	104	202	300	354	414	410	367	284	241	178	110
6	165	305	423	461	528	523	454	352	306	228	141
3	168	297	397	417	473	477	411	324	292	223	140
0	118	202	264	270	307	318	277	223	210	164	106
-3	61	100	128	130	148	160	142	118	115	93	62
-6	22	37	47	46	55	61	56	49	49	40	28
Panel No.	11	10	9	8	7	6	5	4	3	2	1



EAST RECEIVER:

TARGET PLANE FLUX -KW/M2

15	0	0	0	1	2	3	2	1	0	0	0
12	0	1	3	9	18	23	18	9	3	1	0
9	0	3	14	45	95	122	94	45	14	3	0
6	1	9	45	158	361	485	360	158	45	9	1
3	3	18	95	361	921	1305	919	360	94	18	2
0	3	23	122	486	1306	1895	1303	484	122	22	3
-3	3	18	95	362	921	1305	919	360	94	18	2
-6	1	9	46	158	361	486	361	158	45	9	1
-9	0	3	14	46	95	122	95	45	14	3	0
-12	0	1	3	9	18	23	18	9	3	1	0
-15	0	0	0	1	3	3	3	1	0	0	0
	-15	-12	-9	-6	-3	0	3	6	9	12	15

10.1M [33FT] (horizontal)

10.1M [33FT] (vertical)

TOTAL POWER = 15301.20

DAY - 80.00

TIME = 16.00

AZ =-78.78

ELEV = 27.99

JB

EAST RECEIVER FLUX, kW/m²

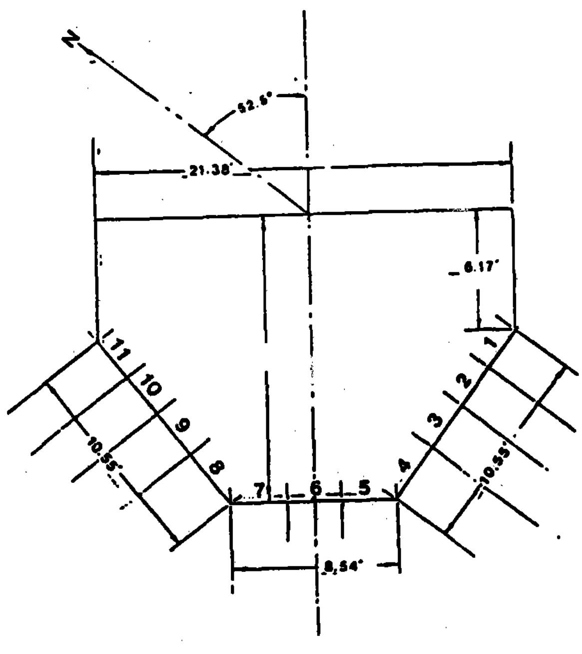
DAY 80.00

TIME 16.00

POWER 15023.25

Distance Above Aperture Centerline, Ft.

	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	3	10	32	82	106	132	148	82	53	31	14
12	20	53	119	185	235	286	290	192	139	87	40
9	71	168	299	389	485	529	498	369	276	172	84
6	141	307	486	576	697	741	603	513	408	262	133
3	157	324	482	525	639	678	603	473	403	272	145
0	108	210	301	322	377	406	360	293	265	189	104
-3	46	88	122	126	149	164	147	125	120	33	52
-6	13	25	34	34	40	46	43	38	39	30	18
Panel No.	11	10	9	8	7	6	5	4	3	2	1



WEST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	1	2	4	8	12	14	12	8	4	2	1
12	2	6	14	27	4	49	42	27	14	6	2
9	4	14	37	77	123	145	122	76	36	14	4
6	8	28	77	171	289	347	288	171	76	27	8
3	12	42	123	258	518	622	509	288	123	42	12
0	14	49	146	348	624	766	622	347	144	49	14
-3	12	42	124	281	512	624	518	289	123	42	12
-6	8	28	77	172	281	348	282	171	77	27	8
-9	4	14	37	77	124	145	123	77	37	14	4
-12	2	6	14	28	42	49	42	28	14	6	2
-15	1	2	4	8	12	14	12	8	4	2	1

10.1M [33FT] (horizontal and vertical)

TOTAL POWER = 11017.39

DAY - 80.00

TIME = 16.00

AZ = -78.78

ELEV = 27.99

JB

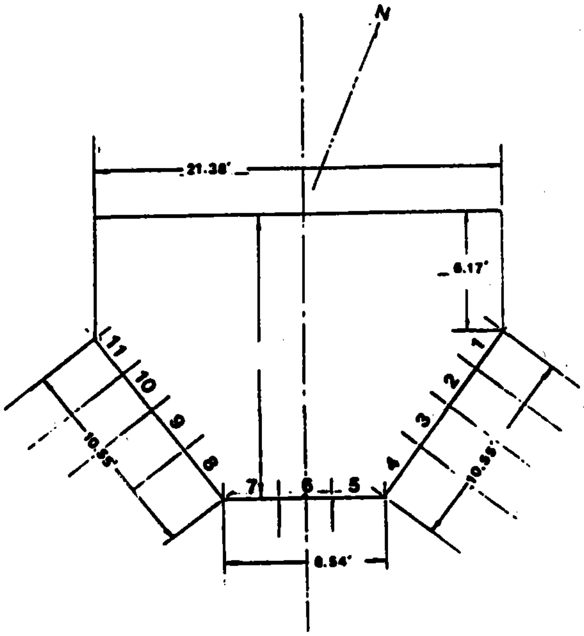
WEST RECEIVER FLUX, kW/m²

DAY 80.00

TIME 16.00

POWER 10410.49

	10.65				8.54			10.55			
Distance Above Aperture Centerline, Ft.	2.84	2.39	2.84	3.17	2.88	2.78	2.88	3.17	2.84	2.39	2.34
15	14	28	49	75	103	101	95	72	56	42	29
12	49	89	134	171	208	200	176	132	108	82	55
9	107	198	260	294	406	315	266	197	165	126	85
6	157	266	349	368	370	384	315	233	202	155	104
3	159	260	331	337	255	353	290	218	195	153	103
0	116	185	231	231	137	252	209	162	150	120	82
-3	63	98	122	121		140	120	96	92	76	53
-6	26	42	51	50	58	62	56	46	46	40	28
Panel No.	11	10	9	8	7	6	5	4	3	2	1



EAST RECEIVER:

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	2	5	9	15	22	22	28	15	9	5	2
12	5	11	22	37	52	56	52	37	22	11	5
9	9	22	45	78	118	12[illegible]	118	78	45	22	9
6	15	37	78	148	223	231	224	148	78	37	15
3	28	51	111	284	381	345	382	284	111	51	28
0	22	56	125	232	346	386	346	232	125	56	22
-3	28	51	111	284	382	347	383	284	111	51	28
-6	15	37	79	141	224	233	285	141	78	37	15
-9	9	22	46	79	111	125	111	79	46	22	9
-12	5	11	22	37	51	57	51	37	22	11	5
-15	2	[illegible]	5	15	22	22	[illegible]3	15	9	5	2

10.1M (33FT) (horizontal and vertical)

TOTAL POWER = 8316.32

DAY - 172.00

TIME = 8.00

AZ = 104.68

ELEV = 34.78

JB

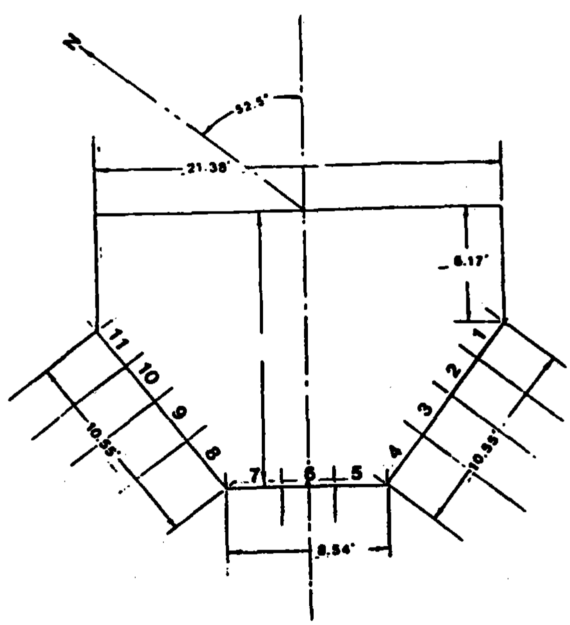
EAST RECEIVER FLUX, kW/m²

DAY - 172.22

TIME = 8.[illegible]

TOTAL POWER = 7644.41

Distance Above Aperture Centerline, Ft.	10.55				8.54				10.55		
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	26	38	52	69	97	110	112	87	69	51	33
12	45	67	88	108	148	172	173	141	122	93	61
9	65	94	120	140	189	220	221	184	168	134	90
6	77	109	137	153	203	238	239	204	191	156	108
3	77	107	132	143	186	219	217	188	181	151	107
0	65	89	107	113	145	168	166	145	143	122	87
-3	47	63	74	77	96	110	107	93	93	81	59
-6	29	38	44	44	54	61	59	51	52	46	33
Panel No.	11	10	9	8	7	6	5	4	3	2	1



WEST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	1	3	5	8	12	8	5	3	1	0
12	1	3	12	22	36	42	36	22	12	3	1
9	3	10	32	71	123	149	124	71	32	12	3
6	5	22	71	181	333	423	342	182	71	22	5
3	8	36	123	338	688	879	682	340	124	36	9
0	10	42	149	423	878	1153	882	426	150	42	10
-3	8	36	123	338	682	882	684	341	124	36	9
-6	5	22	71	182	340	425	341	183	72	22	5
-9	3	10	30	71	124	150	124	72	30	10	3
-12	1	3	10	22	36	42	36	22	10	3	1
-15	0	1	3	5	9	10	9	5	3	1	0

10.1M [33FT] (horizontal and vertical extent)

TOTAL POWER = 13152.71

DAY - 172.00

TIME = 8.00

AZ = 104.68

ELEV = 34.78

JB

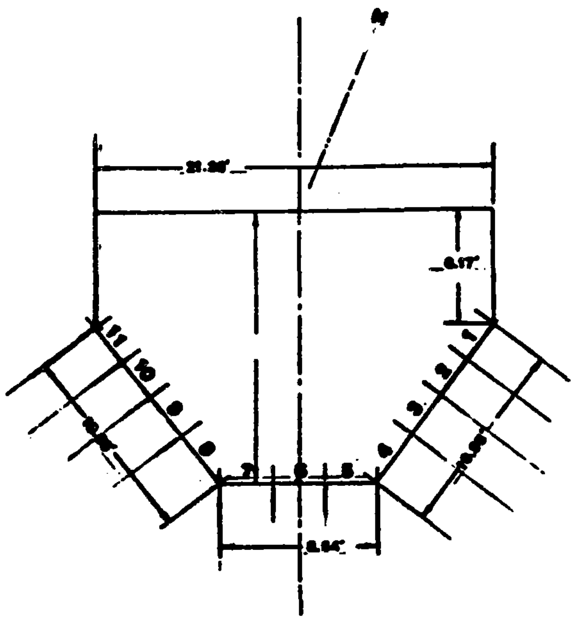
WEST RECEIVER FLUX, kW/m²

DAY 172.00

TIME 8.00

POWER 12615.16

Distance Above Aperture Centerline, Ft.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	19	31	49	73	99	105	108	83	69	46	21
12	47	78	114	151	205	228	235	213	180	132	64
9	87	142	199	248	336	393	411	365	334	244	125
6	119	190	260	309	417	501	527	481	456	337	185
3	121	191	252	288-	381	460	476	438	431	330	189
0	93	143	186	203	260	310	311	283	285	223	132
-3	56	84	106	111	136	158	150	134	136	108	65
-6	27	39	47	47	54	61	56	48	49	39	28
Panel No.	11	10	9	8	7	6	5	4	3	2	1



EAST RECEIVER

TARGET PLANE FLUX -KW/M2

15	1	3	6	10	15	17	15	10	6	3	1
12	3	7	17	32	48	55	48	32	17	7	3
9	6	17	42	83	124	132	125	83	42	17	6
6	10	32	83	175	281	342	285	175	83	32	10
3	15	46	129	285	481	597	482	287	129	48	15
0	17	55	150	341	596	732	598	342	158	55	17
-3	16	48	124	287	484	602	484	288	129	48	15
-6	10	32	83	176	283	343	286	176	84	32	10
-9	6	17	42	84	132	151	132	84	42	17	6
-12	3	7	17	32	48	55	48	32	17	7	3
-15	1	3	6	10	15	17	15	10	6	3	1
	-15	-12	-9	-6	-3	0	3	6	9	12	15

10.1M [33FT] (horizontal); 10.1M [33FT] (vertical)

TOTAL POWER = 11119.38

DAY - 172.02

TIME = 10.03

AZ = 100.90

ELEV = 62.15

JB

EAST RECEIVER FLUX, kW/m²

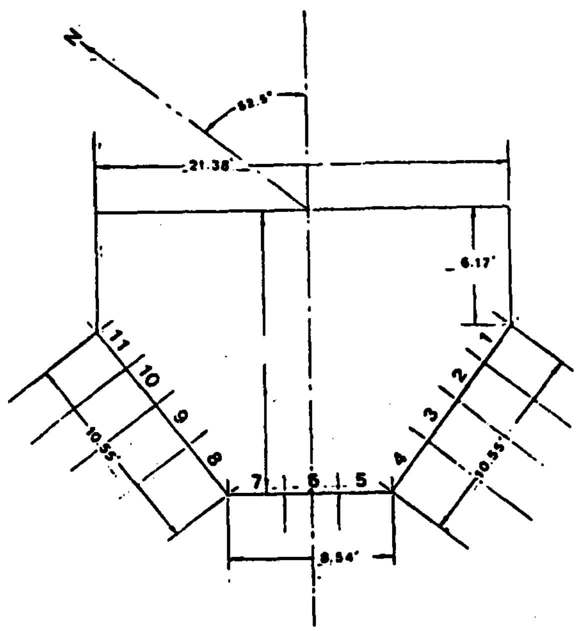
DAY - 172.02

TIME = 10.27

TOTAL POWER = 10501.66

Distance Above Aperture Centerline, Ft.

	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	22	38	58	85	123	139	141	103	75	49	27
12	49	82	119	154	212	244	241	185	151	51	61
9	83	133	184	221	293	336	328	264	227	166	99
6	107	168	223	256	333	380	369	305	269	206	128
3	109	166	214	238	303	345	333	280	260	203	130
0	88	131	164	176	221	251	239	203	194	156	103
-3	57	83	102	106	130	147	138	117	116	95	64
-6	31	44	52	52	63	70	64	55	55	46	31
Panel No.	11	10	9	8	7	6	5	4	3	2	1



WEST RECEIVER :

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	1	2	5	7	9	7	5	2	1	0
12	1	3	9	28	34	40	34	28	9	3	1
9	2	9	28	69	122	149	122	69	28	9	2
6	5	28	69	[illegible]	347	[illegible]	348	153	69	28	5
3	7	34	122	349	710	-943	721	349	123	34	7
0	9	40	149	[illegible]	911	1261	945	440	152	40	9
-3	7	34	122	348	721	947	724	350	123	34	7
-6	5	28	69	184	357	441	350	184	70	28	5
-9	2	9	28	70	123	58	123	70	28	9	2
-12	1	3	9	28	34	40	34	28	9	3	1
-15	0	1	2	5	7	9	7	5	2	1	0

10.1M [33FT] (horizontal)

10.1M [33FT] (vertical)

TOTAL POWER = 13616.98

DAY - 172.00

TIME = 10.00

AZ = 100.90

ELEV = 62.15

JB

WEST RECEIVER FLUX, kW/m²

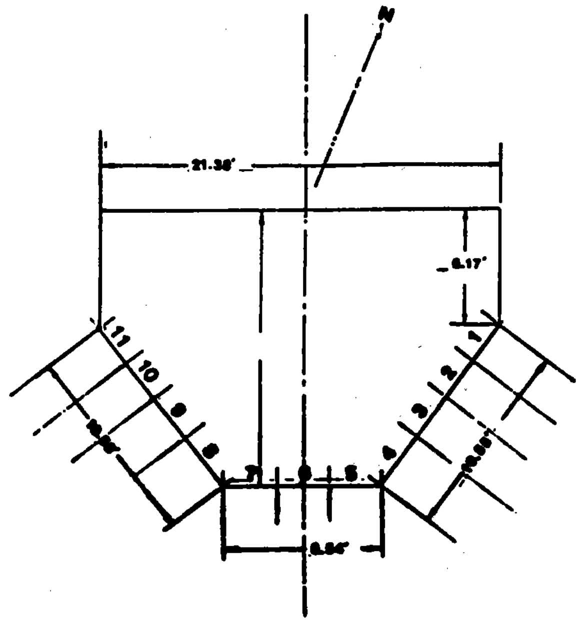
DAY 172.00

TIME = 10.00

POWER = 13891.86

Distance Above Aperture Centerline, Ft.

Distance (ft)	2.04	2.20	2.04	2.17	2.00	2.70	2.00	2.17	2.04	2.20	2.04
15	15	27	47	78	106	107	114	84	69	46	21
12	46	81	126	171	224	238	242	193	181	134	65
9	95	163	234	289	376	417	449	360	324	234	122
6	136	227	312	363	468	534	534	468	434	318	176
3	137	224	233	332	422	485	478	423	407	309	180
0	102	163	212	229	281	322	310	275	274	212	127
-3	58	90	134	118	142	160	149	132	132	105	68
-6	26	39	47	47	53	60	55	47	49	39	24
Panel No.	11	10	9	8	7	6	5	4	3	2	1



EAST RECEIVER 1

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	1	3	6	9	11	9	6	3	1	0
12	1	4	11	23	38	45	38	23	11	4	1
9	3	11	32	75	128	153	128	75	32	11	3
6	6	24	75	185	340	423	340	183	75	24	6
3	9	38	128	341	678	876	678	340	128	38	9
0	11	45	154	424	879	1155	879	424	154	45	11
-3	9	38	128	342	681	881	681	342	128	38	9
-6	6	24	75	187	342	426	342	187	75	24	6
-9	3	11	33	75	129	155	129	75	33	11	3
-12	1	4	11	24	39	45	39	24	11	4	1
-15	0	1	3	6	9	11	9	6	3	1	0

10.1M [33FT] (horizontal) — 10.1M [33FT] (vertical)

TOTAL POWER = 13381.81

DAY - 172.00

TIME = 12.00

AZ = 179.86

ELEV = 87.45

.10

EAST RECEIVER FLUX, kW/m²

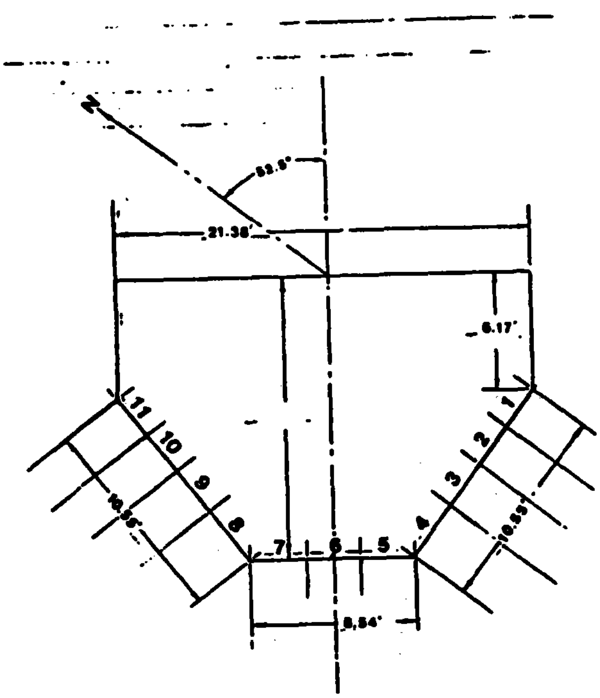
DAY - 172.00

TIME = 12.00

POWER [illegible]

Distance Above Aperture Centerline, Ft.

	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	14	28	53	92	129	151	156	102	71	42	20
12	42	81	136	189	251	292	287	206	162	107	54
9	89	162	244	303	390	437	417	305	264	180	97
6	130	226	321	376	475	526	496	395	336	237	135
3	136	228	310	347	433	478	443	362	324	238	141
0	104	170	223	241	294	326	298	247	231	176	108
-3	60	95	122	127	131	168	153	128	124	98	61
-6	27	42	51	52	60	67	60	52	52	42	27
Panel No.	11	10	9	8	7	6	5	4	3	2	1



WEST RECEIVER:

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	1	2	5	8	10	8	5	2	1	0
12	1	3	10	22	37	43	37	22	10	3	1
9	2	10	32	73	127	153	127	73	31	10	2
6	5	22	73	186	342	426	342	186	73	22	5
3	8	37	127	343	680	873	680	343	127	37	8
0	10	44	154	428	876	1141	876	428	154	44	10
-3	9	37	127	344	683	878	683	344	127	37	9
-6	5	22	74	187	345	429	345	187	74	22	5
-9	2	10	31	74	128	154	128	74	31	10	2
-12	1	3	10	22	37	44	37	22	10	3	1
-15	0	1	2	5	9	10	9	5	2	1	0

10.1M [33FT] (horizontal); 10.1M [33FT] (vertical)

TOTAL POWER = 13243.78

DAY - 172.00

TIME = 12.00

AZ = 179.86

ELEV = 87.45

JB

WEST RECEIVER FLUX, kW/m²

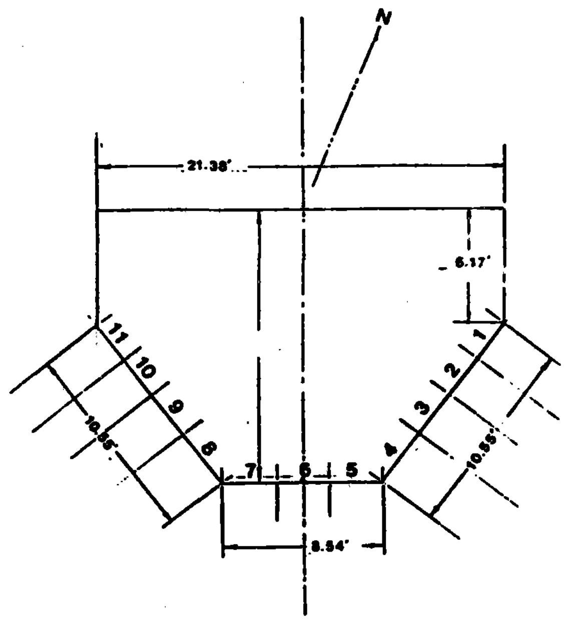
TOTAL POWER = 12675.86

DAY - 172.00

TIME = 12.00

Distance Above Aperture Centerline, Ft.

	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	14	26	46	81	113	110	114	89	70	49	26
12	46	84	133	181	232	278	237	191	167	125	69
9	101	178	256	307	321	[illegible]	384	318	278	210	120
6	47	250	340	384	409	535	476	396	339	269	160
3	148	244	322	349	421	459	427	360	314	260	160
0	109	175	225	236	281	309	285	243	236	186	118
-3	60	95	120	121	144	159	145	125	124	101	65
-6	26	40	49	49	57	63	58	50	51	42	28
Panel No.	11	10	9	8	7	6	5	4	3	2	1



EAST RECEIVER:

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	2	4	6	7	6	4	2	0	0
12	0	2	7	17	30	35	30	17	7	2	0
9	2	[illegible]	25	[illegible]	116	146	118	64	25	7	2
6	4	17	[illegible]	[illegible]	[illegible]	[illegible]	362	161	[illegible]	17	[illegible]
3	6	32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35	7
-3	6	32	119	303	803	1084	801	352	119	32	6
-6	4	17	65	182	363	466	363	161	65	17	4
-9	2	7	25	65	119	147	119	65	25	7	2
-12	0	2	7	17	30	35	30	17	7	2	0
-15	0	0	2	4	6	7	6	4	2	0	0

10.1M [33FT] (horizontal and vertical extent)

TOTAL POWER = 14519.59

DAY - 172.00

TIME = [illegible]

AZ = [illegible]

ELEV = [illegible]

JB

EAST RECEIVER FLUX, kW/m²

DAY 172.00

TIME 14.00

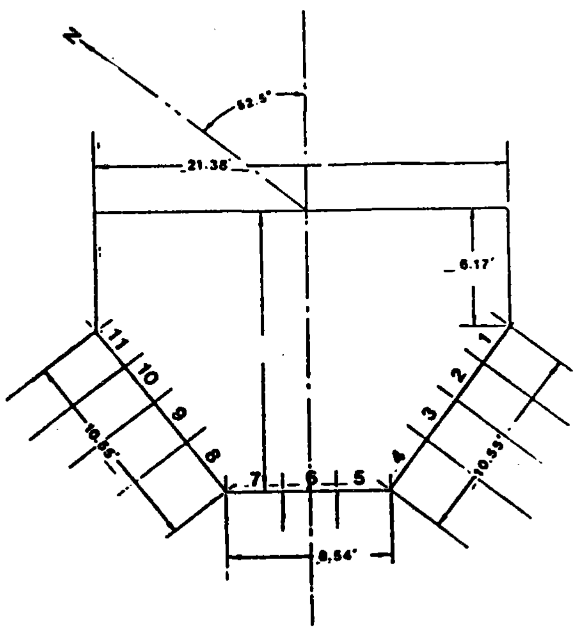
POWER 14297.00

Distance Above Aperture Centerline, Ft.

Distance (ft)	11 (2.34)	10 (2.39)	9 (2.64)	8 (3.17)	7 (2.88)	6 (2.78)	5 (2.88)	4 (3.17)	3 (2.64)	2 (2.39)	1 (2.34)
15	9	19	44	94	124	148	159	94	63	38	18
12	33	71	138	203	259	304	301	205	154	100	49
9	85	174	285	363	454	495	461	344	270	177	92
6	139	270	408	487	594	633	574	442	362	244	134
3	150	275	394	444	539	577	514	406	352	250	142
0	110	193	265	289	345	372	330	267	244	180	107
-3	57	97	128	135	230	175	155	130	124	95	58
-6	22	35	46	46	55	60	55	47	47	37	23

Panel widths: 10.55 (panels 11–8), 8.54 (panels 7–5), 10.55 (panels 4–1)

Panel No.



WEST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	1	2	4	8	12	14	12	8	4	2	1
12	2	5	14	28	43	50	43	28	14	5	2
9	4	14	37	80	129	153	129	80	37	14	4
6	8	28	80	182	312	377	312	182	80	28	8
3	12	43	130	313	562	683	562	312	130	43	12
0	14	50	154	379	695	864	694	378	153	50	14
-3	12	43	130	314	565	696	564	313	130	43	12
-6	8	28	80	183	314	380	314	183	80	28	8
-9	4	14	37	81	131	154	130	80	37	14	4
-12	2	5	14	28	43	50	43	28	14	5	2
-15	1	2	4	8	12	14	12	8	4	2	1

10.0M [33FT] (horizontal) ; 10.0M [33FT] (vertical)

TOTAL POWER = 11906.62

DAY - 172.00

TIME = 14.00

AZ =-100.90

ELEV = 62.15

JB

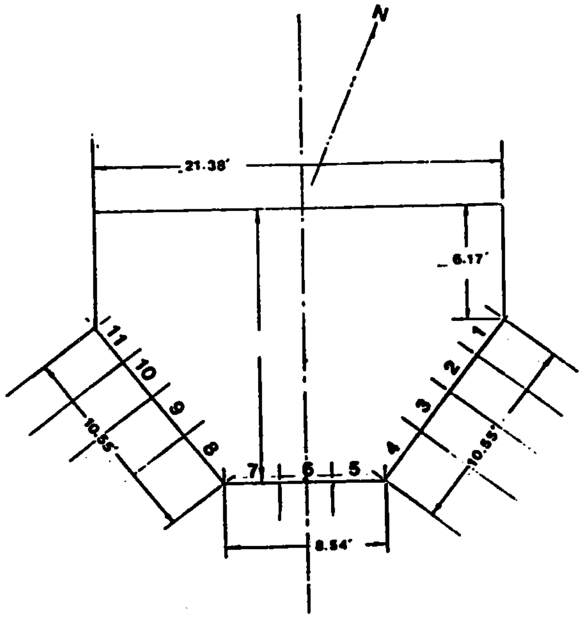
WEST RECEIVER FLUX, kW/m²

TOTAL POWER = 11265.34

DAY - 172.00

TIME = 14.00

Distance Above Aperture Centerline, Ft.	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
-15	16	29	50	82	113	111	111	84	68	50	31
-12	50	89	136	177	221	222	209	165	140	106	67
9	105	181	251	290	344	347	314	248	217	166	107
6	150	248	327	355	412	417	371	293	263	204	132
3	150	241	308	322	372	382	337	270	249	197	130
0	111	175	218	223	257	269	238	194	185	150	100
-3	63	97	120	120	139	149	133	110	109	90	62
-6	10	43	52	52	61	66	60	50	51	43	30
Panel No.	11	10	9	8	7	6	5	4	3	2	1



EAST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	1	3	5	6	5	3	1	0	0
12	0	2	6	16	28	34	28	16	6	2	0
9	1	6	23	63	118	147	118	62	23	6	1
6	3	16	63	184	374	482	373	183	62	16	3
3	5	28	118	375	828	1186	825	373	118	28	5
0	6	34	147	484	1189	1588	1185	481	146	34	6
-3	5	28	118	376	829	1188	827	374	118	28	5
-6	3	16	63	185	375	483	374	184	62	16	3
-9	1	6	23	63	118	147	118	63	23	6	1
-12	0	2	6	16	28	34	28	16	6	2	0
-15	0	0	1	3	5	6	5	3	1	0	0

10.1M [33FT] (horizontal) — 10.1M [33FT] (vertical)

TOTAL POWER = 14777.51

DAY - 172.02

TIME = 16.00

AZ = 104.67

ELEV = 34.79

JE

EAST RECEIVER FLUX, kW/m²

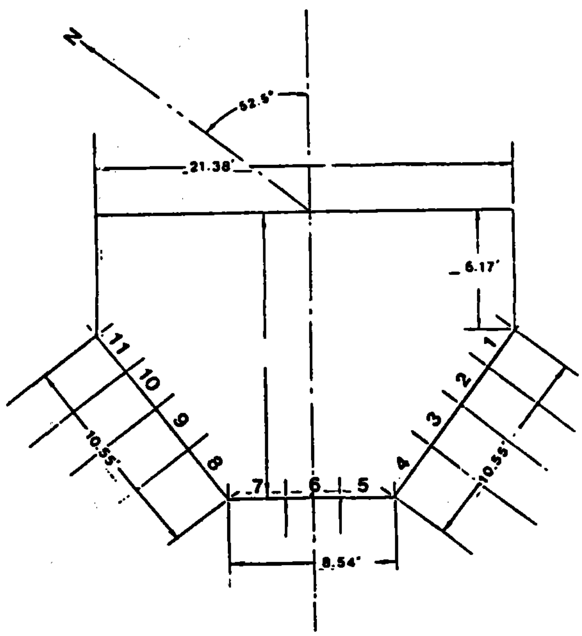
DAY _172.02

TIME ..16.02

POWER 14363.66

Distance Above Aperture Centerline, Ft.

Distance (Ft.)	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
	10.55				8.54			10.55			
15	9	18	44	94	123	138	148	91	57	36	19
12	34	72	136	201	262	297	288	195	141	91	49
9	89	176	253	368	458	510	459	333	255	169	91
6	150	294	425	515	644	670	584	433	[illegible]	236	131
3	163	299	429	489	591	614	527	401	341	240	137
0	117	209	289	313	370	390	335	264	238	174	103
-3	58	100	134	139	162	176	154	127	121	92	57
-6	20	33	44	44	52	57	53	45	46	37	23
Panel No.	11	10	9	8	7	6	5	4	3	2	1



WEST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	1	3	6	11	16	18	16	11	6	3	1
12	3	8	18	33	48	55	48	33	18	8	3
9	6	18	42	81	122	141	122	81	42	18	6
6	11	33	81	163	254	296	253	162	81	33	11
3	16	48	123	255	408	460	407	254	122	48	16
0	18	55	142	297	481	569	480	296	141	55	18
-3	16	48	123	255	409	482	408	254	122	48	16
-6	11	33	82	164	255	298	255	163	81	33	11
-9	7	18	43	81	123	142	123	82	43	18	6
-12	3	8	18	33	48	55	48	33	18	8	3
-15	1	3	7	11	16	18	16	11	7	3	1

10.1M [33FT] (horizontal)

10.1M [33FT] (vertical)

TOTAL POWER = 9856.24

DAY - 172.00

TIME = 16.00

AZ =-104.67

ELEV = 34.70

JB

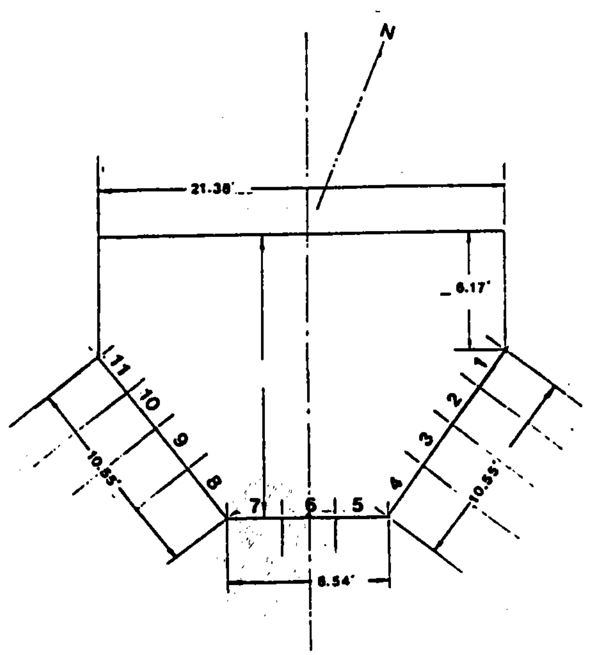
WEST RECEIVER FLUX, kW/m²

DAY 172.00

TIME 16.00

POWER 9164.68

Distance Above Aperture Centerline, Ft.	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.76	2.88	3.17	2.64	2.39	2.34
-15	22	37	57	78	104	103	95	73	58	45	31
-12	56	92	129	156	189	184	163	123	104	82	56
-9	105	166	217	241	276	265	227	172	149	118	92
6	141	219	272	285	319	305	258	196	175	140	97
3	141	212	259	262	292	254	238	183	168	135	95
0	108	159	191	190	212	210	178	140	131	108	77
-3	65	95	112	111	124	127	110	98	86	72	52
-6	31	46	54	52	60	64	56	46	46	40	29
Panel No.	11	10	9	8	7	6	5	4	3	2	1



EAST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	1	2	5	9	13	14	13	9	5	2	1
12	2	6	14	27	40	45	40	27	14	6	2
9	5	14	35	69	106	124	107	69	35	14	5
6	9	27	69	144	233	275	233	145	69	27	9
3	13	40	106	232	388	465	389	234	107	40	13
0	14	45	124	275	464	559	466	276	125	46	14
-3	13	40	106	233	389	466	390	234	107	40	13
-6	9	27	69	145	234	276	234	145	69	27	9
-9	5	14	35	69	107	124	107	69	35	14	5
-12	2	6	14	27	40	46	40	27	14	6	2
-15	1	2	5	9	13	14	13	9	5	2	1

10.1M [33FT] (horizontal); 10.1M [33FT] (vertical)

TOTAL POWER = 6956.13

DAY - 355.00

TIME = 8.00

AZ = 56.03

ELEV = 16.68

TOTAL POWER = 8459.33

DAY - 355.00

TIME = 8.00

EAST RECEIVER FLUX, kW/m²

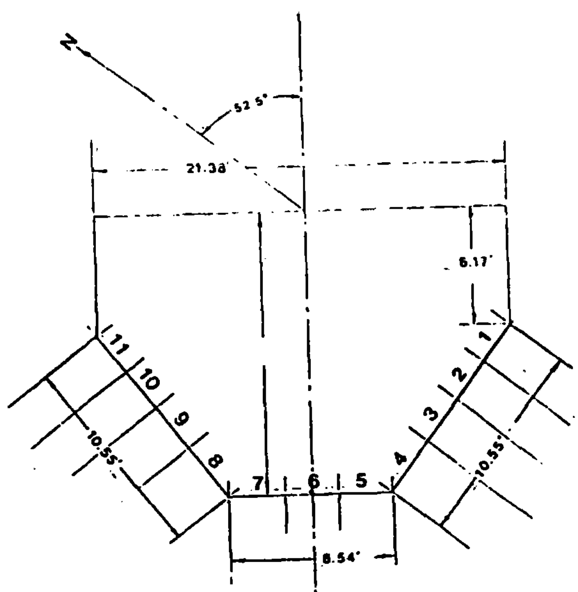
DAY

TIME

POWER

Distance Above Aperture Centerline, Ft.

	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	20	30	42	57	87	101	107	83	63	42	22
12	37	57	78	101	149	180	193	158	131	93	53
9	57	87	117	144	209	259	281	240	211	156	92
6	71	107	141	168	241	300	331	289	266	203	125
3	52	107	139	159	223	278	300	268	258	204	129
0	60	87	111	123	167	203	214	192	190	153	99
-3	41	58	72	77	100	120	121	107	108	89	58
-6	23	32	39	40	50	57	55	47	48	40	27
Panel No.	11	10	9	8	7	6	5	4	3	2	1



WEST RECEIVER:

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	0	1	2	3	2	1	0	0	0
12	0	1	3	9	17	21	17	9	3	1	0
9	0	3	13	42	86	110	86	42	13	3	0
6	1	9	42	143	323	432	324	143	42	9	1
3	2	17	86	322	803	1125	806	324	86	17	2
0	3	21	110	431	1122	1601	1125	433	111	21	3
-3	2	17	86	322	803	1123	805	324	86	17	2
-6	1	9	42	143	322	432	323	143	42	9	1
-9	0	3	13	42	86	110	86	42	13	3	0
-12	0	1	3	9	17	21	17	9	3	1	0
-15	0	0	0	1	2	3	2	1	0	0	0

10.1M [33FT] (horizontal); 10.1M [33FT] (vertical)

TOTAL POWER = 13437.27

DAY - 355.00

TIME = 8.00

AZ = 56.03

ELEV = 16.66

JB

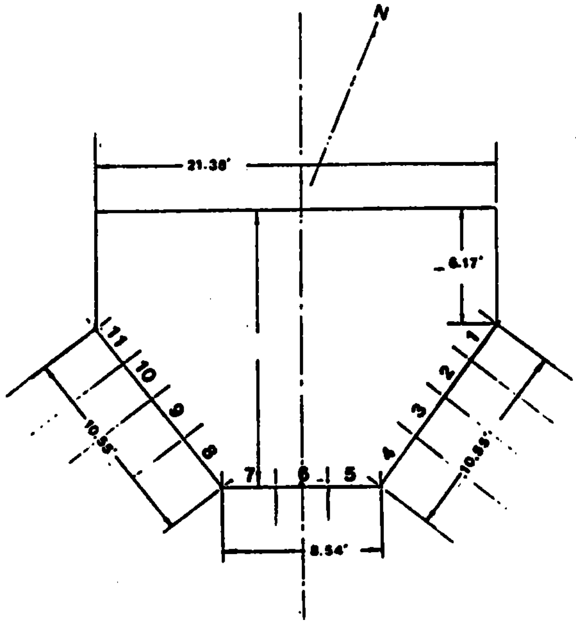
WEST RECEIVER FLUX, kW/m²

DAY - 355.00

TIME = 8.00

TOTAL POWER = 13120.91

Distance Above Aperture Centerline, Ft.	10.55				8.54			10.55			
	2.34	2.30	2.04	3.17	2.88	2.78	2.88	3.17	2.04	2.30	2.34
15	8	16	32	58	79	76	86	59	48	32	13
12	32	63	98	148	192	197	200	159	140	100	43
9	81	150	230	297	391	429	431	366	313	207	93
6	127	233	341	414	542	618	619	543	472	331	159
3	132	235	333	383	488	565	556	494	469	332	169
0	93	161	221	240	296	340	323	288	283	206	110
-3	47	78	104	105	124	139	127	112	112	84	46
-6	17	27	34	33	37	40	34	30	31	23	13
Panel No.	11	10	9	8	7	6	5	4	3	2	1



EAST RECEIVER

TARGET PLANE FLUX -KW/M2

15	0	1	3	6	9	11	9	6	3	1	0
12	1	4	11	23	37	44	37	23	11	4	1
9	3	11	32	72	123	148	123	73	32	11	3
6	6	23	72	179	326	404	327	179	73	23	6
3	9	37	123	326	636	813	638	327	124	37	9
0	11	44	148	405	813	1054	816	406	149	44	11
-3	9	37	123	326	638	816	640	328	124	37	9
-6	6	23	73	179	327	406	328	180	73	23	6
-9	3	11	32	73	124	149	124	73	32	11	3
-12	1	3	11	23	37	44	37	23	11	4	1
-15	.0	1	3	6	9	11	9	6	3	1	0
	-15	-12	-9	-6	-3	0	3	6	9	12	15

10.1M [33FT] (horizontal); 10.1M [33FT] (vertical)

TOTAL POWER = 12597.65

DAY - 355.00

TIME = 10.00

AZ = 35.00

ELEV = 36.91

JB

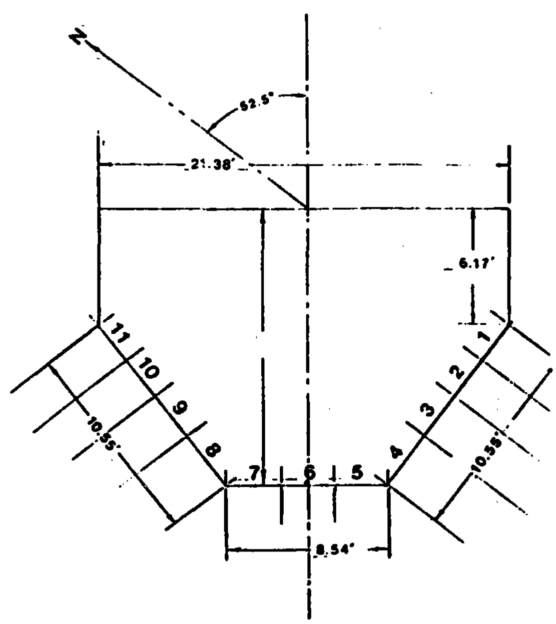
EAST RECEIVER FLUX, kW/m²

DAY - 355.22

TIME = 12.22

TOTAL POWER = 12122.23

Distance Above Aperture Centerline, Ft.	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	18	32	50	75	[illegible]	137	139	99	71	39	16
12	44	76	112	149	216	265	270	209	170	102	49
9	79	131	186	234	328	402	420	350	292	193	97
6	107	173	239	287	394	489	515	469	294	275	149
3	111	175	233	270	365	447	464	412	383	282	140
0	92	126	177	195	255	306	307	273	264	201	118
-3	55	82	103	110	137	159	153	134	132	103	62
-6	27	40	48	48	58	64	59	50	50	40	24
Panel No.	11	10	9	8	7	6	5	4	3	2	1



WEST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	0	1	2	3	2	1	0	0	0
12	0	1	3	8	17	21	17	9	3	1	0
9	0	3	13	44	93	120	93	44	13	3	0
6	1	9	44	157	364	494	365	157	44	6	1
3	2	17	93	364	952	1365	952	365	93	17	2
0	3	21	120	494	1365	2010	1366	494	121	21	3
-3	2	17	93	365	953	1366	953	365	93	17	2
-6	1	9	44	157	365	495	365	157	44	9	1
-9	0	3	13	44	93	121	93	44	14	3	0
-12	0	1	3	9	17	22	17	5	3	1	0
-15	0	0	0	1	2	3	2	1	0	0	0

10.1M [33FT] (horizontal and vertical extent)

TOTAL POWER = 15712.00

DAY - 355.00

TIME = 10.00

AZ = 35.00

ELEV = 36.91

JB

WEST RECEIVER FLUX, kW/m²

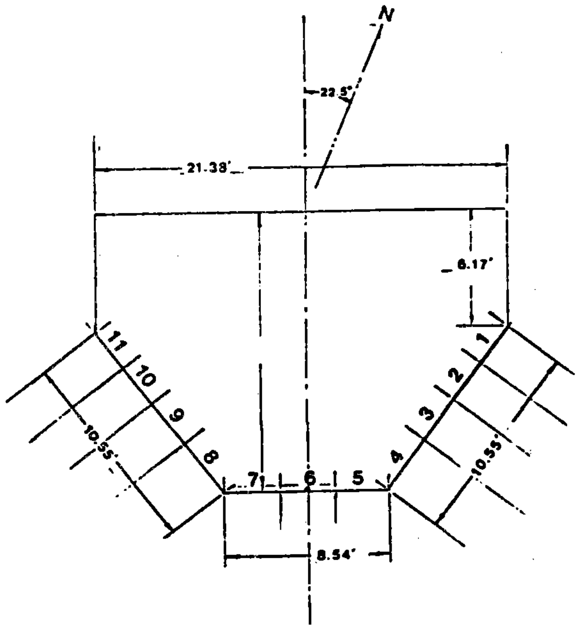
DAY 355

TIME 10:00

POWER 15375 KW

Distance Above Apperture Centerline, Ft.

	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
-15	7	12	29	55	99	85	105	56	56	37	15
-12	29	64	117	178	226	223	233	197	162	113	51
9	70	156	296	403	490	508	497	436	347	232	107
-6	101	306	457	617	679	740	711	682	530	359	175
3	95	305	439	592	603	669	632	653	504	356	185
0	61	199	276	369	353	394	366	398	303	225	122
-3	27	89	119	157	141	157	143	163	126	95	53
-6	8	28	36	46	39	43	39	46	36	27	16
Panel No.	11	10	9	8	7	6	5	4	3	2	1



740 kW/m² = 234,530 Btu/hr-ft²

EAST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	1	3	5	6	5	3	1	0	0
12	0	2	6	15	26	32	26	15	6	2	0
9	1	6	22	59	112	140	112	59	22	6	1
6	3	15	59	176	363	472	364	176	59	15	3
3	5	26	112	363	834	1144	836	364	113	27	5
0	6	32	140	472	1144	161	1148	474	141	32	6
-3	5	26	112	364	836	1148	839	365	113	27	5
-6	3	15	59	176	365	474	365	177	60	15	3
-9	1	6	22	60	113	141	113	60	22	6	1
-12	0	2	6	15	27	32	27	15	6	2	0
-15	0	0	1	3	5	6	5	3	1	0	0

10.1M [33FT] (horizontal)

10.1M [33FT] (vertical)

TOTAL POWER = 14785.00

DAY - 355.00

TIME = 12.00

AZ = 0.00

ELEV = 45.67

JB

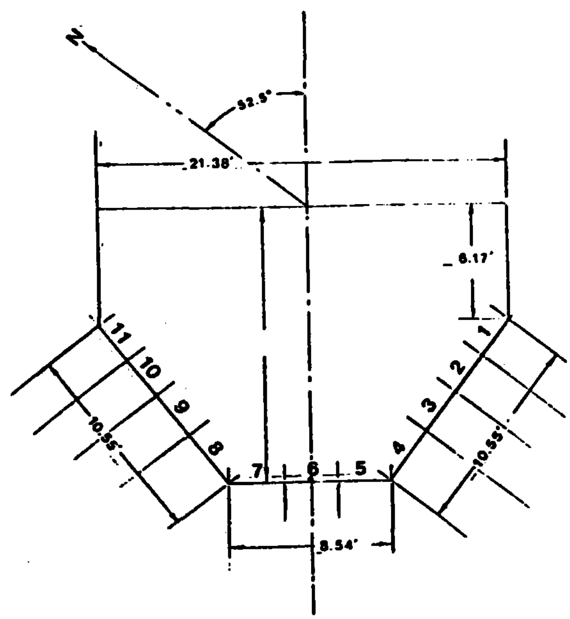
EAST RECEIVER FLUX, kW/m²

DAY - 355.02

TIME = 12.02

TOTAL POWER = 14419.22

Distance Above Aperture Centerline, Ft.	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	[illegible]	23	46	21	114	140	155	72	67	33	[illegible]
12	38	75	126	178	247	356	356	214	175	105	39
9	[illegible]	157	242	311	423	522	510	416	321	193	[illegible]
6	132	231	337	415	552	655	627	565	473	363	[illegible]
3	137	237	331	385	504	597	594	514	464	320	165
0	103	172	234	252	325	379	364	317	300	216	117
-3	56	92	119	126	152	172	159	137	134	99	55
-6	23	36	45	45	52	57	51	43	42	32	18
Panel No.	11	10	9	8	7	6	5	4	3	2	1



WEST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	1	2	3	4	3	2	1	0	0
12	0	1	4	10	20	25	20	10	4	1	0
9	1	4	16	50	101	129	101	49	16	4	1
6	2	10	50	166	372	496	371	166	49	10	2
3	3	20	101	372	929	1300	927	371	101	20	3
0	4	25	130	498	1311	1892	1300	496	129	25	4
-3	3	20	101	373	931	1311	929	372	101	20	3
-6	2	10	50	167	373	498	373	167	50	10	2
-9	1	4	16	50	101	130	101	50	16	4	1
-12	0	1	4	11	20	25	20	10	4	1	0
-15	0	0	1	2	3	4	3	2	1	0	0

10.1M [33FT] (horizontal); 10.1M [33FT] (vertical)

TOTAL POWER = 15633.70

DAY - 355.00

TIME = 12.00

AZ = 0.00

ELEV = 45.67

JB

WEST RECEIVER FLUX, kW/m²

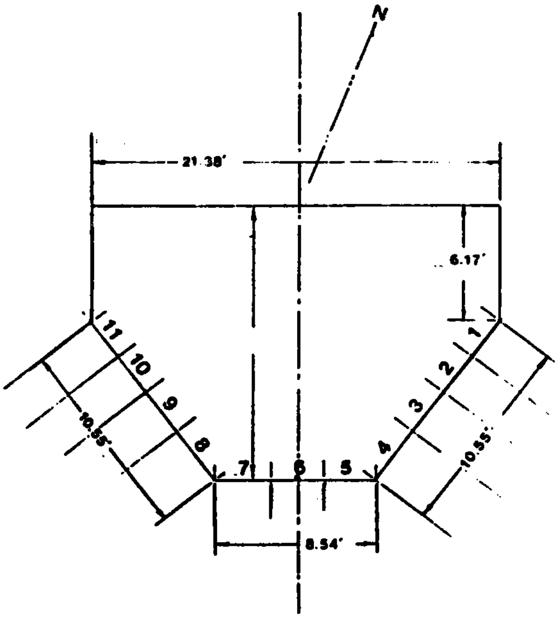
DAY 355.00

TIME 12.00

POWER 15254.70

Distance Above Aperture Centerline, Ft.

	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	7	16	[illegible]	74	102	89	111	77	58	40	20
12	27	[illegible]	120	187	237	232	240	189	159	116	57
9	93	[illegible]	[illegible]	[illegible]	[illegible]	505	[illegible]	379	317	220	114
6	[illegible]	[illegible]	[illegible]	[illegible]	692	[illegible]	654	524	[illegible]	316	169
3	71	[illegible]	[illegible]	524	614	[illegible]	582	478	[illegible]	310	173
0	114	[illegible]	296	312	364	390	350	275	[illegible]	209	120
-3	51	93	[illegible]	127	146	162	147	128	127	92	58
-6	16	[illegible]	36	36	42	48	44	40	41	23	20
Panel No.	11	10	9	8	7	6	5	4	3	2	1



EAST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	0	1	2	3	2	1	0	0	0
12	0	1	3	9	18	22	18	9	3	1	0
9	0	3	14	45	95	122	95	45	14	3	0
6	1	9	45	158	363	490	363	159	46	9	1
3	2	18	95	363	940	135(	941	364	95	18	2
0	3	22	122	490	1350	2002	1352	491	123	23	3
-3	2	18	95	363	941	1352	942	364	95	18	2
-6	1	9	46	159	364	491	364	159	46	9	1
-9	0	3	14	46	95	123	95	46	14	3	0
-12	0	1	3	9	18	23	18	9	3	1	0
-15	0	0	0	1	2	3	2	1	0	0	0

10.1M [33FT] (horizontal); 10.1M [33FT] (vertical)

TOTAL POWER = 15655.00

DAY - 355.00

TIME = 14.00

AZ =-35.00

ELEV = 36.91

JB

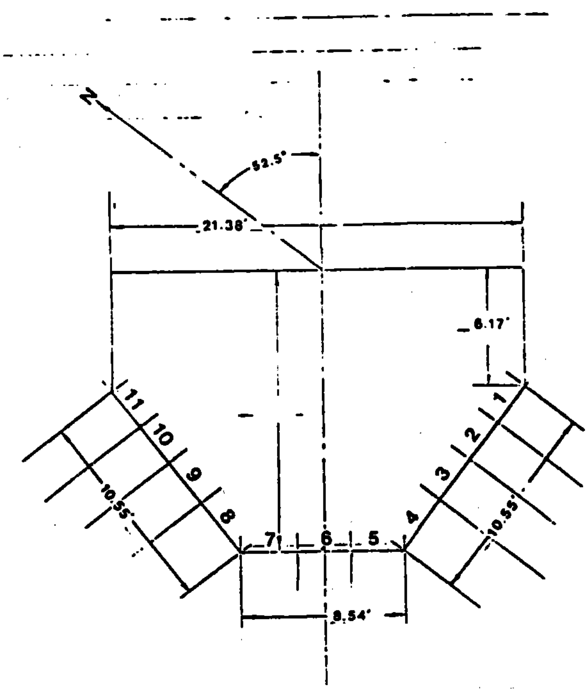
EAST RECEIVER FLUX, kW/m²

DAY - 355.00

TIME = 14.00

TOTAL POWER = 15377.90

Distance Above Aperture Centerline, Ft.	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	6	14	37	81	155	143	156	81	60	29	9
12	27	62	123	182	237	303	305	200	159	94	33
9	78	164	274	359	473	544	538	420	315	192	77
6	137	272	419	511	664	759	743	610	492	303	140
3	150	234	415	480	607	692	661	555	437	323	157
0	106	194	272	299	365	413	384	327	303	212	110
-3	51	90	121	126	149	166	151	130	126	91	49
-6	17	29	38	37	43	46	41	35	36	27	15
Panel No.	11	10	9	8	7	6	5	4	3	2	1



759 kW/m² = 240,662 Btu/hr-ft²

WEST RECEIVER 1

TARGET PLANE FLUX -KW/M2

15	0	0	1	3	5	6	5	3	1	0	0
12	0	2	6	15	27	33	27	15	6	2	0
9	1	6	22	60	112	139	112	59	22	6	1
6	3	15	60	175	358	461	357	174	59	15	3
3	5	27	112	359	800	1073	797	357	112	27	5
0	6	33	140	464	1076	1468	1072	461	139	33	6
-3	5	27	113	359	802	1075	799	357	112	27	5
-6	3	15	60	176	359	463	358	175	59	15	3
-9	1	6	22	60	113	140	112	60	22	6	1
-12	0	2	6	15	27	33	27	15	6	2	0
-15	0	0	1	3	5	6	5	3	1	0	0
	-15	-12	-9	-6	-3	0	3	6	9	12	15

10.1M [33FT] (horizontal); 10.1M [33FT] (vertical)

TOTAL POWER = 14232.44

DAY - 355.00

TIME = 14.00

AZ =-35.00

ELEV = 36.91

JB

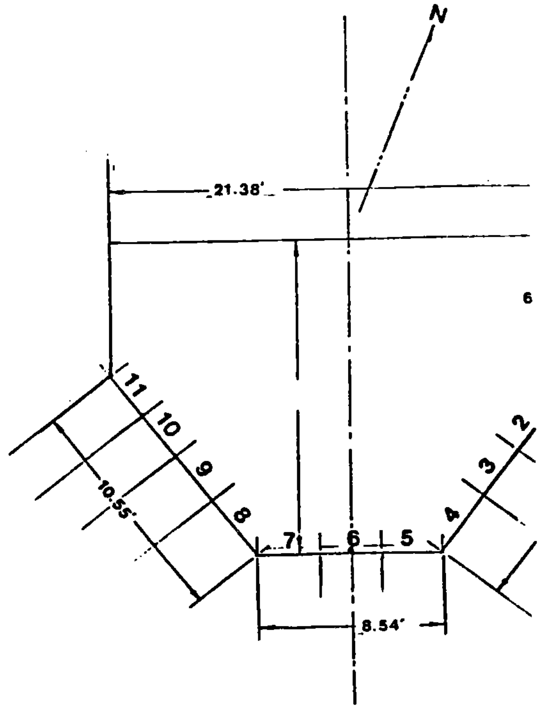
WEST RECEIVER FLUX, kW/m²

DAY - 355.00

TIME = 14.00

TOTAL POWER = 13780.69

Distance Above Aperture Centerline, Ft.	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
-15	5	12	30	71	105	95	103	79	58	42	25
-12	29	67	125	185	236	231	225	175	141	102	61
9	94	204	324	390	456	448	403	308	254	182	109
6	167	339	493	544	616	606	523	400	340	246	147
3	173	331	463	491	551	553	473	369	327	242	147
0	116	214	291	300	339	351	304	245	228	175	103
-3	53	95	127	129	147	160	142	120	117	93	60
-6	17	30	40	40	47	54	51	44	46	38	25
Panel No.	11	10	9	8	7	6	5	4	3	2	1



EAST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	0	0	1	2	2	2	1	0	0	0
12	0	0	2	6	13	17	13	6	0	0	0
9	0	2	10	35	77	100	77	35	10	2	0
6	1	6	35	132	315	429	314	132	35	6	1
3	2	13	77	314	836	1198	835	314	76	13	2
0	2	17	100	429	1197	1754	1197	429	100	17	2
-3	2	13	77	314	834	1196	834	314	76	13	2
-6	1	6	35	132	314	428	314	132	35	6	1
-9	0	2	10	35	77	100	76	35	10	2	0
-12	0	0	2	6	13	17	13	6	2	0	0
-15	0	0	0	1	2	2	2	1	0	0	0

10.1M [33FT] (horizontal)

10.1M [33FT] (vertical)

TOTAL POWER = 13579.56

DAY - 355.00

TIME = 16.00

AZ =-56.02

ELEV = 16.68

JB

EAST RECEIVER FLUX, kW/m²

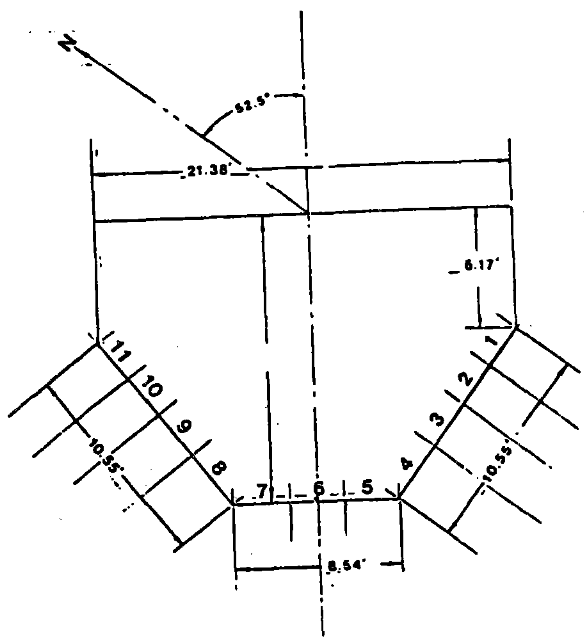
DAY 355.00

TIME 16.00

POWER 13363.33

Distance Above Aperture Centerline, Ft.

	10.55				8.54			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	3	9	28	65	84	113	124	67	45	25	10
12	19	48	100	152	198	245	249	165	121	76	30
9	63	142	247	326	420	471	456	346	256	152	68
6	120	254	401	487	615	680	642	507	403	250	118
3	134	269	402	460	566	623	575	467	401	265	132
0	91	176	296	276	330	365	331	276	253	176	92
-3	40	74	104	108	126	140	127	109	105	76	42
-6	12	21	28	28	32	37	33	30	30	22	13
Panel No.	11	10	9	8	7	6	5	4	3	2	1



WEST RECEIVER

TARGET PLANE FLUX -KW/M2

	-15	-12	-9	-6	-3	0	3	6	9	12	15
15	0	1	2	5	8	9	8	5	2	1	0
12	1	3	9	19	31	36	31	19	9	3	1
9	2	9	26	61	185	127	185	61	26	9	2
6	5	19	61	154	282	349	281	153	61	19	5
3	8	31	185	283	549	695	547	281	184	31	8
0	9	37	127	351	697	888	694	348	126	36	9
-3	8	32	185	283	550	695	548	281	185	31	8
-6	5	19	61	154	283	350	282	153	61	19	5
-9	2	9	26	61	185	127	185	61	26	9	2
-12	1	3	9	19	31	37	31	19	9	3	1
-15	0	1	2	5	8	9	8	5	2	1	0

10.1M [33FT] (horizontal)

10.1M [33FT] (vertical)

TOTAL POWER = 10754.16

DAY - 355.00

TIME = 16.00

AZ =-56.02

ELEV = 16.66

JG

WEST RECEIVER FLUX, kW/m²

DAY 355.00

TIME 16.00

POWER 10291.19

Distance Above Aperture Centerline, Ft.

	10.55				8.64			10.55			
	2.34	2.39	2.64	3.17	2.88	2.78	2.88	3.17	2.64	2.39	2.34
15	8	17	34	61	87	84	82	63	47	34	23
12	33	69	114	154	192	186	167	126	100	74	49
9	89	174	257	298	341	322	275	202	165	123	90
6	144	269	371	395	439	414	341	251	211	159	102
3	148	265	353	364	399	382	313	235	207	157	102
0	103	178	233	236	260	260	216	168	154	120	80
-3	51	86	111	114	125	132	114	93	89	72	49
-6	18	31	39	40	46	52	47	40	40	34	24
Panel No.	11	10	9	8	7	6	5	4	3	2	1