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EL PASO ELECTRIC COMPANY NEWMAN UNIT 1 SOLAR REPOWERING ADVANCED CONCEPTUAL DESIGN

Final Report. Volume 1

April 1982

Work Performed Under Contract No. AC03-81SF11566

El Paso Electric Company
El Paso, Texas

U.S. Department of Energy

Solar Energy

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FINAL REPORT

EL PASO ELECTRIC COMPANY NEWMAN UNIT 1 SOLAR REPOWERING ADVANCED CONCEPTUAL DESIGN

APRIL 1982

VOLUME 1

Prepared for
U.S. Department of Energy
Contract No. DE-AC03-81SF11566

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SECTION 1

EXECUTIVE SUMMARY

This executive summary presents the programmatic, technical, and economic results of El Paso Electric Company's (EPE) Newman Unit 1 Advanced Solar Repowering Program.

1.1 BACKGROUND

The development of solar thermal power system technology for utility applications is an important and necessary outgrowth of the United States' desire to reduce its usage of conventional oil and natural gas fuels in the generation of electrical energy. The U.S. Department of Energy (DOE) Solar Thermal Program has had the overall goal of providing the technological and industrial base that is required to progress towards the commercialization of promising solar thermal technologies. Solar repowering existing gas and oil fueled power plants utilizing the central receiver concept has been identified as the most promising near-term application of this technology, and commercially solar repowered units are expected to be cost effective alternatives.

The Newman Unit 1 Advanced Solar Repowering Program was funded by DOE for the period of September 30, 1981 to May 10, 1982. The principal objective of this most recent effort was to refine the Baseline Conceptual Design developed in 1979-80 under DOE Contract No. DE-AC03-79-SF-10740 for solar repowering Newman Unit 1. This previous conceptual design study effort identified that the solar repowering conceptual design and the water/steam technology selected for Newman Unit 1 would be cost-effective under certain future circumstances such as when heliostat costs are reduced through mass production.

A refined conceptual design was developed in this Advanced Program with improvements and additional information available since the previous study. Indications are that with the application of innovative financing, risk sharing by equipment suppliers, and cost sharing by state and federal governments, construction and operation of a solar repowered Newman Unit 1 can be cost effective. This design has the potential for construction and operation by 1986, making use of the most advanced solar thermal technology, and providing the best economics for this application. An artist's concept of solar repowering Newman Unit 1 is shown in Figure 1.1-1.

Solar repowering consists of modifying an existing unit to employ solar energy as an alternate heat source. The solar repowering concept utilizes central receiver technology and consists of the addition of a solar collector field, a central receiver (solar boiler superheater and reheater), and possibly a thermal energy buffer storage subsystem to existing generation facilities; the integration of the solar hardware with the existing systems; and appropriate modifications to the existing unit. The ability to operate on fossil fuel is retained, thus providing full backup capability and maximum operational flexibility during periods of inclement weather, at night, or during power emergencies. The potential for conventional electric power generation is completely retained, thus eliminating the need for costly energy storage systems.

The specific objectives of the Advanced Solar Repowering Conceptual Design Program were to review recent accomplishments in the Department of Energy (DOE) Technology Development Program, including component/subsystems data and operational experience at the Central Receiver Test Facility (CRTF) and the Barstow Pilot Plant; to select appropriate developments for incorporation into the conceptual design; to prepare a refined conceptual design; to establish performance of the refined design; to update cost estimates; and to reaffirm economic attractiveness of solar repowering Newman Unit 1.

The Advanced Solar Repowering Program objectives were accomplished using a work breakdown structure defining two major tasks: Task 1100, Refined Baseline Conceptual Design; and Task 1200, Program Management. Subtasks for Task 1100 are as follows:

Subtask 1110 - Assessment of Technology Advancements
Subtask 1120 - Functional Requirements
Subtask 1130 - Engineering Diagrams/Drawings
Subtask 1140 - Operating Modes
Subtask 1150 - Performance Estimates
Subtask 1160 - Economic Analysis

EPE, continuing as prime contractor, had overall responsibility for conducting this program including program definition, cost and schedular control, utility interface definition, and utility operations. EPE was supported directly by two subcontractors: Stone & Webster Engineering Corporation (SWEC) and Westinghouse Electric Corporation (WEC). Babcock & Wilcox Company (B&W) was a subcontractor to SWEC.

SWEC continued to provide architect/engineer services that included the refined conceptual design of solar repowered Newman Unit 1, cost estimating in support of the economic analysis and demonstration program, evaluation of environmental concerns, preparation of preliminary specifications for solar equipment, and construction planning for the subsequent demonstration program. SWEC was the architect/engineer for Newman Unit 1 and is familiar with the design of the unit and site-related working conditions. In addition, SWEC had subcontract support from B&W for the purpose of refining the receiver conceptual design.

WEC's Advanced Energy Systems Division continued to be responsible for project integration and refining the solar subsystem design including heliostat field layout, performance modeling, receiver flux interface, safety analysis, analysis of economic and network impacts and assessments, and program planning for the demonstration phase of the project.

DOE, as project funding agent, provided contractual and technical program guidance. Contractual communication was through DOE's San Francisco Operations Office (DOE-SAN) and technical guidance was provided by Sandia National Laboratories-Livermore as well as DOE-SAN. The programmatic and technical experience of these organizations with respect to solar power generation was recognized and utilized by EPE in the course of accomplishing this program.

EPE was also supported by the Texas Energy and Natural Resources Advisory Council; the Regional Development Division, Office of the Governor of Texas; and the Public Utilities Commission of Texas. These agencies provided assistance in identifying and defining the institutional and regulatory barriers, and public issues associated with solar repowering. In addition, EPE continued the Southwest Solar Repowering Utility Advisory Council consisting of 29 members representing investor-owned, municipal, state, federal, district, and rural electric cooperatives. The council provided an assessment of the program results from a broad utility perspective and also provided a means for early dissemination of the results to other utilities. The Utility Advisory Council's role in maintaining the interest in solar thermal repowering as a viable power generation option and the ability of EPE and its team to maintain a widespread level of interest and technical/economic knowledge of solar thermal repowering in the Southwest is considered an important adjunct to the DOE repowering program. Members of the Advisory Council are included in Table 1.1-1.

TABLE 1.1-1

1982 SOUTHWEST SOLAR REPOWERING UTILITY ADVISORY COUNCIL

Investor Owned Systems

- Pacific Power & Light Co.
- New Mexico Electric Service Co.
- Public Service Company of New Mexico
- Central Telephone & Utilities Corp.
- Utah Power & Light Co.
- Georgia Power Co.
- Dallas Power & Light Co.
- Texas Electric Service Co.
- Texas Power & Light Co.
- San Diego Gas & Electric Co.
- Southern California Edison Co.
- Oklahoma Gas & Electric Co.
- Tampa Electric Co.
- Puget Sound Power & Light Co.
- Gulf States Utilities Co.
- Nevada Power Co.
- Florida Power Corp.
- Florida Power & Light Corp.
- Southwestern Public Service
- Public Service Co. of Colorado

Municipal Systems

- Garland Electric Dept.
- Lubbock Power & Light Dept.

Federal and District Systems

- Salt River Project Agricultural Improvement & Power Dist.
- Comision Federal De Electricidad
- Imperial Irrigation District

Rural Electric Cooperatives

- Arizona Electric Power Coop.
- Colorado Ute Electric Assn. Inc.
- Brazos Electric Power Coop. Inc.
- Western Farmers Electric Coop.

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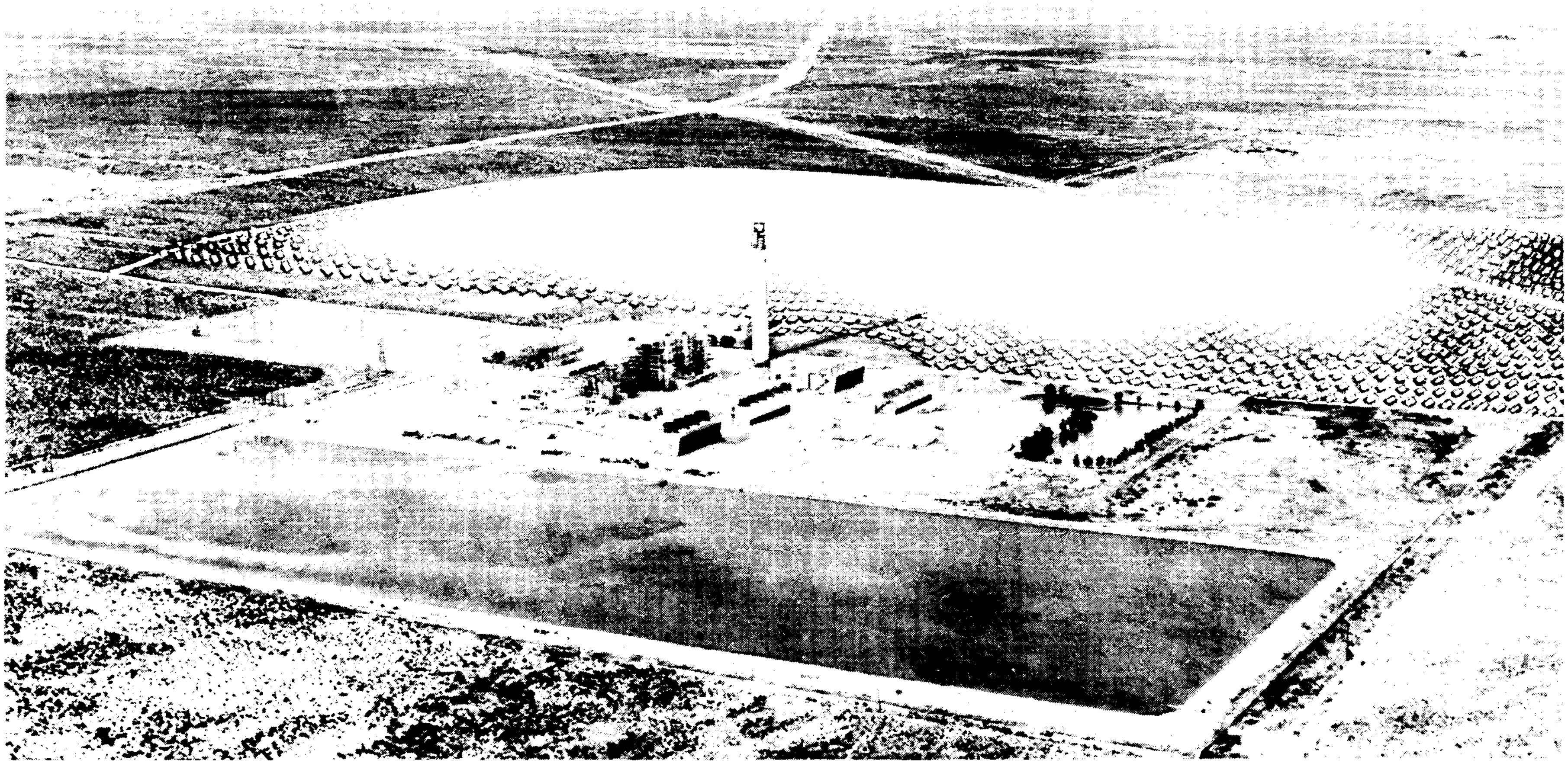


FIGURE 1.1-1
SOLAR REPOWERED NEWMAN UNIT 1

1.2 SITE DESCRIPTION

The El Paso region is in the zone of highest solar insolation in the nation, which facilitates year-round research, development, and demonstration of solar energy applications. The annual variation of solar insolation in the El Paso region is also the lowest in the nation. EPE has three local electric generating stations in the region: Rio Grande Station (New Mexico), along the Rio Grande River west of the Franklin Mountains; Copper Station (Texas), near the major industrial area in southeastern El Paso; and the Newman Station (Texas) near the Texas/New Mexico border on the east side of the Franklin Mountains. The location of Newman Station is illustrated in Figure 1.2-1.

Newman Station is located in a rural area at the north end and within the city limits of the city of El Paso, 24 km (15 miles) northeast of the downtown area, and 19 km (12 miles) from the El Paso Solmet weather station. There are no commercial buildings within a 3 km (1.8 miles) radius and only one residence, a ranch which is located outside the proposed site boundary. Annual mean weather data show an average temperature of 17.4°C (64.4°F), average precipitation of 19.8 cm (7.8 inches), average sunshine of 3,583 hours (83 percent of possible sunshine), and direct normal insolation for the typical meteorological year of 7.26 kW-hr/m^2-day. Average wind speed is 4.24 m/s (9.5 mph) from the north and mean sky cover (tenths) is 3.8, sunrise to sunset. Figure 1.2-2 is an aerial photograph of the Newman Station showing the proposed collector field area to the north.

Newman Station consists of four electric generating units rated at a total of 464 MWe. Newman Unit 1, the unit selected for solar repowering, is an 82 MWe (net) tandem-compound, double-flow, reheat steam turbine built in 1960 for baseload duty using natural gas as the primary fuel. The unit is designed to burn residual fuel oil for short periods of time if the gas supply is interrupted. The unit is currently operated as an intermediate load unit; the 1981 capacity factor was 25 percent. Figure 1.2-3 is a photograph of Newman Units 1-4.

The Newman site, surrounded by over 14 km^2 (3,500 acres) of available public land, is nearly flat with a downward slope of approximately 1 percent from west to east. The land to the north of the station is owned by the El Paso Water Utilities Public Service Board, and the Board agreed in a public meeting held April 25, 1979 in El Paso to make the land available for the demonstration phase of the project.

The site is in the Tularosa Basin, bounded by fault block mountains to the east and west, with 300 to 600 m (1,000 to 2,000 feet) of underlying sediments. El Paso does not experience any significant earthquake activity, and no earthquakes of intensity 4.5 or larger on the Richter Scale have been recorded within 160 km (100 miles) of the site.

Solar repowering will have a beneficial impact on air quality since it will displace the use of fossil fuels and reduce the resultant pollutant emissions. The air quality monitoring unit nearest Newman is in downtown El Paso. Although El Paso air quality is in violation of ambient air quality standards for several pollutants, air quality at Newman Station is in compliance. There is no surface water at the site; however, water is plentiful from nearby wells. There are no known mineral resources or unique geologic/landform features on or near the site. Minor archaeological findings have been identified on the proposed site. No environmental constraints or safety hazards have been identified that would preclude the construction of a solar repowered unit at the Newman Station.

The site is accessible by road from all directions, and a freeway is being completed with a major interchange planned 6.4 km (4 miles) from the generating station. A railway siding is located 9.6 km (6 miles) to the southeast. Newman Station is near, but not directly beneath, two Federal airways. Some aircraft from El Paso International Airport as well as some military aircraft from Biggs Field fly over and south of the power station at altitudes normally greater than 1-2 km (4,000 feet). Preliminary discussions with the Federal Aviation Administration have not identified any constraints that would preclude the construction and operation of the solar repowered Newman Unit 1.

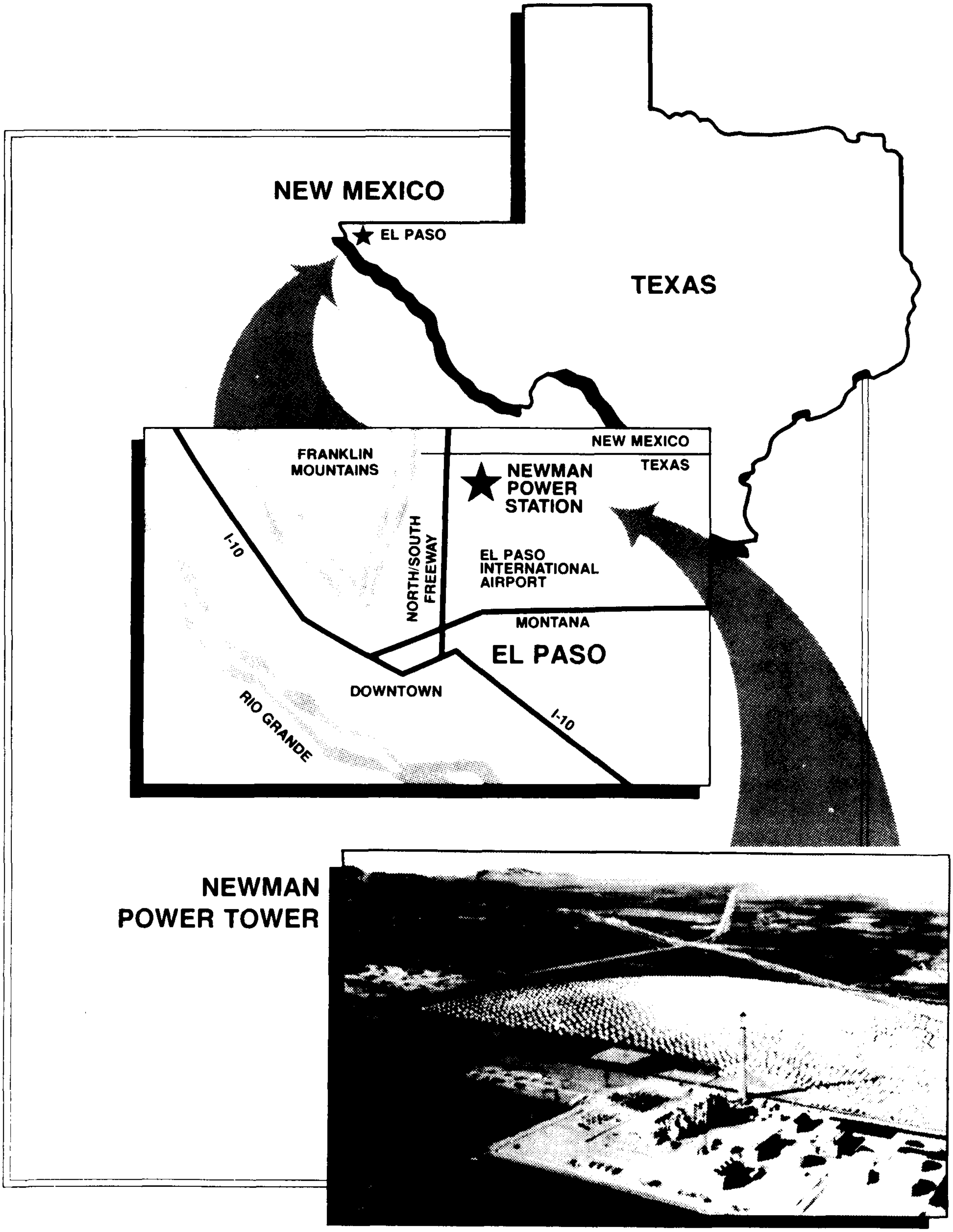


FIGURE 1.2-1
LOCATION OF NEWMAN STATION

The Electric Company
El Paso Electric

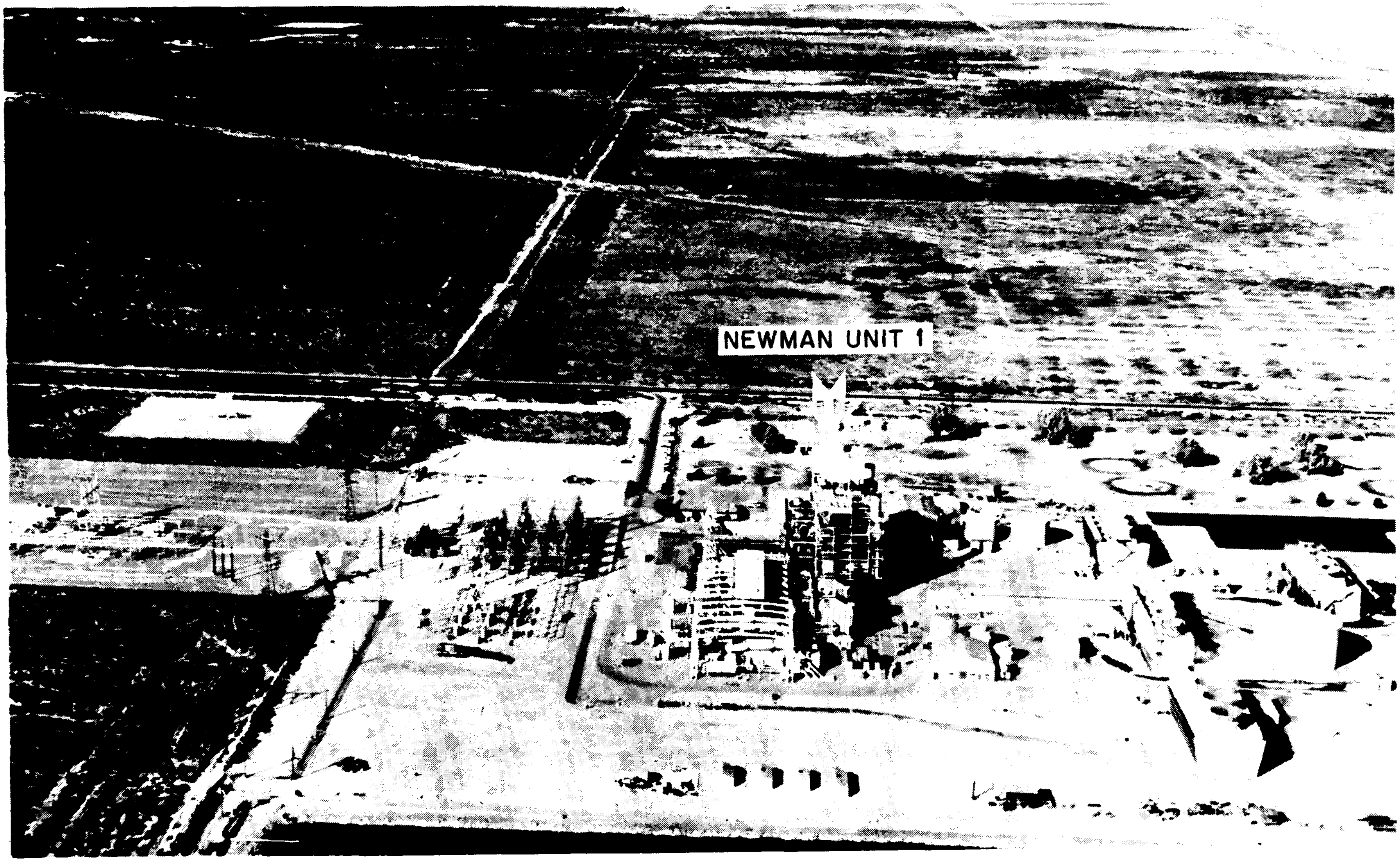


FIGURE 1.2-2
NEWMAN STATION SITE AND SURROUNDINGS

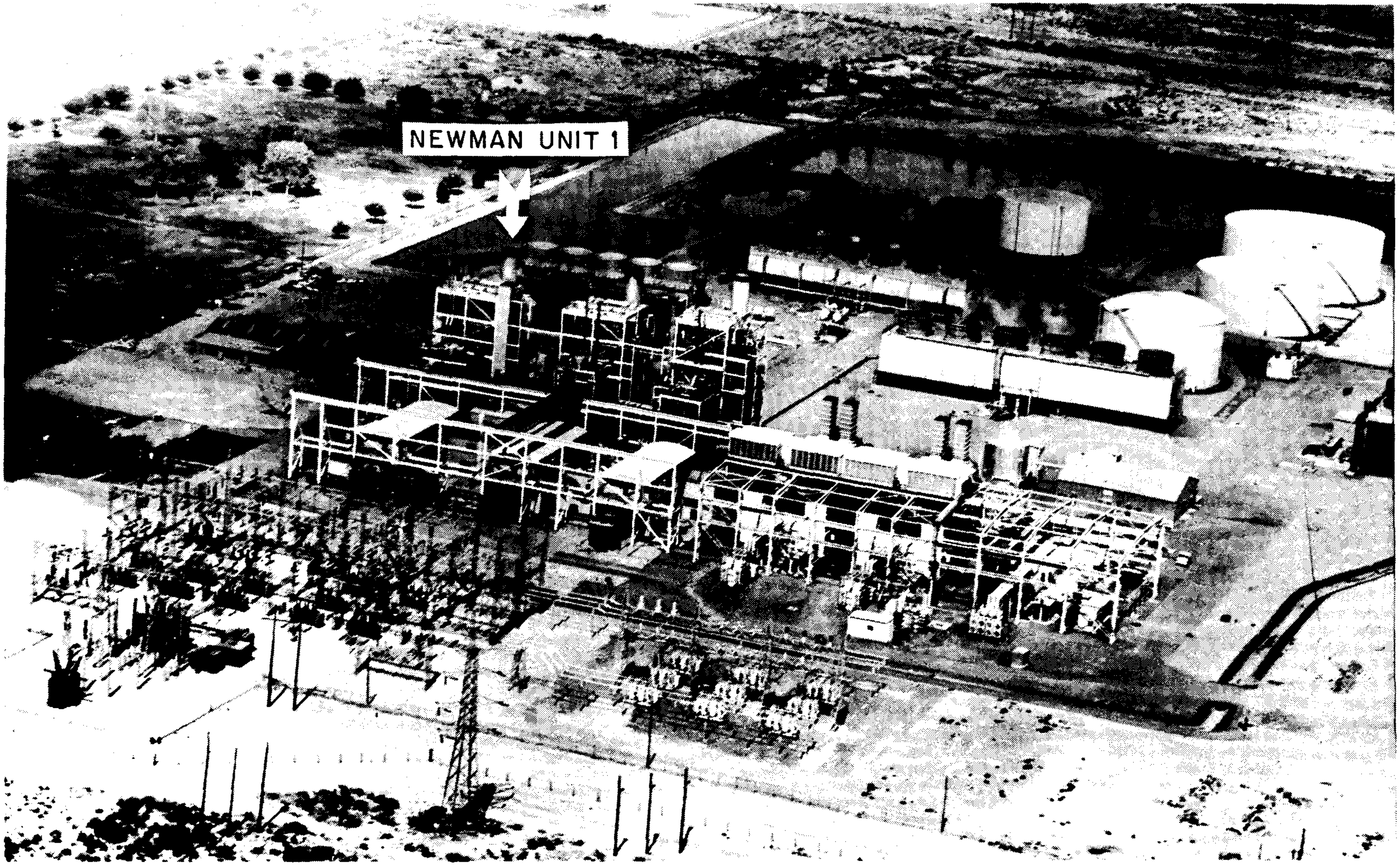


FIGURE 1.2-3
NEWMAN STATION UNITS 1-4

1.3 PROJECT SUMMARY

The principal objective of the Newman Unit 1 Advanced Solar Repowering Program was to refine the Baseline Conceptual Design for solar repowering Newman Unit 1 that has the potential for construction and operation by 1986, making use of the latest advances in solar thermal technology and providing the best economics for overall unit application.

El Paso Electric Company (EPE), in a DOE-funded program, has reviewed recent accomplishments in the DOE Technology Development Program, incorporated selected developments into the conceptual design, prepared a refined conceptual design, analyzed the performance, revised the economics, and prepared a development plan for solar repowering its existing, gas-fueled Newman Unit 1.

The effort of this current program concentrated on major improvement and documentation of the receiver subsystem, the incorporation of a generic heliostat comparable to those presently available, and design changes and economic assumptions reflecting the desires of EPE. The characteristics of these changes and assumptions between the previous conceptual design and this advanced conceptual design are listed below:

Design Characteristic	Conceptual Design -July 1980	Advanced Conceptual Design-April 1982
Design Basis	41 MWe Annual Average Output	Minimize Capital Investment
Reference Time	Noon Summer Solstice	Noon Winter Solstice
Repowering Fraction (%)	50	50
Lifetime (yr)	30	30
Insolation Level (kW/m²)	0.95	1.0
Insolation Source	TMY	TMY
Heliostats Operational (%)	100	99

	Solar Subsystem	
Field Configuration	North Field (160° Arc)	North Field (160° Arc)
Heliostat Area (1,000 m^2)	211	171
Number of Heliostats	2,776	2,998
Primary Receiver (m x m)	12.6 d x 15.7 h - 240° Arc	11.6 d x 15.8 h - 210° Arc
Reheat Receiver (m x m)	12.6 d x 15.7 h - 210° Arc	14.5 d x 13.1 h - 210° Arc
Number of Towers	1	1
Primary Receiver C/L (m)	155	155
Reheat Reveiver C/L (m)	139	140
Heat Flux Constraint	Flux Limit	Variable Flux Profile
	Heliostat	
Type	(W) Second Generation	Generic
Reflective Area (m^2)	81.8	57
Aspect Ratio	1.5:1	1:1
Reflectivity		
Clean (%)	90	92
Annual (%)	90	90
Dimensions (m x m)	7.6 x 11	7.9 x 7.9
Installed Cost ($/$m^2$)	230	198

The EPE system has a total generating capacity of 974 MWe. There is sufficient land available to apply solar repowering to all EPE gas- and oil-fired units, which represent 863 MWe or 89 percent of the total system. EPE selected its Newman Unit 1 for the solar repowering demonstration program for the following reasons: (1) widespread market potential exists for solar repowering of reheat steam turbines similar to Newman Unit 1; (2) more than 14 km² (3,500 acres) of unencumbered, flat land is available adjacent to the Newman Station; (3) the remaining economic life of Newman Unit 1 favors dispatch of the solar repowered unit relative to the balance of the EPE system; (4) no apparent major institutional or environmental constraints exist; and (5) the operating history of the Newman Unit 1 turbine-generator has demonstrated the capability to sustain severe cyclic operating conditions that could result from solar application.

Newman Unit 1 has an 82 MWe (net) tandem-compound, double-flow, reheat steam turbine. It was built in 1960 for baseload duty using natural gas as the primary fuel (oil as the alternate fuel source). The Allis-Chalmers turbine-generator utilizes 10.1 MPa/538°C (1,450 psi/1,000°F) main steam and 3.0 MPa/538°C (425 psia/1,000°F) reheat steam to the intermediate stage. The B&W natural convection boiler is rated at 254,240 kg/hr (560,000 lb/hr) and has a pressurized water-cooled radiant furnace, a two-stage drainable type superheater, and a drainable reheater.

The conceptual design for solar repowering Newman Unit 1 is illustrated in Figure 1.1-1. This design utilizes an advanced water/steam central receiver technology to provide main steam to the high pressure stage and reheat steam to the intermediate stage of the turbine-generator. Fossil energy is used to supplement solar generated steam for intermittent cloudy day operation and for economic dispatch.

EPE selected a solar repowering fraction of 50 percent for this demonstration unit as the appropriate size considered acceptable to adequately demonstrate the engineering, operating, and maintenance aspects of solar repowering. There is little economic incentive for considering higher repowering fractions for a demonstration unit.

The solar subsystem is sized to provide 41 MWe (50 percent repowering) at noon winter solstice based on a direct insolation level of 1,000 watts/m². A 160-degree north heliostat field consisting of 2,998 heliostats (57 m² each) is utilized in the design. A single tower supporting the primary and reheat receivers, total height of 167 m (548 feet), is located adjacent to the turbine building of the unit. The primary receiver design is a drum type boiler with pumped recirculation using an external screened tube concept with eight panels and is based on conventional utility boiler technology utilizing standard boiler materials. The reheat receiver is mounted underneath and adjacent to the primary receiver. The reheat receiver utilizes 16 panels of vertical tubes, with special provision for steam mixing between panels.

The existing boiler and turbine-generator control systems are modified to accommodate the operating characteristics of the solar subsystem. In addition, the turbine-generator will have been modified in 1983 to permit cyclic duty operation consistent with peaking requirements.

The capital cost for this "first-of-a-kind" research demonstration unit is estimated at 136 million dollars (end-of-1986 dollars), allowing 8 percent for material and labor escalation from 1982. Also, an allowance for funds used during construction is included at 13.5 percent. This capital cost estimate is discussed further in Section 1.4. Anticipated operating and maintenance (O&M) costs (excluding fuel) for the first year (1987) have been projected at 1.84 million dollars, using 1981 estimates with 7 percent escalation. The initial operation of the unit can commence in late December 1986, assuming a typical utility-oriented design and construction program is initiated by the fall of 1982.

The solar repowered unit will displace the oil equivalent of 100,000 barrels in gas and coal per year and will yield a cost/value ratio of 2.27 for a gas escalation rate of 7 percent for the "first-of-a-kind" demonstration unit. Based on mass-produced heliostat costs, a commercial unit is expected to have a cost/value ratio of less than 1.0 and be cost competitive with similarly sized coal-fired alternatives.

The EPE team believes the conceptual solar repowering design developed for Newman Unit 1 is not only technically feasible, but also relatively economically attractive for a "first-of-a-kind" demonstration unit. The costs that have been used are realistic and system benefits have been assessed in a conservative economic analysis. The design utilizes conventional water/steam technologies familiar to the utility industry in general and to power plant operators of existing water/steam units specifically. Further, the water/steam technology has been well-proven and has an excellent probability of being built on schedule and within budget. The design satisfies requirements of being a significant demonstration of solar repowering, simple and operable with very high reliability and assured performance. El Paso Electric Company is convinced that demonstrating the feasibility of using technologies familiar to utility operators is a prerequisite to initial utility acceptance of solar repowering as a viable energy option.

1.4 CONCEPTUAL DESIGN DESCRIPTION

Several unique design features distinguish solar repowered Newman Unit 1 as an ideal solar thermal repowering application. These include the use of advanced water/steam receiver technology based on conventional drum-type boiler experience; close proximity of the receivers and tower to the turbine building; a control system that primarily utilizes conventional control philosophy; its location in the area of highest direct insolation in the country; and the demonstration of solar repowering a reheat steam turbine unit.

The advanced conceptual design for Solar Repowered Newman 1 (see Figure 1.1-1) utilizes water/steam central receiver technology to provide main steam to the high pressure stage, 10.1 MPa/538°C (1,465 psia/1,000°F), and reheat steam to the intermediate stage, 2.93 MPa/538°C (425 psia/1,000°F), of the turbine-generator. Fossil energy is used to supplement solar generated steam for intermittent cloudy day operation and for economic dispatch. Important project and design information is summarized in Table 1.4-1, Conceptual Design Summary Table.

Figure 1.4-1 is a simplified flow schematic of the concept. The principal solar/fossil interface between the existing Newman Unit 1 and the solar subsystem consists of (1) steam piping interface from the solar (both primary and reheat receivers) and the fossil steam generators, (2) feedwater piping interface to the solar and fossil steam generators, (3) control interface, and (4) power supply interface to the heliostat field, primary and reheat receivers, valves, and pumps.

Steam generated by the primary solar receiver is mixed with the steam provided by the existing fossil steam generator prior to admission to the high pressure and intermediate stages of the turbine. Attemperation of the fossil and solar generated steam ensures that steam temperatures are maintained within turbine design limits. Solar generated steam is provided based on insolation availability. Fossil steam generation replaces any steam flow reduction due to intermittent cloud cover and for economic dispatch when required.

The feedwater supplied to each steam generator matches the steam flow and pressure requirements of each subsystem by means of a coordinated control system. The control system of the existing unit is modified and interfaced with the solar system through a master control system.

Figure 1.4-2 shows the site arrangement for the advanced conceptual design. The heliostat field is located to the north of the unit. Existing transmission and natural gas pipeline rights-of-way transect this field location. The receiver tower is as close as possible to the turbine building to minimize feedwater and steam piping distances. Transmission lines will be relocated and pipeline rights-of-way will be maintained as exclusion areas.

The collector subsystem consists of a 160-degree array of heliostats. The 2998 heliostats employed in the collector field are similiar to second generation heliostats shown in Figure 1.4-3. A glass reflective surface area of 57 m² (613.5 ft²), an aspect ratio of 1:1, and a clean reflectivity of 92 percent were selected as characteristics of the class of heliostats that will be available in the mid 1980's for solar repowering applications. A specific heliostat design will be selected during the preliminary design phase in order to benefit from the latest design innovations and cost reducing features.

The receiver subsystem provides a means of transferring the incident radiant flux energy from the collector subsystem into superheated steam. The receiver subsystem consists of primary and reheat receivers (Figure 1.4-4) to intercept the radiant flux reflected from the collector subsystem, a single concrete tower structure to support the two receivers, and associated feedwater and steam piping. The external central receiver concepts (primary and reheat) are based on the water/steam pumped recirculation central receiver technology developed by B&W. The receiver subsystem also includes the pumps, valves, and control system within the tower structure necessary to regulate flow, temperature, and pressure; and the required control system components necessary for safe and efficient standby, startup, operation, and shutdown.

The control subsystem is used to sense, detect, monitor, and control all system and subsystem parameters necessary to ensure safe and proper operation of the entire integrated repowered plant. The control subsystem consists of computers, peripheral equipment, control and display consoles, control interfaces, and software.

The fossil boiler subsystem provides a fossil energy source that is used to enhance performance and/or maintain normal unit operation during periods of reduced or no insolation. The fossil boiler subsystem consists of the existing Newman Unit 1 fuel storage, fuel handling, boiler, and related equipment. It also consists of additional fuel supply, fuel storage and transfer facilities, pumps, valves, and control system necessary to regulate flow, temperature, and pressure; and the required control necessary for safe and efficient standby, startup, operation, and shutdown of the fossil boiler subsystem (including air quality control equipment). Essentially all the existing Newman Unit 1 remains after being repowered with a solar steam supply system.

The electrical power generating subsystem (EPGS) provides the means for converting to electrical power the solar thermal input at the receivers and the chemical energy in fossil fuels from the fossil boiler subsystem. The output from the EPGS is regulated for integration into the El Paso Electric Company system network. The EPGS consists of the existing balance-of-plant equipment at Newman Unit 1, and the piping and related equipment required to interface with the receiver subsystem.

The estimated construction cost for solar repowered Newman Unit 1 is approximately 136.4 million dollars (December 1986 dollars). This estimate assumes repowered unit operation by the end of 1986, and includes direct costs, indirects, distributables, escalation, contingency, allowance for funds used during construction, and owners' costs. A breakdown of project construction cost is given in Figure 1.4-5.

Operating and maintenance costs for solar repowered Newman Unit 1 are estimated to be approximately $1.84 million per year in December 1986 dollars, or about 1.4 percent of the total capital cost annually.

TABLE 1.4-1

CONCEPTUAL DESIGN SUMMARY TABLE

1. Prime Contractor:

   El Paso Electric Company

2. Major Subcontractors:

   Stone & Webster Engineering Corporation

   Babcock & Wilcox

   Westinghouse Electric Corporation

3. Site Process:

   Electric power generation

4. Site Location:

   24 km (15 miles) northeast of downtown El Paso, Texas and 19 km (12 miles) from El Paso Solmet Weather Station

5. Design Point:

   Noon winter solstice

   50 percent repowering for an 82 MWe unit

6. Receiver:

   Receiver Fluid: Water/steam

   Configuration: External, superheater tubes screened by boiler tubes

   Type/Elements:

   Primary receiver with preheater, forced recirculating boiler, and superheater

   Reheat receiver

   Output Fluid Temperature:

   Primary receiver: 549°C (1,020°F)

   Reheat receiver: 549°C (1,020°F)

TABLE 1.4-1 (Cont)

Output Fluid Pressure:

Primary receiver: 10.1 MPa (1,465 psia)

Reheat receiver: 2.93 MPa (425 psia)

Size:

Primary receiver: 15.8 m high x 11.6 m dia. x 210°

Reheat receiver: 13.1 m high x 14.4 m dia. x 210°

7. Heliostats:

Number: 2,998

Effective Mirror Area: 171,000 m^2 (57 m^2 per heliostat)

Direct cost: \$33,858,000 (1982 dollars) based on heliostat costs of \$198/m^2 (based on expected heliostat market)

Type: Second Generation Heliostat

Field Configuration: North field/160° angle

8. Energy Storage:

None

9. Total Project Cost:

\$136,400,000 (December 1986 dollars)

10. Construction Time:

51 months (includes design, installation, checkout, and startup)

11. Solar Plant Contribution at Design Point:

41 MWe (net)

TABLE 1.4-1 (Cont)

12. Solar Fraction - Annual (including economic dispatch):

    47 percent lifetime average

13. Annual Fossil Energy Saved:

    3,000,000 barrels oil equivalent over 30-year period. Amount of energy displaced varies substantially from year to year; the average annual equivalent is about 100,000 barrels.

14. Type of Fuel Displaced:

    11×10^{12} Btu Gas

    7×10^{12} Btu Coal

15. Annual Solar Energy Produced: 159,500 MWht

16. Ratio $\frac{\text{Annual Energy Produced}}{\text{Total Heliostat Mirror Area}}$: 0.93 $\frac{\text{MWht}}{\text{m}^2}$

17. Site Insolation:
    Annual Average Daily Direct Normal Insolation:
    7.26 kWh/m^2
    Source: Solmet Weather Tapes for El Paso, Texas

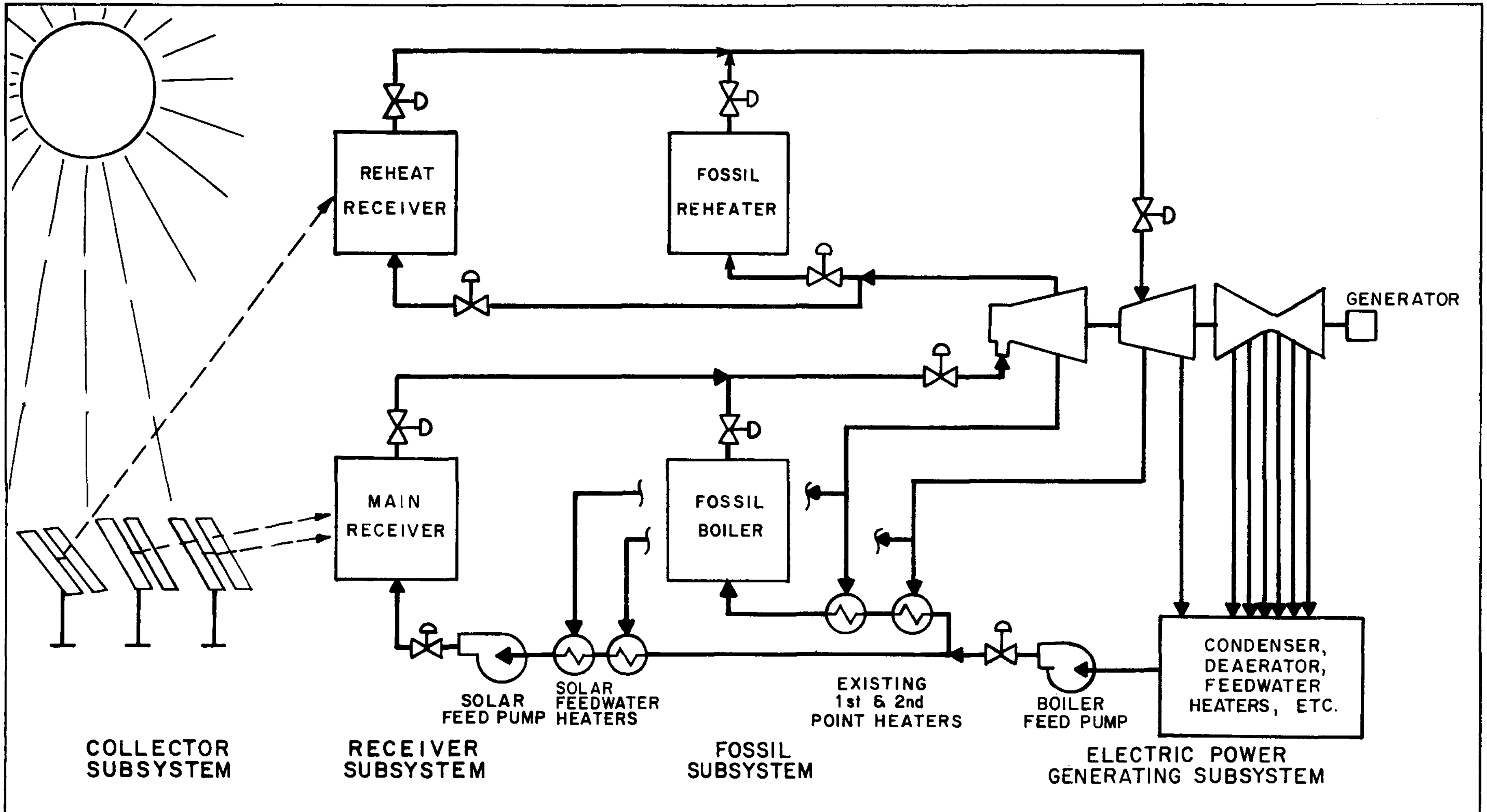


FIGURE 1.4-1
SIMPLIFIED FLOW SCHEMATIC

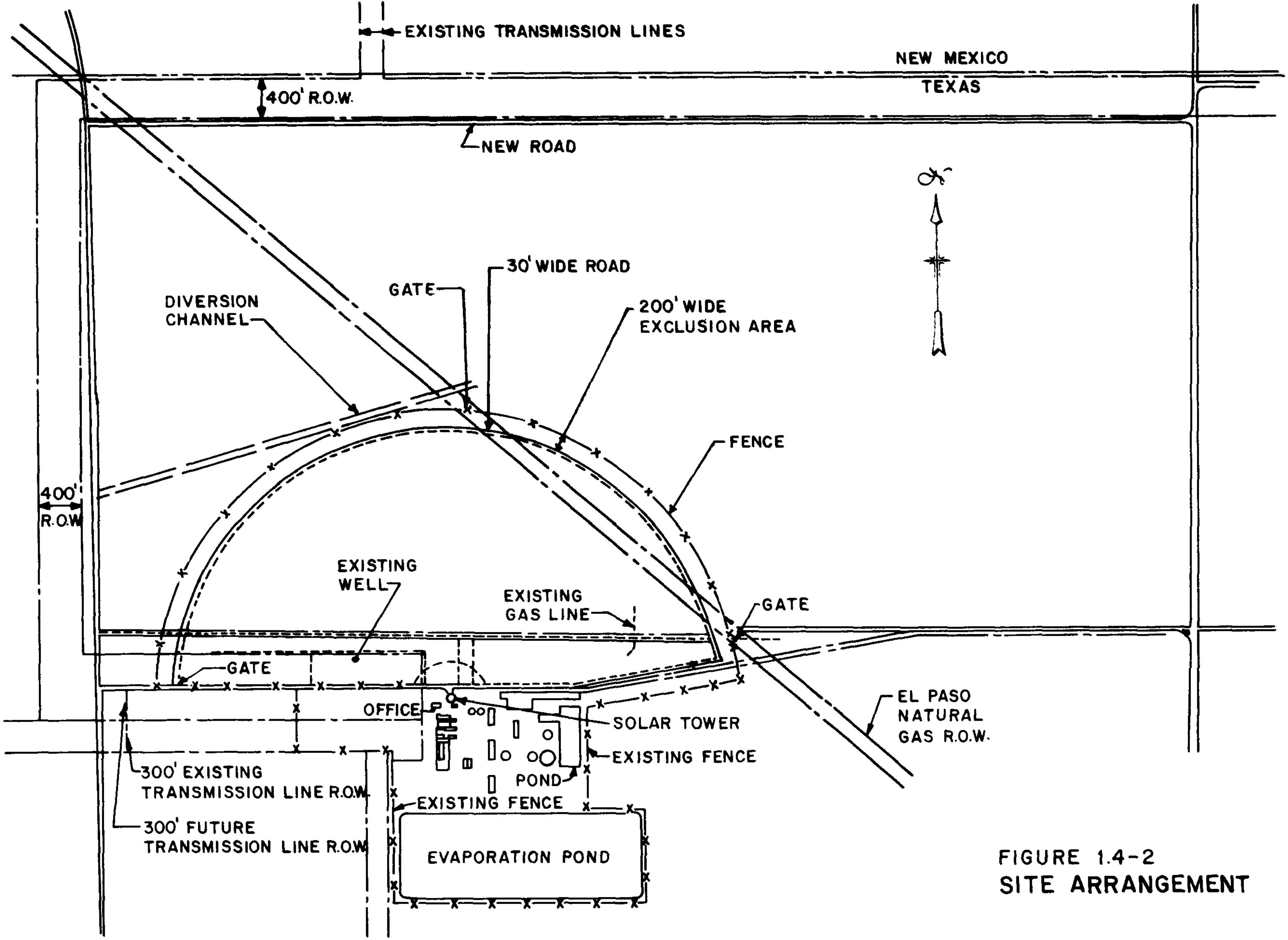
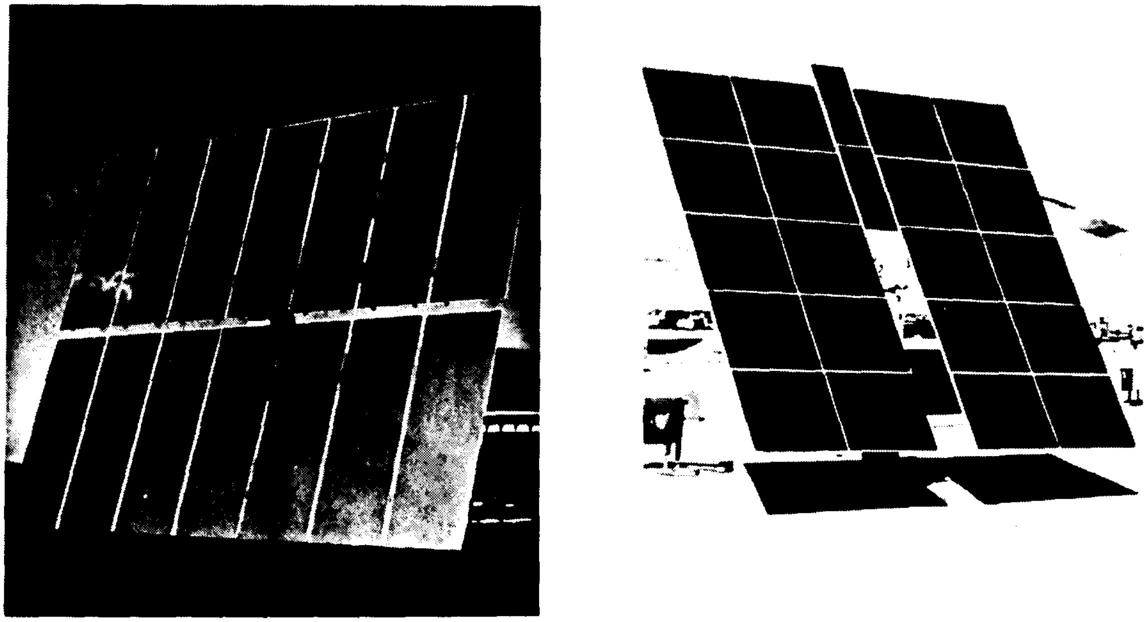
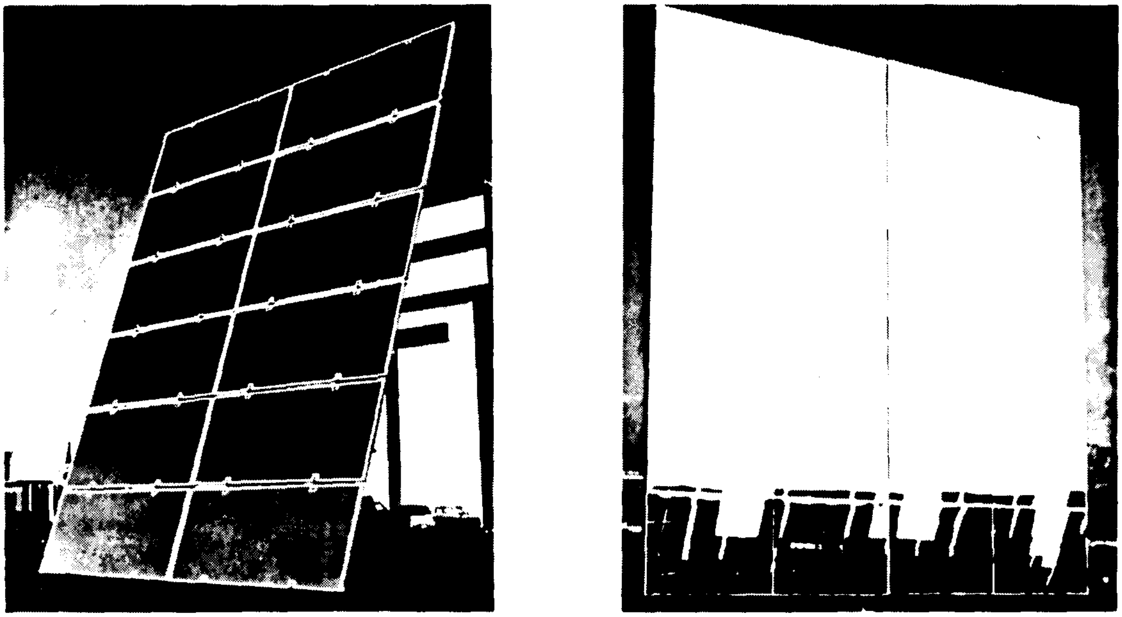


FIGURE 1.4-2
SITE ARRANGEMENT



McDONNELL DOUGLAS

MARTIN MARIETTA



BOEING

ARCO

FIGURE 1.4-3
SECOND GENERATION HELIOSTATS

1.5 SYSTEM PERFORMANCE

Solar repowered Newman Unit 1 can produce electrical power using steam generated from solar energy, fossil energy, or any combination of the two over a broad range of loads. During hybrid operation, feedwater is split and delivered to both the solar receiver and fossil boiler. High pressure superheated steam is then generated in the primary solar receiver and combined with the steam from the fossil boiler/superheater and delivered to the high pressure steam turbine at 10.1 MPa (1,465 psia) and 538°C (1,000°F). After expansion through this turbine, the steam is again split between the solar and fossil reheaters. The steam is reheated and introduced into the intermediate pressure turbine at 2.93 MPa (425 psia) and 538°C (1,000°F).

The solar collector field and receivers are sized to supply steam in sufficient quantity and quality to produce a net electrical output power of 41 MW (50 percent repowering 82 MW net total output) when operating in the hybrid, or combined solar/fossil mode at the design point of noon winter solstice. The collector subsystem design is based on a direct normal insolation of 1000 W/m^2.

The solar repowered unit performance characteristics are summarized in Table 1.5-1 for the noon winter solstice design point. Figure 1.5-1 is a stairstep system efficiency chart at the design point that identifies the various component efficiencies which contribute to the overall plant heat rate. The energy output of solar repowered Newman Unit 1 is shown in Figure 1.5-2. The overall efficiency of converting incident solar flux on the heliostats to net electricity on this basis is 24 percent. This solar plant efficiency varies considerably with total plant output and other factors.

The dynamic response characteristics of the solar subsystems, the fossil boiler subsystem, and the EPGS were evaluated during the previous contract to assess the consequences of cloud shadow passage over the collector field. Transient analyses were performed for cloud cover sizes that represent insolation losses of 10, 50, and 100 percent, and for cloud shadow velocities ranging from 8 to 22 m/s (17-50 mph) which correspond to annual average and maximum design velocities. The results of these analyses were reviewed during this study to assure that the incorporated design modifications did not preclude satisfactory operation of the unit during intermittent cloudy days. This review has further confirmed that the solar repowered Newman Unit 1 can be operated during intermittent cloudy days without requiring a thermal energy storage subsystem to buffer the solar generated steam flow resulting from insolation transients.

TABLE 1.5-1

SYSTEM PERFORMANCE CHARACTERISTICS

Unit Rating	82.3 MWe	
Solar Repowering Percentage*	50 percent	
Electric Power Generation		
High Pressure Turbine Inlet	10.1 MPa/538° C	(1,465 psia/ 1,000°F)
Intermediate Turbine Inlet	2.93 MPa/538° C	(425 psia/ 1,000°F)
Main Steam Flow	257,000 kg/hr	(567,000 lb/hr)
Collector Subsystem		
Power Incident on Primary Receiver	103 MWt	
Power Incident on Reheat Receiver	26 MWt	
Efficiency (including cosine, reflectivity, blocking, atmospheric attenuation, spillage at design point)	77%	
Receiver Subsystem		
Power Absorbed in Primary Receiver	91 MWt	
Primary Steam Outlet Flow and Conditions	129,000 kg/hr 10.8 MPa/549°C	(284,000 lb/hr) (1,567 psia/ 1,020°F)
Peak Heat Fluxes on Primary Receiver Water Cooled Surfaces	0.66 MW/m^2	
Power Absorbed in Reheat Receiver	18 MWt	
Reheat Steam Outlet Flow and Conditions	115,400 kg/hr 2.97 MPa/549°C	(254,000 lb/hr) (431 psia/ 1,020°F
Overall System Efficiency (kWhe net output per kWht energy incident on heliostat reflective surface)	0.24	

NOTE:

* Based on a direct normal insolation level of 1000 $watts/m^2$ at design point.

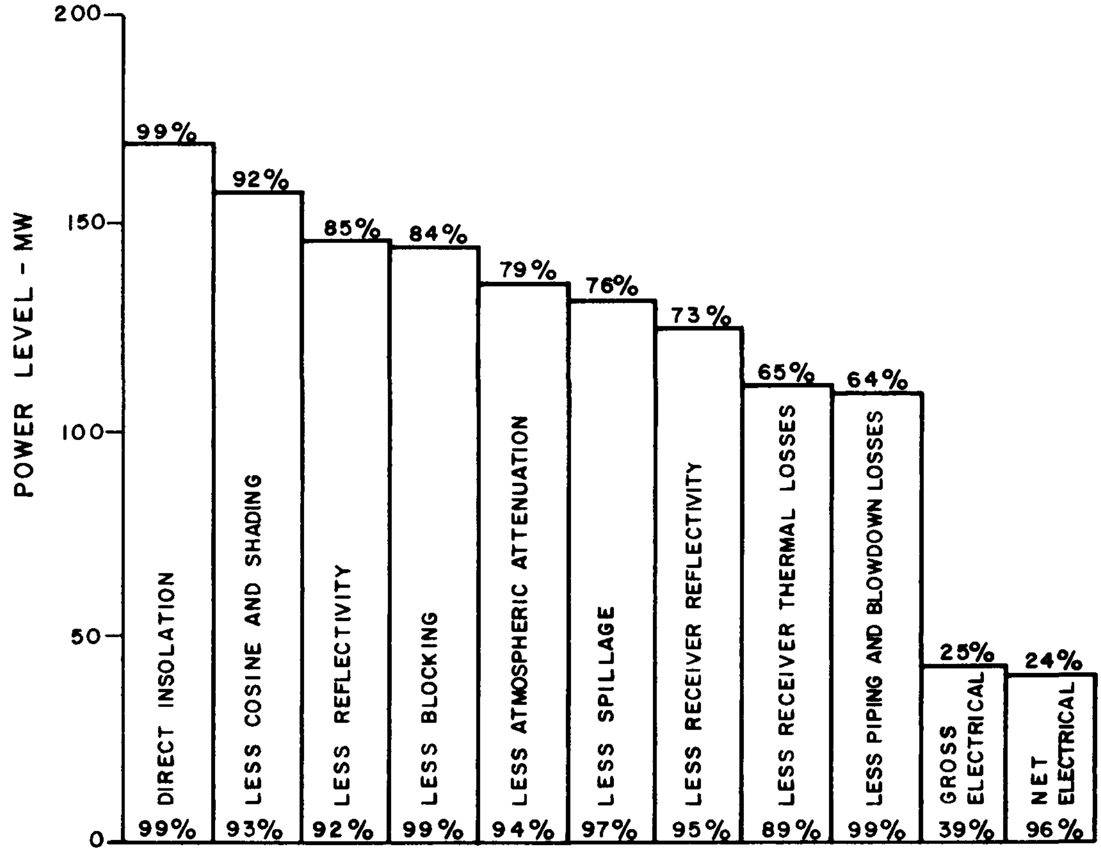


FIGURE 1.5-1
SOLAR REPOWERING NEWMAN
UNIT 1 EFFICIENCY CHART
(DESIGN POINT -
NOON WINTER SOLSTICE -
1000 W/M^2 INSOLATION)

FIGURE 1.5-2
SOLAR REPOWERED UNIT ENERGY OUTPUT

1.6 ECONOMIC FINDINGS

The integration of solar repowered units into electric utility systems raises a number of questions as to the value of the repowered units, problems they might introduce, and requirements that should be placed upon them. In addition to technical feasibility, economic and reliability impacts are major concerns to the El Paso Electric Company. These involve the cost of repowering, the quantity and value of fossil fuels displaced, a capacity credit for unit life extension, and the reliability of the solar repowered unit.

A cost/value analysis was performed to evaluate the economic merit of solar repowering Newman Unit 1 on the EPE system. The analysis was performed utilizing the methodology developed by Westinghouse as part of EPRI Contract RP 648-1 entitled "Requirements Definition and Impact Analysis of Solar Thermal Power Plants."

The intent of the cost/value analysis is to realistically assess the economics of the "first" repowered unit using current cost data based on equipment quotes from hardware manufacturers. The results therefore are not indicative of the true economic potential of solar repowering in general but rather only of the economics of the "first demonstration" unit. The economic potential of solar repowering on the EPE system was established as part of the data presented in earlier work to select the Preferred Configuration and resulted in cost/value ratios less than 1.0 using projected hardware cost estimates for a mature solar industry.

The reference unit used for performing the unit economic analysis is based on the conceptual design presented in Section 1.4. The capital cost for this "first-of-a-kind" demonstration unit is estimated at 136.4 million dollars (end of 1986 dollars) with anticipated total operating and maintenance costs for the first year of 1.84 million dollars. The solar subsystem is sized to provide 41 MWe (50 percent repowering) at noon winter solstice based on an insolation level of 1000 watts/m².

The fossil boiler at Newman Unit 1 will operate on natural gas. EPE currently has gas supply contracts extending into the 1990's and beyond. The operating scenario for the fossil boiler is important in assessing the economic benefit of solar repowering. Since the solar repowered Newman Unit 1 will be a "first-of-a-kind" demonstration unit, an operating strategy for the fossil boiler has been selected to permit the development of operator confidence and experience with the solar subsystem without jeopardizing the integrity of the existing equipment or the ability of the unit to produce power consistent with the present demonstrations of solar technologies at Barstow, California, and at the Central Receiver Test Facility. The operating strategy consists of:

Solar operation initiated end of December 1986

1/87 to 2/87, the fossil boiler produces 41 MWe minimum when the unit is operating on solar; the unit is also economically dispatched on fossil fuel.

3/87 to 4/87, the fossil boiler produces 23 MWe minimum when the unit is operating on solar; the unit is also economically dispatched on fossil fuel.

Beyond 4/87, the fossil boiler operates only when required to offset solar insolation transients on cloudy days or when economical to dispatch the unit on fossil fuel.

After 6 months of engineering test and evaluation, the solar repowered unit is dispatched, as noted above, in a manner similar to conventional units.

The detailed economic evaluation of solar repowered Newman Unit 1 is based on a computer model of the EPE system. The model constructed is representative of the EPE system expansion plan as of March 1982. Approximately 90 percent of the existing system generating capacity is provided by gas- and oil-fired units; however, by 1987 EPE anticipates that 43 percent of their generating capacity will be provided by coal and nuclear units and that this will increase to 68 percent by the year 2000. The system peak load forecasted for 1987 is 995 MWe, and by the year 2000 the system peak load is expected to increase to 1594 MWe.

A detailed multi-year analysis was performed for the solar repowered unit operating on the EPE system. A total of seven individual years of operation were modeled. This multi-year analysis supplied annual production costs and savings incurred by the solar repowered unit. A lifetime cost/value ratio was derived from the yearly operations. In addition, sensitivities to solar system startup energy, repowered unit cost, and economic assumptions were established.

Table 1.6-1 presents the two economic scenarios developed by EPE for the analysis. The first scenario (A) is based on EPE's current long term projection of natural gas and fuel oil escalation rates at 7 percent beyond 1989. Because of the uncertainty in the long term escalation rates for these fuels, a second scenario (B) is also considered in the economic evaluation which is based on an escalation rate of 10 percent for natural gas and oil beyond 1989. The discount rate used in the analysis for both scenarios is 15.7 percent (EPE cost of money) with a fixed charge rate of 16.1 percent.

The lifetime cost and value resulting from the multi-year analysis are summarized in Table 1.6-2. The components of cost and value were determined for both EPE economic scenarios (A and B). The numbers shown in this table are present worth of revenue requirements expressed in millions of 1982 dollars. The base economic scenario (A) resulted in a cost/value ratio of 2.27. Scenario B resulted in a cost/benefit ratio of 2.06. The total lifetime energy displaced is approximately 3.18 x 10^4 MJ (30 x 10^{12} Btu) of gas and 0.74 x 10^4 MJ (7 x 10^{12} Btu) coal. The solar repowered unit consumes about 2.01 x 10^4 MJ (19 x 10^{12} Btu) of gas over its solar repowered life. Thus, the net energy displaced is 1.17 x 10^4 MJ (11 x 10^{12} Btu) of gas and oil, and 0.74 x 10^4 MJ (7 x 10^{12} Btu) of coal. The total cost of electric energy from solar repowered Newman Unit 1 is 10.5 cents per kWh for scenario A.

All costs presented in Table 1.6-2 are discounted to 1982 dollars. The capital cost shown on the table represents the present worth of fixed charges over the assumed 30-year life of the unit. The operation and maintenance (O&M) cost is the present worth of escalating annual O&M costs for that same period.

Solar plant value is the present worth of net savings in fuel and capacity costs. Fuel value represents the savings in fuel costs at other units in the EPE system whose operation is displaced by that of solar repowered Newman Unit 1. Variable O&M represents a credit for O&M costs of other units whose operation is displaced. Fuel cost is the cost of gas burned at solar repowered Newman Unit 1 to support both the solar operation of the unit on cloudy days and for economic dispatch of the unit. Capacity credit is the value of new generating capacity that will no longer be required due to extending the life of Newman Unit 1 beyond its normal retirement date of 2002.

The cost/value ratio of a demonstration program, as viewed from immediate utility impacts, is substantially higher than might be expected for a typical commercial implementation; i.e., cost/value of 2.27 versus 1.00 or less. The higher cost/value ratios are due to higher costs for current solar components (such as heliostats) associated with a first-of-a-kind installation.

TABLE 1.6-1

EPE ECONOMIC SCENARIOS (1987)

	Scenario A	Scenario B
Present Worth Discount Rate (%)	15.7	15.7
Fixed Charge Rate (%)	16.1	16.1
Capital Cost, $/kWe (c-t/c-c/coal/nuclear)	400/700/1600/1800	400/700/1600/1800
Fuel Cost ($/MBtu) (Gas/Oil/Existing Coal/New Coal/Nuclear)	8.77/14.2/1.1/2.77/0.87	8.77/14.2/1.1/2.77/0.87
Fuel Escalation Rate (%) (Gas/Oil/Coal/Nuclear)		
1987	8/13.6/8/8.2	8/13.6/8/8.2
1988	8/9.3/8/6.9	8/9.3/8/6.9
1989	8/10/8/5	8/10/8/5
Beyond 1989	7/7/8/7	10/10/8/7
Capital Escalation Rate (%)	8	8
O&M Escalation Rate (%)	7	7

TABLE 1.6-2

MULTI-YEAR COST/VALUE SUMMARY
1982 M$ PWRR

	Economic Scenario* A	Economic Scenario* B
Solar Plant Cost		
Capital	72.1	72.1
O&M	10.7	10.7
Total Cost	82.8	82.8
Solar Plant Value		
Fuel Value	81.4	89.2
Variable O&M	0.8	0.8
Fuel Cost	-52.5	-57.0
Capacity Credit	6.8	6.8
Total Value	36.5	39.8
Net Value	-46.3	-43.0
Cost/Value Ratio	2.27	2.08
Levelized Busbar Energy Cost (mills/kWh)	104.7	108.1

NOTE:

*Economic Scenario A and B are identical except for oil and gas escalation rates beyond 1989:

	A	B
Gas	7%	10%
Oil	7%	10%

1 of 1

1.7 DEVELOPMENT PLAN

The overall objective of the Solar Thermal Repowering Program is to provide demonstration units that serve to reduce the uncertainty associated with the design, performance, operation, maintenance, cost and safety of this new technology. User perceived risks associated with uncertainty in each of these areas must be reduced considerably before units can be financed entirely on a commercial basis.

The steps required to develop the advanced conceptual design prepared in this study into a successful demonstration project include detailed design, procurement, construction, checkout, startup, performance validation, and commercial operation. Figure 1.7-1 summarizes the major program milestones; it is assumed that preliminary design work will be initiated in October 1982.

The design, procurement, fabrication and erection of the receiver subsystem represents the critical path for this program. Lead times for receivers and heliostats are based on preliminary estimates provided by potential equipment manufacturers.

Construction work is planned to start 27 months after contract award and requires an estimated 18 months to complete. The existing unit is removed from service to complete modifications required for solar repowering during the first half of 1986. The repowered unit is again available for fossil fueled operation during the third quarter of 1986 and for intermittent duty on solar energy as part of the system startup and checkout operations. The unit is completely operational by December 1986.

During the first 4 months of operation, the operating scenario for the fossil boiler assumes continuous boiler firing during solar operation as indicated in Section 1.6. A series of performance tests will be conducted during this time period to validate the unit design. These tests will address plant performance during various operational modes, response to transients, safety, controls and instrumentation performance, and effects of cooling tower drift and stack emissions on heliostat performance.

In addition, the initial portion of the operation phase will address data collection and analysis, and documentation of operation and maintenance experience.

The experience gained from the design, construction, and operation of solar repowred Newman Unit 1 is expected to support future repowering efforts by EPE and other utilities. Transferring this experience to other potential industrial and utility users will be a prime objective of the demonstration program.

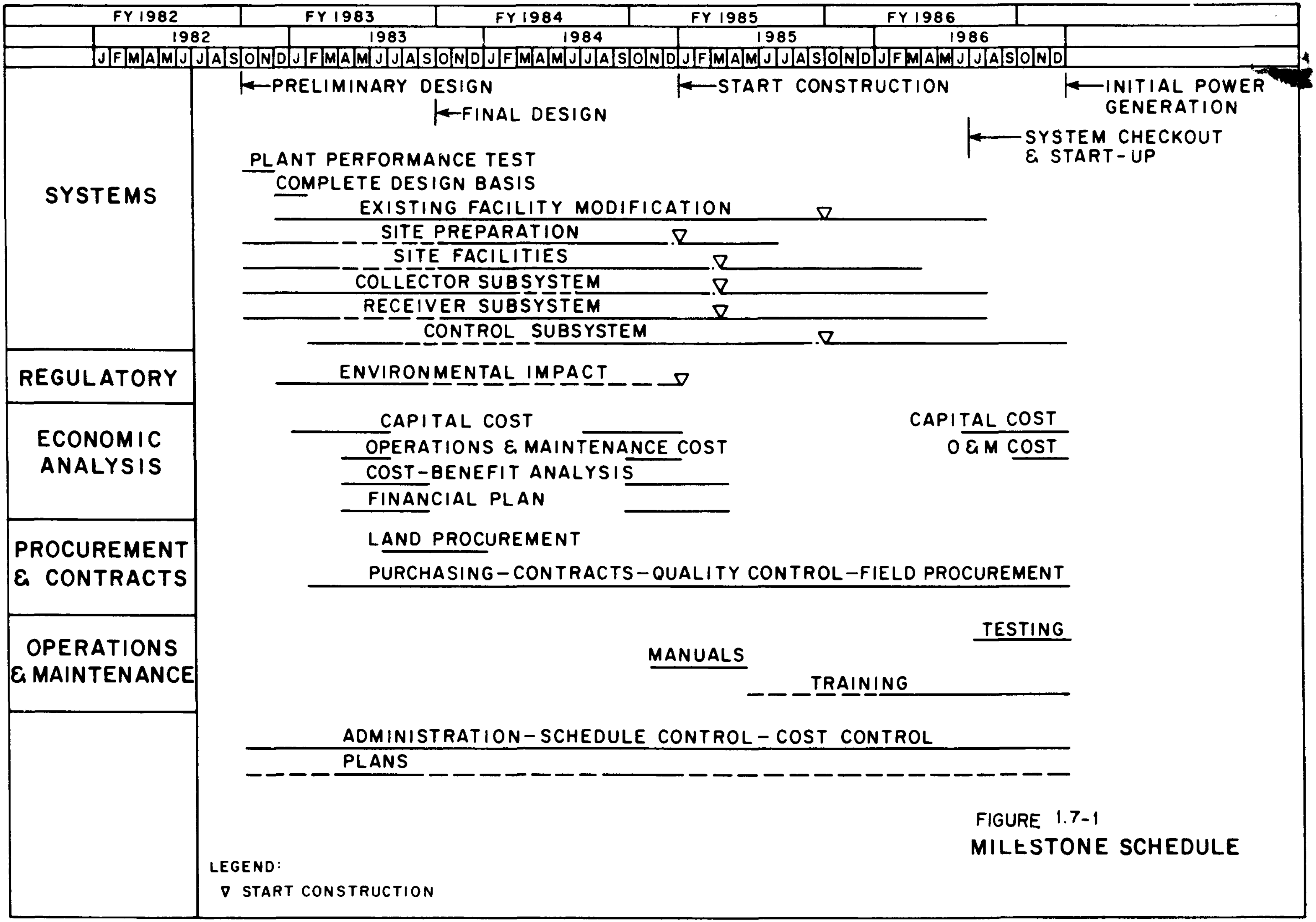


FIGURE 1.7-1
MILESTONE SCHEDULE

1.8 SITE OWNER'S ASSESSMENT

EPE is, at present and historically, a gas burning utility with fuel oil as a secondary fuel. First, the oil embargo and then the severe gas curtailments of the mid-1970s have had major influence upon its system planning. These, along with the enactment of the Fuel Use Act of 1978, and the nation's continued dependence on foreign oil affecting national security and less-than-favorable balance of payments, are indicators that other sources of energy should and must be developed.

Confronted with limited coal and nuclear construction options for the future, the solar thermal option stands out as an attractive energy source. This is particularly significant in the 1990s as EPE retires peaking and intermediate generating units. The solar thermal option can be constructed faster and in smaller sized blocks or increments than is expected for coal-fired units. There are several other advantages. The daily output curve of a solar unit tends to mimic the daily EPE system load requirements curve. The solar option is more adaptable to repowering the existing gas-fired units if a shift from gas or oil is required or becomes more desirable, whereas repowering with coal would introduce the logistical and environmental complexities associated with the coal fuel cycle.

The existing EPE units are considered too small for cost-effective economic coal conversion.

EPE, as site owner and program manager for the "Newman Unit 1 Advanced Solar Repowering" contract, has technically directed each of the tasks and subtasks described earlier. EPE is pleased with, and supportive of, the refined conceptual design for solar repowering Newman Unit 1. EPE believes the attractiveness of water/steam technologies for a near-term demonstration of the concept has been confirmed through the results of this program. Further, EPE sincerely believes that solar repowering demonstrations are a necessary step for early commercialization of solar thermal central receiver power generation.

Gaining utility/industry confidence is an essential part of the commercialization process for new power generating equipment. Solar repowering concepts have now been explored through the definition of technical requirements for various conceptual designs. Testing of solar hardware at the Central Receiver Test Facility has developed some experience, familiarity and needed information. The 10 MWe Barstow Pilot Plant will demonstrate solar thermal central receiver system operation. Utilities now need full-scale, conclusive demonstration of reliable service over extended periods of time, firm data on capital investment and O&M costs over expected lifetimes, details of regulatory and environmental requirements, and assurance of operational compatibility with conventional generating systems.

What are the key ingredients for achieving these types of demonstration-related information? First, the technology must exist, and it does, particularly for repowering applications using water/ steam receivers. The major detriment to the rapid implementation of solar power systems is the absence of adequately-funded field testing and evaluation programs that will provide the basis for validating cost and performance estimates. A second major ingredient will be utility, industry, and investment community confidence in the hardware. Will the systems last? A full-scale field testing program with proven water/steam technology will provide a portion of the answer with suitable warranties, quality assurance programs, insurance, and financing mechanisms (which are certain to be developed) providing the remaining elements necessary to limit a utility buyer's risk.

In order to commercialize a capital intensive industry such as solar thermal power generation, the business community will need to invest substantial capital in production facilities, particularly those for heliostats. This investment community bases much of its financial decision-making on the relative level of Federal commitment toward emerging energy technologies. If the Federal commitment to programs such as the development of large-scale solar capabilities is questionable, industry at large will be reluctant to undertake large capital obligations to support and further commercialization.

EPE evaluates promising alternative sources of electrical generation in a manner consistent with its historical assessments of conventional generation systems, a methodology based upon standard utility long-range generation expansion planning procedures and criteria. Areas such as cost/value, financial concerns, technical risks, operation and maintenance projections, environmental impacts, licensability, and schedular considerations impact all assessments of electrical system additions by an electric utility.

Life-cycle (cost/value) calculations are perhaps the most important evaluation criteria to senior management when making capital investment decisions. When solar repowering an existing unit, the trade-offs are similar to those made when deciding to modify or replace an old piece of machinery with newer (and possibly more efficient) parts, machine(s), or processes. The present worth cost of the new machine or process when compared to the net value (present worth) of the new machine or process (considering all definable factors of cost and value) enables the cost/value ratio to be determined. In a standard business sense, a cost/value less than 1.0 will justify the purchase of a new machine or process, provided that the initial investment capital can be obtained at a reasonable cost.

The methodology involves analyzing revenue requirements of the capital investment, the investment related costs, and the fuel and O&M costs. EPE has approached its analysis of solar repowering on this same basis and is comfortable with its estimated cost/value ratio of 2.27 for a first-of-a-kind research and development (R&D) demonstration for solar repowering Newman Unit 1. This ratio was calculated using EPE's projected economic factors, the most significant of which was a gas escalation rate of 7 percent. A cost/value ratio of 2.27 essentially says that a site-specific and system-specific repowering of Newman Unit 1 with solar energy has a cost which is approximately double the monetary value of the solar repowering modifications and additions.

This cost/value analysis is very encouraging for a number of reasons:

EPE believes that realistic costs and benefits have been employed in the economic analysis.

It is based on a first-of-its-kind demonstration constrained to be operational by late December 1986.

It utilizes a 1982 cost of $198/m² for heliostats which has the potential to be reduced almost two-fold, given future market economies and research advancements in heliostat related technologies. Heliostats and their associated subsystems comprise 59 percent of the direct capital costs.

A number of other cost reductions, such as the receiver subsystem, attributable to mature commercial markets as well as further research advancements, are possible in other aspects and portions of the overall solar repowering system.

The analyzed system integrates well into the planned expansions of the EPE system and will operate in a manner consistent with the established operational philosophies of EPE.

It shows a substantial reduction in the use of natural gas and oil as boiler fuels.

And although not cost effective at present, it shows that future applications of solar repowering and solar stand-alone can be cost effective, once realistic demonstrations are made and heliostat costs are reduced.

Although the cost/value ratio provides an indicator of overall economic attractiveness, the key economic issue involves the one-time large capital expenditure with the potential for a much greater indirect financial return resulting from the large-scale implementation of a new, more economical technology. In addition to the potential for economic breakeven costs, a mature solar thermal power industry can provide an "insurance policy" that stabilizes fuel costs to the rate payers.

The question of technical risk will be an important one in early solar repowering demonstrations. The goal of a solar repowering demonstration will be to verify the technical viability of solar repowering concepts, develop solar hardware, and serve as a necessary step to build large-scale stand-alone solar facilities. An unfavorable solar repowering demonstration may imply that solar is not an acceptable generation alternative for the 1990s. In EPE's opinion, the systems chosen for an initial, large-scale demonstration must have the highest probability of successfully being constructed and operated within schedule and budget, being widely integrated into electric utility systems, and satisfying the national interest aspect of the overall solar research program.

Thus, the rationale for EPE's choice of water/steam as the working fluid in its solar repowering conceptual design is that the simplest, most familiar technology solution to solar repowering existing generating units will minimize technical risk. One of the major requirements of this study was that the system must have very high reliability and assured performance. EPE believes that water/steam technology represents this type of solution.

Some of the advantages of water/steam usage as a working fluid are:

> Water/steam is a technology familiar to the utility industry and permits application of steam generation technology which is mature, reliable, and well-established with potential users. No special considerations are required in the boiler loop of a water/steam system.
>
> Water/steam systems use proven materials in proven applications; the behavior and lifetimes of the materials are known under all expected operating conditions, and the risks associated with combining materials to perform in uncertain operating regimes are eliminated.
>
> Water/steam receiver fluid design criteria are well understood. B&W stands ready to support the installation of a water/steam receiver with similar commercial warrantees as would be provided for a fossil-fired steam generator.
>
> Use of a water/steam receiver permits generation of steam whose pressure and temperature conditions easily match those currently in use at power stations.

Additionally, materials compatibility and water chemistry behavior at solar receiver operating conditions are well known.

EPE's economic analyses utilized an initial O&M cost equivalent of 1.4 percent of the capital costs, escalated by 7 percent each year. This appears to be a realistic projection of O&M costs based on known parameters; however, it is important to note that current O&M estimates are a "best guess." An important aspect of the demonstration will be to gather hard data on actual O&M costs and related considerations. Additionally, the life-cycle O&M costs for repowering Newman Unit 1 are approximately equal to 15 percent of the total present worth cost of the installation. If the EPE Team's estimate of O&M costs proves to be high in an actual demonstration, the cost effectiveness and commercial potential of solar generation will be enhanced.

EPE's chosen site is located outside high traffic, high density areas which will limit any potential safety hazards and will alleviate possible ground glare impacts to the general public. No major negative environmental/ecological impacts are foreseen by EPE and a positive impact will result from the reduction of air pollutant emissions. Its location is nondetrimental to the area's scenic attractions, historic sites, or public recreational facilities. There are no nearby residents and the installation of such a solar facility at this site has received broad acceptance by local, State, and Federal governmental bodies. Location of a solar thermal repowering at El Paso enhances the perceived role of the area as a major growth center and as a leader in industrial development.

The Newman Unit 1 site is also located such that access for construction and for the many expected visitors will be quickly and easily accomplished through an excellent system of roads. It is situated relatively near a major airport. The El Paso community area, with a population of about 500,000, has the facilities to easily absorb workers and visitors to a demonstration project. Additionally, the El Paso region has a labor market saturated with the skills necessary to successfully accomplish construction of a demonstration; it also is an area of extremely high unemployment. These considerations will yield high public acceptance and visibility of a federally-sponsored activity.

The solar generated power can be fully utilized on the EPE system and results in substantial savings in fuel consumption. EPE currently has a generation mix which is 89 percent gas or oil-fired and also an extremely limited potential to apply other alternative energy sources. Situated in one of the best solar insolation areas, EPE looks toward solar energy to play an important role in its future expansion plans.

In summary, EPE's assessment of its site-specific solar repowering design for Newman Unit 1 is highly positive. This design supports the Department of Energy's objectives of verifying the technical feasibility, economic attractiveness, and environmental acceptability of conserving vital fossil resources through utilization of solar energy. The construction of such a facility is not expected to be cost-effective in a direct business sense, but cost-effective in terms of the long-term benefits associated with the introduction of a new energy technology that will serve to limit the spiraling growth of fossil fuel prices. Future commercial applications of this technology are expected to be cost-effective given the specifics of future cost reductions in heliostats and related solar components. EPE's solar repowering concept utilizes water/steam as the working fluid that will minimize technical risks and maximize the potential of a successful demonstration that meets schedular and budgetary goals. Predemonstration O&M estimates appear reasonable, but subsequent actual data from a future demonstration may lower projections for this significant cost item, and thus enhance commercialization and acceptance of the solar repowering concept.

SECTION 2

INTRODUCTION

This report covers work performed for the Department of Energy (DOE) for a program entitled "Newman Unit 1 Advanced Solar Repowering Program." The period of performance was September 30, 1981 to May 10, 1982. The programmatic data pertaining to this contract are:

Contract Number - DE-AC03-81SF11566
Contract Cost - $275,631
Prime Contractor - El Paso Electric Company
P.O. Box 982, El Paso, TX, 79960
Principal Investigator - James E. Brown (915-543-5616)

The solar thermal technology selected was a water/steam central receiver concept supplying superheated steam to Newman Station Unit 1. The conceptual design developed during this program for solar repowering Newman Unit 1 is technically feasible for a 1986 demonstration of the concept. This concept uses conventional water/steam technology which is reliable, mature, and familiar to the electric utility industry, in general, and to plant operators of existing water/steam electric generating units specifically. EPE is convinced that demonstrating the feasibility of using technologies familiar to utility operators is a prerequisite to utility acceptance of solar repowering as a viable commercial energy option.

2.1 STUDY OBJECTIVE

The principal objective of this study was to develop a refined Baseline Conceptual Design for solar repowering Newman Unit 1 that has the potential for construction and operation by 1986, makes use of existing solar thermal technology, and provides the best economics for this application. Specific objectives were: (1) to review recent accomplishments in the Department of Energy (DOE) Technology Development Program, including, as appropriate, component/subsystems data and operational experience at Central Receiver Test Facility (CRTF) and the Barstow Pilot Plant; (2) select appropriate developments for incorporation into the conceptual design; (3) prepare a refined conceptual design; (4) establish the performance of the refined design; (5) update cost estimates; and (6) reaffirm the economic attractiveness of solar repowering Newman Unit 1.

2.2 TECHNICAL APPROACH AND UNIT SELECTION

Section 2.2.1 describes the technical approach for the project, including a description of each task. The rationale for selecting Newman Unit 1 is discussed in Section 2.2.2

2.2.1 Technical Approach

The Newman Unit 1 Advanced Solar Repowering Program was divided into two major tasks and six subtasks:

Task 1100 - Refined Baseline Conceptual Design

Subtask 1110 Technology Assessment
Subtask 1120 Functional Requirements
Subtask 1130 Receiver and Heliostat Field Arrangement
Subtask 1140 Operating Modes
Subtask 1150 Performance Estimates
Subtask 1160 Economic Analysis

Task 1200 - Program Management

The EPE Team approach to accomplish the program was based upon two concepts: (1) using high caliber technical personnel with directly applicable experience in solar applications, and (2) implementing effective schedule and cost control measures on a monthly basis.

The foundation of the program was a technology readiness assessment to select those recent improvements in components and subsystems that have matured in development in time to be incorporated into a demonstration unit scheduled for initial operation in 1986.

2.2.2 Selection of Newman Unit for Solar Repowering

The EPE system has a total generating capacity of 974 MWe and has sufficient land available neighboring its local Copper, Rio Grande, and Newman Stations to solar repower all 11 of its existing gas- and oil-fired units, which represent 863 MWe or 89 percent of the total system. EPE selected Newman Unit 1 for the program from its other available candidates for the following reasons:

Widespread market potential for solar repowering reheat steam turbines similar to Newman Unit 1 - A Public Service of New Mexico market survey identified a total regional repowering generation capacity of 5,190 MWe, based on available land and the ability to repower at least 50 percent of the unit's rated capacity. Sixty percent of identified capacity was for reheat steam turbines. Reheat units in general have more modern and efficient equipment than do non-reheat units, with a longer remaining useful life. Forty percent of all reheat steam turbine candidates, regardless of nameplate rating, have steam conditions identical to Newman Unit 1, and 60 percent of the reheat steam units, rated 100 MWe or less, have conditions similar to Newman Unit 1. These steam conditions are 10.1 MPA/538°C(1,465 psia/1,000°F).

Availability of unencumbered, flat land - More than 14.2 km² (3,500 acres) of public land are available adjacent to the Newman Station. The land is owned by the El Paso Water Utilities Public Service Board. The Board agreed in a public meeting held April 25, 1979 in El Paso to make the land available.

Economics of operating the solar repowered plant relative to the balance of the utility system - Of the 11 existing gas- and oil-fired units on the EPE system, the net heat rate for Newman Unit 1 is better than seven of the units and comparable to three. Newman Unit 1 commenced power operation in 1960 and has a longer remaining economic life than most of the candidate units. Considering system economics, solar repowering of Newman Unit 1 will require lower capital costs for the same output than most of the other units and can be economically dispatched as a fossil-only plant as well as a solar unit.

No apparent institutional or environmental constraints - Results of preliminary reviews by the El Paso Water Utilities Public Service Board and the City of El Paso Department of Planning, Research, and Development indicate that there are no institutional or regulatory constraints that would impede use of land adjacent to Newman Unit 1 for solar repowering. An environmental assessment was performed in 1974 for Newman Unit 4 and the surrounding land for transmission line use. A preliminary review of this assessment relative to solar repowering indicates no known environmental constraints. Present regulations of regulatory agencies are not considered to contain any major institutional obstacles.

Proven history showing it to be extremely durable - Through 21 years of reliable operation, Newman Unit 1 has demonstrated that it has an unusual ability to sustain abnormal or rugged operating conditions such as might be encountered during initial operation of a solar repowered unit. Current EPE studies indicate the desirability of relegating this unit to peaking operation in the next few years and modifications to the turbine are scheduled for 1983.

EPE currently owns approximately 146 acres occupied by the Newman Station. Solar repowering Newman Unit 1 would require acquisition of approximately 410 acres of land adjacent to the Newman Station at the north side of the site, of which 269 acres would be used for the collector field.

2.2.3 History of Conceptual Design Evolution

A Baseline Configuration for solar repowering Newman Unit 1 was presented in the proposal originally submitted to DOE. The Baseline Configuration utilized first generation water/steam central receiver technology to provide main steam to the high pressure stage, 10.1 MPa/538°C (1,465 psia/1,000°F), and reheat steam to the intermediate stage 2.93 MPa/538°C (425 psia/1,000°F) of the turbine-generator. Fossil energy was used to supplement solar generated steam for intermittent cloudy day operation, for economic dispatch, or when solar energy is not available. A solar repowering fraction of 75 percent at 2 p.m. winter solstice (based on an insolation level of 950 watts/m²) could be achieved with a 1.4 km² (350 acre) surround field north of the unit.

The performance and economic attractiveness of the Baseline Configuration were assessed against several Alternative Configurations during the initial program. The Alternative Configurations considered included: (1) a configuration incorporating thermal energy buffer storage subsystems (15 to 30 minute capacity) in the primary and reheat steam flow paths, (2) a configuration incorporating thermal energy buffer storage in only the primary steam flow path with an auxiliary boiler being used to supplement the solar generated reheat steam, and (3) a configuration using solar energy (with the option of buffer storage) to provide primary steam to the high pressure stage and using fossil energy, through incorporation of an auxiliary boiler, to provide reheat steam conditions.

The attributes of using improved water/steam receiver technology in place of first generation solar central receiver technology (Solar One in Barstow, California) were also assessed as part of these trade studies. The trade studies focused on the solar/non-solar interface complexity versus the econcmic advantage, in terms of cost/value ratios, to be gained from less complex systems. The output from these trade studies was the selection of a specific system configuration for the conceptual design and performing detailed economic evaluations during subsequent program tasks. Criteria were developed and reviewed with DOE to guide the selection of the system configuration.

A conceptual design was prepared for the preferred system configuration selected. The Preferred Conceptual Design emphasized the solar/non-solar interface and was prepared in sufficient detail to permit an assessment of technical feasibility, and to support cost estimates and the performance and economic evaluations. Potential limitations of the concept were identified and an impact assessment performed.

A detailed performance evaluation of the concept emphasizing operation of the solar, fossil, and combined solar/fossil modes of the unit was prepared and revised. Heat balances were prepared for the various normal operating modes. The transient response characteristics of the solar repowered unit to intermittent cloudy operation were also established.

A detailed economic evaluation of the solar repowered Newman Unit 1 operating on the EPE system was performed. The evaluation established the cost/value ratio, fossil fuel and associated O&M savings, net plant value, and busbar energy cost. The solar repowered option was assessed relative to other repowering options such as coal. Downtime cost to EPE to implement solar repowering unit modifications was also established.

A development plan for solar repowering Newman Unit 1 was prepared. Emphasis in the plan was placed on identifying the major steps to be accomplished during the construction phase, on formulating a realistic schedule for a demonstration plant, and on highlighting the construction critical path.

The technical approach taken by the EPE Team during this initial program provided a utility user-oriented evaluation of the technical feasibility and economic attractiveness of solar repowering reheat steam turbine units using advanced water/steam technologies. This approach provided EPE with the technical and economic data necessary to support a decision to pursue a cost-shared demonstration program.

This Preferred Conceptual Design is described in Appendix A.

The Advanced Conceptual Design described in this report builds on the initial program summarized above and incorporates the latest receiver, heliostat field and economic data available.

2.3 SITE LOCATION

Newman Station (Figure 2.3-1) is located in El Paso, Texas 1.6 km (1 mile) south of the Texas/New Mexico border on the east side of the Franklin Mountains. This station is sited in a rural area at the north end of the city of El Paso, 24 km (15 miles) northeast of the downtown area, and 19 km (12 miles) from the El Paso Solmet weather station at El Paso International Airport.

The site is accessible by road from all directions and a freeway is being completed with a major interchange 7 km (4 miles) south of the generating station. A railway siding is located 10 km (6 miles) to the southeast. Newman Station is not directly beneath a Federal airway, although some aircraft fly over and south of the site.

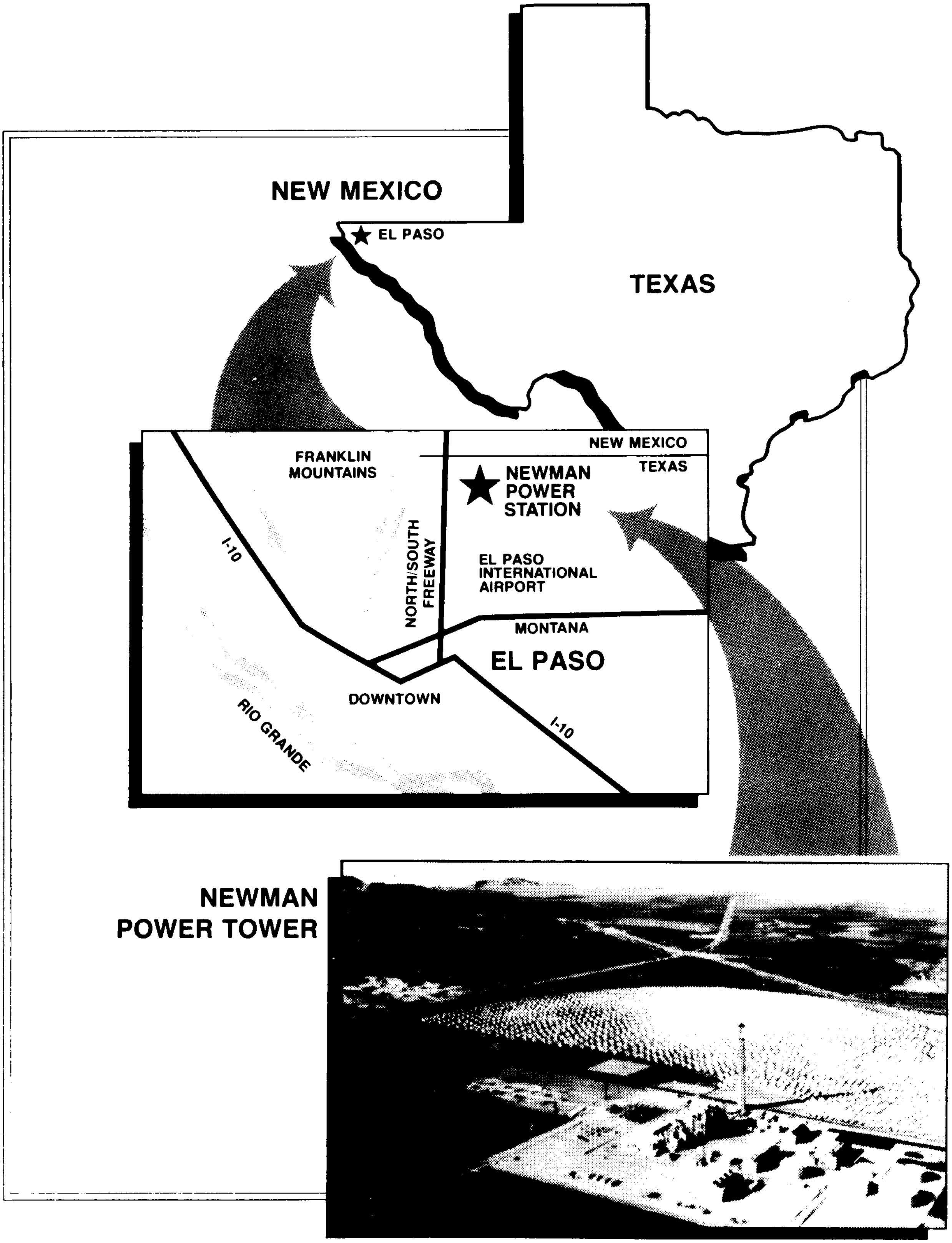


FIGURE 2.3-1
LOCATION OF NEWMAN STATION

2.4 SITE GEOGRAPHY

The Newman Site is in the Tularosa Basin bounded by fault block mountains to the east and west with 300 to 600 m (1,000 to 2,000 feet) of underlying sediments. El Paso does not experience any significant earthquake activity, and no earthquakes of intensity 4.5 or larger on the Richter Scale have been recorded within 160 km (100 miles) of the site. Newman Station was designed for a Zone II earthquake.

Important site features include the War Road (extension of North/South Freeway) one-half km west of the station, Farm Road 2529 adjacent to the existing station on the north side, McCombs Road to the east, and the large evaporation pond south of the station. Flood control is provided to some extent by the War Highway drainage system to the west of the proposed field. Other pertinent site characteristics are summarized in Table 2.4-1.

The air quality monitoring unit nearest the site is in downtown El Paso. Although El Paso air quality is in violation of ambient air quality standards for several pollutants, air quality at Newman Station is somewhat better due to its rural location. Solar repowering Newman Unit 1 will have a beneficial impact on air quality since it will replace fossil fuels and their pollutant emissions.

Surface water at the site is not a constraint since nearby wells are drawing water from several hundred feet down. Existing water supplied to Newman Station is purchased from El Paso Water Utilities and is within allowable drinking water standards.

There are no known mineral resources or unique geologic/land form features on or near the site. There have been no known significant archaeological findings on the site or in close proximity. No rare or endangered species of plant or animal substance have been found at the proposed site. Environmental considerations are therefore expected to be minimal.

TABLE 2.4-1

GEOGRAPHIC CHARACTERISTICS OF NEWMAN STATION

Existing Site

Land Area	0.6 km^2 (146 acres)
Latitude	31° 59'N
Longitude	106° 25'W
Elevation	4,069 feet (above mean sea level)
Owner	El Paso Electric Company

Collector Field Site

Location	North of Existing Site
Land Area	1.09 km^2 (269 acres)
Owner	El Paso Water Utilities Public Service Board

2.5 CLIMATOLOGY

The climate of the Newman site is well represented by the long-term meteorological data collected at the El Paso International Airport located approximately 19.3 km (12 miles) southeast of the site. This 30-year data base indicates that the climate of the region is characterized by mild winters and hot summers with very little annual rainfall, very low humidity, and an abundance of sunshine. Climatological averages of the El Paso data are summarized in Table 2.5-1; Table 2.5-2 presents climatological extremes.

2.5.1 Climatological Discussion

The El Paso region is in the zone of highest solar insolation in the nation, facilitating year-round research, development, and demonstration of solar energy applications. The annual variation of solar insolation in the El Paso region is also the lowest in the nation. Annual mean weather data show an average sunshine of 3,583 hours (83 percent of possible sunshine) and direct normal insolation for the typical meteorological year of 7.26 kW-hr/m^2-day (Solmet tape).

El Paso winters are generally mild and dry with daytime temperatures reaching 12.7° to 15.5°C (55° to 60°F) on the average and falling below freezing at night about half the time. The record low temperature is -22.2°C (-8°F), but sub-zero readings are rare. Snowfall occurs commonly during winter, with an annual average amount of 11.7 cm (4.6 inches). However, snow does not normally remain on the ground for more than a day. Total precipitation is usually less than 1.3 cm (0.5 inch) for each of the winter months.

Summer daytime temperatures are high, frequently above 32.2°C (90°F) and occasionally above 37.7°C (100°F). However, nighttime temperatures usually fall into the sixties. The summer months are the wettest of the year with nearly half of the annual precipitation total falling during this period. Thunderstorms provide much of the summer rainfall, occurring 36 days per year on the average, but tornadoes are an extremely rare occurrence with only one funnel ever sighted in the area.

The prevailing wind direction at El Paso is from the north, although there is considerable variation from season to season. The dominant wind direction during autumn and winter is north, but shifts to west-southwest in the spring and south during the summer. The annual average wind speed is 4.2 m/s (9.5 mph) with higher monthly average wind speeds normally occurring in the spring. Figure 2.5-1 illustrates the average wind distribution and velocity with respect to wind direction for the El Paso area.

While wind speeds are not excessively high, occasional strong winds during the spring season combined with the dry and loose soil conditions result in blowing dust and sandstorms. The highest monthly average frequency of occurrence of dust storms with visibility reduced to less than 10 km (6 miles) is nearly 40 hours during the month of March. Dust storms are comparatively rare during the period between July and December.

The El Paso climate is very dry with daytime relative humidities annually averaging about 30 percent and 50 percent during the night and early morning hours. During the spring and summer months, with the temperature above 32.2°C (90°F), relative humidities of 10 to 20 percent are most common. This low humidity lends itself to an extremely high percentage of possible sunshine with an annual average value of 83 percent. In addition, there is little variation of this percentage throughout the year, maximizing at 89 percent in May and June and reaching a low of 78 percent during December and January.

2.5.2 On Site Meteorological Data

A complete weather station has been established at Newman Station since the Fall of 1980. This weather station contains two pyranometers, one pyrheliometer, a rain gauge, a temperature and humidity gauge, and an anemometer. Weather data is taken at 1-minute intervals. It is averaged and recorded at 10-minute intervals along with certain peak data within each 10-minute interval.

TABLE 2.5-1

CLIMATOLOGICAL 40 YEAR AVERAGES FOR EL PASO*

Month	Temperature °C (°F)	Precip. cm (in.)	Snowfall** cm (in.)	Wind Speed m/sec (mph)	Wind Direction	Relative Humidity (%)	Percent of Possible Sunshine
January	6.4 (43.6)	0.99 (0.39)	3.56 (1.4)	4.0 (9.0)	N	8	78
February	9.1 (48.4)	1.07 (0.42)	1.78 (0.7)	4.4 (9.8)	N	40	82
March	12.6 (54.6)	0.99 (0.39)	1.02 (0.4)	5.3 (11.8)	WSW	31	85
April	17.7 (63.9)	0.61 (0.24)	T	5.3 (11.8)	WSW	25	87
May	22.3 (72.2)	0.81 (0.32)	0.0	4.9 (11.0)	WSW	26	89
June	26.8 (80.3)	1.52 (0.60)	0.0	4.5 (10.0)	S	29	89
July	27.9 (82.3)	3.38 (1.33)	0.0	4.0 (8.9)	SSE	44	79
August	26.9 (80.5)	2.84 (1.12)	0.0	3.8 (8.4)	S	45	80
September	23.4 (74.2)	2.95 (1.16)	0.0	3.7 (8.2)	S	50	82
October	17.8 (64.0)	1.98 (0.78)	T	3.6 (8.0)	N	44	84
November	10.9 (51.6)	0.81 (0.32)	2.79 (1.1)	3.8 (8.4)	N	46	83
December	6.9 (44.4)	1.27 (0.50)	2.54 (1.0)	3.8 (8.5)	N	49	78
Annual	17.4 (63.4)	19.74 (7.77)	11.68 (4.6)	4.2 (9.5)	N	40	83

NOTES:

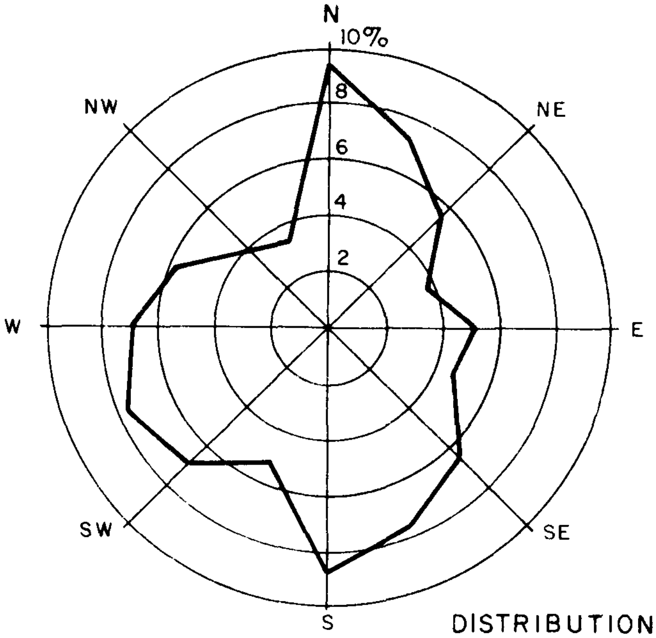
* Based on Local Climatological Data for El Paso International Airport, 1976, Summary National Climate Center, Ashville, N.C. PLease note that these data are customarily reported in English units by the National Climatic Center.

** T refers to trace

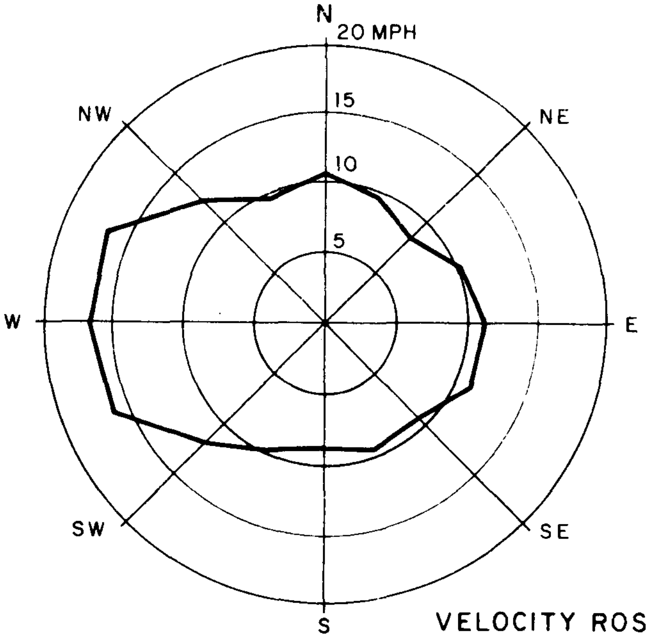
TABLE 2.5-2

CLIMATOLOGICAL EXTREMES

Weather Parameter	Extreme	Date
Lowest temperature	-22.2°C (-8°F)	January 1962
Highest temperature	44.4°C (112°F)	July 1979
Precipitation		
maximum monthly	20.8 cm (8.18 inches)	July 1881
maximum 24-hr	16.5 cm (6.50 inches)	July 1881
Snowfall		
maximum monthly	32.2 cm (12.70 inches)	November 1976
maximum 24-hr	21.3 cm (8.40 inches)	November 1906
Highest wind speed	112.6 km/s (70 mph)	May 1950
Highest sustained gust	135 km/s (84 mph)	March 1977



DISTRIBUTION ROSE
(CALM 1.4%)



VELOCITY ROSE

FIGURE 2.5-1
EL PASO WIND ROSES

2.6 EXISTING UNIT DESCRIPTION

A description of the most important characteristics of existing Newman Unit 1 design is provided in Appendix E.1.

2.7 EXISTING UNIT PERFORMANCE SUMMARY

Operating characteristics and performance of existing Newman Unit 1 are presented in Appendix E.2.

2.8 PROJECT ORGANIZATION

The project organization for the current study consisted of El Paso Electric Company (as the prime contractor to DOE), directly supported by Stone & Webster Engineering Corporation (SWEC); Westinghouse Electric Corporation (WEC); the Texas Energy and Natural Resources Advisory Council; the Regional Development Division, Office of the Governor of Texas; the Public Utilities Commission of Texas; and the Southwestern Solar Repowering Utility Advisory Council in performing the program. Babcock & Wilcox Company (B&W) supported EPE as a subcontractor to SWEC.

The EPE Program Manager, Mr. J. E. Brown, continued to be responsible for the technical and programmatic direction of the program in all aspects and provided utility inputs including preparation of functional design requirements and system specifications, operational and maintenance considerations, unit data, land acquisition and permits, and the overall program technical, cost, and schedular control. Mr. Brown had single-point management responsibility for the project.

Stone & Webster Engineering Corporation provided architect/engineer services which included the refined conceptual design of the solar repowered Newman Unit 1, cost estimating in support of the economic analysis, preparation of preliminary specifications for solar equipment, and construction planning for the demonstration program. Stone & Webster was the architect/engineer for Newman Unit 1 and is familiar with the design of the unit and site-related working conditions. In addition, Stone & Webster had subcontract support from Babcock & Wilcox Company for the purpose of refining the receiver conceptual design. Mr. R. W. Kuhr continued to be the Stone & Webster Project Manager.

Westinghouse Electric Corporation's Advanced Energy Systems Division was responsible for solar subsystem design including heliostat field layout, performance modeling, receiver flux interface, safety analysis, and economic and network impacts and assessments. Mr. W. G. Parker continued to be the Westinghouse Project Manager.

The Texas Energy and Natural Resouces Advisory Council and the Regional Development Division of the Office of the Governor of Texas continued to provide the capabilities required to identify and resolve the institutional barriers and public issues associated with solar repowering. They reviewed the project and helped to determine the most effective avenues of state support for the project. The Public Utilities Commission of Texas provided the capability to identify any conflicts with existing regulatory policies.

EPE continued its highly successful Southwestern Solar Repowering Utility Advisory Council (UAC) to provide an assessment of the program results from a broad utility perspective and to provide for early dissemination of results to other utilities. UAC members bring a wide range of expertise and experience in technical and utility-related areas and help to interpret the needs of the utility community. Most participants of the previous UAC gave positive indication of a desire to continue active membership in the UAC.

In addition, EPE solicited new members not previously active to further broaden the base and interests represented by the UAC.

Of special interest is the response of Mexico to the UAC. The Instituto de Investigaciones en Materiales UNAM (The National University of Mexico) participated in the program. The Comision Federal de Electricidad (National Utility) and the Instituto de Investigaciones Electricas [equivalent of Electric Power Research Institute (EPRI)] continued to participate.

It is hoped that the Mexican members will bring an international viewpoint and pave the way to further cooperation.

Table 2.8-1 identifies the utilities that plan to participate in the program.

TABLE 2.8-1

1982 SOUTHWEST SOLAR REPOWERING UTILITY ADVISORY COUNCIL

Investor Owned Systems

- Pacific Power & Light Co.
- New Mexico Electric Service Co.
- Public Service Company of New Mexico
- Central Telephone & Utilities Corp.
- Utah Power & Light Co.
- Georgia Power Co.
- Dallas Power & Light Co.
- Texas Electric Service Co.
- Texas Power & Light Co.
- San Diego Gas & Electric Co.
- Southern California Edison Co.
- Oklahoma Gas & Electric Co.
- Tampa Electric Co.
- Puget Sound Power & Light Co.
- Gulf States Utilities Co.
- Nevada Power Co.
- Florida Power Corp.
- Florida Power & Light Corp.
- Southwestern Public Service
- Public Service Co. of Colorado

Municipal Systems

- Garland Electric Dept.
- Lubbock Power & Light Dept.

Federal and District Systems

- Salt River Project Agricultural Improvement & Power Dist.
- Comision Federal De Electricidad
- Imperial Irrigation District

Rural Electric Cooperatives

- Arizona Electric Power Coop.
- Colorado Ute Electric Assn. Inc.
- Brazos Electric Power Coop. Inc.
- Western Farmers Electric Coop.

1 of 1

2.9 FINAL REPORT ORGANIZATION

This report is organized to provide a synopsis of study findings in the Executive Summary, followed by sections providing detailed study results.

Section 2, Introduction, describes the overall study objective, approach, and organization. Also, detailed background information regarding existing Newman Unit 1 is provided in Appendix E.

Section 3, Selection of Preferred System, briefly refers the reader to Appendix A. This information is appendicized because it was completed during the initial conceptual design effort and many of the economic assumptions and costs have changed since that work was completed. This appendix documents the methodology and trade iterations used by the EPE team to modify its original Baseline Configuration for solar repowering Newman Unit 1.

The conceptual design is detailed in Section 4 on an overall system level. Considerations with respect to performance, operation and maintenance, safety, environment, institutional, and regulatory impacts are discussed and analyzed. Section 5 involves a closer look at the conceptual design on a subsystem level with emphasis on the collector, receiver, fossil boiler, electric power generating, and control subsystems. The support facilities needed for a demonstration of the solar repowering concept at Newman Station and the necessary site preparation activities are also described.

Section 6 reviews the economic analyses performed and describes the assumptions and methodology used to generate the results. The development plan for subsequent final design, construction, startup, and operations phases is contained in Section 7.

The completed Systems Requirements Specification (SRS) is presented as Appendix B. This document is intended to provide a summary-level design basis for the project.

Drawings and diagrams describing solar repowered Newman Unit 1 are presented in Appendix D.

SECTION 3

SELECTION OF PREFERRED SYSTEM

The Preferred Configuration developed during the Conceptual Design Study for solar repowering Newman Unit 1 was selected on the basis of trade studies performed as part of DOE Contract DE-AC03-79SF10740. These system and subsystem trade studies are included for completeness as Appendix A of this report. Trade studies performed as part of the Advanced Conceptual Design effort are described in Sections 4 and 5.

SECTION 4

SYSTEM CONCEPTUAL DESIGN

This section provides a description of system-level functional requirements, design, operation, performance, cost, safety, environmental, institutional, and regulatory considerations.

Unique aspects of the solar repowered Newman Unit 1 design include the use of an advanced water/steam receiver technology founded on conventional drum-type boiler technology, location of the receivers and tower in close proximity to the existing turbine building, use of primarily conventional control philosophy, and the demonstration of a reheat application.

4.1 SYSTEM DESCRIPTION

Newman Station consists of four electric power generating units rated at a combined total of 490 MWe. Newman Unit 1, the unit selected for solar repowering, is an 82 MWe (net) tandem-compound, double-flow, reheat steam turbine built in 1960 for baseload duty using natural gas as the primary fuel (oil as the alternate fuel source).

The configuration for solar repowering Newman Unit 1 is illustrated in Figure 4.1-1. Conceptual design drawings are presented in Appendix D. The concept utilizes water/steam central receiver technology to provide main steam to the high pressure stage, 10.1 MPa/538°C (1,465 psia/1,000°F), and reheat steam to the intermediate stage, 2.9 MPa/538°C (425 psia/1,000°F), of the turbine-generator. Fossil energy is used to supplement solar generated steam for intermittent cloudy day operation and for economic dispatch.

The principal solar/fossil interface between the existing Newman Unit 1 and the solar subsystem consists of (1) steam supply interface from the solar (both primary and reheat receivers) and the fossil steam generator, (2) feedwater supply interface to the solar and fossil steam generators, (3) control interface between the fossil and solar subsystems, and (4) power supply interface to the heliostat field, primary and reheat receivers, valves, and pumps.

The feedwater supplied to each steam generator matches the steam flow and pressure requirements of each unit by means of a coordinated control system. The control system of the existing unit is modified and interfaced with the solar system by means of a master control system.

Figure 4.1-3 shows the site arrangement. The heliostat field is located north of the unit. The receiver tower is as close as possible to the turbine building to minimize feedwater and steam piping distances. Existing transmission and natural gas pipeline rights-of-way transect this field location but do not present a constraint to locating the heliostat field in this region other than providing access for inspection.

The collector subsystem, a 160-degree array of heliostats, consists of:

> Heliostats, including reflective surface, structural support, drive units, control sensors, pedestals, foundations, cabling, and cable array installations, and
>
> Electromechanical and electrical controllers, including individual heliostat and heliostat field controllers, control system interface electronics, and power supplies.

A simplified flow schematic is shown in Figure 4.1-2. Steam generated by the solar subsystem is mixed with the steam provided by the existing fossil steam generator prior to admission to the high pressure and intermediate stages of the turbine. Attemperation of the solar and fossil generated steam ensures that temperatures are maintained within turbine design limits. Fossil steam generation replaces steam flow reductions due to intermittent cloud cover and for economic dispatch, or when solar energy is nonavailable.

The receiver subsystem provides a means of transferring the incident radiant flux energy from the collector subsystem into superheated steam. The receiver subsystem consists of primary and reheat receivers to intercept the radiant flux reflected from the collector subsystem and a single tower structure to support the two receivers. The receivers are of the external panel type configuration with forced recirculation boilers and are located at the top of the tower. The external central receiver concepts (primary and reheat) are based on the improved water/steam pumped recirculation central receiver boiler technology being developed by DOE. The conventional non-solar equivalent of this technology is well known throughout the utility industry. The receiver subsystem also includes the pump, valves, and control system within the tower structure necessary to regulate flow, temperature, and pressure; and the required control system components necessary for safe and efficient operation, startup, shutdown and standby.

The master control subsystem is used to sense, detect, monitor, and control all system and subsystem parameters necessary to ensure safe and proper operation of the entire integrated repowered plant. The control subsystem consists of computers, peripheral equipment, time code generator, control and display consoles, electric power control interfaces, and software.

The fossil boiler subsystem provides a fossil energy source that is used to enhance performance and/or maintain normal plant operation during periods of reduced or no insolation. The fossil boiler subsystem consists of the existing Newman Unit 1 fuel storage, fuel handling, boiler, and related equipment. It also consists of any additional fuel supply, fuel storage and transfer facilities, energy conversion source, pumps, valves, and control system necessary to regulate fluid flow, temperature and pressure; and the required control necessary for safe and efficient operation, startup, shutdown and standby of the fossil boiler subsystem. Essentially all of the existing Newman Unit 1 remains after being repowered with a solar steam supply system.

The electrical power generating subsystem (EPGS) provides the means for converting to electrical power the thermal output from the solar receivers and the fossil boiler subsystem. The output from the EPGS is regulated for integration into the EPE system network. The EPGS consists of the existing balance-of-plant equipment at Newman Unit 1, and the piping and related equipment required to interface the solar steam supply system.

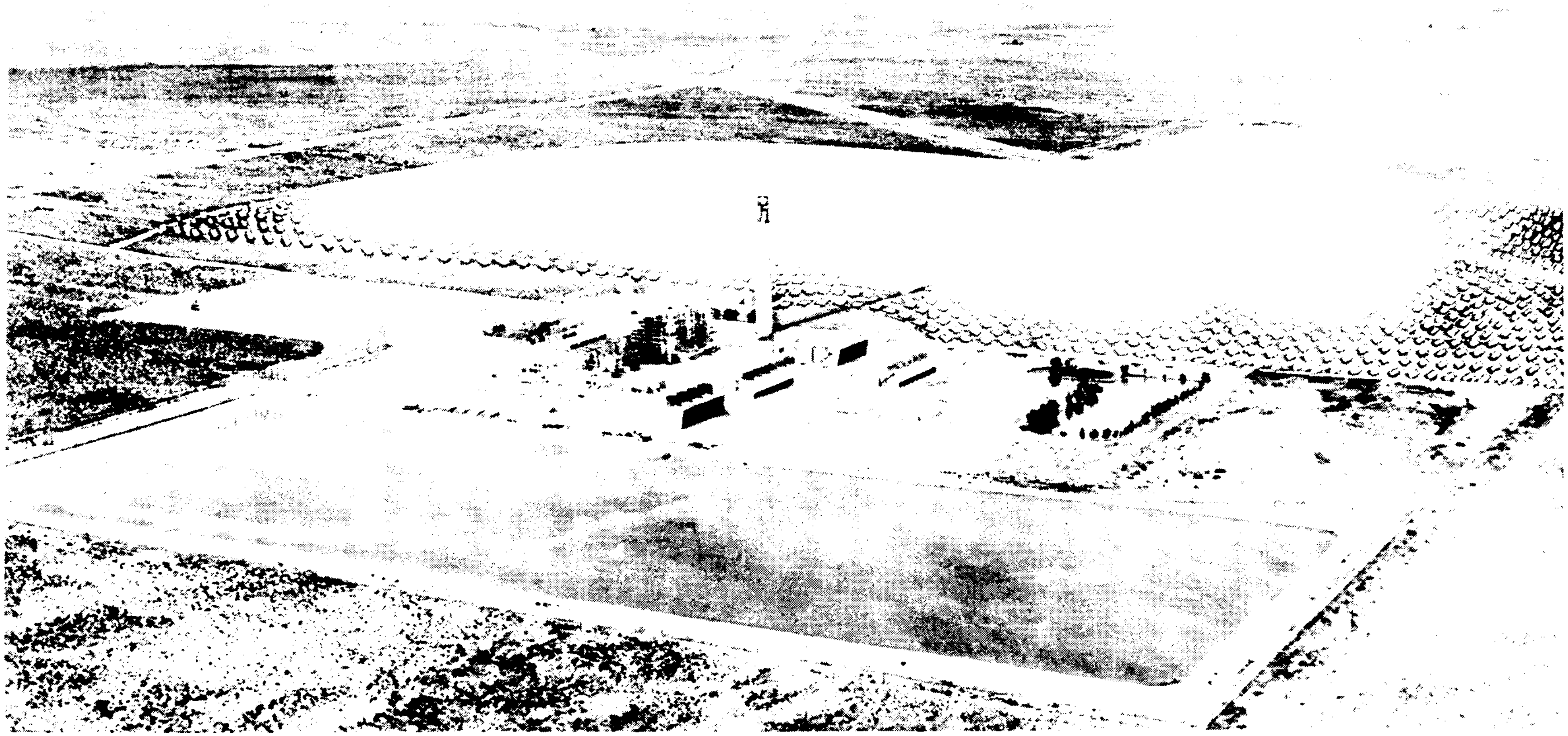


FIGURE 4.1-1
SOLAR REPOWERED NEWMAN UNIT 1

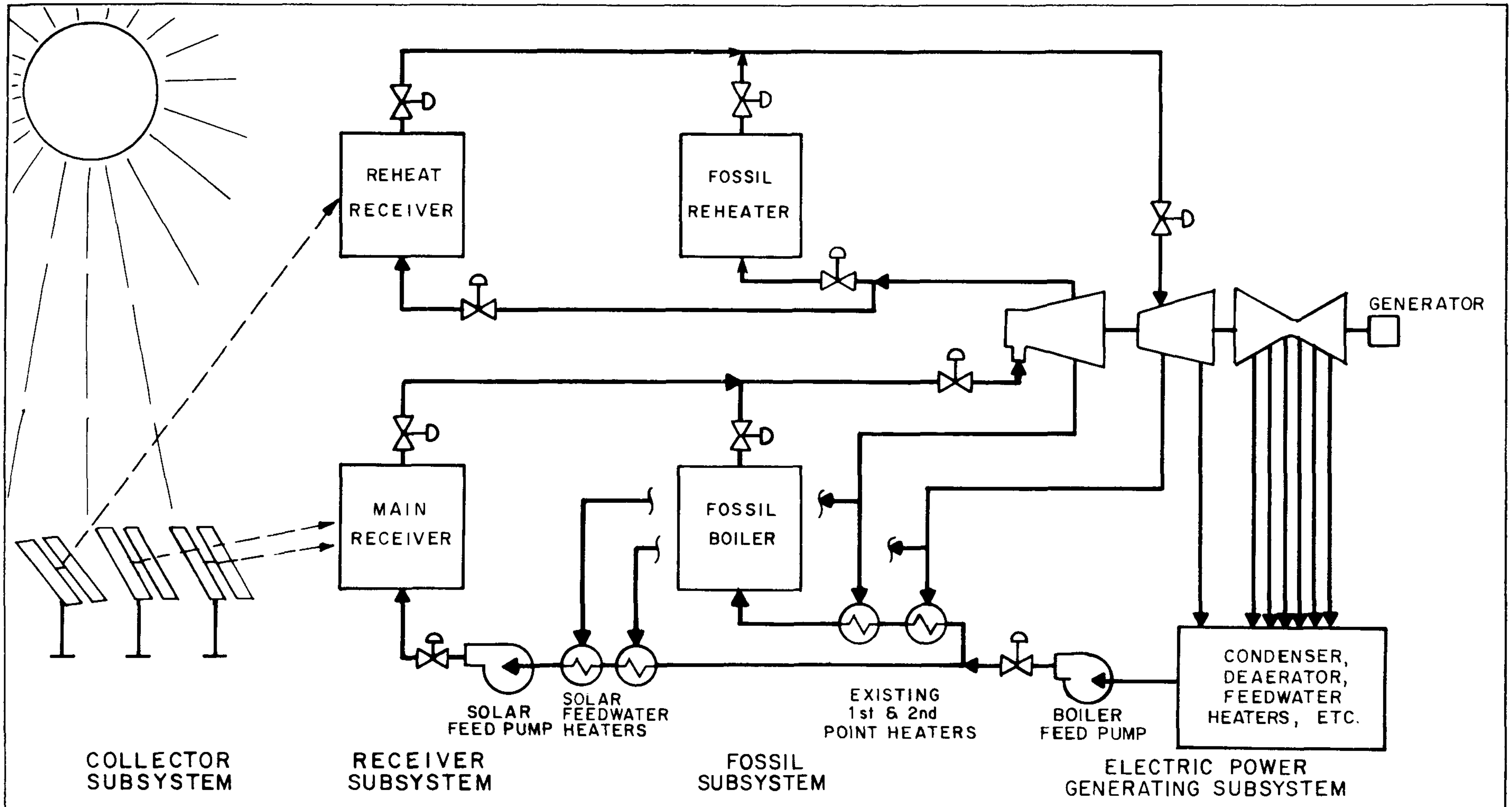


FIGURE 4.1-2
SIMPLIFIED FLOW SCHEMATIC

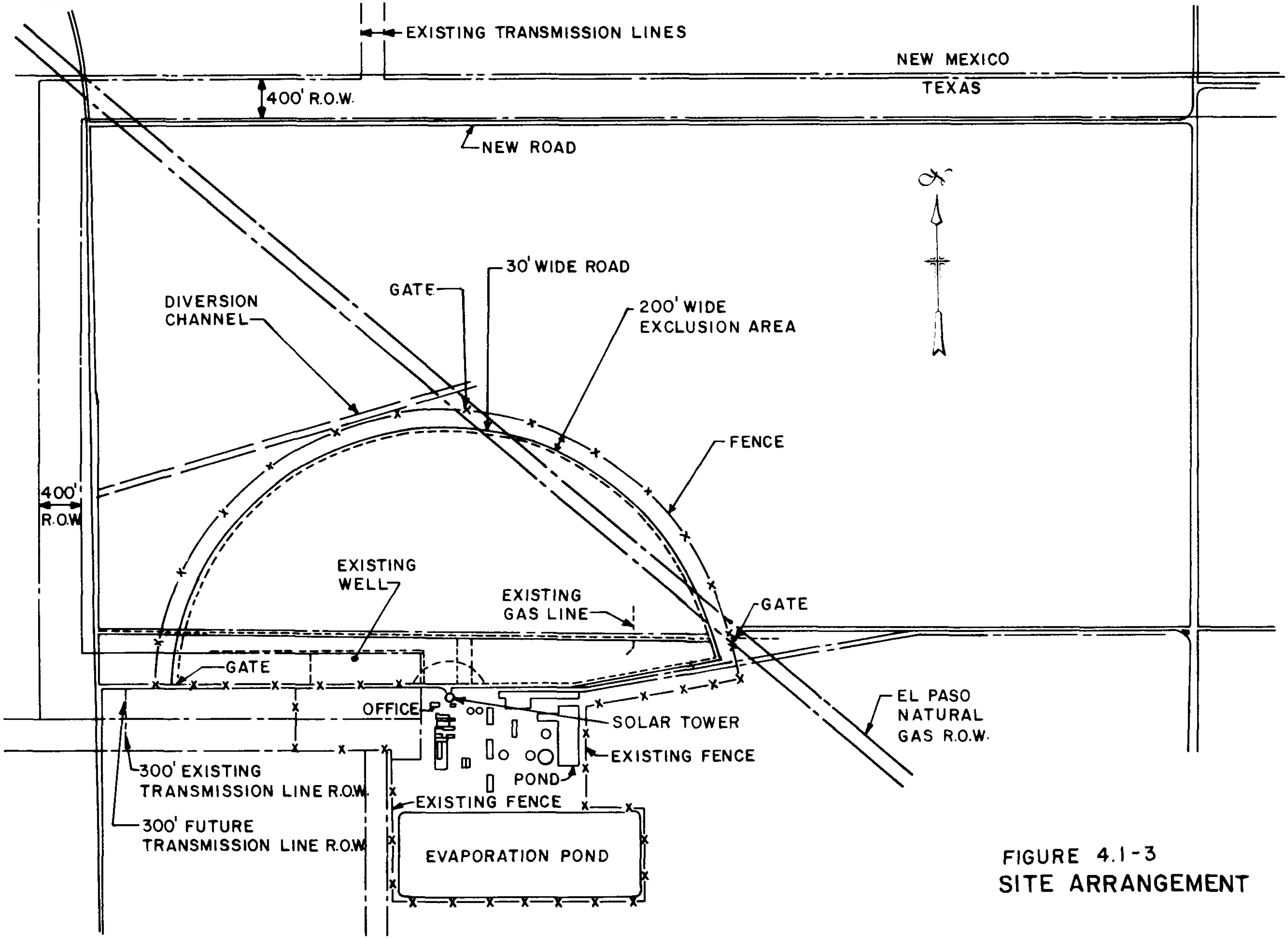


FIGURE 4.1-3
SITE ARRANGEMENT

4.2 FUNCTIONAL REQUIREMENTS

To provide a significant and meaningful demonstration of solar repowering of an existing electric power generating unit, certain system level functional requirements must be established and met. Two general classes of requirements need to be fulfilled. The first class pertains to those requirements that will ensure operation of the existing unit. The second class of requirements provides the bases for assuring a meaningful demonstration from the standpoint of size, performance, flexibility, and economics.

Generic system level requirements envisioned for a solar repowering of Newman Unit 1 include the following:

Unit capable of operating on fossil fuel only, fossil fuel/solar energy, and solar energy only.

Water/steam shall be the working fluid.

System must be compatible with utility demand characteristics to greatest extent possible.

System must be capable of operation under normal daily variations encompassing morning startup, normal hourly insolation variations, cloud cover transients, and evening shutdown.

System must be compatible with the environment.

System must meet lifetime and availability requirements consistent with normal utility practices.

System must demonstrate ultimate economic viability.

System must be compatible with all applicable codes and regulations.

The solar repowered unit shall be designed to produce 50 percent (41 MWe) of the rated net electrical output, 82 MWe, at the design point solar conditions corresponding to noon winter solstice. The design lifetime shall be 30 years. The repowering system shall include both a primary and reheat receiver mounted on a single tower to collect the solar energy and directly produce steam to supply the high pressure and intermediate pressure turbines at rated conditions. The collector subsystem shall include an array of heliostats arranged in a north field orientation designed to meet heat flux and focusing requirements. The collector subsystem shall include an automated control system designed to respond to commands from a master control system for normal operational variations and emergency/environmentally induced variations. Table 4.2-1 summarizes the key system and solar subsystem performance requirements that need to be met to maintain plant performance requirements. These requirements are consistent with the utilization of the generic second generation heliostat concept and the forced recirculation external receiver concept.

The solar repowered unit shall be designed to operate in parallel with the existing gas/oil fired boilers and to meet the total daily electrical demand requirements in a stand-alone solar powered mode. The solar system shall be designed to operate during various modes including startup, solar operation, combined solar/fossil fuel operation, and shutdown. Incorporated in the design are instrumentation and control systems to assure that allowable ramp rates on the boiler, receiver, and steam turbines are not exceeded. Methods of control shall include attemperation, flow redistribution through the receiver, and defocusing of the heliostats. Sufficient instrumentation shall be provided to monitor flow, pressure, and temperatures throughout the system and to monitor the focusing of heliostats. The requirements for instrumentation shall encompass not only sensing for control purposes but also provide diagnostic information for measuring performance.

A master control subsystem shall be developed to monitor sensors and to provide proper control of all central mechanisms to meet all subsystem response criteria. This subsystem shall:

Provide automated control of solar subsystems with operator override capability.

Provide automated control of present fossil boiler and EPGS subsystems with operator override capability.

Maintain present unit control systems as backup and to override automated systems.

Maintain design simplicity utilizing standard control practices and simple well defined interfaces between new and existing control systems.

Provide for design and operational reliability through redundancy in critical areas, separation of controls from data acquisition, and maintaining manual override systems.

Provide cost effective design through selection of off-the-shelf equipment, modularity, and selection of generically similar equipment.

Successful unit operation for the 30-year lifetime requires that the various subsystems be designed to be compatible with the local environment. The solar subsystems shall be designed to meet specific sets of environmental criteria for operation and/or survival. These criteria shall encompass appropriate combinations of ambient temperature ranges, wind profiles, earthquake levels, dust and sandstorm environments, snow, rain, and ice.

TABLE 4.2-1

SYSTEM PERFORMANCE REQUIREMENTS

Unit Rating	82 MWe
Solar Repowering Percentage*	50 percent
Design Point	Noon winter solstice
Electric Power Generation	
Cycle	Steam
Net unit efficiency (solar/fossil)	34.3/33.1
High pressure turbine inlet	10.1 MPa/538°C (1465 psia/1000°F)
Intermediate turbine inlet	2.93 MPa/538°C (425 psia/1000°F)
Main steam flow	257,143 kg/hr (567,000 lb/hr)
Collector Subsystem (Design Point Conditions)	
Power incident on primary receiver	
Noon Summer	96 MWt
Noon Winter	103 MWt
Power incident on reheat receiver	
Noon Summer	24 MWt
Noon Winter	26 MWt
Receiver Subsystem**	
Power absorbed in primary receiver (Noon Summer)	91.3 MWt
Primary steam outlet flow	129,000 kg/hr (284,000 lb/hr)
Primary receiver outlet pressure/ temperature	11.7 MPa/549°C (1697 psia/1020°F)
Allowable primary receiver pressure drop	1.93 MPa (280 psia)

1 of 2

TABLE 4.2-1 (Cont)

Design heat flux (water/steam tubes) in primary receiver (noon winter)	0.66/0.3 MW/m²
Power absorbed in reheat receiver	17.5 MWt
Reheat steam outlet flow	115,400 kg/hr (254,000 lb/hr)
Reheat receiver outlet pressure/ temperature	2.97 MPa/549°C (1431 psia/1020°F)
Allowable reheat pressure drop	193 kPa
Fossil Energy Subsystem	
Efficiency	84.4%
Automatic operation	28% minimum load
Cold condition startup energy	10.6x10⁷kJ (100 MBtu)
Warm standby startup energy	1.6x10⁷kJ (15 MBtu)

<u>NOTES</u>:

* Based on an insolation level of 1000 watts/m²

** Receiver subsystem to be designed to meet efficiency requirements for noon summer solstice and to meet design heat flux limits for the noon winter solstice.

2 of 2

4.3 DESIGN AND OPERATING CHARACTERISTICS

Newman Unit 1 represents an ideal repowering situation for a water/steam reheat configuration. Utilizing a 160° north heliostat field and single tower, with main and reheat receivers located adjacent to the existing turbine building, the preferred configuration offers a simple repowering design. Main steam, feedwater, and reheat piping runs from the turbine to the receivers are reduced to approximately 213 m (700 feet).

The solar primary and reheat receivers operate in parallel with the existing fossil boiler. Superheat and reheat steam temperatures in both systems are controlled primarily by attemperation. In the fossil boiler burner selection, excess air and cold reheat steam flow are also used to control steam temperature. For the solar reheat receiver, flux control is also utilized. Operation of the fossil boiler is necessary to protect the turbine from excessive temperature transients without tripping the unit whenever sudden loss of insolation is possible.

4.3.1 Plant Arrangement

The plant arrangement minimizes feedwater, main steam, and reheat piping to the solar receivers by locating the receiver tower adjacent to the turbine building. This reduces piping costs, pressure drop, and thermal losses associated with long piping runs, and the likelihood and extent of maintenance problems such as exfoliation in high temperature steam lines.

Figure 4.1-1 is an artist's rendition of Solar Repowered Newman Unit 1 superimposed on an aerial photograph of the plant. Figure 4.1-3 is a plot plan showing the approximate location of the tower and heliostat field relative to the existing unit.

An existing state highway, Farm-to-Market Road 2529, will be rerouted to the north of the collector field. Existing transmission lines currently located along a right-of-way north of the Newman Station switchyard will be rerouted to the west of the collector field.

An existing underground natural gas pipeline which transects the northern portion of the field will remain, with an exclusion area provided along its 36.6 m (120 foot) right-of-way. Right-of-way for pipelines currently along Farm-to-Market Road 2529 will be maintained.

4.3.2 Design Characteristics

Design characteristics of the solar repowered Newman Unit 1 are summarized in Table 1.4-1. Detailed design characteristics are discussed by subsystem in Section 5.

4.3.3 Operational Characteristics

The primary functions of solar repowered Newman Unit 1 are to supply reliable electric power and to maximize fossil fuel savings to the El Paso Electric Company and its customers. Figure 4.1-2 is a simplified flow schematic showing the solar repowered system flow paths to and from the existing unit.

The operation of the repowered system is automatic during most operational modes. The operational modes should not pose any operational problems to unit personnel that cannot be addressed within their experience and training.

The Newman Unit 1 control system and existing power plant equipment shall be modified to allow daily cycling of the unit and to utilize fossil and solar energy for generation of electrical power. The master control system shall control the solar steam supply system and the existing plant equipment in a safe and reliable condition under all modes of operation.

4.3.3.1 Operational Modes

The master control subsystem allows the operator to select one of three plant operating modes: a fossil mode, solar mode, or combined solar/fossil mode.

When the fossil mode has been selected, the solar repowering system is isolated from the existing fossil-fueled power plant. In this mode, the control system allows the unit to be placed in either boiler-following or turbine-following control modes.

During boiler-following control, the fossil boiler maintains required steam conditions and flow required by the turbine generator in response to a set load.

Turbine-following control allows the boiler to operate independently with the turbine generator maintaining required steam pressure at the turbine inlet, responding to whatever steam flow is made available.

With clear day insolation available, the operator may select a solar mode of operation. The fossil boiler is isolated from the balance of plant (BOP) equipment and the solar repowering system and the unit is placed in a turbine-following mode. The solar main receiver, solar reheat receiver, and the collector subsystem are automatically controlled to maximize thermal energy output from the solar steam supply system. The turbine inlet control valves are automatically positioned to maintain stable steam conditions to the turbine.

When meteorological conditions are unstable or when it is economical to operate the fossil portion of the unit, the master control system may control the plant in a solar/fossil mode. In the solar/fossil mode, the steam from the solar receivers and the fossil boiler are combined prior to being admitted to the turbine. The control system operates the solar steam supply system to maximize thermal output and uses the fossil boiler to supplement steam to meet the unit's load demand.

4.3.3.2 Plant Operating Control Philosophy

The master control subsystem shall operate the plant under all conditions including startup, shutdown, transient, steady state, and emergency operation.

The plant control system controls superheat and reheat steam temperatures and pressure from the solar receivers, and protects the turbine generator from excessive transients.

During operation of the solar receivers, feedwater flows through two new solar feedwater heaters in series to the solar feed pumps. A conventional three-element control system maintains stable receiver operation during normal and transient operation by controlling feedwater flow in response to changes in steam flow and drum level. Solar main steam flow leaving the superheater section of the main receiver combines with the fossil main steam system upstream of the high pressure turbine inlets. Part of the cold reheat steam flow exiting the high pressure section of the turbine is diverted to the reheat receiver. High temperature reheat steam flow from the solar reheater combines with the fossil boiler reheat steam upstream of the inlets to the intermediate stage of the turbine. Reheat temperature is controlled by attemperation and, if necessary, varying incident flux on the reheat receiver.

The turbine is modified to provide improvements in long-term cycling capability. The existing turbine controls are modified to allow turbine-following operation. Boiler controls are replaced as necessary with a state-of-the-art computer-based system to provide additional control flexibility response and a natural interface with the solar subsystem controls. The Newman Unit 1 control room is expanded to integrate the solar repowering controls with the existing equipment.

Splitting low temperature (LT) reheat flow between the reheat receiver and the reheat section of the fossil boiler provides additional advantages. Operating the fossil boiler at low loads generally results in some loss of reheat temperature, which can be compensated for somewhat by burner manipulation and increasing excess air. If the unit is ever converted to oil, it is expected that convective heat absorption in the reheat section will be further reduced due to increased radiant energy produced by an oil flame, resulting in a significant degradation in reheat temperature. Splitting LT reheat flow between fossil and solar reheaters provides the capability of increasing fossil boiler reheat temperature by reducing LT reheat steam flow to the fossil boiler. Since the solar reheater is oversized to supply reheat steam at low insolation levels, the excess solar reheat capability is available to accept higher reheat flow and to provide full reheat temperature at the higher insolation levels. Fossil reheat temperature is maintained in this way without increasing excess air and, therefore, the fossil boiler operates more efficiently at lower loads.

Operator decisions will be required regarding solar-only operation. Approximately 1 to 2 hours is required to bring the fossil boiler from warm standby to minimum automatic operation (28 percent load). Whenever there is a significant possibility of rapid loss of solar steam, operation of the fossil boiler will be required to protect the turbine from excessive temperature gradients and to avoid loss of steam pressure which will trip the turbine. Until operating experience is obtained with the unit, it will be necessary to operate the fossil boiler whenever the solar receivers are in operation.

4.4 SITE REQUIREMENTS

The solar repowering system requires approximately 1.09 km^2 (269 acres) of land adjacent to Newman Unit 1 for the solar collector field. The concrete tower for the solar receivers and the solar feed pump house is located as close as practical to the existing unit to minimize the cost of piping and electricals between the existing unit and the solar equipment. An air conditioned equipment room is located at a level just below the platform supporting the receiver superstructure.

Site preparation for the solar repowering system includes minor grading and surface preparation. Farm to Market Road and a transmission line that currently transect the site will be rerouted. A new paved access road to the Newman Station and a paved perimeter road around the heliostat field are provided to support vehicular traffic and provide for heliostat field maintenance and security, respectively.

Heliostats will be excluded from portions of the collector field where existing equipment and piping rights-of-way are required, and where relocated and future transmission line rights-of-way will be established.

Drainage ditches are required to channel rainwater from the solar collector field to minimize erosion of the graded surfaces and protect foundation integrity. The solar repowering site requirements include fences to protect against unauthorized entry to the site.

New site facilities require additions to the existing control room and maintenance building, and a new solar feedwater pump house.

The control room requires a second level to house the solar repowering electronic equipment. The extended control room areas are air conditioned to provide correct ambient temperature for the new computers and associated equipment. The second level provides new toilet facilities. An addition to the maintenance building is required to enable plant personnel to repair and test complete heliostat assemblies. Additional ventilation equipment is required to circulate fresh air through the maintenance area.

The solar feedwater pump house is required for the solar feed pumps and the solar repowering equipment switchgear.

The existing fire protection system must be extended to protect the new site facilities. Hydrants and hose stations are necessary around the solar feedwater pump house and maintenance area. Hose stations will be provided at the various levels inside the solar receivers tower.

Outdoor lighting is to be provided along the solar collector field perimeter road and at the base and upper levels of the tower. Aviation warning lights will also be provided.

4.5 SYSTEM PERFORMANCE

A simplified flow schematic of the solar repowered Newman Unit 1 is shown in Figure 4.1-2 with the primary solar receiver in parallel with the fossil boiler and the solar reheater receiver in parallel with the fossil reheater. In this concept the turbine-generator can produce electrical power with steam provided from either the solar or fossil boiler/reheater or from a combination of both. In the hybrid operational mode (steam supplied by both solar and fossil), the feedwater exiting the feedwater pumps is split, with part of the flow going to the fossil boiler and the remainder passing through two solar feedwater heaters to the suction of the solar feed pumps. The solar feed pumps boost the feedwater pressure to overcome pressure losses in the solar receiver and piping due to the height of the receiver. High pressure steam is generated and superheated in the primary solar receiver. This steam is combined with the steam generated in the fossil boiler/superheater and expanded through the high pressure turbine. The steam from the high pressure turbine is then split (in approximately the same fractions as on the high pressure cycle) between the solar and fossil reheaters. After the steam is reheated, it is combined and introduced into the intermediate pressure turbine. The existing turbine extraction cycle remains unchanged.

4.5.1 Normal Operating Analysis

The conceptual design of the solar repowered Newman Unit 1 is based on the following design and performance parameters.

- Solar collector field is sized and configured to produce a net electrical output power of 41 MW when operating in the combined solar/fossil mode (total net electrical output 82 MW at noon winter solstice).
- Solar insolation is 1,000 W/m².
- Heliostats are placed in a radial stagger arrangement so as to minimize the effects of blocking and shading.
- Solar energy is used both to generate and superheat primary steam and is used for reheat.
- Heliostat design is based on a typical second generation heliostat.
- Repowered unit is operated with steam produced from either the solar or fossil boiler, or from a combination of both.

- Heliostat field size is based on the use of the MIRVAL computer code, which has been developed by Sandia Livermore, along with two preprocessor codes.

Overall system performance has been estimated at the noon winter solstice design point and for annual average conditions.

During the previous study, the design point for the repowered unit was selected to achieve 50 percent repowering at noon summer solstice with an insolation level of 950 watts/m². This design point matched EPE's system peak demand for the unit utilizing a conservative estimate of the available insolation in the El Paso region. During this study, the design point was reassessed on the basis of EPE's anticipated demand for the unit, insolation data representative of the typical meteorological year (TMY), and preliminary data from insolation measurements currently being obtained at the Newman Weather Station. The design point has been revised to achieve 50 percent repowering at noon winter solstice with an insolation level of 1,000 watts/m². The reverse design point was primarily selected in order to minimize investment in capital equipment (noon winter versus noon summer) while at the same time meeting the unit demands of the EPE system. The insolation level of 1,000 watts/m² was selected based on TMY data. The preliminary short term data from Newman Weather Station, however, indicates that insolation levels in excess of 1,000 watts/m² frequently occur; thus, the design insolation level may be adjusted in future phases, if warranted, from "long term" weather data.

At the design point, 108.9 MW of thermal power is absorbed by the steam in the two solar receivers. The thermal power incident on the receiver surfaces is 129 MW which is based on the above thermal power absorbed by the steam and includes the losses that account for reradiation and convection from the receivers, and the loss due to the reflectivity of the receiver surface.

The efficiency chart showing the various losses from the direct insolation to net electrical output is shown in Figure 4.5-1 for the design point operating mode at noon winter solstice. The efficiency chart for annual average conditions is shown on Figure 4.5-2. This chart identifies the various components and their respective efficiencies which contribute to the overall design point efficiency.

The thermal power incident on the receivers at various times of the year for the conceptual solar field design (2,998 heliostats) is shown in Table 4.5-1 with the direct solar insolation at 1,000 W/m².

Receiver thermal efficiency was calculated to be 89 percent at the design point. Annual average receiver efficiency was estimated to be 75%. A more detailed description of receiver thermal efficiency is provided in Section 5.3.5.

The electric power generating subsystem (EPGS) efficiency is discussed in Section 5.5.3. Piping and blowdown losses are assumed to be 1 percent.

4.5.2 Solar Receiver/Fossil Boiler Transient Interaction

This section describes the solar transient analysis that was performed during the previous contract to evaluate the consequences of cloud shadow passage over the collector field. The results described herein were reviewed during this study to assure that the incorporated design modifications did not preclude satisfactory operation of the unit during intermittent cloudy days. The results from the previous study are included herein for completeness.

The basic objective of the model is to obtain the dynamic system response to various cloud cover transients. A second objective is to establish a reference system control scheme based upon the system dynamics. The dynamic model Newman Solar Repowering Model (NSRM) used to analyze the solar receiver subsystem and the existing unit is based upon the mass, energy, and momentum dynamic equations representing the repowered unit.

Most of the dynamics of the model addresses the behavior of the solar receiver subsystem. The desired output is system response characteristics and trends which are a function of the solar receiver steam transport subsystem, solar insolation transients, solar receiver subsystem controller characteristics, and solar receiver subsystem geometry.

The analysis was performed using the TAF analysis code. Using this digital simulation code, parameters, constants, and functions are easily modified. The model equations are written in FORTRAN language.

4.5.2.1 Assumptions for the Computer Simulation

<u>Design Cloud Shadow Velocity</u>

Since the transient response of the solar repowered unit is highly dependent on the rate of change of the solar insolation, representative cloud shadow velocities for annual average conditions and maximum allowable conditions have been determined. In Figure 4.5-1 the average wind velocity at ground level for the year 1978 is reported to be approximately 4 m/s (9 mph).

Based on the relationship for wind speed defined in Figure 4.5-2, the average wind speed is 8 m/s (17 mph) at a height of 609 m, which is the projected average cloud height. Also, the maximum wind operational limit for heliostat operation without degradation is defined to be 12 m/s (27 mph), which corresponds to 22 m/s (50 mph) at the 609 m (2,000 feet) elevation. For this analysis, therefore, an average cloud velocity of 8 m/s was used to observe the control system response and set up initial controller gains for the model. A maximum operational limit cloud velocity of 22 m/s was used to observe the control system response to rapid transients.

Cloud Characteristics

The design clouds are assumed to be sharp-edged and opaque and to have shadows that are circular in form. While real clouds obviously do not conform to these criteria, these assumptions are made in order to facilitate computer modeling and are conservative in that they lead to more severe insolation transients for a given wind speed than would occur with real clouds. Three different cloud shadow sizes are modeled: 1609 m (1 mile) in diameter, which results in a 100 percent loss of solar insolation incident on the collector field, one 549 m (1,800 feet) in diameter resulting in a 50 percent loss, and one 187 m (615 feet) in diameter resulting in a 10 percent loss.

Linear Relationship Between Receiver Absorbed Heat and Steam Flow

Heat energy absorbed by the receiver from solar insolation is used as the forcing function. Absorbed energy is normalized to percent of the full power design point for the receiver with a 100 percent equal to the full power steady state condition with 50 percent fossil steam flow and 50 percent solar steam flow, after losses supplying full design flow to the turbine. It is assumed that solar receiver steam drum inlet steam flow is directly proportional to the absorbed normalized power.

Relationship Between Primary Solar Receiver and Solar Reheat Receiver and the Absorbed Heat Energy

The efficiencies of the primary solar receiver and solar reheat receiver are different. As cloud cover attenuates the solar insolation and the absorbed energy going into the solar receiver decreases, the reheat receiver absorbed energy drops faster than the primary receiver absorbed energy. To maintain the proper energy ratio into the primary and reheat receivers as insolation decreases, it is, therefore, necessary to refocus some of the heliostats from the primary receiver to the reheat receiver. The distribution of heliostats aimed at the reheat and primary receivers is altered to maintain the energy ratio. This gives identical primary and reheat receiver forcing function shapes with no time lags between primary and reheat receiver insolation transients. Figure 4.5-3 shows the general cloud transient forcing functions shape.

Relationship for the Fossil Boiler Primary and Reheat Steam Flow and Steam Temperature

The fossil boiler primary steam flow is simulated by a first order lag which is a function of the pressure error at the high pressure turbine throttle valve inlet. The output steam flow is controlled by a proportional controller driven by the pressure error. Output steam flow demand is limited to a user determined maximum rate (initially 20 percent/min). The fossil boiler superheater and reheater are assumed to have perfect temperature control and outlet temperature is set to 538°C. The reheat steam flow demand is directly proportional to fossil boiler primary steam flow, and flow control developed from a flow error between demanded fractional flow and actual fossil reheat section flow.

Dynamic Model Working Fluid

The primary working fluid, superheated steam, is assumed to be a compressible gas of single phase. This assumption simplifies the computer model, and transients from the full power operating points are not affected by this assumption.

Total Power Output

The computer simulation model is based on total gross power generation under steady state conditions. It is assumed that the solar portion would be operated at the maximum possible output for the insolation conditions and the balance of the gross electrical generation would be produced using fossil boiler steam. Two different solar/fossil operating conditions are considered. The first operating point is 50 percent solar steam flow and 50 percent fossil boiler steam flow which results in a net power generation of 82 MWe. The second operating point considers 50 percent solar steam flow and 28 percent fossil boiler steam flow which results in a net power generation of 63 MWe. The 28 percent fossil boiler steam flow is the minimum stable operating point for the boiler without temperature degradation to the turbine. From an economic standpoint, this combination represents a preferred operating mode, therefore, it is considered in the transient analysis. For all cases, power output is assumed to be a linear function of the high pressure turbine steam flow and the intermediate turbine steam flow.

4.5.2.2 Computer Simulation Model

The transient analysis performed using TAF simulates an analog computer on a high-speed digital machine. The program solves a set of simultaneous differential and algebraic differential equations using numerical techniques. The problem is described using a state variable representation of linked first order linear differential equations. NSRM is composed of 16 control volumes with appropriate linking input and output variables. A block diagram of the model showing the independent and dependent variables is shown in Figure 4.5-4. As the figure indicates, most of the dynamics of the NSRM are located in the solar receiver subsystem. The primary solar receiver consists of two stages of superheaters with the outlet temperature controlled by attemperator spray. The solar boiler section inlet mass flowrate is a function of the solar energy absorbed by the primary solar receiver.

The primary fossil boiler outlet temperature is assumed constant at 538°C to simplify the model. The primary fossil boiler outlet mass flowrate is a function of the pressure error of demanded turbine inlet pressure and actual turbine inlet pressure. The rate of fossil boiler outlet mass flowrate demand increase (decrease) is limited by use of an input variable.

For the reheat section, high pressure turbine outlet flow is split between the fossil reheater and the solar reheater. In the solar reheater, the outlet pressure is controlled to maintain a preset total pressure drop between the high pressure turbine outlet and the intermediate turbine inlet. In the fossil boiler reheater, the mass flowrate demanded is a preset fraction of the total primary fossil boiler outlet mass flowrate. A proportional band controller is used to drive the fossil boiler reheater control valve based on the error between demanded reheat flow and actual fossil boiler reheat flow.

4.5.2.3 Cases

To observe the effect on the dynamic response of the repowered system to clouds traveling across the collector field, several transients were analyzed. Two operating points were considered: total turbine steam flow (71.4 kg/s) and 78 percent flow (55.7 kg/s). Table 4.5-2 presents a list of the cases examined in the analysis.

4.5.2.4 Conclusions

Figures 4.5-5 to 4.5-12 present the results of the analysis for the 50 percent solar power and 50 percent fossil power initial condition. Steam pressures, temperatures, and flows are plotted for the cases considered. There are two basic objectives which determine the control system settings. One is to maintain turbine steam flow constant in order to maintain electrical power output and to prevent turbine-generator degradation due to transients. Second, it is necessary to hold turbine inlet pressure within 5 percent to avoid a turbine pressure trip.

Several key observations can be made from the transient analyses. The results show in Figures 4.5-5 through 4.5-7 that, for the average 8.0 m/s (17 mph) cloud velocity, the control system is able to maintain electrical power output nearly constant. High pressure turbine inlet steam flow varies only ±10 percent for the 50 percent field cover transient. The turbine throttle valve inlet pressure also changes by less than ±10 percent for this severe solar transient. There is little change in system response for the 50 and 100 percent field cover transients.

The rate of change of outlet steam flow of the fossil boiler is not a limiting factor for the average cloud velocity. This can be seen by comparing the 10 and 20 percent output limited cases (Figures 4.5-6 and 4.5-11). With the 20 percent limit, the fossil boiler responds more rapidly; however, because of the system pressure response lag, with decreasing fossil flow and increasing solar receiver flow, there is still an overshoot in flow and pressure created at the inlet to the high pressure turbine throttle valve. A lower ramp limit will give less overshoot of fossil steam flow, but as solar steam flow increases, it will take longer to reduce the fossil boiler outlet flow. This will also generate a pressure transient. To reduce the transient time, it is better to have rapid fossil boiler response.

In general, the high pressure section (primary solar and fossil steam superheaters) for the high pressure turbine sees more severe transients due to cloud cover. In the reheater section, the transient response is less severe. This attenuation in part is due to the lower operating pressures of this system.

For this analysis, the solar receiver is assumed to have similar attemperator spray flows as the existing fossil boiler design, approximately 2.0 percent flow. The results indicate that the attemperator spray should be increased and more steam should be generated in the superheat sections of the solar receiver since the response of the model indicates that the attemperator spray quickly drops to zero for the 22 m/s cases, and steam temperature control is lost. With increased attemperator flow output, steam temperature transients can be reduced and the system will maintain pressure, flow, and power more easily.

At the 22 m/s maximum cloud cover velocity, the steam flow to the high pressure turbine is stable with fluctuations less than ±5 percent for the 10 percent cloud cover case (Figure 4.5-8). Likewise, power output remains very stable. With 50 percent cloud cover (Figure 4.5-9), steam flow variations as high as ±15 percent are observed which results in a power-out variation of similar magnitude. For 100 percent cloud cover (Figure 4.5-10), the variations in turbine steam flow and power reach levels of ±100 and ±20 percent, respectively. Although the transient rates for the 100 percent cloud cover are high, they are not excessive and can be reduced to acceptable levels by proper adjustments to the control system and additional control inputs.

Figures 4.5-13 through 4.5-15 present the results of the analysis for the 50 percent solar power and 28 percent fossil power initial condition. This operating condition requires less usage of the fossil boiler, and the fossil boiler can reduce the turbine throttle valve steam flow transient. Comparing Figures 4.5-9 and 4.5-14, the throttle valve steam flow varies ±13 kg/s (28.7 lb/s) maximum for the 50 percent solar/50 percent fossil condition and varies ±10.9 kg/s (24.0 lb/s) maximum for the 50 percent solar/28 percent fossil condition. In all cases the pressure and flow overshoot can be reduced if the time rate of change of solar steam output is used as an additional control input. Currently the steam is controlled only on steam pressure and this allows flows and pressures to overshoot.

Figure 4.5-15 shows the 50 percent solar power and 28 percent fossil power transient with a variable throttle valve position. Comparing Figures 4.5-15 and 4.5-6 shows that the turbine pressure transient is significantly reduced. Also, no significant steam flow overshoot is observable. The power output transient is related to the initial decrease in steam flow and the output does not overshoot when solar input again increases.

All cases considered indicate that the system is able to handle average velocity clouds with little degradation of the quality of electric power output. Some improvements can be made if other control inputs are added to the turbine inlet pressure control scheme, such as solar steam flow rate. Also, reducing the operating steam flow of the fossil boiler, using 80 percent rated turbine steam flow as the steady state operating condition, will reduce transients. Reducing the system operating pressure with the reduced steam flow will improve transient operation by allowing a slightly more severe pressure transient before causing a turbine trip.

4.5.3 SOLTES-1 Computer Data

SOLTES 1 is a Sandia National Laboratories (SNL) Computer Code simulating the steady state performance of thermal energy systems. The code consists of a set of computer algorithms modeling individual components of a thermal power plant.

Figure 4.5-16 shows the flow schematic used for the SOLTES code to portray the solar repowered Newman Unit 1. The flow schematic defines the state points and the components included in the simplified system model. The input data for the code is listed in Appendix C along with the EPGS efficiency for part load and a graphic representation of the solar boiler efficiency.

Input and decks for two preprocessing programs and for MIRVAL input data were prepared by Westinghouse and sent to SNL. The first preprocessing program calculated the optimum heliostat locations for the specific heliostat and field dimensions used in this study. The second preprocessing program, BOX, grouped the heliostats into sets to allow faster computations in MIRVAL. The MIRVAL input card deck included design point input data and program update commands.

The data provided is to be used as input to SNL's system modeling effort. It should be noted that the work completed is only a partial effort and further work is necessary to arrive at a accurate dynamic model of the system. The current SOLTES code does not permit dynamic efficiency modeling of the various components. Development of dynamic algorithms and a more complete flow schematic, including feedwater heaters and all piping, are required to accurately model the system.

TABLE 4.5-1

CONCEPTUAL SOLAR FIELD PERFORMANCE

	Power Incident on Receivers (MWt)
Noon summer solstice	120
Noon equinox	128
Noon winter solstice	129
10 a.m. winter solstice	110
9 a.m. winter solstice	84
Annual average	71

TABLE 4.5-2

LIST OF CASES

Cloud Cover (%)	Cloud Shadow Velocity (m/s)	Initial Conditions Solar/Boiler, % Flow	Fossil Boiler Flow Output Ramp Limit, % Per Minute	Turbine Throttle Valve Position Demand
10	8.0	50/50	20.0	Constant
50	8.0	50/50	20.0	Constant
100	8.0	50/50	20.0	Constant
10	22.0	50/50	20.0	Constant
50	22.0	50/50	20.0	Constant
100	22.0	50/50	20.0	Constant
50	8.0	50/28	20.0	Constant
50	22.0	50/28	20.0	Constant
50	8.0	50/50	10.0	Constant
50	22.0	50/50	6.3	Constant
50	8.0	50/28	20.0	Variable

1 of 1

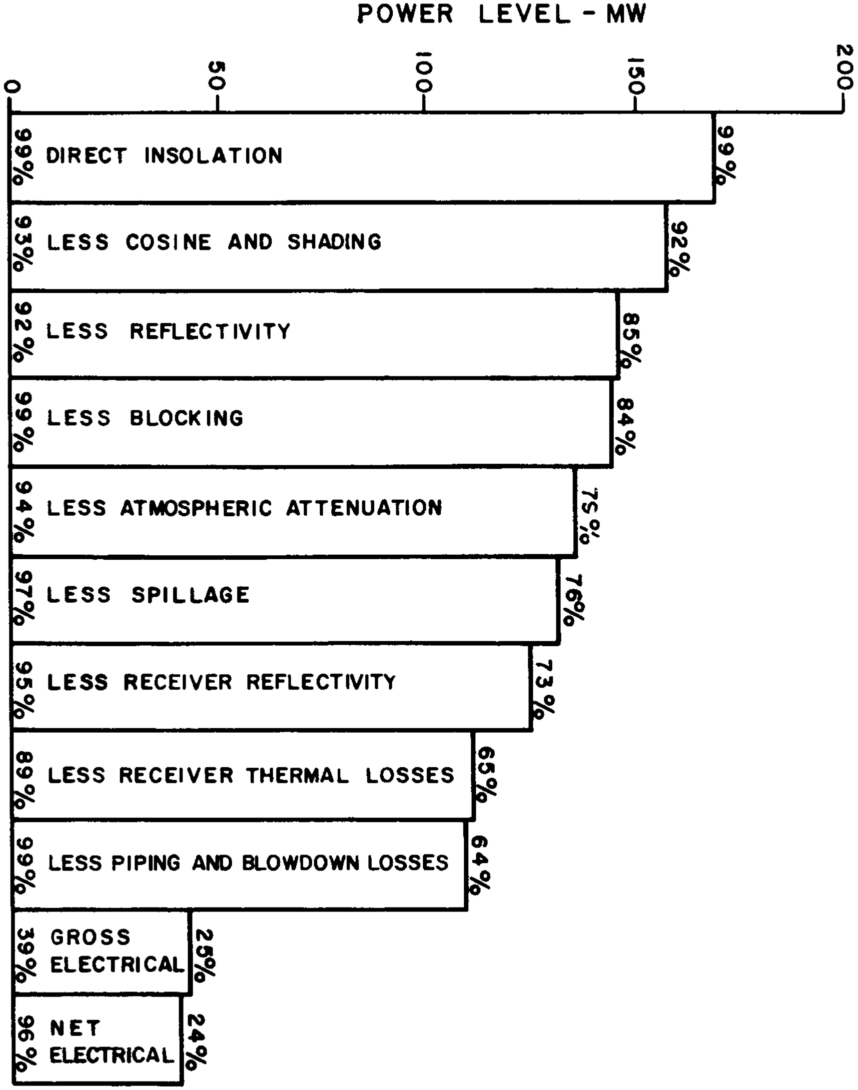


FIGURE 4.5-1
SOLAR REPOWERING NEWMAN
UNIT 1 EFFICIENCY CHART
(DESIGN POINT –
NOON WINTER SOLSTICE –
1000 W/M^2 INSOLATION)

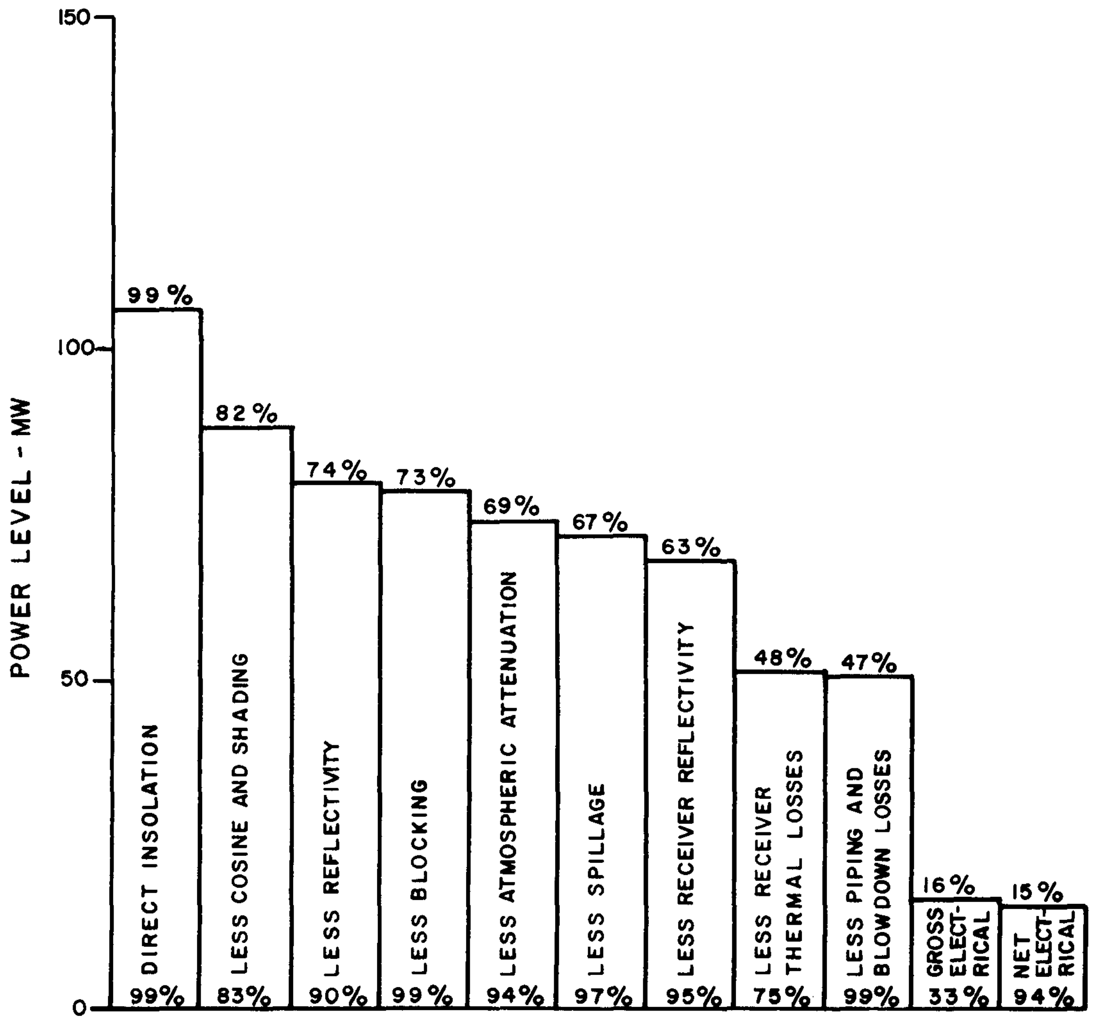


FIGURE 4.5-2
SOLAR REPOWERING NEWMAN
UNIT 1 EFFICIENCY CHART
ANNUAL AVERAGE

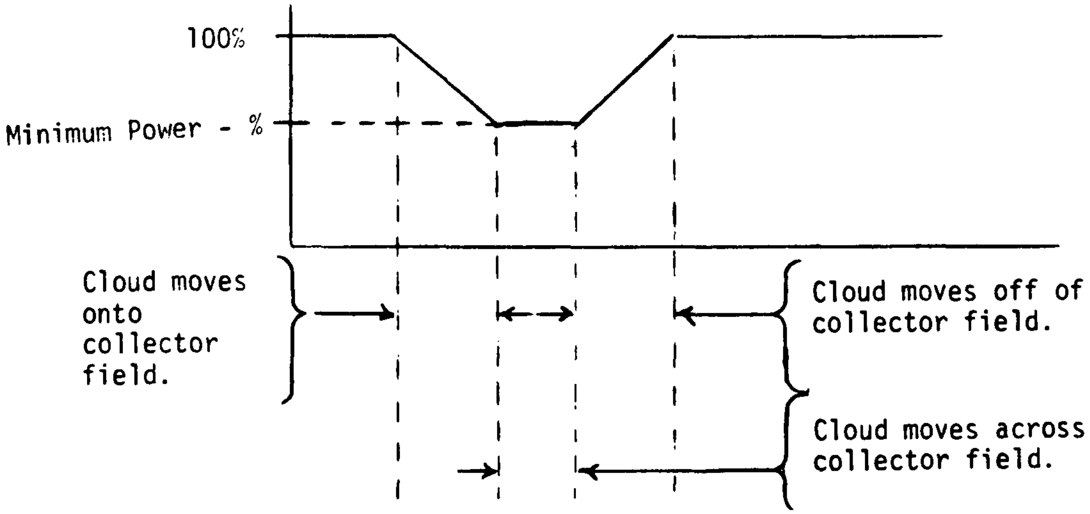


FIGURE 4.5-3
NSRM FORCING FUNCTION

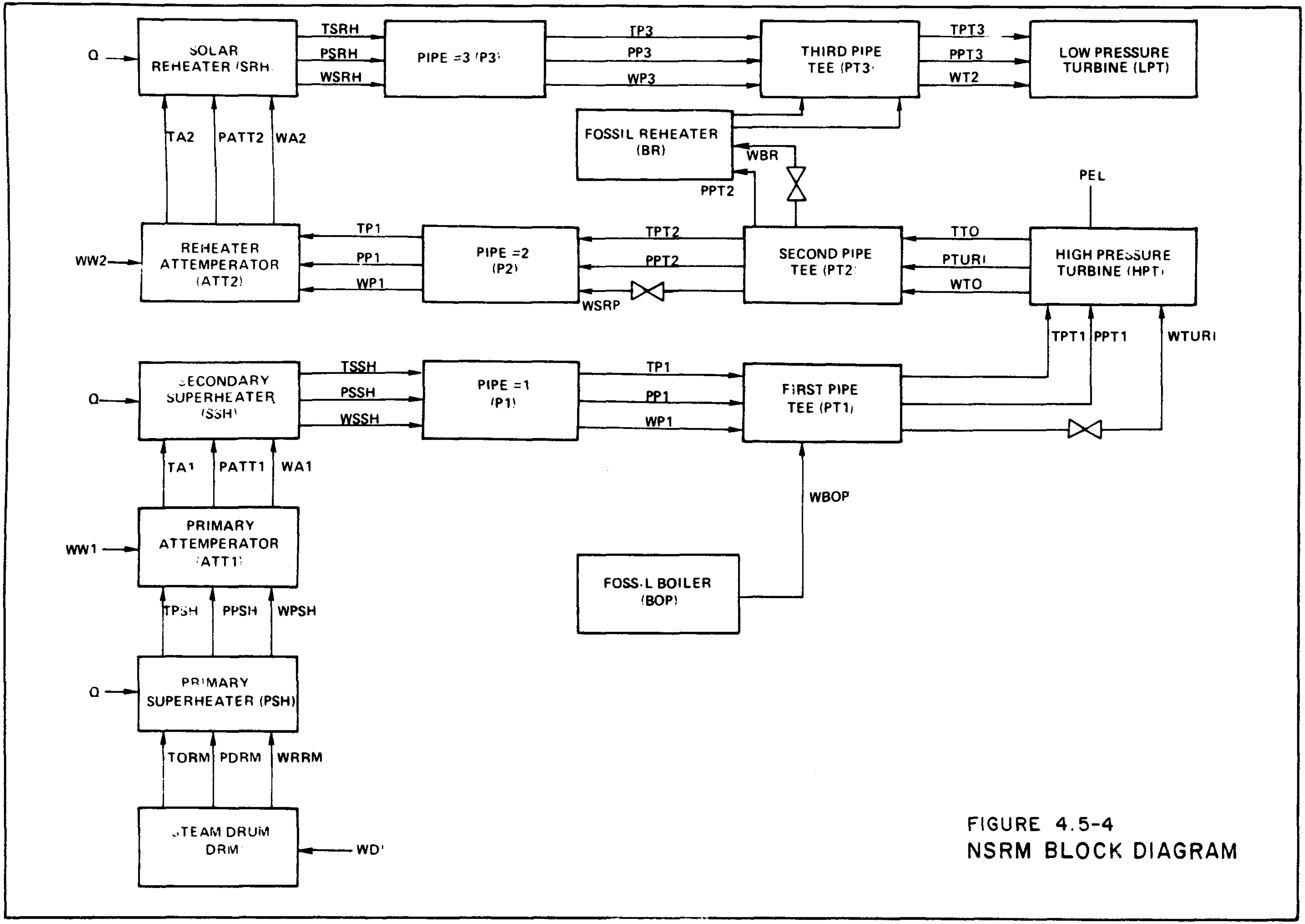
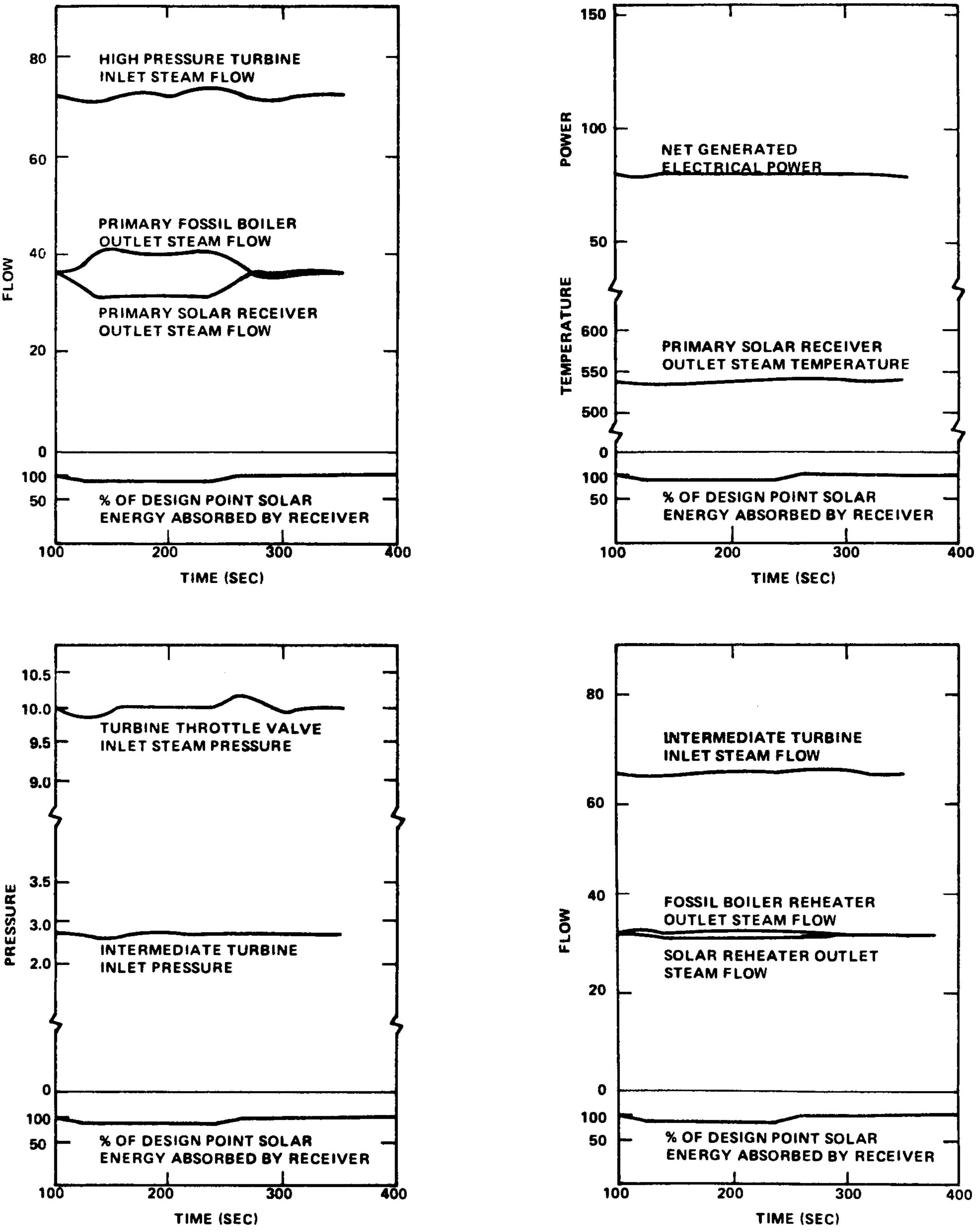
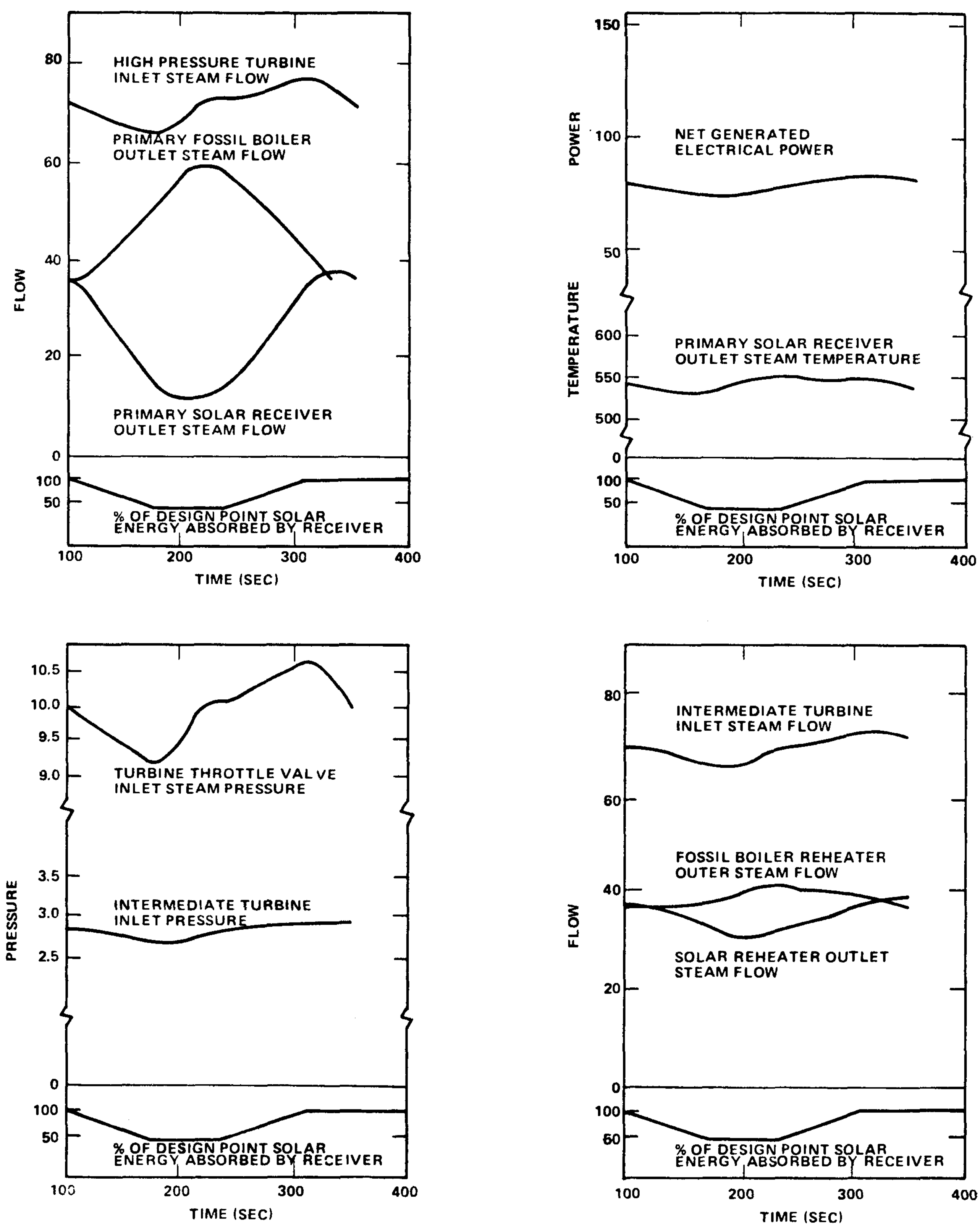


FIGURE 4.5-4
NSRM BLOCK DIAGRAM



NOTE: 20%/MIN BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

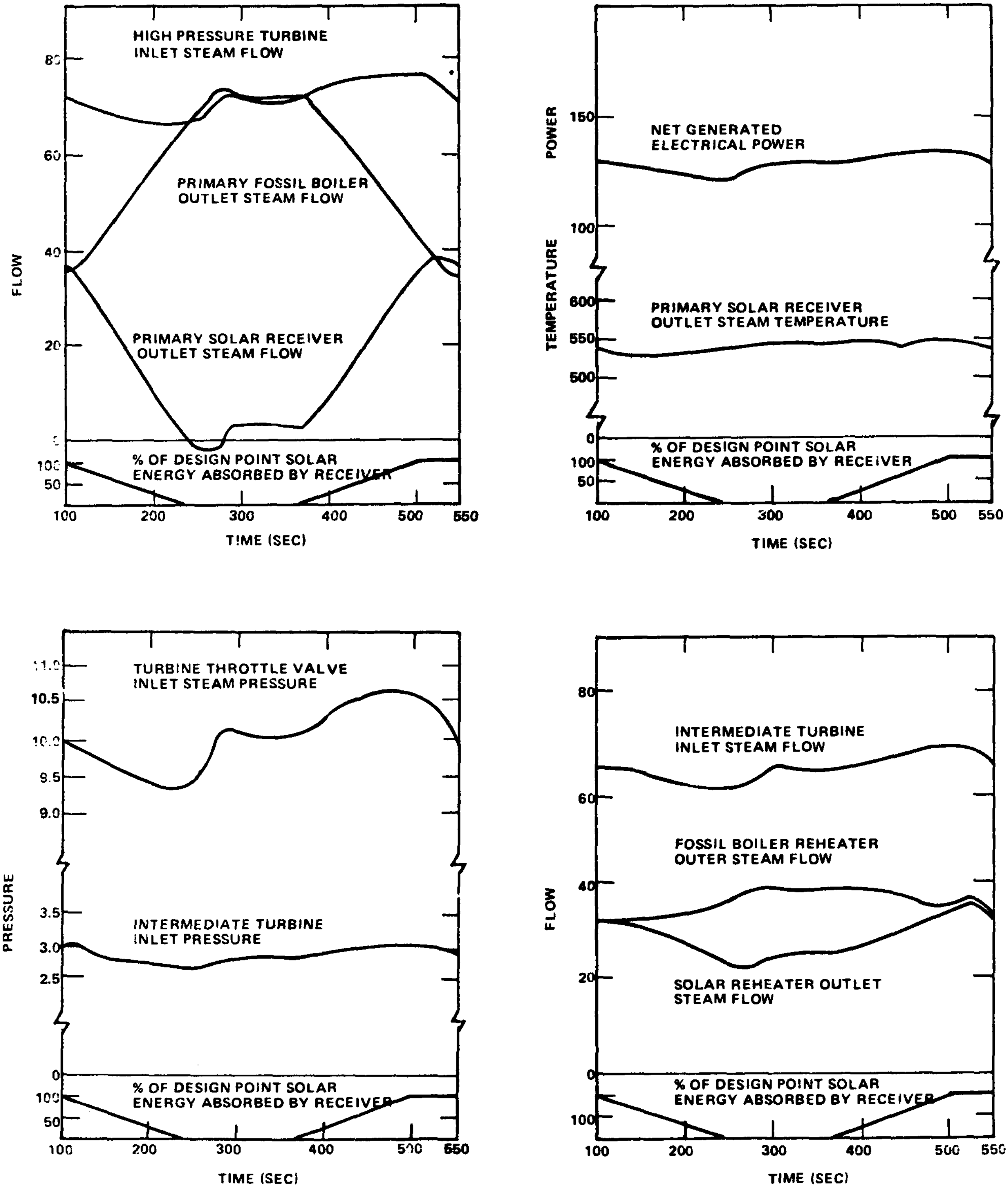
FIGURE 4.5-5
NSRM TRANSIENT RESPONSE TO 10% CLOUD COVERAGE WITH 8 m/sec VELOCITY



NOTE: 20%/MIN BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

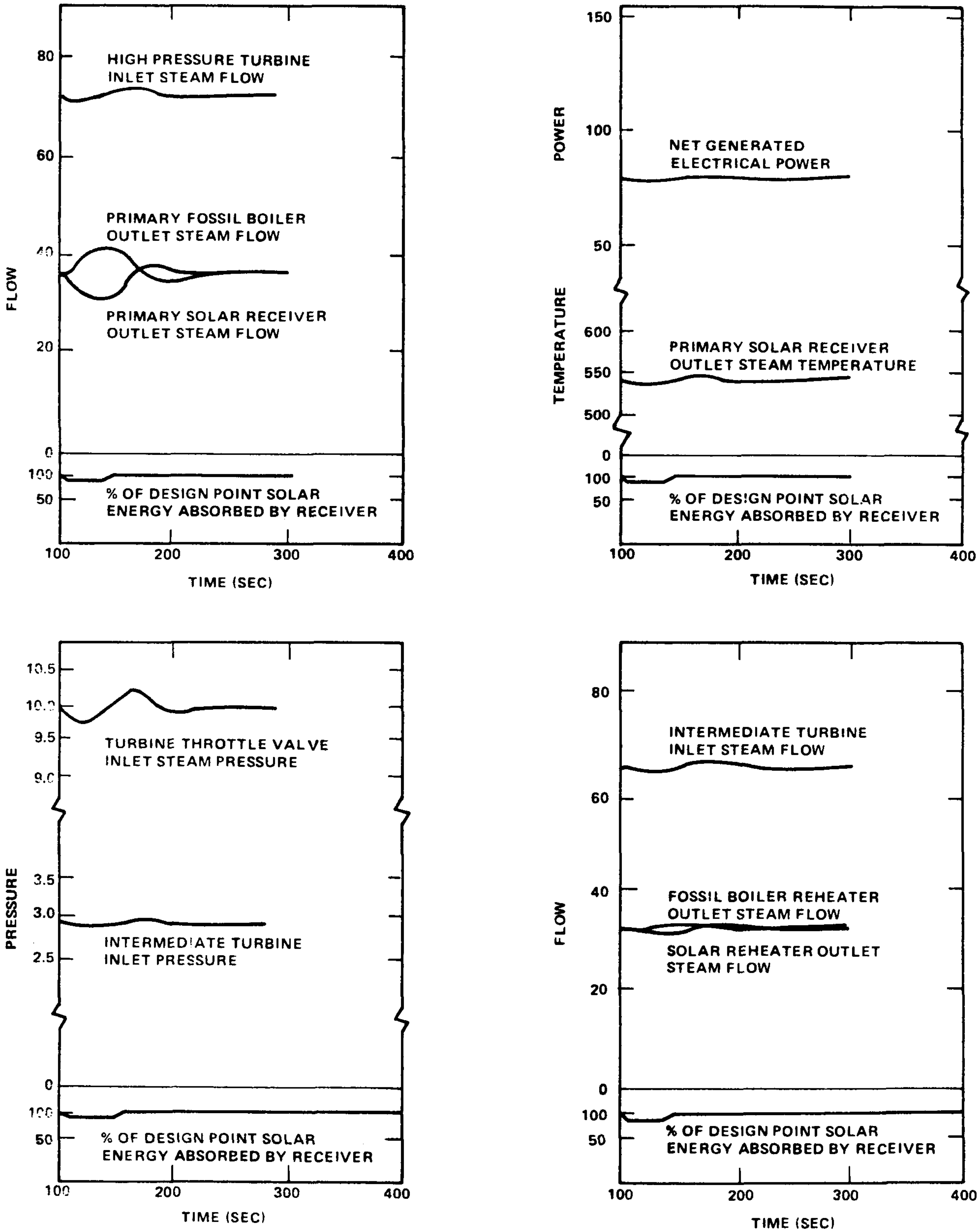
FIGURE 4.5-6

NSRM TRANSIENT RESPONSE TO 50% CLOUD COVERAGE WITH 8m/sec VELOCITY



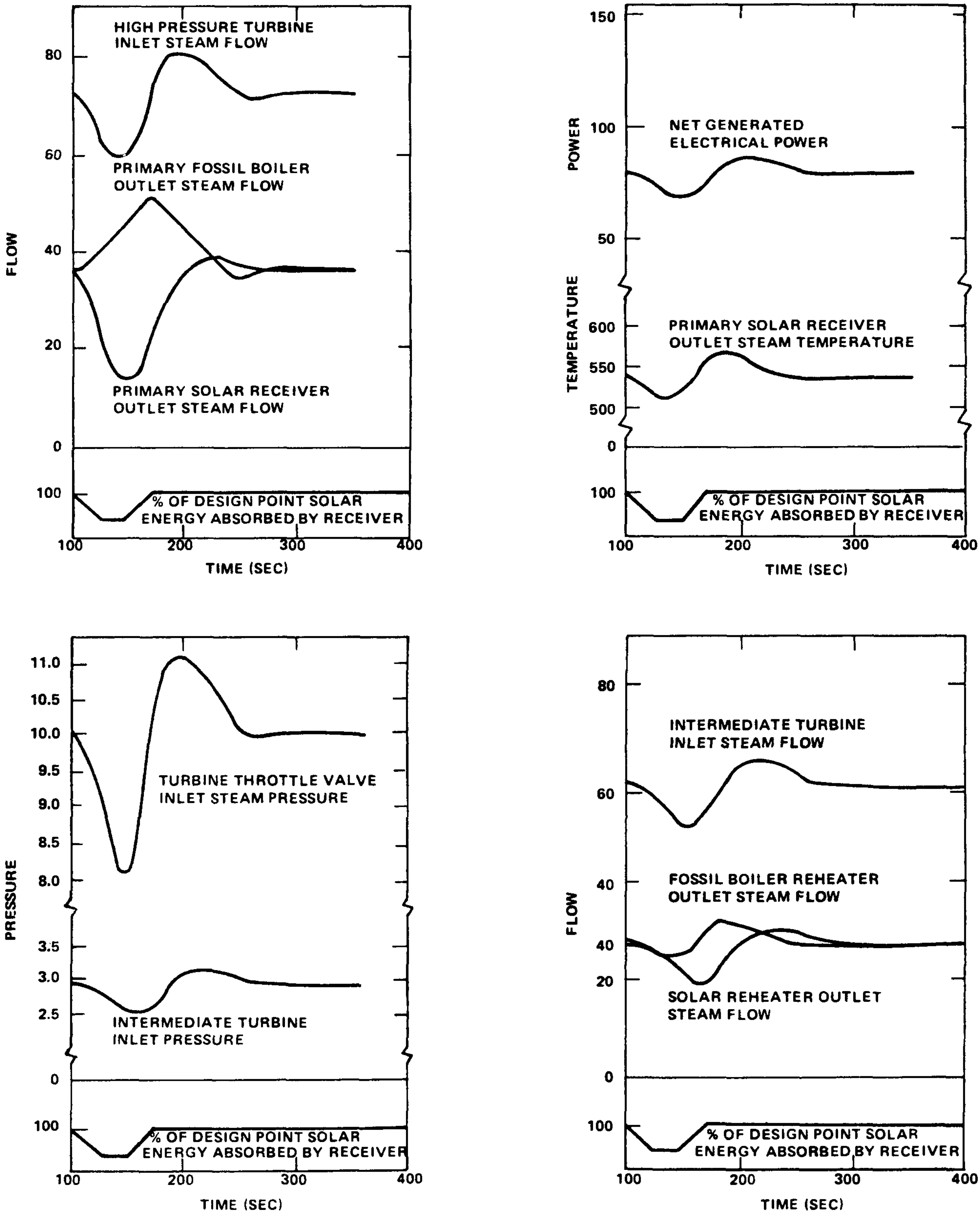
NOTE: 20%/MIN BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

FIGURE 4.5-7
NSRM TRANSIENT RESPONSE TO 100% CLOUD COVERAGE WITH 8 m/sec VELOCITY



NOTE: 20%/MIN BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

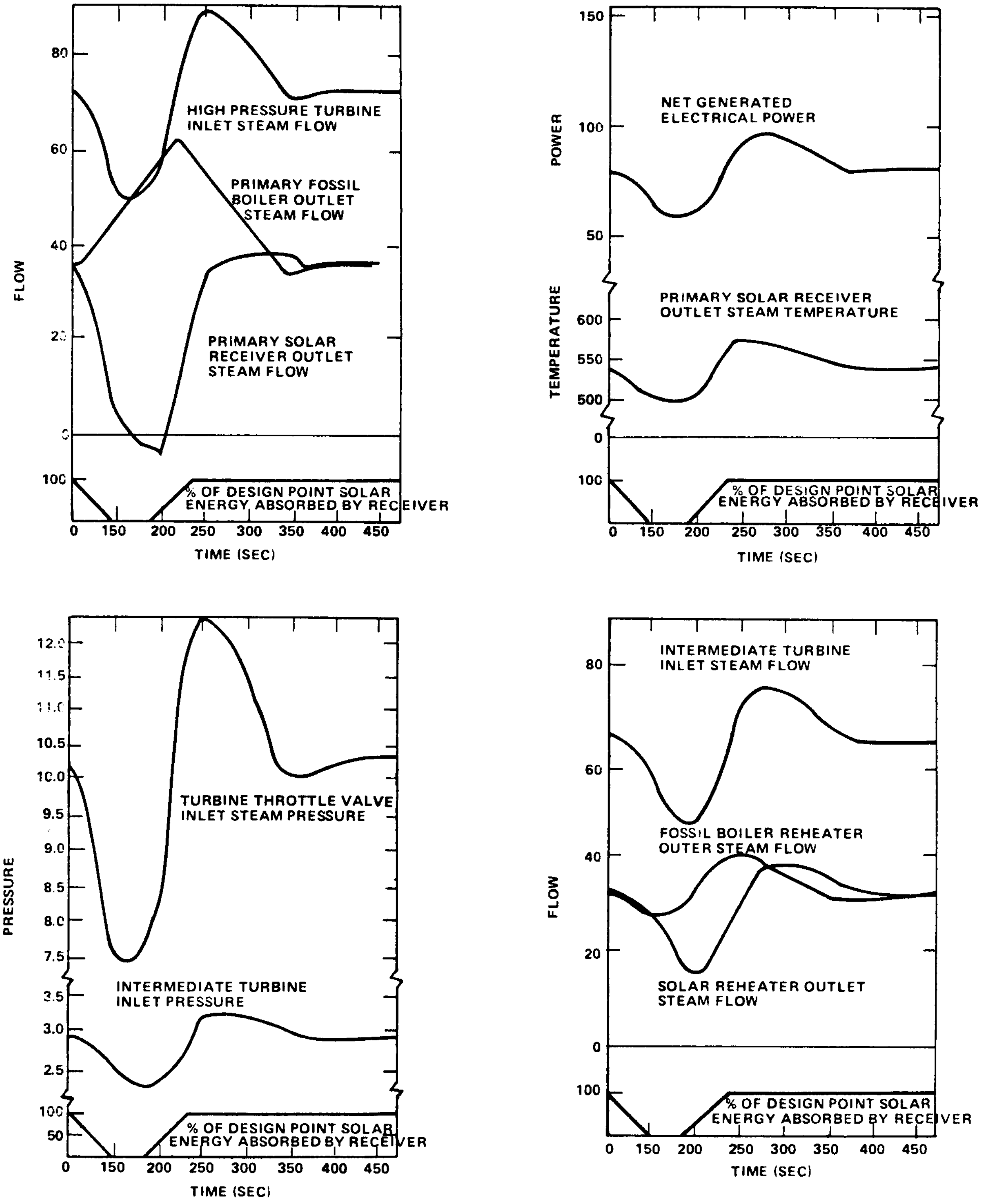
FIGURE 4.5-8
NSRM TRANSIENT RESPONSE TO 10% CLOUD COVERAGE WITH 22 m/sec VELOCITY



NOTE: 20%/MIN BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

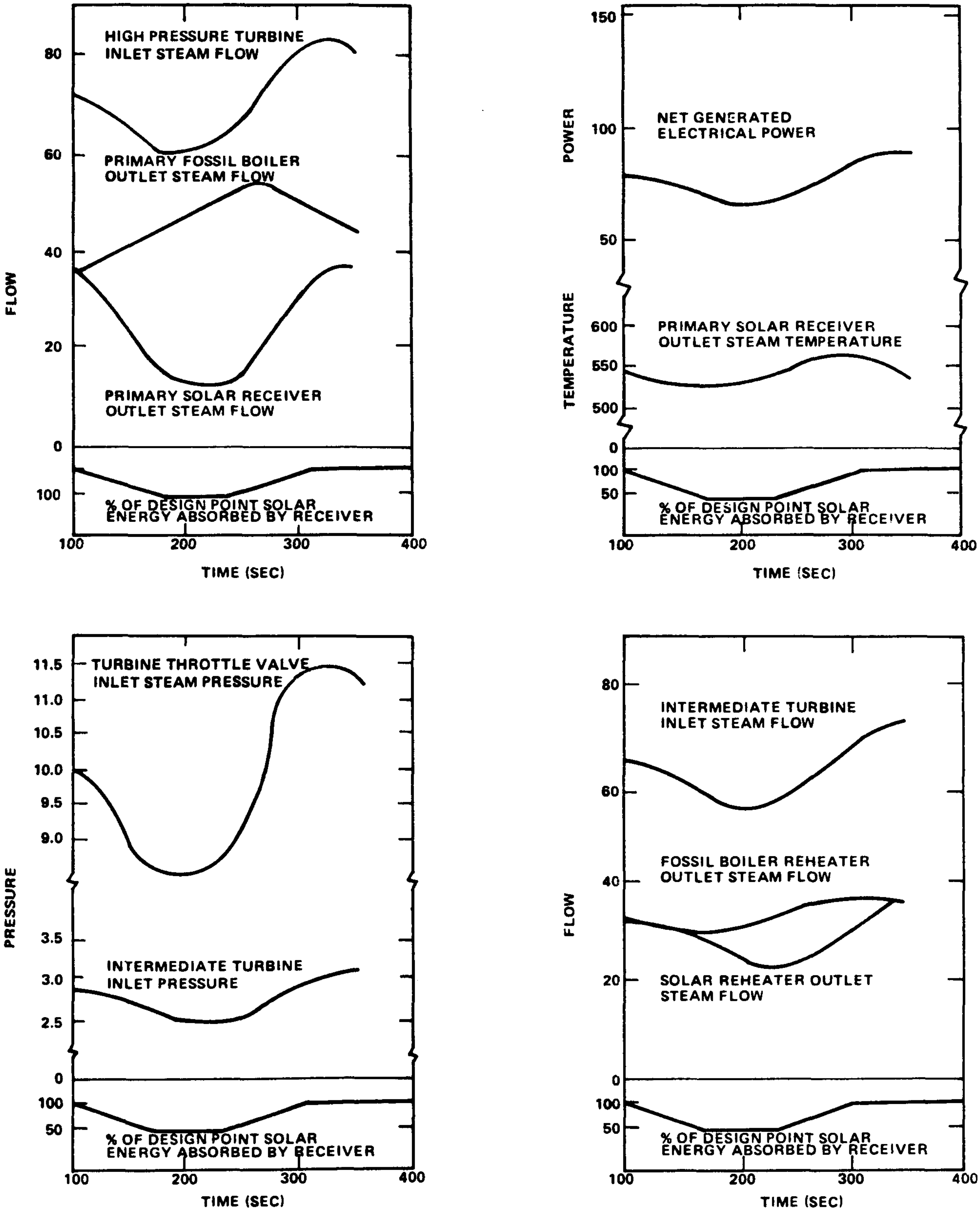
FIGURE 4.5-9

NSRM TRANSIENT RESPONSE TO 50% CLOUD COVERAGE WITH 22 m/sec VELOCITY



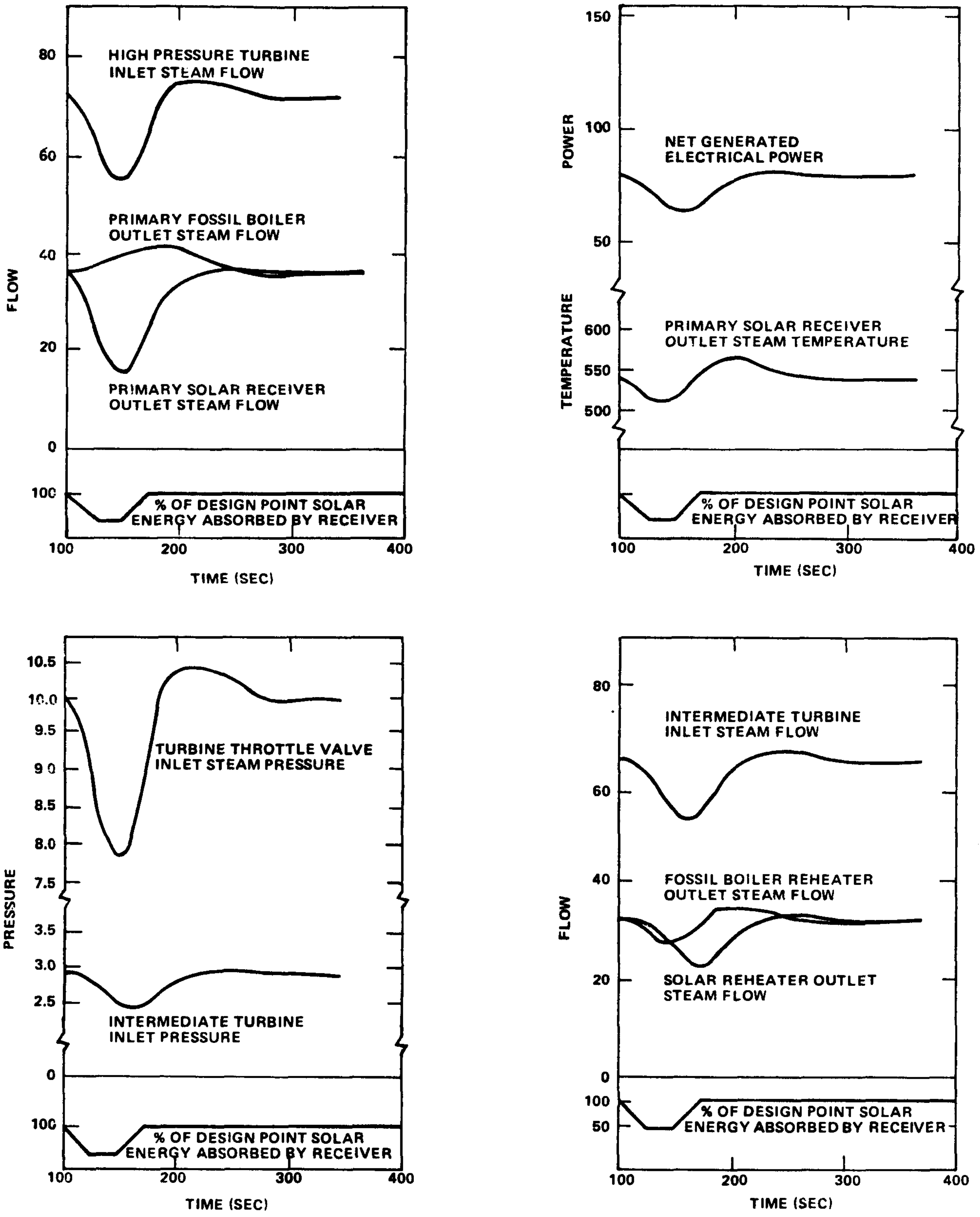
NOTE: 20%/MIN. BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

FIGURE 4.5-10
NSRM TRANSIENT RESPONSE TO 100% CLOUD COVERAGE WITH 22 m/sec VELOCITY



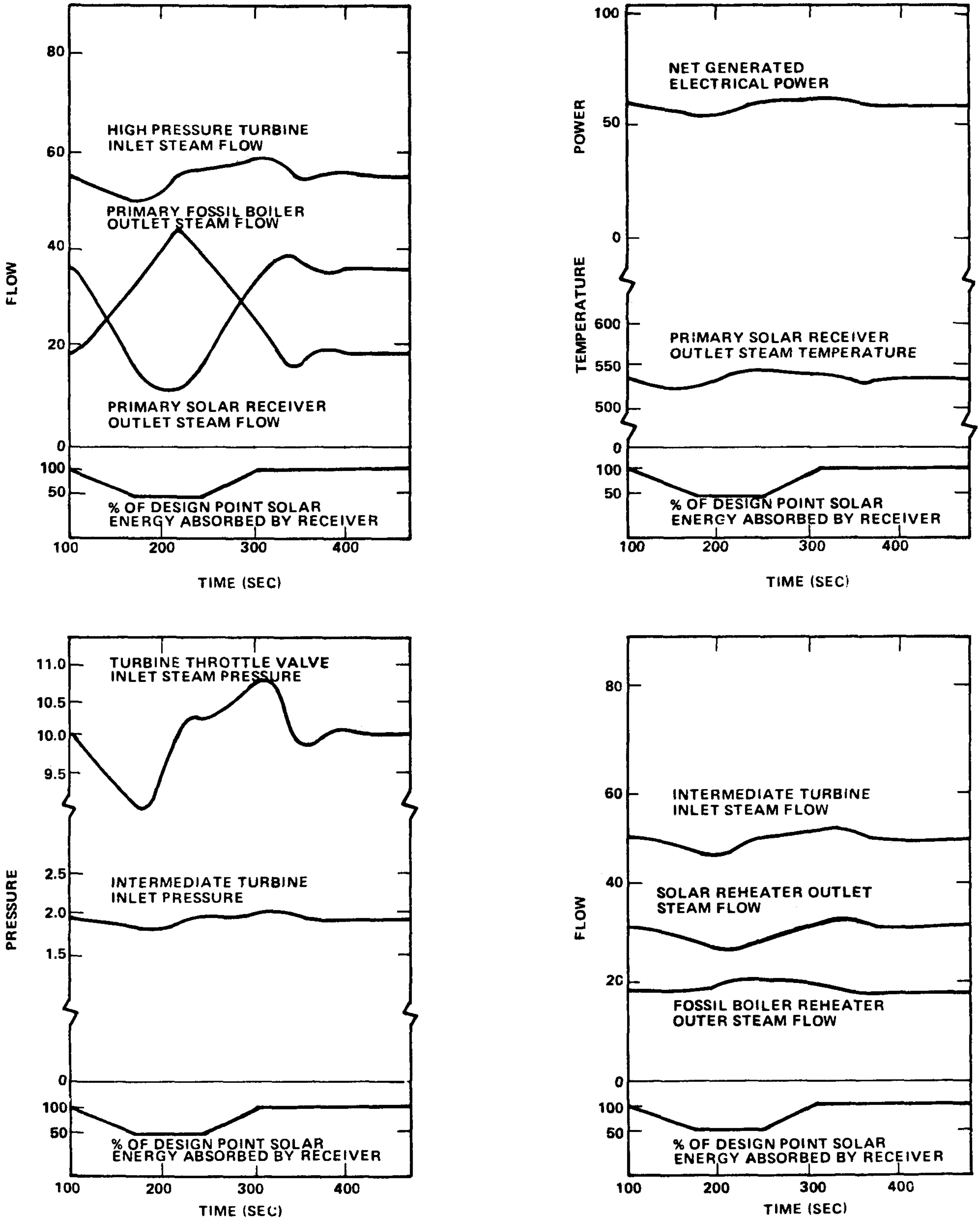
NOTE: 10%/MIN. BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

FIGURE 4.5-11
NSRM TRANSIENT RESPONSE TO 50% CLOUD COVERAGE WITH 8 m/sec VELOCITY



NOTE: 6.3%/MIN. BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

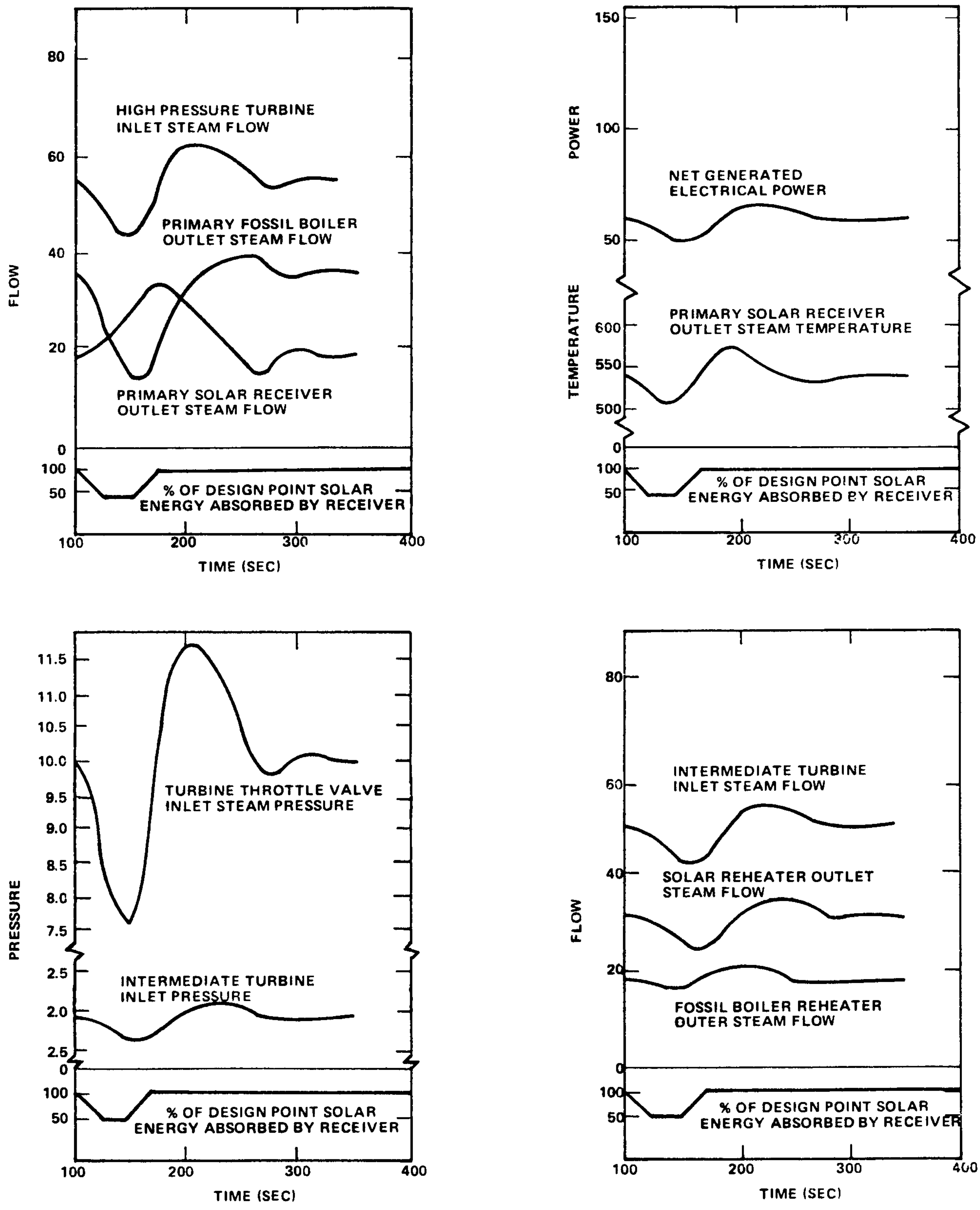
FIGURE 4.5-12
NSRM TRANSIENT RESPONSE TO 50% CLOUD COVERAGE WITH 22m/sec VELOCITY



NOTE: 20%/MIN. BOILER RESPONSE LIMIT
28/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

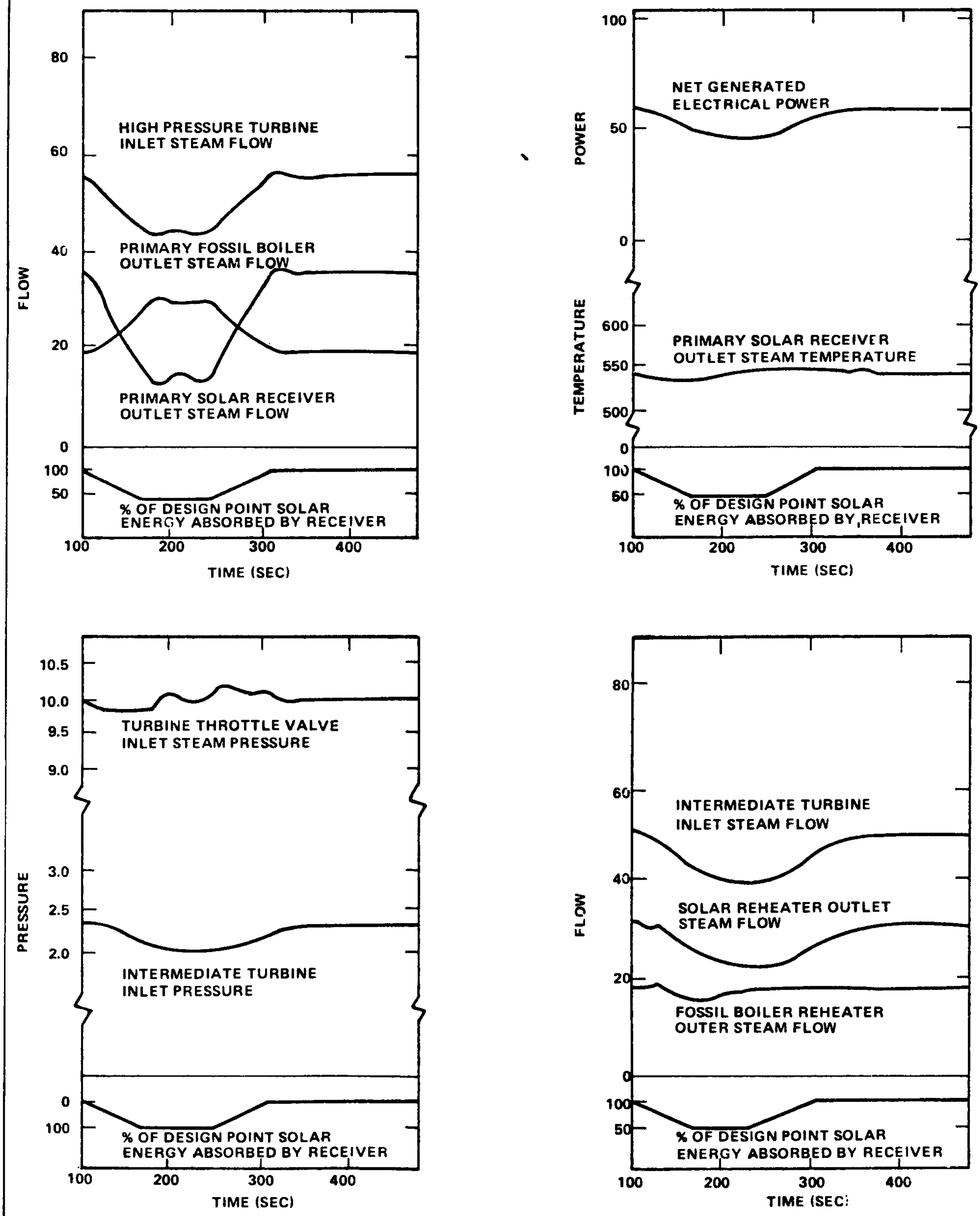
FIGURE 4.5-13

NSRM TRANSIENT RESPONSE TO 50% CLOUD COVERAGE WITH 8m/sec VELOCITY



NOTE: 20%/MIN. BOILER RESPONSE LIMIT
28/50 FOSSIL/SOLAR FLOW DISTRIBUTION

FIGURE 4.5-14
NSRM TRANSIENT RESPONSE TO 50% CLOUD COVERAGE WITH 22m/sec VELOCITY



NOTE: 20%/MIN. BOILER RESPONSE LIMIT
28/50 FOSSIL/SOLAR FLOW DISTRIBUTION
VARIABLE THROTTLE VALVE

FIGURE 4.5-15

NSRM TRANSIENT RESPONSE TO 50% CLOUD COVERAGE WITH 8m/sec VELOCITY

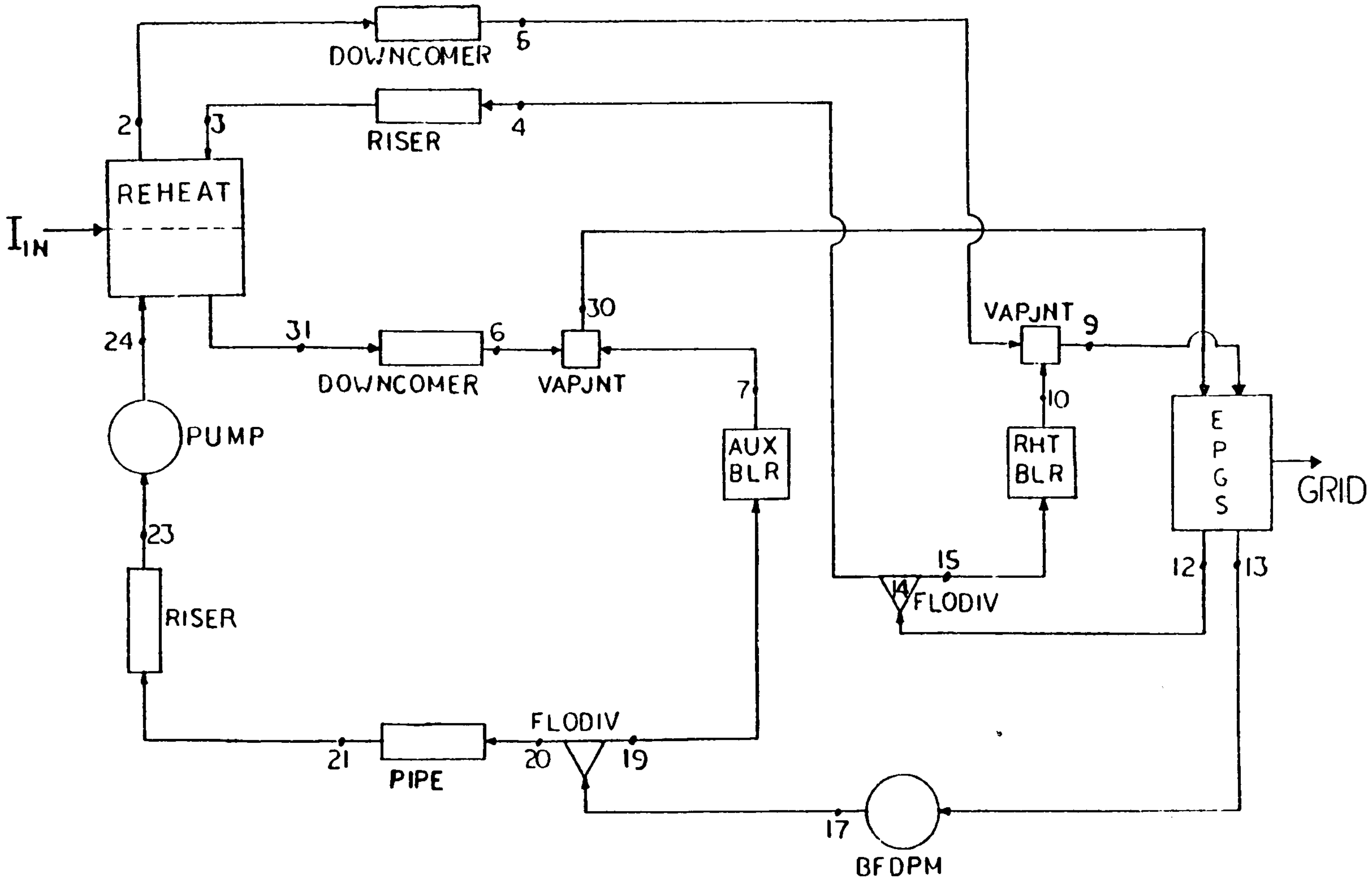


FIGURE 4.5-16
ADVANCED SOLAR REPOWERING
SOLTES MODEL: NEWMAN UNIT 1

4.6 PROJECT CAPITAL COST SUMMARY

The capital cost estimate for solar repowering of Newman Unit 1 is summarized in Table 4.6-1. The costs shown include the direct costs, distributable (construction-related) costs, indirect (engineering and project management) costs, an allowance for indeterminates (contingency), escalation, owner's costs, and an allowance for funds used during construction (AFUDC). The basis for calculating the direct costs for each subsystem is presented in Section 5. The basis for each of the costs other than direct cost is discussed in this section. Also, the approach and methodology utilized in developing the cost estimate and the accuracy and sensitivity of the estimate relative to key assumptions are described. A definition of cost accounts included in the direct cost estimate is presented in Table 4.6-2.

The total estimated construction and related costs for solar repowered Newman Unit 1 is $136,400,000 (December 1986 dollars). This estimate is based on an assumed installed collector field cost of $198/m², including foundations, field wiring, installation, and the delivered cost of collector equipment. The accuracy of the balance of the estimate is approximately ±20 percent. The accuracy of the heliostat field cost is very difficult to determine at this time, and variations in this cost have a substantial impact on the total estimate. For example, if the installed cost of collector hardware were to vary from $150/m² to $350/m², the corresponding total estimated construction cost would vary from $121.7 to $182.9 million (December 1986 dollars). The total cost is based on the engineering and construction schedule discussed in Section 7, requiring approximately 27 months of engineering, 18 months of construction, and 6 months for checkout and startup.

4.6.1 Direct Costs

The total direct costs estimated for this project are $61.8 million. Direct costs are defined as the present day (1982) material and labor costs associated with the delivery and installation of each subsystem identified in the initial conceptual design.

The approach utilized to estimate direct costs involves the development of engineering data; preparation of equipment lists or descriptions of groups of equipment or subsystems; the accumulation of data for materials costs, based on similar estimates for other projects, information provided by equipment vendors, and published data; the development of estimates for labor associated with installation of each subsystem or major piece of equipment based on experience with similar installations; and the application of labor rates representative of the El Paso area.

Labor rates are based on a rate survey by Stone & Webster's Construction Department. Contract labor rates used vary from \$19.00 to \$36.00, depending on the craft. Total direct labor cost is \$17.7 million.

Figure 4.6-1 visually summarizes the major portions of the direct costs. The largest cost element is the cost of collector equipment. The sensitivity of the total direct cost to the cost of collector equipment is illustrated in this figure. As shown in the direct cost breakdown, the heliostat cost is approximately 59 percent of the total direct cost. Figure 4.6-2 shows the high (\$350/m^2) and low (\$150/m^2) heliostat cost cases in comparison to the base case (\$198/m^2). The heliostat cost ranges from 53 percent of the total direct cost for the \$150/m^2 case to approximately 71 percent for the \$350/m^2 case.

4.6.2 Distributable Costs

Distributable costs include the cost of construction equipment, a field office and office supplies, construction management, insurance, overhead, and taxes. They are estimated using 14.7 percent of the direct labor cost. This percentage was derived based on experience with similar construction activities. The estimated distributable cost for this project is approximately \$2.6 million in 1982 dollars.

4.6.3 Indirect Costs

Indirect costs primarily include the cost of engineering and design work. Principal activities include the development of detailed engineering information; preparation of drawings, equipment lists, and specifications; procurement of subcontractors and major pieces of equipment; development of detailed cost and scheduling information; and project management. Indirect costs are estimated at 15 percent of the total direct costs. This percentage was based on very preliminary estimates of engineering labor developed for most of the expected engineering and design effort, and includes an allowance for extensive detailed engineering for the collector system.

The total estimated indirect cost is approximately \$9.3 million in 1982 dollars.

4.6.4 Allowance for Indeterminates

An allowance for indeterminates of about 15 percent is applied to the sum of directs, indirects and distributables, and included due to the uncertainty associated with the cost estimate in terms of the current state of evolution of technical information. This allowance is intended to cover possible cost increases resulting from the development of more specific information during detailed design. This percentage is based primarily on judgment applied by the El Paso Electric Company. This is considered the most reasonable approach pending the receipt of firm cost estimates from manufacturers. An example of the impact of doubling the delivered cost of collector equipment is provided at the beginning of this section to illustrate the implications brought about by considerable uncertainty in the cost of the collector equipment.

The allowance for indeterminates included in the estimate is approximately $10.7 million in 1982 dollars. This amount was calculated based on 15% of the directs, indirects, and distributables reduced by $.4 million to account for a slight increase in direct costs that accurred after the economic analysis was initiated.

4.6.5 Escalation

Escalation is computed on the basis of 8 percent/year to allow for increases in the costs of material and labor between 1982 and the actual dates equipment is procured. Escalation was applied to the total present-day cost (excluding owner's costs) for the projected expenditures schedule resulting in an average escalation period of 3.6 years. The resulting escalation is 32.3 percent of the present-day cost or approximately $27.4 million.

4.6.6 Owner's Costs

Owner's costs estimated for this project are approximately $4.1 million. A breakdown of the owner's costs is presented in Table 4.6-3. Each component of the owner's costs includes appropriate escalation allowances and is described in the following sections:

4.6.6.1 Relocation of Transmission Lines

The proposed plant arrangement for repowering Newman Unit 1 will require relocating some existing and planned transmission facilities. Engineering and construction costs for relocating existing transmission facilities are $0.36 million, and $0.32 million for relocating future transmission facilities (which would be installed before 1986) for a total of $0.68 million. In addition, the cost of an estimated 0.49 km^2 (121 acres) of right-of-way are included.

4.6.6.2 Highway Relocation

The estimated cost for relocating Farm to Market Road 2529 which borders the existing Newman Station at its northern boundary is estimated to be approximately $1.04 million. This estimate is based on relocating the highway to the north as shown in Figure 4.1-3.

4.6.6.3 Wastewater Disposal

Existing wastewater at the Newman Station is utilized for irrigation of land just to the north of the site. Location of the collector field in that area will necessitate an alternative arrangement for waste water disposal. The cost of relocating this irrigation activity has not yet been determined, however, it should be relatively small.

4.6.6.4 Environmental Studies

An allowance of $0.1 million is included to cover the cost of environmental studies, which may include a survey of archaeological sites, transportation impacts, site surface preparation alternatives, and the study of other environmental considerations that may be necessary to support licensing and public relations efforts.

4.6.6.5 Public Relations

An allowance of $0.05 million is included to cover the cost of public relations activities associated with future phases. This would not be sufficient to cover the cost of a Visitor Center at the site, but is intended to include the development of information to secure public support for the project.

4.6.6.6 Site Land Procurement

An estimated 1.1 km^2 (270 acres) of land will be required for the new facilities associated with repowering Newman Unit 1. The cost of this land is approximately $0.94 million at an assumed cost of $0.86 per m^2 ($3,500 per acre).

4.6.6.7 Relocation of Employee Park

The cost of relocating the existing employee park located north of Newman Unit 1 is estimated to be approximately $0.2 million. This estimate is based on the cost of procuring 0.08 km^2 (20 acres) of land elsewhere at an assumed cost of $0.86/$m^2$ ($3,500 per acre), plus an allowance of $0.1 million for the development of recreational facilities.

4.6.6.8 Perimeter Lighting

An estimated 51 fixtures spaced every 250 feet around the perimeter of the heliostat field will be used for perimeter lighting. Each fixture will include a 30-foot wood pole with a 250-watt high pressure sodium lamp. The cost for perimeter lighting is approximately $0.16 million in 1982 dollars.

4.6.7 Allowance for Funds Used During Construction (AFUDC)

AFUDC is included to cover the cost of capital invested in plant equipment before plant commercial operation. AFUDC is calculated at an annual simple interest rate of 13.5 percent applied to the total estimate (excluding owner's costs) using the projected expenditures schedule. This results in an equivalent AFUDC period of about 1.3 years. AFUDC is therefore estimated at approximately $19.5 million.

4.6.8 Spare Receiver Panels

Two spare receiver panels have been included in the budget estimate. The cost has been escalated to the commercial operation date (Dec. 1986) and is approximately $0.7 million.

TABLE 4.6-1

CONSTRUCTION COST ESTIMATE SUMMARY

Account/Description	(In Thousands Of Dollars)	
5000 Facility Cost		
5100 Site Improvements	$ 1,900	
5200 Administrative Areas	600	
5300 Collector System	36,600	
5400 Receiver System	13,700	
5500 Control System	4,300	
5600 Fossil Energy System	-	
5700 Energy Storage System	-	
5800 Electric Power Generation	5,900	
Total Direct Cost		63,000
Productivity Adjustment of 0.95		(900)
Total Direct Cost Including Productivity Adjustment		62,100
Distributable Costs		2,600
Total Construction Cost		64,700
Indirect Costs		9,300
Total Construction and Indirects		74,000
Allowance for Indeterminates		10,700
Total Present-day Estimate (1982 dollars)		84,700
Escalation		27,400
Escalated Cost		112,100
Owner's Costs		4,100
AFUDC		19,500
Spare Receiver Panels		700
Total (1986 Dollars)*		$136,400

* The term "1986 dollars" used in this report refers to the estimated total cost of the project for December 1986 commercial operation including escalation and AFUDC allowances consistent with anticipated cash flow.

TABLE 4.6-2

DIRECT COST ACCOUNT SCOPE DEFINITION

Account	Definition/Scope	Direct Cost (1982 $)
5000	Total Direct Cost - Solar Repowering Newman Unit 1	
5100	Site Improvements	1,905,000
5110	Clearing and Grubbing - heliostat field and roads	495,000
5120	Diversion Channel and Drainage - heliostat field	308,000
5130	Crushed Rock Surface - heliostat field	86,000
5140	Roads and Fencing - entire site	1,016,000
5200	Site Facilities (Structural and Electrical Work Only)	586,000
5210	Control Room Extension	199,000
5220	Solar Feed Pump Building	105,000
5230	Maintenance Building Extension	282,000
5300	Collector Subsystem	36,522,000
5310	Heliostats - delivered and assembled	21,086,000
5320	Heliostat Installation	2,102,000
5330	Heliostat Foundations	3,525,000
5340	Field Wiring, Electrical, and Controls	7,187,000
5350	Power and Control to Battery Limit of Field	1,446,000
5360	Beam Characterization System (BCS)	1,176,000

1 of 2

TABLE 4.6-2 (Cont)

Account	Definition/Scope	Direct Cost (1982 $)
5400	Receiver Subsystem	13,715,000
5410	Receivers - Primary and Reheat	11,140,000
5420	Tower - includes foundation, platforms, equipment room, etc	2,460,000
5430	Electricals - power supply to tower and receiver	115,000
5500	Control Subsystem	4,327,000
5510	Master Control System - Includes all new control and control modifications except BCS (5360), DEH (5810), and miscellaneous instrumentation (5520)	3,049,000
5520	Miscellaneous Instruments - Fossil boiler combustion controls, feedwater controls, and steam temperature and and flow controls	1,278,000
5800	Electrical Power Generating Subsystem	5,951,000
5810	Turbine-generator - Digital Electronic Hydraulic Control System (replaces existing mechanical hydraulic controls)	1,186,000
5820	Piping, Heaters, and Pumps - solar feedwater heaters; solar feedwater pumps; main and reheat steam piping and feedwater piping from receiver to interface with existing piping at the turbine building. Includes pipe supports, insulation, and all valves except control valves (in 5520)	4,110,000
5830	Electrical - All electrical equipment and power supplies except heliostat field wiring, receiver, and tower electricals	665,000

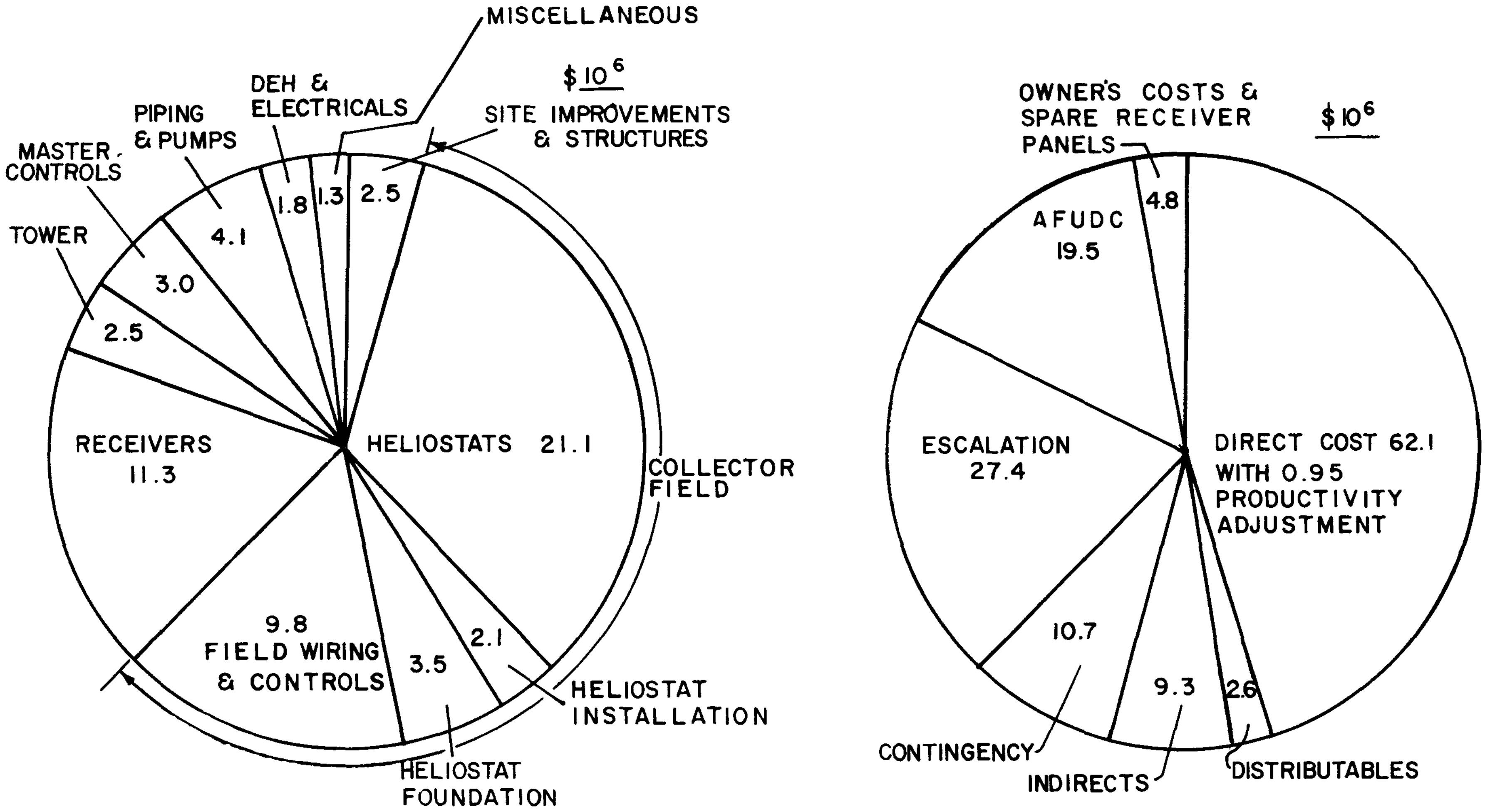
2 of 2

TABLE 4.6-3

OWNER'S COSTS

Description	(In Thousands of 1982 Dollars)
Relocation of Transmission Lines	
Right-of-Way Land	$ 566.0
Engineering and Construction	679.0
Relocating State Highway	1,040.0
Environmental Studies	100.0
Public Relations Activities	50.0
Site Land Requirement	942.0
Relocating Employee Park	199.0
Perimeter Lighting	156.0
Total	$3,732.0
Total Owner's Cost With Escalation	$4,078.0
Use	$4,100.0

1 of 1



TOTAL - $63,000,000
(1982 DOLLARS, SUBJECT TO 0.95 PRODUCTIVITY ADJUSTMENT)

DIRECT COST BREAKDOWN

TOTAL-$ 136,400,000
(CURRENT DOLLARS FOR DEC., 1986 OPERATION)

CONSTRUCTION COST BREAKDOWN

FIGURE 4.6-1
CONSTRUCTION COST BREAKDOWN

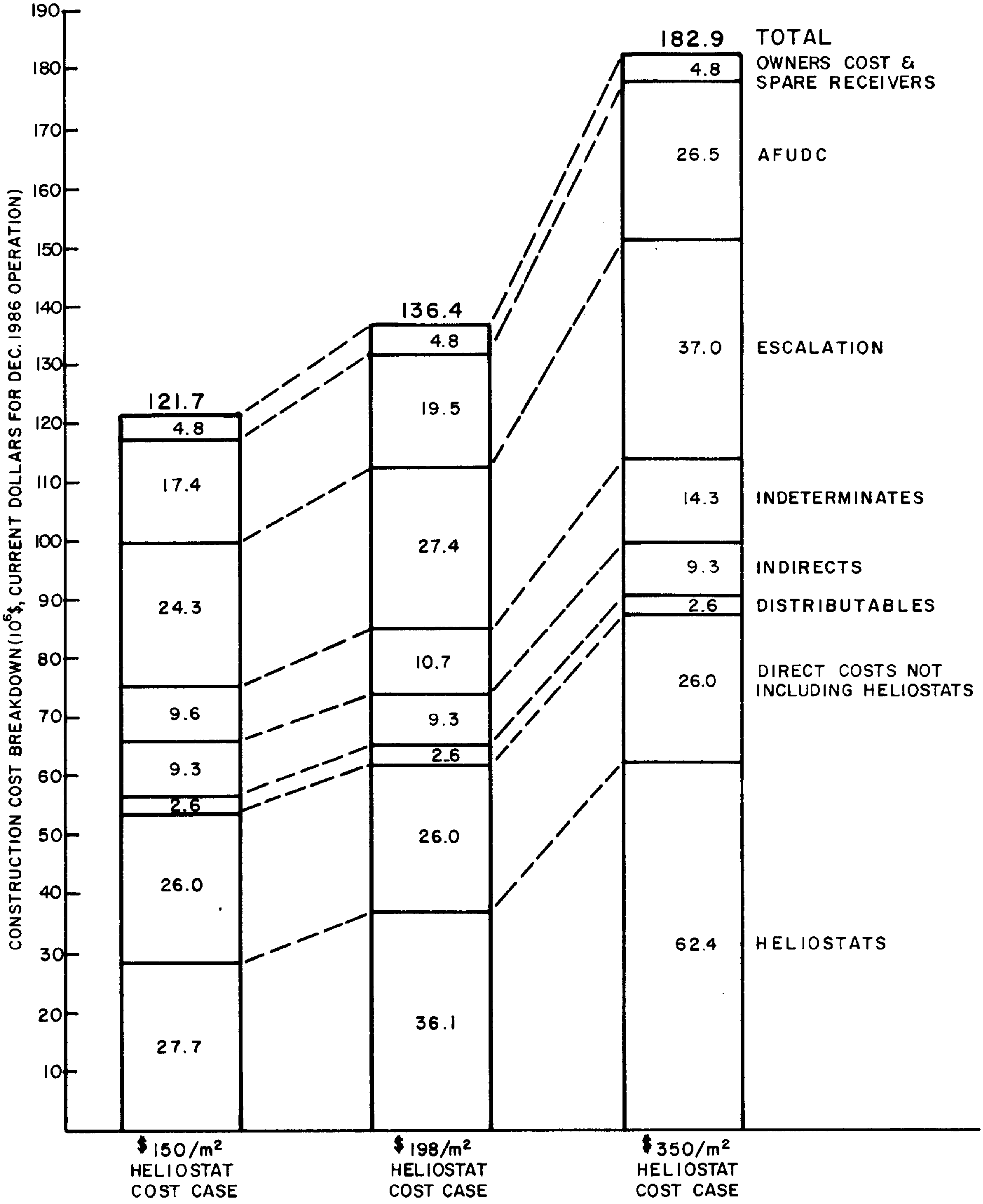


FIGURE 4.6-2

CONSTRUCTION COST BREAKDOWN FOR VARYING HELIOSTAT COSTS

4.7 OPERATIONS AND MAINTENANCE COSTS AND CONSIDERATIONS

Operations and maintenance (O&M) costs in Dec. 1986 dollars have been estimated for solar repowered Newman Unit 1. Annual fossil O&M costs are approximately $1,002 thousand/year. Annual additional O&M costs for the solar portion only are estimated at approximately $832 thousand/year in Dec. 1986 dollars. Total annual O&M is estimated at $1.8 million/year. These costs are broken down into operations, maintenance materials, and maintenance labor in Table 4.7-1 and discussed in the following sections.

4.7.1 Operations

The operations costs category, OM100, includes the cost of wages for unit operating personnel, the cost of operating consumables, and other fixed costs incurred whether or not the unit operates.

Unit operating personnel for the existing and repowered Newman Unit 1 are listed in Table 4.7-2. An estimated 13 full-time (equivalent) employees are currently assigned to Newman Unit 1. This number would be expanded to approximately 24 employees for solar repowered Newman Unit 1. Since various employees are shared among the four units at the Newman Station, fractions of employees represent the estimated amount of their time spent working on Unit 1. Salaries and overhead for the fossil portion of the unit were found to be approximately $284,000 per year in 1982 dollars. Estimated additional salaries and overhead for the solar portion is about $76,000 per year in 1982 dollars. Total operations costs for OM110 escalated to Dec 1986 dollars are $382,000/year or an addition of $106,000/year for the solar addition only.

A total allowance of $89,000/year in Dec 1986 dollars is included for supplies consumed at the site on a regular basis, such as makeup water, water treatment chemicals, cleaning supplies, office supplies, paint, lubricants, etc. Current costs for these items at Newman Unit 1 in operating consumables, OM120, are approximately $51,400/year in 1982 dollars.

Other fixed operating expenses, OM130, include items such as rents, wastewater disposal, etc. A total allowance of $11,000/year in Dec 1986 dollars is included to cover these costs. Current cost for these items is approximately $5,350 (1982 dollars).

Total costs for OM100, Operations, is approximately $568,000 in Dec 1986 dollars, or an additional $127,000/year for the solar addition only.

4.7.2 Maintenance Materials and Maintenance Labor

Maintenance material and labor costs were estimated based on judgment and experience with maintenance and repair costs associated with power plant equipment. Maintenance costs were considered primarily for three categories: heliostats, receivers, and balance-of-plant. Heliostats and receivers are considered developmental; therefore, the allowance for maintenance of these components is greater than for the balance-of-plant equipment.

Heliostat annual maintenance and repair costs are assumed to be $100 per heliostat per year, or approximately $449,000/year when escalated to Dec 1986 dollars.

Receiver maintenance and repair cost is assumed to be similar to fossil boiler costs, or $235,000/year in Dec 1986 dollars.

Total balance-of-plant maintenance and repair costs are estimated based on recently reported maintenance-related costs for the Newman Station escalated to Dec 1986, or approximately $561,000/year. This sum includes an additional allowance of $20,000/year in Dec 1986 dollars for additional component maintenance and repairs associated with modifications of existing unit.

The above values were distributed per O&M costs accounts for OM200 and OM300, utilizing the following assumptions:

55/45 material/labor split for all solar addition maintenance

Split between OM210 Spare Parts and OM220 Material for Repairs based on historical levels; except additional heliostat maintenance and repair materials are allocated to OM220 based on anticipated restocking capability.

No items applying to OM230 Other.

33/67 split between scheduled and corrective labor in OM300 recognizing the continuous maintenance activity required for the heliostat field.

Total annual OM200 Maintenance Materials cost is approximately $738,000 in Dec 1986 dollars. Total annual OM300 Maintenance Labor is estimated at $510,000 in Dec 1986 dollars.

Solar only Maintenance Materials, OM200, cost is $383,000 in Dec 1986 dollars, or approximately 50 percent of the account total. Solar only Maintenance Labor, OM300, is estimated at $322,000 per year in Dec 1986 dollars, or approximately 63 percent of the account total.

TABLE 4.7-1

ANNUAL PLANT OPERATION AND MAINTENANCE COSTS
(In Thousands of Dec. 1986 Dollars)

	Fossil Existing	Solar Addition	Annual Total
OM100 Operations			
OM110 Operating Personnel	382	106	488
OM120 Operating Consumables	72	17	89
OM130 Other Fixed Expenses	7	4	11
Subtotal	461	127	588
OM200 Maintenance Materials			
OM210 Spare Parts			
OM211 Turbine and Electrical Plant	10		10
OM212 Collector Equipment	0	60	60
OM213 Receiver Equipment	0	27	27
OM214 Thermal Storage Equipment	0		0
OM215 Fossil Boiler Equipment	27		27
Spare Parts Subtotal	37	87	124
OM220 Materials for Repairs	316	296	612
OM230 Other	0		
Subtotal	353	383	736
OM300 Maintenance labor			
OM310 Scheduled Maintenance	94	104	198
OM320 Corrective Maintenance	94	218	312
Subtotal	188	322	510
Total	1,002	832	1,834

TABLE 4.7-2

UNIT OPERATING PERSONNEL

Operations	Allocation of Employees Assigned to Solar Repowered Newman Unit I	Allocation of Existing Employees at Newman Unit I	New Employees For Solar Repowering of Newman Unit I
Station Superintendent	0.25	0.25	
Supervisor of Operations	0.25	0.25	
Supervisor of Maintenance	0.25	0.25	
Plant Engineer	0.25	0.25	
Station Clerk	1.25	0.25	1
Operating Shift Supervisor	1.00	1.00	
Control Operator	2.75	0.75	2
Assistant Control Operator	0.75	0.75	
Plant Equipment Operator	0.75	0.75	
Maintenance			
Electrician	3.50	1.50	2
Boiler and Condenser Mechanic	5.00	3.00	2
Maintenance Helper	3.00	1.00	2
Utility Man	0.75	0.75	
Instrument Technician	2.75	0.75	2
Chemical Technician	0.50	0.50	
Janitors and Landscaping	1.00	1.00	
	24.00	13.00	11

4.8 SYSTEM SAFETY

A preliminary review of the safety considerations for the conceptual design of the solar repowered Newman Unit 1 is reported in this section. The potential safety hazards associated with this (or any) application of solar central receiver technology are those related to the use of a large field of 2,998 heliostats to reflect sunlight to a receiver located at the top of a relatively tall tower with a centerline height of 155 m (509 feet). This review did not identify any hazards that would preclude the safe construction and operation of the solar repowered unit. The conclusions resulting from this review are:

> Recent experimental data tend to confirm the validity of analytical models used to predict the effects of sunlight reflected from heliostats and solar receivers. Safety hazards peculiar to the solar subsystem can be controlled, eliminated, or mitigated by the use of personnel protective equipment, exclusion zones, careful design and location of equipment and combustible materials, and the use of approved procedures for operation, maintenance, and emergency situations.
>
> Specific restrictions are imposed by FAA regulations on the construction of tall towers. It may be necessary to create an aircraft exclusion zone around the solar repowered facility due to the height of the tower and reflected sunlight, and this can be accomplished in cooperation with the FAA.
>
> Other safety hazards which are identified are not unique to a solar repowered facility but rather relate to mature technology typically used in the electric utility industry. These hazards can be controlled, eliminated or mitigated using standard utility industry safety practices and by applying existing codes, regulations and standards.

4.8.1 Technical Approach

The technical approach employed to develop and evaluate preliminary health and safety considerations consisted of (1) reviewing the system safety analyses reports prepared for the Central Receiver Test Facility (CRTF) in Albuquerque, New Mexico and the Barstow Pilot Plant at Barstow, California and (2) identifying potential hazards and the corresponding subsystem(s) in which these hazards can occur. This approach results, in most cases, in identifying possible causes for the hazardous conditions and specific corrective actions to be pursued to mitigate the severity or frequency of occurrence, or to eliminate the hazard entirely. A complete health and safety assessment of the solar facility at EPE Newman Unit 1 will be required in subsequent phases of this program. This assessment will be based on the final design of the solar subsystem as well as on the specific components and working fluids selected for the solar repowered unit.

In developing an approach to specifying the health and safety considerations appropriate to the solar repowering program, several items will need to be delineated and/or evaluated: 1) the objectives of the health and safety program, 2) the applicable design guidelines, requirements, and regulations for health and safety, many of which have already been identified for the Barstow Plant, 3) the types of hazards which need to be considered during the subsequent phases of the program, and 4) the definition of a recommended set of safety related categories to be utilized in the analysis. A detailed health and safety analysis which will need to be performed will treat the following types of hazards associated with the solar repowering application: solar reflectance, working fluid (steam and hot water), electrical, mechanical, malfunction, and maintenance hazards.

In addition, several other potential problems which extend beyond the normal health and safety of operating personnel will require investigation. These include a) the health and safety considerations of the general public, as well as visitors to the facility, b) transportation (both vehicular and airline modes) and its impact on safety, and c) the environmental and reliability considerations.

4.8.2 Literature

A number of reports have been issued that address the safety aspects that are unique to the application of a solar central receiver system. The primary reports of interest to the solar repowering of Newman Unit 1 are:

- Barstow Pilot Plant System Safety Analysis, prepared by McDonnell Douglas for the U.S. Department of Energy, SAN/0499-55, December 1980 Revision.
- Safety Plan, 10 MWe Solar Central Receiver Pilot Plant, U.S. Department of Energy Memorandum, February 19, 1982
- Haus, S.; Duncan, L.; Alkon, P; and Pratt, J.; The MITRE Corporation. Preliminary Environmental Assessment Concerning the Construction and Operation of a 5-MW Solar Thermal Central Receiver Test Facility. MITRE Working Paper 11290, November 1975.
- Brumleve, T.D. Sandia Laboratories, Livermore. Eye Hazard and Glint Evaluation for the 5-MWt Solar Thermal Test Facility. SAND 76-8022, May 1977.
- Young, L.L., III, Sandia Laboratories, Albuquerque. Solar Energy Research at Sandia Laboratories and Its

Effects on Health and Safety. SAND 77-1412, October 1977.

These reports were reviewed in establishing the design guidelines presented in the following section.

4.8.3 Design Guidelines

Numerous codes and regulations such as the U.S. Department of Energy Directive 5481.1, dated 3-20-79 and entitled, Safety Analysis and Review System for DOE Operations are applicable to the health and safety considerations of the solar repowered Newman Unit 1. Special attention was devoted to the design of the solar collector (heliostat) field and the central receiver/tower subsystems because of the relatively less mature technology of these components compared to the existing Newman Unit 1 equipment. The electrical power generation subsystem (consisting of piping, components, controls, and wiring for fluid power and electrical power generation), the fossil boiler subsystem, and the auxiliary subsystems are based on a more mature technology and, in fact, are mostly in existence at Newman Unit 1. Accordingly, the applicable codes and standards which are now available for the electrical power generation and auxiliary power subsystems are to be observed for the new construction or modifications to these subsystems. These same codes and standards, appropriately applied, can serve to ensure safe design of the components and subsystems unique to solar repowering.

An extensive list of standards, regulations, manuals, and codes includes:

American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code:

Section I, Power Boilers

Section II, Material Specifications

Section V, Nondestructive Examination

Section VIII, Pressure Vessels

Section IX, Welding and Brazing Qualifications

National Fire Protection Association (NFPA):

Fire Protection Handbook

National Fire Protection Association (NFPA) National Fire Codes (NFC):

Volume 2, Water Spray Fixed Systems

Volume 5, Explosion Prevention Systems

Volume 6, National Electrical Code

American National Standards Institute (ANSI):

ANSI A13.1, Scheme for the Identification of Piping Systems

ANSI A17.2, Elevators

ANSI A58.1, Building Code Requirements for Minimum Design Loads in Buildings and Other Structures

ANSI B31.1, Power Piping Code

ANSI Z53.1, Safety Color Code for Marking Physical Hazards and Identification of Equipment

Occupational Safety and Health Administration (OSHA):

OSHA 2206, General Industry Standards

American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE):

ASHRAE Standards for Design of HVAC Equipment

ASHRAE Standard 90-75, Energy Conservation in New Building Design

Air Conditioning and Refrigeration Institute (ARI):

Standards for Cooling Towers and Condensers

National Board of Fire Underwriters (NBFU):

Codes for Buildings and Equipment

National Electric Manufacturers Association (NEMA):

Standards for Electrical Equipment and Controls

Safety Rules for the Installation and Maintenance of Electric Supply and Communication Lines

Steel Boiler Institute (SBI):

Codes for Boilers

Tubular Exchanger Manufacturers Association (TEMA):

Standards for Heat Exchangers

Underwriters' Laboratory (UL) Standards

Uniform Building Code

Standards of American Institute of Steel Construction and American Concrete Institute

Interstate Commerce Commission (ICC) Shipping Standards and Regulations

National Safety Council

Accident Prevention Manual for Industrial Operations

Federal Aviation Authority Advisory Circular 79/7460-1E

American Society of Mechanical Engineers (ASME) Requirements

Pressure Relief Devices UG-125, 126, 129, 131, 132, 133, and 134.

Pressure Vessel Tests UG-99

4.8.4 Solar Reflectance Hazards

Several different hazardous conditions could result from the effects of concentrated solar insolation or reflectance from individual or multiple heliostats in the collector subsystem. Thus, a potential safety hazard associated with the solar repowering site could stem from emergency or accidentally misdirected solar radiation. This concentrated and focused solar radiation can potentially cause fires and burns as well as create glare problems. At the focal point, there is a concentrated beam of focused radiation. Beyond the focal point, this beam becomes increasingly dispersed and eventually becomes more diffuse than the original solar radiation. So there is a range around the focal point where the beam is concentrated to a degree that causes potential safety hazards of fires, burns, and glare.

A severe eye hazard exists for those personnel whose eyes are looking at, and happen to be located near the focal point of, several heliostats during periods of sunshine. Depending upon the concentration ratio for these heliostats and the eye location, temporary "flash" blindness or permanent blindness (from the burn damage to the choroid and retina of the eye) can occur. A glare hazard may also exist when personnel are located in or near the collector field. As discussed above, a glint or glare hazard is also a safety consideration to the general public outside and above the boundaries of the solar repowered facility.

A skin hazard (concentrated sunburn) is also a consideration for the design of a solar central receiver system. Although the above-mentioned eye hazard is more critical, serious burns from concentrated insolation (reflectance) could occur near the focal point. However, multiple sun intensities would be sufficiently uncomfortable on the skin that evasive action would probably be taken immediately.

While not as hazardous as burns or fire, glare is a potential problem resulting from misaligned or even properly aligned heliostat collectors. This is due to its ability to impact both onsite and offsite human eye receptors including those in overflying aircraft. The intensity of this glare will be a function of the distance of the receptor from the heliostat field or individual heliostats producing the glare. As this distance increases, the intensity of the glare will decrease.

Nuisance glare and glint caused by reflected sunlight from the heliostats may affect future nearby residents, aircraft pilots and passengers, highway travelers, station personnel, and visitors.

Several studies have been conducted that describe the potential environmental and safety hazards that exist for solar plants. One of the safety considerations most frequently cited is variously termed distractive glint, nuisance glare, misdirected light, or spurious reflections. These can result during normal operations, from misaligned heliostats, or during mirror washing operations. The impact can range from nuisance glare and brief temporary blindness to serious skin burns and permanent eye damage, depending on the proximity and length of exposure. The occurrence of these impacts will depend upon the proximity of the field to residences and traffic corridors, upon the terrain, and upon the presence of other structures within the line of sight, as well as the orientation of the heliostats. Several mitigating measures can be taken, when proven necessary, that will eliminate or greatly reduce these potential hazards or annoyances. For example, fencing or vegetative screening can be used to surround the heliostat collector field to prevent nuisance glare or glint to residents and motorists.

Most of the above solar reflectance hazards are of concern primarily to the construction, testing, operating and maintenance personnel, and visitors to the solar repowered facility. Techniques which might be used to eliminate, mitigate, or reduce the frequency of these potential hazards include the use of fencing to enclose the collector field; requiring eye protection, protective clothing, and/or gloves when working near the heliostat collector field or the receivers at the top of the tower; proper instruction of personnel on the methods to avoid these hazards; proper design of the controls for the collector subsystem (particularly for quick and safe emergency shutdown conditions); storing combustible materials in places inaccessible to misdirected radiation; and the use of safety and warning devices or signs.

4.9 ENVIRONMENTAL CONSIDERATIONS

A summary of the major environmental considerations associated with the solar repowering of Newman Unit 1 is presented in Section 4.9.1. Section 4.9.2 describes site characteristics pertinent to these major considerations. The descriptions are preliminary and are based on currently available data.

Sections 4.9.3 and 4.9.4 discuss the environmental impacts, which can be identified at this stage of the project, resulting from both construction and operation. Only potential major impacts related solely to the solar aspect of the facility are considered, since any impacts induced by actions relative to the remainder of the station are beyond the scope of this study.

4.9.1 Summary of Major Environmental Considerations

Preliminary assessments have been made of major environmental considerations using available information and preliminary conceptual designs. It appears, at present, that there will be no major environmental impacts resulting from construction or operation of solar repowered Newman Unit 1. Because information to address some environmental aspects is presently lacking, these items will be reviewed and evaluated after future data collection has been completed. However, it is considered extremely unlikely that any environmental impacts would preclude development of the demonstration facility.

The major environmental considerations can be summarized as follows:

Air Quality - Operation of the solar powered unit will result in a net reduction in air emissions associated with burning 475 - 525 x 10^{12} J/year (450-500 x 10^{9} Btu/year) of natural gas or oil at the Newman Station and will thus have a positive effect on local air quality.

Hydrology - Additional consumptive water use will consist only of domestic use for station personnel and for heliostat cleaning. Surface water flows through the heliostat field area will be rerouted. This will not adversely affect local hydrology or other local water users.

Water Quality - No new liquid discharges are anticipated from the solar repowered facility.

Vegetation - Vegetation will be cleared from approximately 1.09 km^2 (269 acres) at the heliostat field site; however, the species present are not unique to the region and do not represent critical habitat.

Endangered Species - Based on available information, no endangered or threatened species of plants or animals are known to occur on the site; some endangered birds may pass through the area during seasonal migration.

Land Use - Land is available for construction of the heliostat field; future land use plans do not conflict with the proposed project.

Socioeconomics - It is anticipated that the necessary craftsmen will be available locally and will not strain existing services. Positive benefits will include added wages and salaries, tax revenues, and decreased unemployment (within a Surplus Labor Area). Local traffic congestion near Newman Station may occur during construction; however, during construction of the existing unit, this has been a minor inconvenience.

Archaeology - Numerous archaeological sites are indicated in the area proposed for the collector field. Although some survey work has been completed, the significance of the sites is not known (though expected to be minor) at this time and will require a subsequent field study.

Aesthetics - The collector field will be visible for only a few miles in this undeveloped industrial area and should not represent a major visual impact. Concerns related to possible ground glare have been reviewed and are considered minimal. The primary receiver centerline height is 155 m (508 feet) and will be visible over the flat terrain for about 8 km (5 miles), and will represent an intrusion in the viewscape. Radiated and reflected light from the north facing receiver will be directed north, away from the more populated areas to the south of the site. The existence and design of the tower should not preclude the licensability of the project.

4.9.2 Environmental Site Description

The following description of the Newman Station site and immediate vicinity is based on available information from a variety of sources. This information serves as the basis for impact identification and assessment described in subsequent sections. Where present information has proven insufficient to allow evaluation of potentially major impacts, an indication is given of further studies that should be conducted prior to seeking necessary permits.

4.9.2.1 Site Location

The four-unit Newman Station is located in a rural area 24 km (15 miles) northeast of downtown El Paso. The existing site is bounded on the north by Farm to Market Road 2529 and on the west by War Road. Surrounding Newman Station, more than 14.2 km^2 (3,500 acres) of land owned by the El Paso Water Utilities Public

Services Board are available for placement of heliostat field(s). The land is basically flat and well suited for the anticipated use.

4.9.2.2 Hydrology

A small quantity of ephemeral surface water flow occurs in several arroyos draining from the Franklin Mountains west of the site. A shallow (less than 0.3 m) arroyo passes through the proposed solar collector field. This arroyo drains Hitt Canyon and has about a 10.4 km² (4 sq mile) drainage area west of War Road. A playa (a shallow central basin of a desert plain in which water gathers after a rain and is evaporated) is located near the eastern edge of the field.

Subsurface water is present and is currently tapped by four wells to satisfy water needs at Newman Station.

4.9.2.3 Ecology

The following descriptions of the terrestrial ecosystem of the proposed heliostat field are derived from a site visit made in March 1980 by an SWEC ecologist, a visit by Dr. R. D. Worthington, and from available information.

General Site Characteristics

The site is located in the Hueco Bolson, a nearly level (0.5 to 20 percent slope) basin-like area of moderate to deep soils and unconsolidated sediments (DPRD, 1979). Soils at the site are part of the Turney-Berino Association which has a moderately alkaline calcareous surface layer composed of sandy loam and loam below (U.S. Soil Conservation Service, 1971). The heliostat field, approximately 1.09 km² (269 acres), represents about 0.001 percent of the 1,100 km² (270,000 acres) of similar soils and geography in the county. The climate in El Paso is dry with wide temperature fluctuations and low rainfall (see Section 2.5). The area historically was a desert grassland but overgrazing and drought have created undulating dune and desert shrub communities (DPRD, 1979).

Flora

The dominant species on the site are creosote bush (Larrea tridentata) and range ratang (Krameria pavifolia). Other shrubs and native grasses are found only sparingly and generally indicate an increase in species adapted to disturbed sites (Table 4.9-1). Plant groups similar to those found on the site are found throughout the undeveloped areas of the Hueco Bolson (DPRD, 1978).

Fauna

Wildlife in the site area has not been comprehensively surveyed; however, a variety of animal species are likely to occur there. Mammals likely to be found include the kangaroo rat (Dipodomys sp.), jackrabbit (Lepus californicus), coyote (Canis latrans), bobcat (Lynx rufus), mule deer (Odocoileus hemionus), and many small rodents (Table 4.9-2). The most conspicuous of the birds include the mourning dove (Zenaidura macroura), Gambel's quail (Lophortyx gambelii), blue quail (Callipepla squamata), road runner (Geococcyx californianus), eagles (Aquila chrysetos and Haliaeotus leucocephalus), sparrow hawks (Falco sparverius), marsh hawk (Circus cyaneus), vultures (Cathartes aura), loggerhead shrike (Lanius ludovicianus), and crows (Corvus brachyrhynchos).

There are no species of federally or state listed endangered or threatened animals known to use the site as nesting or breeding areas and no critical habitat has been designated in the general site area (Bryant, 1980; U.S. FWS, 1978; U.S. FWS, 1979). The American peregrine falcon (Falco peregrinus var. anatum) may use the site on occasion for nesting but the species' primary range in the area is along the Rio Grande (Halverson, 1980).

Of the species most likely to be found on the site, mourning dove, quail, and mule deer may be taken during the hunting season (Texas Parks & Wildlife, 1979-1980). However, the site used for the heliostat field is private property and it is unlikely that hunting will be permitted in the vicinity.

Sensitive areas

The ecologically sensitive area nearest to the site is the Franklin Mountains State Park located about 3 km (2 miles) to the west. The state park, which encompasses about 89 km² (22,000 acres) of the Franklin Mountains Range, was established to preserve the relatively pristine condition of the northern canyons and slopes (DPRD, 1978). Efforts are continuing to acquire additional privately owned mountainous land for inclusion in the park boundaries.

4.9.2.4 Socioeconomic Considerations

The City of El Paso is divided into five Planning Areas; the proposed facility will be located in the Northeast Planning Area (NPA). Data for the NPA, the County, and the City were analyzed. Emphasis has been put on county-wide and NPA considerations since socioeconomic impacts generated by construction and operation of this facility will affect the County as a whole and the NPA in particular.

4.9.2.4.1 Demography

A review of the area's demographic data shows it has experienced rapid growth since 1970. The U.S. Bureau of the Census reported a 1980 population of 479,899 (an increase of 34 percent) for El Paso County and 425,259 (an increase of 31 percent) for the City of El Paso. The El Paso Department of Planning, Research, and Development estimated the January 1, 1982 population of the county to be 486,700 and 431,500 for the city (El Paso PRD, 1982).

The NPA had a 1970 population of 55,337 and, as of January 1, 1981, was estimated to have a population of 75,398 (El Paso PRD, 1980), an increase of 36 percent.

The county's population is projected to reach about 535,000 in 1985 and 585,000 in 1990; the city's projected population for the same years is 475,000 and 525,000; and the NPA's projected population for 1985 is 86,400 and 99,800 for 1990 (El Paso PRD, 1980 and 1981).

Since 1960, population in the NPA has increased at a higher rate than the city's average, so that an increasingly larger portion of the city's population lives in this Planning Area. This high growth rate is likely to be sustained by completion of the North-South Freeway and development of the Castner Range properties. An additional growth factor is this area's availability of large parcels of land and the relatively level terrain (El Paso PRD, 1978). Surveys in 1982 ranked the El Paso metropolitan area as at least the sixth fastest growing area in the United States.

4.9.2.4.2 Employment

The civilian labor force for El Paso County as of January 1982 numbered 173,450, with 157,300 employed and 16,150 unemployed, giving an average unemployment rate of 9.3 percent (El Paso Area Fact Book, 1981-1982). Manufacturing accounted for 23 percent or over 35,000 jobs of the total employment in 1981; contract construction accounted for more than 8,000 jobs in 1981. El Paso is designated as a Surplus Labor Area by the U.S. Department of Labor.

4.9.2.4.3 Land Use

The site is located in a vacant/undeveloped portion of the 197.9-km² (48,900-acre) NPA. Vacant land comprises 88 percent of the acreage in the NPA, including the Franklin Mountains State Park. The NPA Land Use Plan, however, proposes that 22 percent of this land (39 percent of the usable land) be developed as low density residential areas by the year 2000 (DPRD, 1981).

A working sand quarry is located approximately 1.6 km (1 mile) north-northeast of the proposed site, a sanitary landfill is about 2.4 km (1 1/2 miles) northeast, and a natural gas pumping station is about 3.2 km (2 miles) north-northeast. Most of the projected industrialization in the vicinity of the site will be to the north and east of the Texas-New Mexico border (1.6 km north of Newman Station) (Land Use Plan, 1978).

The nearest residences are a ranch approximately 2 km (1 1/4 miles) north and a small New Mexico residential development about 3.2 km (2 miles) north-northeast. Projected low density residential development will be to the south, southwest, and southeast of the site (Land Use Plan, 1978).

Commercial land use in the NPA is less than the city-wide average. Approximately 2.4 km² (600 acres) of commercial development are proposed to serve the projected population. Industrial development is also below the city-wide average. However, it is anticipated that completion of the North-South Freeway will increase commercial and industrial land use and improve the movement of truck traffic, a problem which now exists (Land Use Plan, 1978).

4.9.2.4.4 Historical and Archaeological Sites

There are 13 historic sites in El Paso and the surrounding area listed in the National Register of Historic Places, February 6, 1979. Three more were added as of March 18, 1980 (Federal Register, 1979-1980). None of these sites is located on or near the site of the proposed facility and therefore should not be impacted by the facility.

The NPA has been found to contain approximately 10 to 15 sites of archaeological significance per 2.6 km² (per mile²). The sites contain artifacts such as pottery, tools, chipped stone and grinding materials, dwelling foundations, and hearth areas (Land Use Plan, 1978; Telecon Dr. R. Gerald, 1980).

In February 1979, the El Paso Archaeological Society, through the Texas Antiquities Committee, contracted with the Public Service Board (PSB) to conduct a surface archaeological survey on PSB land between War Road and Dyer Street (U.S. Highway 54). The work under this contract (Permit No. 200) consists of collecting samples, mapping, photographing, and recording the archaeological finds (Land Use Plan, 1978; Telecon J. Hendrick, 1980). No excavation work is being undertaken for this survey (El Paso Park Plan, 1978). At the present time, over 40 archaeologically significant sites and numerous scattered artifacts have been found near the site (Telecon J. Hendrick, 1980). As of September 1979, the Archaeological Society had located 15 sites between War Road 1.2 km (0.75 mile) west of site and McCombs Street 2.0 km (1.25 miles) east of site. It is anticipated that a report detailing the results of this survey was published by the end of 1980 (Telecon J. Hendrick, 1980).

It is not known what type of artifacts are located within the site boundaries; however, the abundance of significant sites in the area indicates that onsite archaeological finds are likely. Therefore, prior to commencement of construction activities, a detailed survey, with excavations, will have to be performed.

4.9.2.4.5 Community Services

Community services are those that serve the general public; i.e., schools, recreation facilities, police and fire protecton, hospitals, etc.

El Paso County has nine school districts with a total 1981-1982 enrollment of 119,278 (El Paso Fact Book, 1981-1982). Three school districts are located in the NPA and, as of October 1981, this enrollment was 21,666. It is anticipated that by the year 2000, the NPA will require approximately double the existing school facilities (DPRD, 1976). El Paso County has 21 private schools with a 1981-1982 enrollment of 5,817 (El Paso Fact Book, 1981-1982). Three institutions of higher education are located in El Paso.

The El Paso park system has a total of 13 km² (3,190 acres) of developed and undeveloped recreation facilities (El Paso Park Plan, 1978-2000). The NPA has 3 district parks and 13 neighborhood parks, all offering varied recreational activities. Additional park and recreational facilities are planned throughout El Paso County between now and the year 2000, including the development of the Franklin Mountains State Park. Additions to the NPA park system include, but are not limited to, further development of existing parks, development of new neighborhood parks and hiking trails (DPRD, 1981).

El Paso County has 1 public and 14 private hospitals. Area fire protection is provided by the City of El Paso Fire Department. There is a County Sheriff's Department, and police protection is provided by the City of El Paso Police department (El Paso Fact Book, 1981-1982).

4.9.2.4.6 Transportation

The proposed solar repowering site is immediately north of Farm to Market Road 2529, a local two-lane east-west road which is not heavily traveled. War Road is about 1.2 km (.75 miles) west of the site and McCombs Street is about 2 km (1.25 miles) east. Both these roads are major two-lane north-south highways. The 1980 Average Daily Traffic Count (ADT) for War Road was 2,830; the ADT for McCombs Street was 2,600 (Texas Department of Public Safety, 1982).

Extensive expansion of the transportation network is planned for the NPA. The completion of the North-South Freeway, which will bisect the northern portion of the Planning Area southwest to northeast, will reduce travel time within the NPA. Interchanges are planned for War Road and McCombs Street, as well as at arterial roads planned for the residential areas (DPRD, 1978). These improvements will increase development opportunities for this area through increased accessibility.

There are three airports in and around El Paso (El Paso Fact Book, 1981-1982). El Paso International Airport is almost 19.3 km (12 miles) southeast of the site, adjacent to Biggs Army Air Field and Fort Bliss. A landing strip associated with the McGregor Guided Missile Range in New Mexico is about 16.1 km (10 miles) northeast. A landing strip 4.8 km (3 miles) south-southeast is presently used only for skydiving and radio-controlled model planes.

4.9.3 Environmental Impacts of Construction

During the construction phase of the solar repowering project, the potential exists for a variety of environmental impacts to occur. Many such impacts are limited by local, state, or federal regulations and others can be mitigated by careful planning and use of control technologies. The following sections identify and describe to the extent possible potential major construction impacts.

4.9.3.1 Effects on Air Quality

The most significant air quality impact of the construction phase is related to fugitive dust formation due to clearing and regrading activities. Fugitive dust is defined as particulate matter that becomes airborne due to natural causes and/or human activities. According to Prevention of Significant Deterioration (PSD) regulations, the impacts of emissions during the construction phase of a project are exempted from PSD review and do not have to be quantified using mathematical models. These emissions will only be temporary and can be minimized by employing control measures such as surface wetting and reducing vehicle speeds in the area.

The emissions from construction equipment can be minimized by proper operation and maintenance procedures and should not significantly affect the air quality in the area.

4.9.3.2 Socioeconomics

4.9.3.2.1 Land Use

The area designated for the collector field is presently vacant/undeveloped land, owned by the Public Service Board (PSB). No homes or other buildings will have to be relocated, purchased, or destroyed.

An irrigation system, installed by EPE and using water from the present Newman Station evaporation pond, makes the land usable as a leased grazing area for cattle from a nearby ranch. This irrigation system will be moved to another portion of land nearby; thus, a grazing area will still be available.

The PSB has agreed that if EPE notifies them that the land is needed for the solar project, the PSB will offer the required acreage in one parcel. This land will be offered pursuant to the public notice and bidding procedures required by law (Letter to R.E. York, 1979).

An existing El Paso Gas Company pipeline which traverses a portion of the site will not be moved as it would not be cost-effective to do so. A right-of-way of 36.6 km (120 feet) will permit access to the pipeline. The existing north-south EPE transmission line will be moved to the west side of War Road. The existing east-west transmission line and a transmission line to be added in the near future will be along the southern boundary of the site.

F.M. 2529 will be rerouted north of the site. The existing road will be closed possibly where it intersects with War Road west of the site and with an unpaved road to the east, between the site and McCombs Street. EPE and the Texas Highway Department have discussed the rerouting of F.M 2529 and, although plans have not been finalized, no problems are anticipated.

A perimeter road will be constructed around the site. This will connect with the closed portions of F.M. 2529 and will be a service road for use by authorized personnel only. To prevent large animals from wandering onto the site, a fence will be constructed 60 m (200 feet) outside of the perimeter road.

An archaeological survey of the site, performed prior to construction, will ensure no loss of potential archaeological information.

4.9.3.2.2 Work Force

The peak work force will be approximately 400 workers onsite. This peak work force will be maintained for most of the construction activities.

Construction of this facility should not create any long-term, adverse socioeconomic impacts. This conclusion is based on several factors relating to the overall population of El Paso, which includes the size of the civilian labor force, percentage of local unemployment, size of the construction work force required, and duration of the construction period.

With the average size of El Paso's civilian labor force at 173,500 with a 9.3 percent unemployment rate, it is possible to conclude that most of the 400 construction workers will be from the local area.

There should not, therefore, be a large influx of people from outside El Paso. Some specialized construction workers, technical people, and project management personnel may move into the area, but the number will be small. Since El Paso will easily be able to absorb these people, adverse impacts on community services should be minimal.

The sanitary waste system at the existing Newman Station may be expanded during construction in order to accommodate some of the work force although it is planned to contract this service.

Positive socioeconomic effects include increased tax revenues through wages and salaries, employment of several hundred workers in an area where unemployment is high (9.3 percent), and additional secondary jobs created through a multiplier effect during construction.

4.9.3.2.3 Transportation

During construction, traffic congestion generated by the commuting work force and by movement of construction materials may be a significant impact. Since an accurate assessment of transportation impacts cannot be made at this time, it is recommended that a transportation study be undertaken prior to construction. A study of this type will survey the roads and highways by which the work force will travel to and from work; present the associated problems; and present recommendations that will alleviate and/or possibly eliminate potential problems.

4.9.3.3 Effects on Aesthetics

The visual impacts associated with construction activities will be of a short-term duration and should be minimal. There are no homes immediately adjacent to the site, therefore construction activities will be visible primarily to people traveling on War Road as it is close to the site. Construction of the facility will be visible from McCombs Street but due to the distance which is over 1.6 km (1 mile), and due to duration of viewing time, the impact should be minimal.

4.9.3.4 Ecological Effects

Ecological impact to the site during construction will be both biotic and abiotic in nature. The most immediate impact will result from the physical removal of the vegetation on the site. This will involve the loss of about 1.09 km² (269 acres) of desert shrub community and the associated animal populations. Depending on the manner in which the surface of the heliostat field is maintained (paving, gravel, chemical stablizers, or vegetation), this loss will last from several years to the life of the facility. The severity of this impact, however, should be small as the level of productivity of the land at this time is low, due to desert conditions, and the amount of land lost is small compared to the extensive desert in this area.

Other factors including soil compactions, erosion, and fugitive dust will also impact the terrestrial ecology of the site. For each of these factors, environmental control techniques can be utilized during construction which should limit any impact to acceptable levels.

4.9.3.5 Hydrological Effects

For flood protection, a preliminary drainage system for the solar collector field was designed for the 100-year intense rainfall runoffs. The arroyo, which presently passes through the proposed solar collector field, will be displaced northward to clear the field as shown in Figure 5.7-2. The diversion will be accomplished by a channel with a bottom width of 12.2 m (40 feet) and a depth of 1.2 m (4 feet) at the War Road bridge over the arroyo. The bottom width and the depth will be increased and decreased to 30.5 and 1.1 m (100 and 3.5 feet), respectively, at the intersection of the existing R.O.W. and the new perimeter road. The channel is designed for a peak flow of about 28 m^3/s (1,000 cfs) caused by an intense rainfall of 43 mm/hr (1.7 inches/hr) for approximately 1 1/2 hours duration. The channel will be about the size of the natural arroyo. The flow in the channel is expected to be slightly increased by the fact that the flow inside the perimeter road will be drained into the channel. The impact on the change of siltation rate is expected to be minimal.

The flow in the solar collector field will be channeled by several shallow ditches which will be 0.6 m (2 feet) deep and 3.05 m (10 feet) wide. The shallow ditches will discharge into collection ditches 0.9 m (3 feet) deep and 6.1m (20 feet) wide located along the perimeter road. The flow will then be discharged by a total of ten 1.5 x 0.9 m (58 x 36 inch) corrugated arch-pipe culverts under the perimeter road. Each culvert is estimated to be approximately 24.4 m (80 feet) long. The ditches will have a 3 to 1 side slope and will be lined with a 0.1-m (4-inch) gravel layer.

The ditch culvert system is designed to drain a total peak flow of about 400 cfs from the field subject to an intense rainfall of 5 inches/hour for 15 minutes duration. Erosion downstream of the culverts may increase due to the concentration of flows at the culvert outlets.

In general, construction activities will slightly alter some surface drainage patterns and may temporarily increase runoff and siltation over the construction area. Drinking water and other water needed for construction will be supplied by existing wells.

4.9.4 Environmental Impacts of Operation

The following sections discuss unique impacts resulting from operation of the solar repowered facility. As noted, impacts may be both positive and negative.

4.9.4.1 Air Quality Impacts

Solar repowering will have a beneficial impact on air quality in the region due to the displacement of fossil fuels with solar power. The resultant reduction in pollutant emissions will reduce the air quality impact by the same percentage. Table 4.9-3 presents the estimated reductions in annual air pollutant emissions from Newman Unit 1 resulting from the operation of solar repowered Newman Unit 1.

In regard to possible climatic effects of solar repowering, it has been theorized that a large heliostat field could produce changes in temperature, wind patterns, humidity, and turbulence characteristics (see Section 4.9.4.4). Although these effects cannot be quantified at this time due to a lack of field data, any effect of the heliostat field would be confined to the microclimate in the immediate vicinity of the field and should not noticeably alter the larger scale climatic features that govern pollutant transport and diffusion. Therefore, the presence of the heliostat field is not expected to alter the local climate in the site area and should not affect the dispersion of pollutants from the stacks and subsequently the air quality impact of the station.

4.9.4.2 Socioeconomic Effects

Land Use

The use of approximately 1.09 km^2 (269 acres) for this facility will preclude the land from being used for other purposes for which it may be suitable. Since the existing Newman Station will be immediately adjacent to the solar facility and since the land use proposed for the area is industrial, the potential for land use conflict is slight. The land between the facility and proposed residential development is classified as vacant/underdeveloped and will serve as a buffer zone between the two uses.

Work Force

The operating work force for this facility will be equivalent to 24 full-time employees. When considering the area's growth, this is small when compared to the overall population and the total labor force. The operating work force will not cause any adverse socioeconomic impacts.

Positive socioeconomic benefits from this facility will be increased tax revenues through taxes on wages and salaries, personal property taxes, and sales tax.

4.9.4.3 Aesthetic Effects of Operation

The proposed solar project will be adjacent to the EPE's Newman Station which has a 45.7-m (150-foot) stack visible for several miles, and a plume that is visible for approximately 1.6 km (1 mile).

Since the area is already industrial, the proposed solar facility will not change the general visual character. The solar facility's tower will, however, be more visible than the existing stack because of its greater height. As a result, this will create a new dominant feature in the viewscape for viewers within an 8 km (5-mile) radius. Reradiation and reflection from receiver and beam characterization system screens will be visible only to the north of the site, not from the more populated areas to the south.

The terrain in this area is relatively level and the heliostat field will also be visible from residences and highways which have a long viewing range. From distances beyond 3.2 km (2 miles), the heliostat field will be a small portion of the total viewshed and, therefore, will not be a dominant visual feature.

Since the proposed facility will be a visual intrusion on the natural landscape and since the tower will be a dominant feature in the area, a visual study may be required.

4.9.4.4 Ecological Effects

The impacts of operation will depend to a large extent on the form of surfacing used within the heliostat field. Any approach except revegetation, i.e., paving, gravel, or chemical stablizer, will result in the elimination of essentially all flora and fauna from the site. Proper maintenance of these surfaces should preclude the possiblity of impact from dust or erosion, although erosion offsite may still occur.

Should revegetation of the site be used, both shading and wind deflection by the heliostat should be considered. The presence of the heliostat in the field will, by design, reflect a large percentage of the solar radiation. The shade produced by the heliostat may cause a decrease in temperatures, an increase in soil moisture, and, as a result, an increase in plant diversity and biomass (Patten, 1977). Wind deflection by the heliostat over the area of the field may also result in increased soil moisture. Recent work by Patten and Smith (1979, unpublished manuscript) supports these possibilities.

4.9.4.5 Hydrological Effects

As noted in Section 4.9.3.5, surface water drainage will be slightly modified during operation of the facility. No permanent water bodies are affected and the existing arroyo has simply been rerouted around the heliostat field. Thus, the basic drainage pattern in the region is maintained and any percolation of rainfall into the ground has not been precluded in the area of the heliostat field. Minor changes in the rate of runoff or percolation may occur as a result of the presence of gravel rather than the exiting sandy loam. The impact of the minor alteration of the surface drainage system on the groundwater replenishment is expected to be insignificant (Worthington, 1980).

4.9.5 References

Bryant, Debbie. Letter. Texas Parks and Wildlife, Resources Protection Department, Austin, Texas. February 25, 1980.

Department of Planning, Research and Development (DPRD), 1980. City of El Paso, Texas.

Department of Planning, Research and Development (DPRD), 1981. City of El Paso, Texas.

Department of Planning, Research and Development (DPRD), 1978. Environmental Report, City of El Paso, Texas.

Department of Planning, Research and Development, 1979. Land Use Plan, Northeast Planning Area. City of El Paso, Texas.

El Paso Area Fact Book, 1981-1982 Edition. El Paso Industrial Development Commission, El Paso, Texas.

El Paso Park and Recreation Plan, 1978-2000. Department of Planning, Research, and Development, City of El Paso, Texas, 1978.

Federal Register - February 6, 1979 and March 18, 1980. Department of the Interior, Heritage Conservation and Recreation Service, National Register of Historic Places.

Halvorson, Gary L. Telephone conversation, U.S. Fish and Wildlife Services, Albuquerque, New Mexico. February 12, 1980.

Land Use Plan, Northeast Planning Area, El Paso Comprehensive Plan - 1978. Department of Planning, Research, and Development, City of El Paso, Texas.

New Mexico Environmental Institute, 1974. An Environmental Impact Study of Proposed 345 kV Power Transmission Line Corridor From Dona Ana County, New Mexico to Greenlee County, Arizona. Prepared for El Paso Electric Company.

Patten, Duncan T. 1977. Solar Energy Conversion: An Analysis of Impacts on Desert Ecosystems. U.S. Department of Energy Report C00/4339-1.

Patten, Duncan T. 1978. Report on the Workshop on Ecological Impacts of Solar Energy Conversion. U.S. Department of Energy Report C00/4339-4.

Patten, Duncan T. and Smith, Stanley D. 1979. Report to The Laboratory of Nuclear Medicine and Radiation Biology/U.C.L.A. University of California (manuscript - may not be quoted without approval).

Population Report - El Paso Comprehensive Plan - 1980. Department of Planning, Research, and Development, City of El Paso, Texas.

Population and Housing Trends. City of El Paso Department of Planning, Research, and Development, April 1981.

Telephone communication with Dr. R. Gerald, Archaeology Department, University of Texas at El Paso, El Paso, Texas. February 29, 1980.

Telephone communication with J. Hendrick, El Paso Electric Company, El Paso, Texas. March 31,1980.

Telephone communication with Texas Department of Public Safety. April 9, 1982.

Texas Parks and Wildlife Department, A Guide to 1979-1980 Texas Hunting and Sport Fishing Regulations.

U.S. Fish and Wildlife Service 1978. Threatened and Endangered Species of Texas. U.S. Department of the Interior.

U.S. Fish and Wildlife Services 1979. Endangered Species of Arizona and New Mexico 1979. U.S. Department of the Interior.

U.S. Soil Conservation Service, 1971. Soil Survey - El Paso County, Texas. Supt of Documents, U.S. Govt Printing Office.

Worthington, R.D., Letter. The University of Texas at El Paso, El Paso, Texas. April 13, 1980.

Letter to R.E. York, Sr. Vice President, El Paso Electric Company from J.T. Hickerson, General Manager, El Paso Water Utilities Public Services Board. April 25, 1979.

TABLE 4.9-1

PLANTS OCCURRING IN THE AREA OF THE NEWMAN POWER PLANT SITE

Scientific Name	Common Name	Origin	Source
AMARANTHACEAE (Amaranth Family)			
Amaranthus cf. palmeri Wats.	Palmer Amaranth	N	1
ANACARDIACEAE			
Rhus microphuila	Little-leaf Sumac		2
BORAGINACEAE (Borage Family)			
Cryptantha sp. (poss. two species)	__________	N	1
Heliotropium greggii Torr.	Fragrant Heliotrope	N	1
Lappula redowskii (Hornem.) Greene	Flatspine Stickseed	N	1
CACTACEAE (Cactus Family)			
Opuntia phaeacantha Engelm.	Brownspine Prickly Pear	N	1
Opuntia violacea Engelm.	Purple Prickly Pear	N	1
Yucca baccata	Banana Yucca		2
Yucca sp.	Yucca		2
CHENOPODIACEAE (Goosefoot Family			
Atriplex canescene (Pursh) Nutt.	Fourwing Saltbush	N	1,2
Salsola Kali L.	Russian Thistle	I	1
COMPOSITAE (Sunflower Family)			
Aphanostephus ramosissimus DC.	Plains Dozedaisy	N	1
Bahia absinthifolia Benth.	Hairyseed Bahia	N	1
Centaurea melitensis L	Malta Starthistle	I	1
Conyza canadensis (L) Cronq.	Horseweed	N	1
Dyssodia pentachaeta (DC) Robins	Parralena	N	1
Erigeron sp.	Fleabane	N	1
Flourensia cernua DC.	Tarbush	N	1,2
Franseria deltoids	Bur Sage		2
Gutierreziq sarothrac	Broom Snakeweed		2
Machaeranthera scabrella (Green) Shinners	__________	N	1
Machaeranthera tanacetifolia (HBK) Nees	__________	N	1
Parthenium incanum HBK	Mariola	N	1,2
Perezia nana Gray	Desert Holly	N	1
Senecio douglasii DC.	Thread Leaf Groundsel	N	1
Verbesina encelioides (Cav.) Gray	Cowpen Daisy	N	1
Xanthocephalum microcephalum (DC,) Shinners	Threadleaf Snakeweed	N	1
CRUCIFERAE (Mustard Family)			
Lepidium lasiocarpum Nutt.	Hairypod Pepperweed	N	1
Lesquerella gordonii (Gray) Wats.	Gordon Bladderpod	N	1
Sisymbrium irio L	London Rocket	I	1
CUCURBITACEAE (Gourd Gamily)			
Cucurbita foetodissima HBK	Buffalo-gourd	N	1

1 of 3

TABLE 4.9-1 (Cont)

Scientific Name	Common Name	Origin	Source
GERANIACEAE (Geranium Family)			
Erodium cicutarium (L.) L'Her	Alfilerillo	I	1
GRAMINEAE (Grass Family)			
Aristida longiseta	Red three-awn		2
Aristida wrightii Nash.	Wright Three-awn	N	1
Bouteloua curtipendula	Side-oats grama		2
Bouteloua eriopoda	Black grama		2
Erioneuron pulchellum (HBK) Tateoka	Fluffgrass	N	1
Hilaria mutica (Buckl.) Benth.	Tobosa	N	1,2
Muhlenbergia porteri	Bush muhly		2
Muhlenbergia sp.	Sand muhly		3
Muhlenbergia sp.	Ear muhly		3
Scleropogon brevifolius	Burro grass		2
Setaria leucopila (Scribn.& Merr.) K.Schum.	Bristlegrass	N	1,3
Sporobolus cryptandrus	Sand dropseed		2
Sporobolus flexuosus	Mesa dropseed		2,3
Tridens pulchellus	Fluffgrass		2,3
Tridens sp.			3
Vulpia octoflora (Walt.) Rydb.	Sixweeks Fescue	N	1
LEGUMINOSAE (Legume Family)			
Acacia constricta Gray	Mescat Acacia	N	1,2
Dalea sp.	Dalea		3
Hoffmanseggia glauca (Ort.) Eifert	Indian Rush-pea	N	1
Mimosa biuncifera	Wait-a-minute Bush		2
Prosopis glandulosa Torr.	Honey Mesquite	N	1
Prosopis juliflora	Mesquite		2
MALVACEAE (Mallow Family)			
Sphaeralcea sp.	Globemallow	N	1
MARTYNIACEAE (Unicorn-plant Family)			
Proboscidea althaeafolia Dcne.	Desert Unicorn-plant	N	1
ONAGRACEAE (Evening Primrose Family)			
Gaura coccinea Pursh	Scarlet Gaura	N	1
PLANTAGINACEAE (Plantain Family)			
Plantago patagonica Jacq.	Wooly Plantain	N	1
POLEMONIACEAE (Phlox Family)			
Eriastrum diffusum (Gray) Mason	__________	N	1
POLYGONACEAE (Knotweed Family)			
Rumex hymenosepalus Torr.	Canaigre	N	1

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TABLE 4.9-1 (Cont)

Scientific Name	Common Name	Origin	Source
SOLANACEAE (Nightshade Family)			
Lycium sp.	Wolf-berry		2
Solanum elaeagnifolium Cav.	Silverleaf Nightshade	N	1
VERBENACEAE (Vervain Family)			
Verbena wrightii Gray	Desert Verbena	N	1
ZYGOPHYLLACEAE (Caltrop Family)			
Larrea tridentata (DC.) Cav.	Creosote Bush	N	1,2

NOTES:

* N = native, I = introduced

** Sources: 1. Worthington, 1980. Species observed at the site April 13.

2. Kearney, T. H. and Peebles, R. H. Arizona Flora - cited in New Mexico Environmental Institute, 1974.

3. DPRD, 1979.

TABLE 4.9-2

MAMMALS LIKELY TO BE FOUND AT THE NEWMAN STATION

Scientific Name	Common Name
	Order Lagomorpha
	Family Leporidae
Lepus californca	California Jack Rabbit
Syvilagus Floridanus	Cottontail Rabbit
	Order Rodentia
	Family Sciuridae (Squirrels)
Spermophilus spilosoma	Spotted Ground Squirrel
	Family Heteromyidae
Perognathus	Apache Pocket Mouse
Perognathus	Silky Pocket Mouse
Perognathus hispidus	Hispid Cotton Rat
Dipodomys ordii	Ord's Kangaroo Rat
	Family Crietidae (New World Rats and Mice)
Peromyscus eremicus	Cactus Mouse
Peromyscus maniculatus	Deer Mouse
Onychomys leucogoster	Northern Grasshopper Mouse
	Order Carnivora
	Family Canidae
Canis Latrans	Coyote
	Family Mustelidae
Taxidea Taxus	Badger
	Family Felidae
Lynx rufus	Bobcat
	Order Artiodactyla
	Family Ceruidae
Odocoileus hemionus	Mule Deer

Source: DPRD, 1978; New Mexico Environmental Institute, 1974.

TABLE 4.9-3

REDUCTIONS IN AIR POLLUTANT EMISSIONS RESULTING FROM OPERATION OF SOLAR REPOWERED NEWMAN UNIT 1

	kg/yr (tons/yr)	
	Gas-fired	Oil-Fired
Particulates	1,100-3,200 (1.2-3.5)	47,000 (52)
SO_2	130 (0.14)	185,000 (204)
NO_2	152,000 (168)	159,000 (175)
CO	3,600 (4.0)	7,500 (8.3)
Hydrocarbons	220 (0.24)	1,500 (1.7)

Assumptions:

1. Annual savings in fossil energy - 527 x 10^{12} J/yr (500 x 10^9 Btu/yr)
2. Gas sulfur content - 4.6 x 10^{-3} g/cm^3 (2,000 gr/$10^6$$ft^3$)
3. Oil sulfur content - 2.8%
4. Natural gas heat content - 39.1 x 10^6 J/m^3 (1,050 Btu/ft^3)
5. Oil heat content - 41.8 x 10^9 J/m^3 (150,000 Btu/gal)
6. EAP's AP-42 Emission Factors (Texas SO_2 Emission Standard)

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4.10 INSTITUTIONAL AND REGULATORY CONSIDERATIONS

El Paso Electric Company sees no institutional or regulatory barriers that would preclude a demonstration of solar repowering at Newman Unit 1. However, there are a number of institutional and regulatory "constraints" that could unduly impact the economics of an initial demonstration. These constraints are believed to be applicable throughout the United States and would impact any large-scale solar electric construction effort.

Institutionally, taxes appear to be the most significant constraint that EPE can readily identify. Ad valorem and sales taxes would be applicable to solar facilities in many, if not all, locales. In Texas, legislation has been created that suspends sales taxes and directs local taxing authorities to grant ad valorem tax exemptions on solar property. EPE believes that these taxes should certainly be suspended.

A higher-than-normal investment tax credit should also be established for any large-scale solar application. EPE perceives the greatest barrier to eventual commercialization of solar repowering will be the high capital costs of constructing solar-repowered facilities. Even assuming that eventually solar-repowered applications are cost-effective to a utility and its customers, the impact of the effect of prepaying 20 to 30 years of conventional fuel expenditures in initial capital investments will strain a utility's financial structure, causing it to fall back on a lower capital alternative. In addition to solar repowering expenditures, electric utilities will simultaneously be assuming the huge capital obligations associated with their almost continual additions of new generating capacity. The debt and security markets, already saturated by utility offerings, will be expected to absorb the increased capital requirements necessitated by large-scale solar applications. This increased demand for money will raise the cost of investment capital in the money markets as demand increases with respect to supply. A higher-than-normal investment tax credit should help to alleviate this situation.

There are other means to lessen the impact of solar-related capital expenditures on the utility and the market. Accelerated depreciation of solar facilities will release cash during the critical early years which will allow a utility to plow this cash into other concurrent capital obligations. This will reduce a utility's demand for money market investment capital.

The current lead times required by the multitude of agencies involved in licensing and approving electric generating plans pose an institutional constraint to solar. Accelerating the licensing process for solar facilities will reduce the overall cost of the new facilities by allowing construction to begin at an earlier date, as well as reducing licensing expenses. El Paso Electric hopes that the licensing requirements for a solar application could be identified in advance and fixed to avoid the ever-changing licensing requirements, procedures, and attitudes prevalent in site and construction approvals today for conventional electric facilities.

A fourth possible means to help alleviate the strain associated with large solar capital expenditures would be some sort of low-interest loans made by the federal government. This would share the risk in funding a demonstration effort.

A final possible constraint to commercial-type investment in solar repowering or other large-scale solar facilities that EPE wishes to address relates to the fact that solar technology is currently in a development stage. An electric utility may be inclined to delay its venture into solar if it feels that there is a high probability that the technology may progress to a level where the cost-effectiveness of a certain solar application could be significantly enhanced. Particularly for solar repowering, delays in solar investment may reduce the market potential for this technology as existing generating units increase in age. To overcome this barrier to commercialization, it is important that research and development are continued at high levels in order to insure that technology maturity will be accelerated. As electric utilities recognize the viability and technological maturity of solar concepts, a spontaneous movement to apply these concepts will contribute to the economies of scale necessary to achieve projected component costs - further enhancing solar commercialization.

Current regulatory considerations and policies generally applicable to electric utilities may not preclude solar investment, but in their present form they do not provide a suitable springboard for involvement in high capital cost and perhaps risky solar ventures. EPE believes that certain "special considerations" by regulatory bodies toward solar will enhance the economics of solar research and construction activities.

Maturity of the various solar technologies, which would result in accelerated commercialization, can be impacted favorably by regulatory policies which allow a substantial amount of solar R&D expenditures to be included in a utility's rate base. A policy of this type would allow an electric utility to earn a return for this type of R&D investment. This ability to earn on R&D expenditures should lead to increased levels of solar research, thereby enhancing the commercialization potential of solar.

Probably the most important regulatory policy change would be to include solar construction work in progress (CWIP) into rate base routinely. This would allow a utility to begin recovering its capital expenditures during the construction period instead of waiting until commercial operation.

Another possible regulatory policy which could enhance solar development, would allow a higher rate of return for solar plant investment compared to conventional plant investment. This would be particularly applicable to early demonstration plants where the technical (and hence financial) risks are at their maximum levels. This type of "premium" return is, of course, common in nonregulated industries where a corporation will only undertake investment opportunities when the expected return is sufficient to compensate for the business risks involved.

Minimizing the difference between the time a utility applies for a rate revision and the time a regulatory body approves the revision will impact the industry in two ways. First, it will allow prompt recovery of solar capital expenditures while reducing inflationary effects on the funds received from revised rate schedules. Second, decreasing regulatory lag will place electric utilities in better overall financial health which will place the high capital cost solar option in a better light.

Finally, EPE is in complete agreement with other electric utilities which have said that it is important for policy makers, particularly Congress, to take a favorable stand on solar energy by establishing stable policies which remain consistent. Fluctuating regulatory policies (as well as federal policies) are not in the best interest of electric utilities who may be contemplating future investments in solar R&D programs, solar demonstrations, or commercial solar facilities. If utilities are unsure of the treatment solar will receive, signals will be sent to solar manufacturers who will be equally unsure and who will "gingerly" approach any opportunities they may have to make significant cost-reducing research expenditures or to build component mass production facilities.

The concerns regarding technical, business, and/or financial risks involved in implementing solar technologies (with an emphasis on solar repowering) will be addressed later in this report in Section 7.7 entitled "Roles of Site Owner, Government, and Industry." EPE realizes that there are risks inherent in early solar demonstrations as well as future benefits, thereby making risk-sharing an important consideration. If either site owner, government, or industry refuses to accept an appropriate share of the risks, then this refusal certainly becomes an institutional barrier to early large-scale solar demonstrations, thus delaying or completely blocking the commercialization process. EPE believes that cost/risk sharing arrangements can be formulated for supportive funds necessary to balance benefit and cost for demonstration units.

SECTION 5

SUBSYSTEM CONCEPTUAL DESIGN, COST, AND PERFORMANCE

5.1 SUBSYSTEM DEFINITION

The configuration for solar repowering of Newman Unit 1 consists of the following subsystems:

Collector Subsystem
Receiver Subsystem
Fossil Energy Subsystem
Electrical Power Generating Subsystem
Master Control Subsystem
Site
Site Facilities

The collector subsystem provides the means for redirecting solar energy to impinge on the primary and reheat receivers. This subsystem includes an array of heliostats arranged in a North Field orientation that encompasses reflective surfaces, structures, drive units, foundation, wiring, etc. This subsystem also includes the field control system composed of a heliostat array controller, heliostat field controllers, and heliostat controllers. The collector subsystem design is based on a "Generic" Second Generation Heliostat concept representative of hardware that could be available for a 1986 application.

The receiver system provides the means of transferring the incident radiant energy from the collector subsystem into superheated steam. This subsystem includes the primary and reheat receivers, receiver support structure, a single tower structure, and riser and downcomer piping. The receivers are of external panel type configuration with a forced recirculation boiler system in the primary receiver. Included in this subsystem are the pumps, valves, and control equipment to regulate flow temperature and pressure and to ensure safe operation. Also included are elevators, crane system, platform, etc to provide for observation and maintenance. An air-conditioned equipment room is provided near the top of the tower to house receiver instrumentation and controls.

The fossil energy subsystem provides a fossil energy source which is used to enhance performance and/or maintain normal plant operation during periods of reduced or no insolation. This subsystem includes the existing Newman Unit 1 fuel storage, fuel handling, boiler and related equipment, and it includes any additional fuel supply, storage and transfer facilities, energy conversion sources, pumps, valves, and control systems to regulate flow, temperature, and pressure

The electrical power generating subsystem (EPGS) provides the means for converting to electrical power the thermal output from the receiver subsystem and/or the fossil energy subsystem. The output from the EPGS is regulated for integration into the EPE system network. This subsystem consists of the existing balance-of-plant equipment at Newman Unit 1 and the piping and piping equipment required to interface with the solar steam supply system.

The master control subsystem is used to sense, detect, monitor, and control all system and subsystem parameters necessary to ensure safe and proper operation of the entire integrated repowered plant. This subsystem includes a central computer, computer peripheral equipment, control and display consoles, and solar/non-solar electrical power control interfaces and hardware.

The site consists of Newman Station located at the north end of the city of El Paso and Public Service Board land directly north of the station. Modifications to the site for the repowering of Newman Unit 1 will include grading, surface preparation, and construction of roads.

New structures and facilities associated with solar repowering include an addition to the existing control room, a solar feedpump house, and an addition to the existing maintenance building.

5.2 COLLECTOR SUBSYSTEM

The collector subsystem provides the means for redirecting the direct solar energy to impinge on the primary and reheat receivers. The collector subsystem is composed of an array of heliostats and supporting power and control elements which interact with the master control system. The heliostat array is arranged in a 2.79 radian (160°) fan shaped configuration north of a single receiver tower. The collector subsystem components include 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, heliostat field and heliostat array controllers, control system interface electronics, power supplies, and beam characterization system components.

The collector subsystem description is based on the "Generic" Second Generation Heliostat. The design description, performance characteristics, and cost data are representative of the class of heliostat configurations that will be available for solar repowering Newman Unit 1.

5.2.1 Design Basis

The collector subsystem will include an array of heliostats arranged in a north field orientation designed to meet receiver heat flux and focusing requirements. The collector subsystem includes an automated control system designed to respond to commands from a master control subsystem for normal operational variations and emergency/environmentally induced variations.

Figure 5.2-1 shows the vertical heat flux profile specified by Babcock and Wilcox as a design goal for the primary and reheat receivers at design point. Along with the vertical heat flux profile, any spillage beyond the absorber surface is specified to be less than 30 kW/m². The vertical flux profile and the maximum spillage requirements are the basis for the final receiver dimensions and aiming strategy.

The collector field is designed so that 103 MWt of the redirected solar energy impinges on the primary receiver and 26 MWt impinges on the reheat receiver at noon winter solstice with a direct normal insolation value of 1000 W/m².

The collector field design considers the following:

Heliostat field cost
Operations and maintenance cost
Land availability

Land cost
Heliostat performance
Receiver aperture size
Receiver tower height
Reliability
Shading and blocking
Atmospheric attenuation
Sun position
Piping cost

The collector subsystem functions as appropriate for all steady-state modes of plant operation. This includes 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 no larger than 10 percent of the total collector field output.

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

Elevation and azimuth drives do not drift from last commanded positions due to environmental loading.

The drive system provides for cost-effective stowage of the reflective surface to minimize reflected beam safety hazards and dust or dirt buildup on the mirrors. Heliostat orientation is available to master control at all times. Calculated gimbal angles are acceptable; orientation sensors are not required.

Heliostat control is by computer. Control functions are accomplished as follows:

Heliostat Array Controller (HAC) shall:

Initiate operational mode commands to HFC
Address commands to HFC groups or individual HC
Respond to PCS commands and requests
Interface with beam characterization system
Provide time base

Heliostat Field Controller (HFC) shall:

Determine sun vector
Transmit sun vector to HC
Transmit status and data to HAC
Initiate safe stowage command
Control groups of HCs

Heliostat Controller (HC) shall:

Determine heliostat azimuth and elevation position requirements

Control drive motors

Provide heliostat axis position data to HFC

The collector subsystem is capable of emergency defocusing upon command to reduce peak incident radiation on the receiver to less than 3 percent of initial value within 120 seconds.

Beam control strategy and equipment will protect personnel and property within and outside the plant facility including air space.

5.2.2 Collector Subsystem Design

5.2.2.1 Design Configuration

Figure 5.2-2 shows the conceptual layout of the heliostat field for Newman Unit 1 for 50 percent repowering. The receiver tower is located as close as possible to the turbine building to minimize feedwater and steam piping distances. The heliostat array is a 2.79 radian (160°) north facing field on a radial stagger arrangement. Heliostats are deleted on the rights-of-way for transmission, water and gas pipelines as detailed on the General Arrangement-Heliostat Field, drawing No. 14067-FM-31B-SR, found in Appendix D. The heliostat array consists of 2,998 Second Generation Heliostats.

The design characteristics of the Second Generation Heliostat are given in Table 5.2-1. The generic heliostat configuration is shown in Figure 5.2-3. The heliostat meets the requirements of the Sandia Specification A10772 for performance, operational requirements, survival loads, and environmental conditions and lifetime.

5.2.2.2 Collector Control

The following is a description for a typical heliostat field, which may change as a result of the selection of a specific heliostat design. The array is controlled by the heliostat array controller (HAC) consisting mainly of a minicomputer with disc drive and other peripheral equipment. The array is divided into four sectors each containing approximately 750 heliostats. Every sector has its separate interface with the HAC. These sectors operate independently from each other under HAC control. A sector is divided into 26 cells of approximately 29 heliostats. Each cell is controlled by the respective heliostat field controller (HFC) located in the vicinity of the cell. Communication between the HAC and the HFCs relative to one sector occurs by means of a single multidrop communication line (twisted pair) operating at 9,600 bauds. Similarly, the communication between the HFC and the respective field heliostats takes place by means of a single multidrop communication line operating at the same baud rate. In this configuration the HAC can communicate with either all or some of the heliostats using proper addressing in the messages. Each heliostat is controlled by the respective heliostat controller (HC).

The HFCs and the HCs are based on the use of microcomputer boards with the HFCs having, in addition, memory extension and I/O serial interface boards. The entire heliostat array is thus controlled through a three level distributed computer network.

The general tasks associated with each computer level are as follows:

Computer Level	General Task
HAC	Control Supervision and Time Synchronization
HFC	Heliostat Control Algorithm in All Details
HC	Pointing Angle Evaluation and Command Execution

The specific task distribution provides the maximum computer autonomy at each level. The HAC furnishes time data and day-dependent sun parameters which are the same for all HFCs. The HFC furnishes time-dependent sun position data to all its HCs. Each HC derives pointing angles and determines heliostat motion to be carried out by the drive motors. Communication among the various computers is thus simplified since, during normal array operation, there is no need for individual HFC or HC addressing. Individual communication is implemented automatically on a periodic basis for array status evaluation and upon request by the operator when part of the array (it could just be one heliostat) is to undergo a special operation (such as alignment, maintenance, or beam removal for power adjustments).

General Operating Strategy

The heliostat array control system, composed of 1 HAC, 104 HFCs, and 2,998 HCs, is designed to enable the operation of a given set of heliostats from a single port. This single port, provided by the HAC, can interface manually with an operator or automatically with the plant's process computer system (PCS). The HAC also communicates with the beam characterization system (BCS) to gather data necessary for the calibration and alignment of each heliostat. Any command data relative to the operation of the array within the solar plant are not, however, generated within the array control system. These data are contingent upon the condition of every subsystem of the solar plant and on the desired plant power output and, therefore, must be generated at the PCS level.

In general, two types of commands are issued to the array. One type deals with the array as a unit when all heliostats are to do the same thing. The other type deals with a fraction of the array and may be applicable to one or more heliostats. In either case, when a collective command applies to at least one sector of heliostats, the command is issued simultaneously to all applicable HFCs. Each cell recognizes this global command and polls one heliostat at a time for execution if a change in the mode of operation is implied. Given the communication baud rates and the typical length of each command message, the polling time is from 10 to 20 milliseconds per heliostat. This means that it takes from 0.26 to 0.52 second to change the mode of operation when many cells are involved. The staggering of the command is done to prevent excessive power drain on the electrical distribution network caused by surge electrical currents in the drive motors. The staggering is done automatically, under control software direction, when the array is started, stowed, and switched from one configuration into another.

The following is a list of the modes of operation which are implemented:

Startup
Shutdown
Track
Standby
Align
Manual
Stow
Communication

The characteristics relative to each mode are described in the following sections.

Startup

The heliostat array is normally in the stowed position prior to startup. The power supply units for the HAC, HFCs, and HCs may or may not be energized. If they are deenergized, the first operation at startup is to apply electrical power to the entire array and load the control software into the HAC random access memory (RAM). Upon power-up, the HFC software is automatically loaded into the HFC RAM from the resident magnetic bubble memory extension. The HC software is permanently stored in erasable programmable read only memory (EPROM) and does not need to be loaded. Within a few seconds from the application of power, all software is loaded and the array is ready to respond to commands (from either a dedicated operator or from the PCS).

The first command is the communication command, aimed at polling all heliostats and obtaining a response which indicates their operational status. The HAC cathode ray tube (CRT) displays provide a summary of the conditions relative to the respective heliostats. The Communication command initializes also the day and time routines at each HFC so that appropriate sun position calculations can be performed at the cell level. Subsequently, the HAC transmits the first sun vector in order to calibrate the HFC sun position algorithm. All this is done by means of the Communication command. At this point the startup procedure can proceed with the issuance of the Standby command. All heliostats, or any portion as commanded, move so as to reflect the sun's image onto the Standby point (adjacent to, and away from, the receiver). The Startup procedure is thus completed, as far as the heliostat array is concerned. The heliostats can, from this point on, be switched from the Standby to the Track position (beam on the receiver) and vice versa as established by the PCS. Motion from the Stow to the Standby position is controlled so as to prevent focusing of any portion of the array onto anything other than the Standby point.

Shutdown

Shutdown is the operation that removes the beam from the receiver and, eventually, places the array in a stowed position so that it is ready for next day's startup operation. When the Shutdown command is issued, a sequence of actions is started at the HAC. The first action removes the beam from the receiver and puts the array in Standby. Once the Standby position is reached, the reversal of the startup motion is initiated, that is, the array is moved from Standby to the Stow position. Again, as during Startup, the array is moved in a way that precludes the focusing of any portion of it onto anything other than the Standby point.

There can be two types of shutdown operation: one is the Normal Shutdown, such as the one executed at sunset; the other is the Emergency Shutdown, called upon at the incipience of an unsafe condition for the array (such as the conditions associated with a wind storm). During a Normal Shutdown the heliostats are stowed with some predetermined orientation, facilitating Standby operation the next morning. A Normal Shutdown is initiated either by the operator (at the HAC or PCS) or automatically when the sun's elevation goes below a predetermined value, which can be changed at any time.

An Emergency Shutdown is executed in a way that achieves the fastest possible realization of a stowed position. Accordingly, as the command is issued, only the azimuth of the heliostats is moved so as to remove the beam from the receiver and place it at an approximate Standby position. As this step is accomplished, the heliostats are stowed with the mirror facing up. Mirror face-up position is used in this case because it constitutes the shortest travel time in elevation to achieve the stowed condition. As the emergency conditions disappear, the array can be commanded to resume normal operation or assume a Normal Shutdown position. The Emergency Shutdown operation is initiated either upon HAC or PCS operator command. It is issued automatically through power failure detectors, storm-early-warning devices, receiver failure, or turbine trip.

Track

The Track command can be given for any number of heliostats through the HAC. At this command the heliostats are switched from standby target tracking to receiver tracking. The number of heliostats to be moved per unit time is determined by the PCS. The Track command implies full execution of the sun position algorithm at the HFC. Occasionally, a HAC (where a more detailed algorithm is implemented) reference sun vector is transmitted to the HFCs for calibration.

Standby

The Standby command is identical to the Track command except that in Standby the heliostats are focused on a volume adjacent to the receiver, in free space. Sun position and pointing angle evaluations are carried out on a continuous basis to maintain the focus away from the receiver. The number of heliostats on Standby and number on Track are constantly varied by the PCS to maintain the desired steam pressure and temperature at the output of the receiver. The Standby mode of operation is always selected automatically during Startup and Shutdown and constitutes the intermediate step for the beginning or termination of power generation.

The data necessary for pointing angle evaluation are available at the HFC/HC at all times so that only the Standby or Track command need to be issued together with the identification of the number of heliostats involved. As for any mode of operation, this command can be issued either automatically by the control system software or manually by the HAC or PCS operator.

Align

Align operation takes place on a continuous basis under the control of the HAC utilizing the beam characterization system (BCS) located below the reheat receiver calibration receivers listed below the reheat receiver. The PCS and the BCS take part in this operation through their respective interfaces with the HAC. The purpose of the operation is to permit the automatic real-time evaluation of the quality of the beam and pointing accuracy provided by a heliostat. Each heliostat is commanded in sequence to reflect the sun's image onto the calibration target. Beam size, shape, centroid, flux distribution, and power are measured for each heliostat. These data are evaluated and presented to the HAC and the PCS operator. Pointing data (beam centroid) are used by the HAC to perform the necessary correction to the specific heliostat angles. The correction biases are stored in the HFC to maintain an accurate heliostat pointing. Data relative to beam quality are used by the PCS operator to determine the need for mirror facet canting adjustment and/or mirror washing. The whole operation is under software control and requires no operator intervention.

There are two types of alignment. One is performed following the installation of the heliostat to determine pointing biases caused by installation irregularities (such as non-perfect leveling of the foundations, orthogonality errors between vertical and horizontal rotational axes, etc). The other type is performed on a regular basis during normal operation. In essence the two operations are identical. The only difference is that initially the alignment operation is repeated several times during a 24-hour period. The pointing biases relative to each operation are stored in the HFC for the specific heliostat. At the completion of the 24-hour alignment cycle, a special software routine is executed on the accumulated biases. Correction coefficients are evaluated so that, when they are applied to the encoder reading of the respective heliostat, compensation for leveling and other mechanical installation errors are achieved.

Regular alignment does not take more than approximately a minute to execute. The heliostat sequence, established in the software, is such that at least one heliostat from each cell is polled for alignment before the next heliostat from the same cell is selected. This procedure insures that any problem associated with an HFC is readily identified. The operator can intervene at any time to modify the sequence or to perform alignment on any heliostat upon command.

Manual

The Manual mode of operation is used to move the specified number of heliostats in any direction, both in azimuth and in elevation. This mode can be implemented at either the HAC or PCS, as for all modes. In addition, it can be imposed locally and individually for each heliostat by means of a control zone located directly on the HC. The Manual command is used when drive system tests are necessary or when the heliostat is to assume a determined position for mirror washing. When in Manual, the heliostat returns the encoder data to the HAC which can be used as a feedback during the local Manual operation.

Stow

The Stow operation places the indicated number of heliostats in a position where the mirror facets are horizontal or vertical. This command is issued automatically during the Startup and Shutdown sequences as well as manually at the HAC or PCS. The heliostats to be stowed are always on Standby as a starting mode.

The features associated with this operation in normal or emergency conditions are described in the preceding Shutdown Section. The Stow command can also be used to position any heliostat to a specific reading of the azimuth and elevation encoders. This is done in connection with the Communication operation (see next section) which enables the downloading (lower tier communication) of any fixed angular position.

Communication

During Communication operation, the HAC, HFCs, and HCs are in contact with each other but no additional action is taken by the heliostats. Data are transferred as needed in the bidirectional communication links. Several options can be selected while the Communication mode is in effect. The HFC software can be downloaded from the HAC when the array is installed. Also, initial downloading of data relative to the heliostat target coordinates (track and standby points), stow position, and alignment biases can be achieved during Communication operations.

Data relative to the array are collected in this mode. Note that the Communication mode does not affect any other mode in which the array is operating. This mode co-exists with any other previously established mode and is called upon only to permit the exchange of any data among the various computers in the control network.

The heliostat control architecture is designed to achieve the intended performance at all levels with very little human intervention. All modes of operations described above can be selected by a single operator by controlling the execution of the appropriate instructions, or set of routines, which are permanently stored in the computer software. Although the operation routines are permanently stored, they can be modified or updated at any time using the standard computer system software without affecting the hardware. Provisions are included, however, to enable manual intervention in any function if so desired by the operator.

The power required by the HAC, HFCs, and HCs can be as high (depending on heliostat manufacturer) as 160 kW and is continuous in all operating modes. During normal operation (Track, Standby, Align, Manual, and Communication modes) approximately 2 percent of the heliostat drive motors are operating at any time which corresponds to an average driving power of as high as 110 kW. Therefore, during normal operation, the array power requirement could be as high as 270 kW.

5.2.3 Collector Performance

The collector field is sized and configured to redirect solar energy so that, at noon winter solstice with a solar insolation of 1000 W/m², 103 MWt of solar power impinges on the primary receiver and 26 MW of solar power impinges on the reheat receiver. The total power impinging on the receivers at 9 a.m. and 10 a.m. on winter solstice is less than the total power at noon. Likewise, with the constant 1000 W/m² insolation, the total power impinging on the receivers is less at noon equinox and noon summer solstice than at noon winter solstice. The effects are shown in Table 5.2-2. Also in Table 5.2-2, power efficiencies for several events are presented for winter solstice, equinox, summer solstice, and annual average.

Heat flux maps for noon, 10 a.m., and 9 a.m. winter solstice are shown in Tables 5.2-3 through 5.2-5. The peak heat flux on the primary receiver is 650 kW/m² and occurs at noon. Although this peak heat flux (650 kW/m²) exceeds the desired maximum vertical profile heat flux (630 kW/m²) shown on Figure 5.2-1, subsequent review by Babcock and Wilcox determined that 650 kW/m² is acceptable on the lower half of the primary receiver. The peak flux on the reheat receiver never exceeds 140 kW/m².

5.2.4 Collector Field Costs

The collector field costs are estimated based on a heliostat price of $198/m² (1982 dollars) which includes all components including the field control unit, foundations, installation, and field wiring costs.

Budget estimates were obtained from three potential manufacturers, ranging from $198/m² to $350/m². A lower value of $150/m² is considered to illustrate sensitivity of capital cost to heliostat field cost.

TABLE 5.2-1

GENERIC HELIOSTAT DESIGN CHARACTERISTICS

Number of Heliostats	2998
Height	7.9 m (25.9 ft)
Width	7.9 m (25.9 ft)
Height to Centerline	4.15 m (13.62 ft)
Effective Mirror Area	57 m^2 (613.5 ft^2)
Percent Reflectivity (Annual Average)	92% (90%)
Heliostat-standard deviation angular errors for pointing	0.75 milliradian each axis
Surface Normal - standard deviation errors	1 milliradian each axis

1 of 1

TABLE 5.2-2

HELIOSTAT FIELD PERFORMANCE

	Noon Winter Solstice	10 am Winter Solstice	9 am Winter Solstice	Noon Equinox	Noon Summer Solstice	Annual Average
Power Incident on Primary Receiver (MWt)	103	88	67	102	96	57
Power Incident on Reheat Receiver (MWt)	26	22	17	26	24	4
Total Power (MWt)	129	110	84	128	120	71
Cosine and Shadowing (percent)	7.2	13.1	22.4	9.5	14.8	17.5
Reflectivity Loss (percent)	8.0	8.0	8.0	8.0	8.0	10.0
Blocking (percent)	1.5	1.4	1.2	1.7	1.2	1.4
Attenuation (percent)	6.2	6.2	6.2	6.0	5.7	6.2
Spillage (percent)	3.1	3.2	3.2	2.9	3.2	3.2
Insolation (W/m²)	1,000	905	765	1,000	1,000	620

TABLE 5.2-3

FLUX MAP - NOON WINTER SOLSTICE MW/m^2

N

% PRIMARY RECEIVER HEIGHT / PRIMARY RECEIVER HEIGHT (m)

100-	.0149	.0348	.0723	.1115	.1353	.1430	.1488	.1429	.1513	.1449	.1149	.0821	.0510	.0199	15.93
90.9-	.0225	.0669	.1391	.1868	.2563	.2775	.2780	.2733	.2543	.2414	.2206	.1655	.0974	.0329	14.48
81.8-	.0293	.0419	.2004	.3050	.3720	.3914	.4139	.3953	.3991	.3781	.3364	.2475	.1584	.0473	13.03
72.7-	.0363	.1129	.2541	.4144	.5065	.4984	.5000	.5144	.4829	.4624	.4440	.3365	.2054	.0700	11.58
63.6-	.0486	.1383	.2845	.4455	.5504	.5908	.5749	.6046	.5795	.5416	.5206	.4198	.2525	.0914	10.13
54.6-	.0481	.1524	.3191	.4866	.5979	.6348	.6520	.6328	.6251	.6134	.5595	.4319	.2416	.0956	8.69
45.5-	.0478	.1731	.3185	.5148	.6213	.6504	.6549	.6448	.6366	.6173	.5899	.4528	.2408	.0853	7.24
36.4-	.0484	.1405	.2948	.4811	.5788	.6009	.6460	.6508	.5840	.5691	.5255	.4288	.2244	.0783	5.79
27.2-	.0378	.1280	.2488	.4159	.4864	.5264	.5380	.5516	.5281	.5088	.4268	.3373	.1878	.0678	4.34
18.2-	.0261	.0799	.1764	.2901	.3365	.3758	.3978	.4061	.3668	.3620	.3186	.2429	.1444	.0481	2.90
9.1-	.0169	.0501	.1119	.1791	.2086	.2379	.2541	.2496	.2309	.2035	.1819	.1405	.0798	.0281	1.45
0.0-															-0.0

-10.62 -9.10 -7.58 -6.07 -4.55 -3.03 -1.52 0.0 1.52 3.03 4.55 6.07 7.58 9.10 10.62

PRIMARY RECEIVER WIDTH (m)

% REHEAT RECEIVER HEIGHT / REHEAT RECEIVER HEIGHT (m)

0.0-	.0085	.0328	.0593	.0951	.1285	.1416	.1478	.1368	.1391	.1204	.1045	.0834	.0497	.0155	13.03
11.1-	.0097	.0247	.0602	.0961	.1149	.1318	.1301	.1255	.1278	.1262	.1006	.0759	.0555	.0166	11.58
22.3-	.0088	.0274	.0593	.1009	.1172	.1170	.1305	.1202	.1253	.1127	.1116	.1004	.0551	.0182	10.13
33.3-	.0079	.0290	.0582	.0959	.1209	.1253	.1327	.1363	.1258	.1215	.1092	.1000	.0504	.0191	8.69
44.4-	.0097	.0238	.0557	.0932	.1112	.1238	.1256	.1152	.1155	.1112	.1038	.0827	.0414	.0121	7.24
55.6-	.0065	.0245	.0528	.0825	.1071	.1161	.1159	.1213	.1125	.1069	.1058	.0789	.0443	.0110	5.79
66.7-	.0097	.0252	.0479	.0836	.1074	.1141	.1083	.1096	.0995	.0993	.0957	.0751	.0454	.0122	4.34
77.7-	.0052	.0194	.0423	.0632	.0811	.0818	.0843	.0843	.0798	.0713	.0748	.0513	.0387	.0079	2.90
88.9-	.0029	.0095	.0252	.0432	.0396	.0506	.0342	.0545	.0450	.0441	.0412	.0351	.0178	.0059	1.45
100.0-															0.0

-13.27 -11.37 -9.48 -7.58 -5.69 -3.79 -1.90 0.0 1.90 3.79 5.69 7.58 9.48 11.37 13.27

REHEAT RECEIVER WIDTH (m)

TABLE 5.2-4

FLUX MAP - 10 AM WINTER SOLSTICE MW/m^2

% PRIMARY RECEIVER HEIGHT

100.0-															15.93
	.0118	.0331	.0774	.0953	.1211	.1334	.1304	.1328	.1216	.1148	.0984	.0646	.0353	.0133	
90.9-															14.48
	.0258	.0694	.1171	.1898	.2229	.2288	.2319	.2315	.2085	.1996	.1755	.1314	.0659	.0234	
81.8-															13.03
	.0320	.0866	.1856	.2824	.3349	.3590	.3396	.3465	.3308	.3091	.2709	.2161	.1049	.0358	
72.7-															11.58
	.0435	.1179	.2385	.3609	.4518	.4611	.4541	.4153	.4139	.3939	.3733	.2695	.1401	.0508	
63.6-															10.13
	.0491	.1421	.2663	.4345	.5113	.5190	.4925	.4920	.4643	.4469	.4155	.3185	.1658	.0499	
54.6-															8.69
	.0473	.1576	.3093	.4611	.5526	.5733	.5573	.5220	.4914	.4786	.4386	.3370	.1703	.0566	
45.5-															7.24
	.0524	.1468	.3128	.4746	.5654	.5985	.5698	.5234	.5179	.4921	.4534	.3446	.1808	.0566	
36.4-															5.79
	.0451	.1304	.2026	.4581	.5466	.5711	.5519	.5298	.5169	.4858	.4274	.3328	.1758	.0518	
27.2-															4.34
	.0368	.1153	.2363	.3648	.4541	.4814	.4463	.4314	.4089	.4051	.3544	.2749	.1436	.0480	
18.2-															2.90
	.0204	.0770	.1763	.2621	.3293	.3556	.3399	.3056	.2915	.2774	.2453	.1985	.0903	.0325	
9.1-															1.45
	.0103	.0463	.1088	.1698	.2039	.2218	.2258	.1928	.1850	.1778	.1401	.1119	.0656	.0198	
0.0-															0.0

-10.62 -9.10 -7,58 -6,07 -4.55 -3,03 -1,52 0,0 1,52 3.03 4.55 6.07 7.58 9.10 10.62

PRIMARY RECEIVER WIDTH (m)

PRIMARY RECEIVER HEIGHT (m)

% REHEAT RECEIVER HEIGHT

0.0-															13.03
	.0113	.0281	.0652	.0882	.1084	.1211	.1250	.1203	.1051	.0962	.0882	.0629	.0375	.0108	
11.1-															11.58
	.0111	.0280	.0554	.0905	.1066	.1233	.1083	.0995	.0965	.0923	.0889	.0655	.0348	.0136	
22.3-															10.13
	.0103	.0299	.0542	.0866	.1111	.1219	.1197	.1021	.1053	.0996	.0871	.0734	.0398	.0128	
33.3-															8.69
	.0086	.0287	.0603	.0749	.1090	.1256	.1122	.1033	.0994	.0979	.0895	.0774	.0397	.0126	
44.4-															7.24
	.0108	.0239	.0527	.0804	.1004	.1153	.1073	.0962	.0910	.0892	.0830	.0660	.0352	.0104	
55.6-															5.79
	.0081	.0270	.0521	.0816	.0924	.1013	.1036	.0947	.0957	.0885	.0838	.0664	.0309	.0101	
66.7-															4.34
	.0057	.0242	.0482	.0712	.0853	.0878	.0947	.0868	.0810	.0781	.0831	.0566	.0305	.0109	
77.7-															2.90
	.0059	.0163	.0346	.0524	.0693	.0852	.0694	.0678	.0608	.0600	.0577	.0461	.0237	.0051	
88.9-															1.45
	.0032	.0093	.0177	.0345	.0396	.0407	.0414	.0380	.0367	.0379	.0328	.0288	.0157	.0032	
100.0-															0.0

-13.27 -11.37 -9.48 -7.58 -5.69 -3.79 -1.90 0.0 1.90 3.79 5.69 7.58 9.48 11.37 13.27

REHEAT RECEIVER WIDTH (m)

REHEAT RECEIVER HEIGHT (M)

TABLE 5.2-5

FLUX MAP - 9 AM WINTER SOLSTICE MW/m^2

% PRIMARY RECEIVER HEIGHT

100.0-															- 15.93
	.0129	.0346	.0575	.0861	.0938	.1011	.1000	.1068	.0925	.0929	.0749	.0445	.0236	.0083	
90.9-															- 14.48
	.0210	.0515	.1060	.1525	.1858	.1815	.1904	.1795	.1750	.1675	.1375	.0929	.0459	.0140	
81.8-															- 13.03
	.0299	.0790	.1596	.2301	.2811	.2826	.2723	.2565	.2489	.2349	.2045	.1445	.0714	.0234	
72.7-															- 11.58
	.0346	.0941	.1921	.2919	.3558	.3505	.3254	.3353	.3075	.2999	.2624	.1843	.0923	.0313	
63.6-															- 10.13
	.0400	.1143	.2299	.3531	.4114	.4151	.3715	.3560	.3636	.3421	.2993	.2184	.1170	.0333	
54.6-															- 8.69
	.0436	.1146	.2471	.3629	.4476	.4386	.4045	.3815	.3779	.3813	.3253	.2458	.1263	.0474	
45.5-															- 7.24
	.0420	.1186	.2473	.3013	.4285	.4439	.4121	.4034	.4059	.3778	.3196	.2581	.1254	.0396	
36.4-															- 5.79
	.0369	.1040	.2319	.3539	.4090	.4474	.3893	.3718	.3765	.3689	.3138	.2325	.1175	.0418	
27.2-															- 4.34
	.0303	.0954	.1961	.2891	.3551	.3456	.3128	.3128	.3144	.2963	.2525	.1833	.0994	.0295	
18.2-															- 2.90
	.0181	.0625	.1323	.2058	.2544	.2519	.2278	.2165	.2219	.2071	.1745	.1320	.0723	.0235	
9.1-															- 1.45
	.0126	.0423	.0805	.1293	.1568	.1539	.1351	.1444	.1365	.1308	.1068	.0784	.0443	.0113	
0.0															- 0.0
-10.62	-9.10	-7.58	-6.07	-4.55	-3.03	-1.52	0.0	1.52	3.03	4.55	6.07	7.58	9.10	10.62	

PRIMARY RECEIVER WIDTH (m)

PRIMARY RECEIVER HEIGHT (m)

% REHEAT RECEIVER HEIGHT

0.0-															- 13.03
	.0084	.0239	.0517	.0761	.0844	.0929	.0891	.0843	.0817	.0721	.0653	.0454	.0230	.0063	
11.1-															- 11.58
	.0072	.0239	.0500	.0684	.0837	.0876	.0785	.0772	.0756	.0689	.0610	.0485	.0253	.0081	
22.3-															- 10.13
	.0079	.0209	.0489	.0716	.0870	.0885	.0810	.0806	.0838	.0797	.0663	.0517	.0297	.0107	
33.3-															- 8.69
	.0068	.0194	.0458	.0659	.0845	.0854	.0761	.0717	.0785	.0743	.0637	.0526	.0259	.0092	
44.4-															- 7.24
	.0074	.0205	.0410	.0626	.0759	.0827	.0765	.0775	.0762	.0674	.0611	.0490	.0288	.0079	
55.6-															- 5.79
	.0069	.0173	.0416	.0667	.0768	.0871	.0726	.0730	.0759	.0686	.0579	.0417	.0255	.0060	
66.7-															- 4.34
	.0073	.0174	.0414	.0595	.0702	.0708	.0667	.0719	.0655	.0671	.0534	.0424	.0230	.0069	
77.7-															- 2.90
	.0038	.0140	.0304	.0444	.0579	.0531	.0515	.0480	.0481	.0454	.0369	.0331	.0166	.0053	
88.9-															- 1.45
	.0027	.0085	.0159	.0251	.0326	.0300	.0294	.0246	.0298	.0261	.0200	.0182	.0089	.0032	
100.0-															0.0
-13.27	-11.37	-9.48	-7.58	-5.69	-3.79	-1.90	0.0	1.90	3.79	5.69	7.58	9.40	11.37	13.27	

REHEAT RECEIVER WIDTH (m)

REHEAT RECEIVER HEIGHT (m)

1 of 1

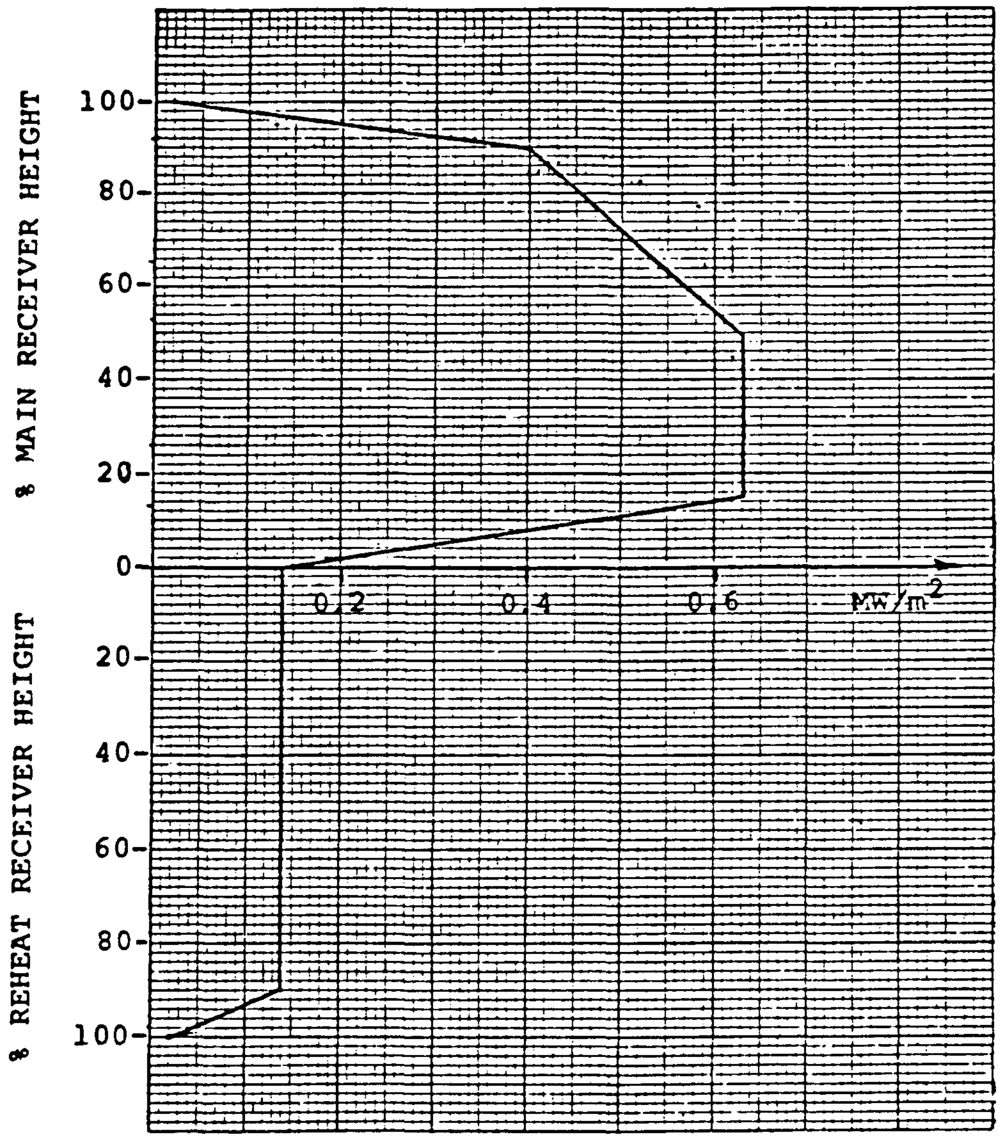


FIGURE 5.2-1
HEAT FLUX PROFILE

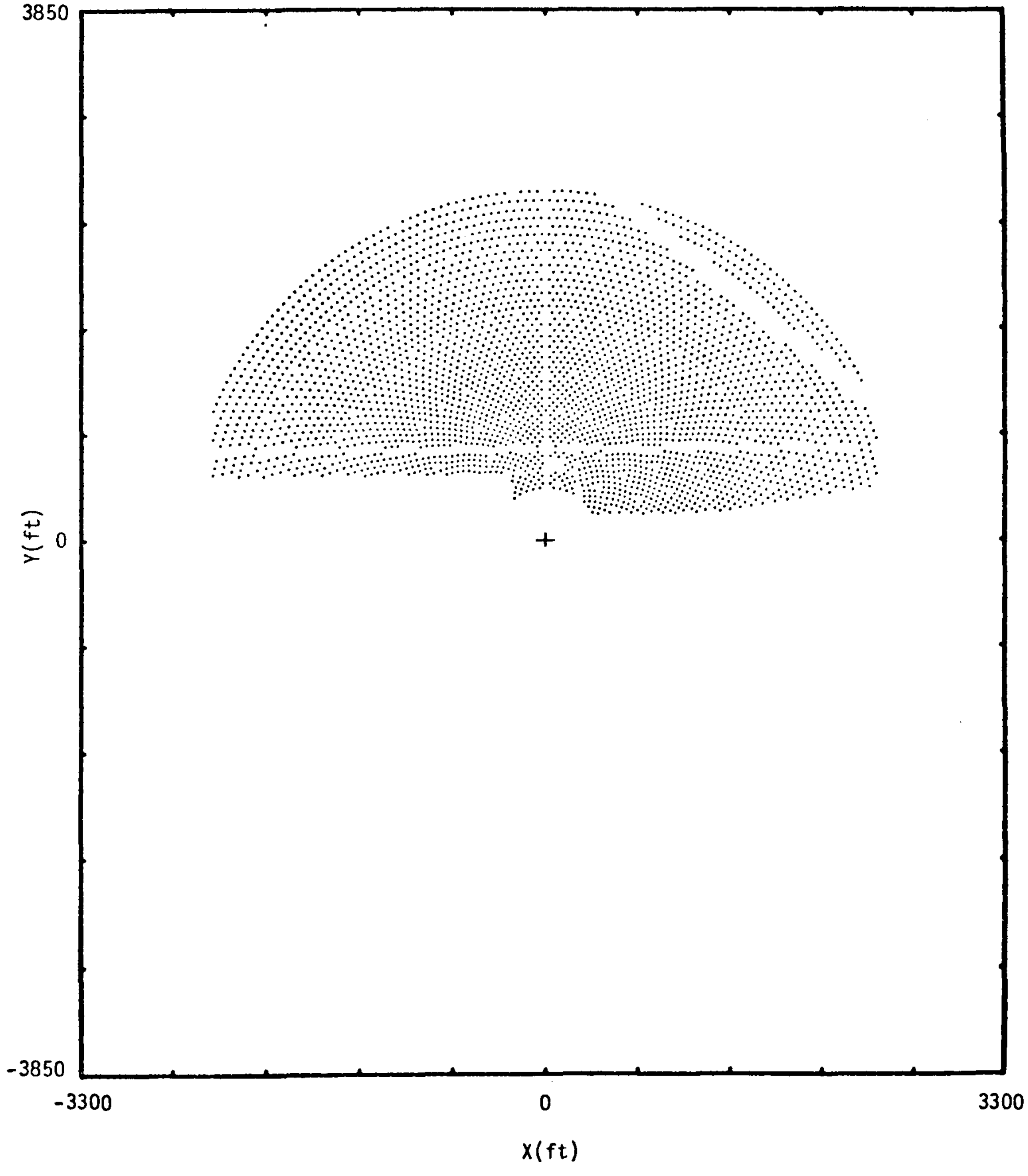
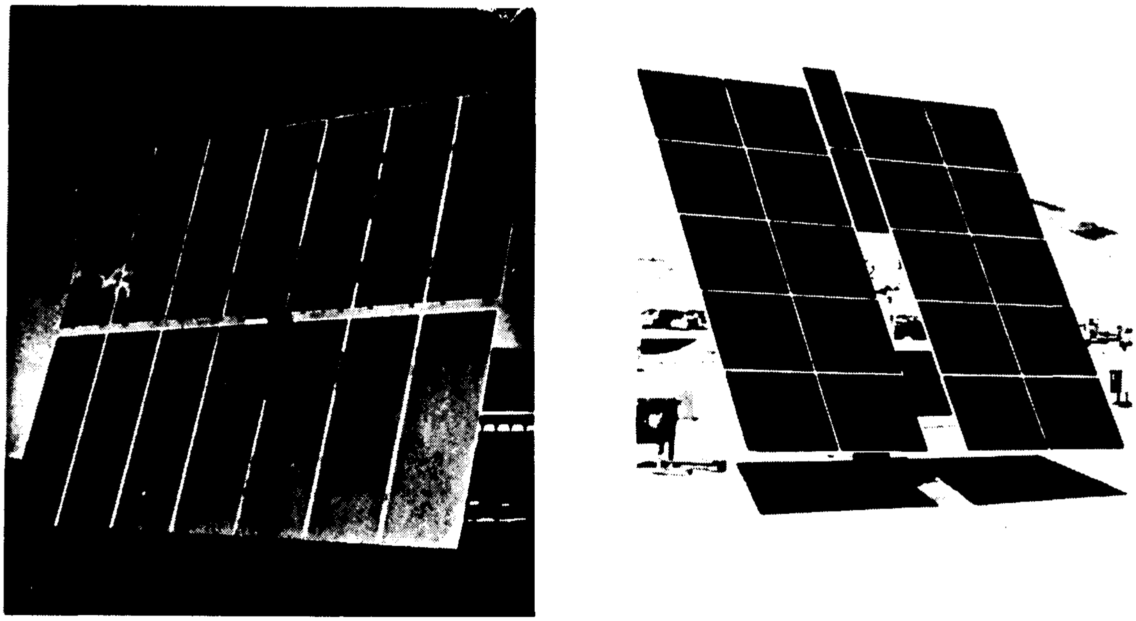
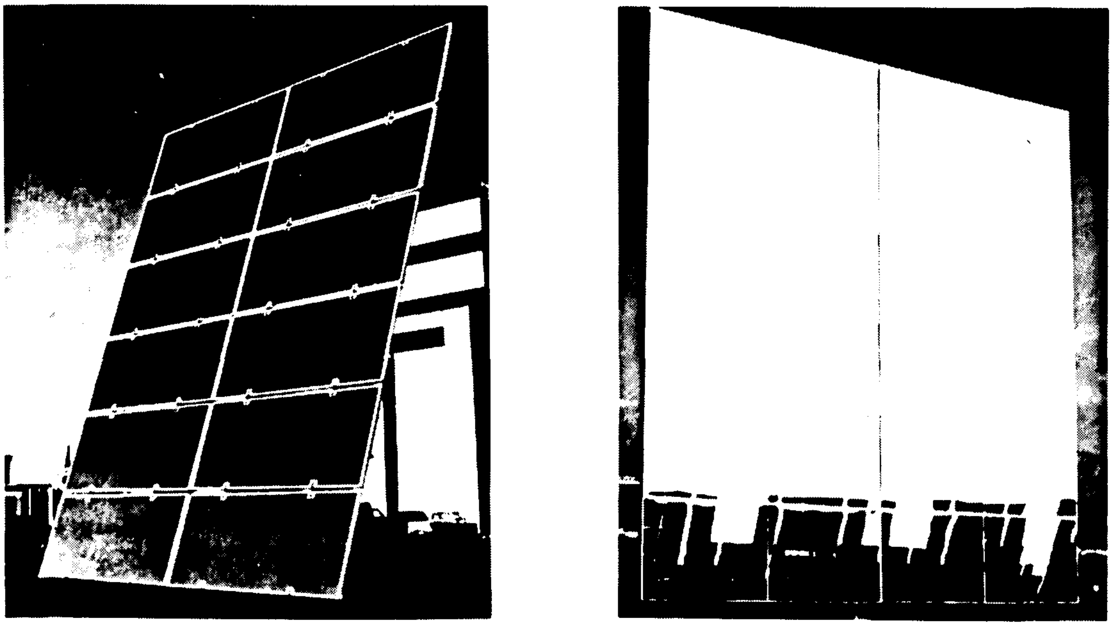


FIGURE 5.2-2
EL PASO HELIOSTAT FIELD
(2998 HELIOSTATS)



McDONNELL DOUGLAS

MARTIN MARIETTA



BOEING

ARCO

FIGURE 5.2-3
SECOND GENERATION HELIOSTATS

5.3 SOLAR RECEIVER SYSTEM

The receiver subsystem consists of primary and reheat receivers, a single tower structure, receiver support structure, riser and downcomer piping, elevator, and stairways. A Preferred Configuration is recommended for this solar repowering application based on the results of a trade-off study described in Appendix A. The Preferred Configuration is an improved external, pumped recirculation, drum type boiler being developed as part of the DOE Advanced Water/Steam Receiver Program. This configuration, selected for the purpose of preparing a conceptual design, is based on the refined Babcock & Wilcox (B&W) external receiver design* utilizing a screened tube concept with a forced recirculation boiler. The primary and reheat receivers are located vertically adjacent to each other on top of the concrete tower and face a 160-degree north field (see Figure 5.3-1).

The receiver subsystem also includes the pump, valves, instrumentation, and control system necessary to regulate the flow, temperature, and pressure; and the required control system components necessary for safe and efficient operation, start-up, shutdown, and standby.

The purpose of this section is to define the conceptual design features of this subsystem. Included is a description of the design encompassing the configuration, support structure, and control system. Also included are a description of the receiver performance for normal steady state conditions, and budgetary cost estimates.

5.3.1 Design Requirements

The solar receiver subsystem, which includes both primary receiver and reheater receiver, requires rigorous design criteria to provide the reliability and cost effectiveness desired by EPE and other electric utilities.

The solar receivers must satisfy the following general requirements:

- High reliability
- Maximum utilization of incident energy
- Endurance of diurnal and cloud cycles
- Tolerance of extreme upsets
- Ease of operation and maintenance
- Fast start-up
- Compliance with applicable codes and regulations

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*Sandia Report SAND 79-8177, Conceptual Design of Solar Advanced Water/Steam Receiver, Babcock & Wilcox, DOE Contract AT(29-1)-789, Sandia Contract 18-6879A, Albuquerque, N.M., March 1980.

- 30-year life
- Minimum size, weight and cost

In addition, the receiver subsystem should also meet the following functional requirements:

> The receiver subsystem shall include a primary receiver and a reheat receiver and shall provide the means of transferring the incident radiant power from the collector into superheated steam and transport of the steam to the high pressure (HP) 10.1 MPa/538°C (1,465 psia/1,000°F) turbine and the intermediate (IP) 2.93 MPa/538°C (425 psia/1,000°F) turbine.
>
> The primary receiver shall be an external panel configuration with a forced recirculation boiler and shall face a north field of heliostats. The peak heat flux on the primary receiver shall not exceed 660 kW/m². At noon winter solstice (design point), the primary receiver shall be capable of absorbing 91.3 MWt with a receiver incident power of 103.2 MWt and shall at least generate the steam at the rate of 129,000 kg/hr (284,000 lb/hr) with outlet conditions of 11.72 MPa/549°C (1,700 psia/1,020°F). The maximum allowable pressure drop in the superheater shall not exceed 1.93 MPa (280 psi).
>
> The reheat receiver shall be an external panel configuration capable of operating safely and reliably with an absorption heat flux level not exceeding 0.149 MW/m². At noon winter solstice, the reheat receiver shall be capable of absorbing 17.5 MWt with a receiver incident power level of 25.8 MWt. Steam is at the rate of 115,400 kg/hr (254,500 lb/hr) (including attemperation) with outlet conditions of 2.97 MPa and 549°C (431 psia and 1,020°F). The corresponding inlet steam temperature is 373°C (703°F), and the maximum allowable pressure drop shall be 193 kPa (28 psig).
>
> The two receivers shall be designed to be subjected to cyclic service with approximately 10,000 startup/shutdown cycles and 50,000 cloud transient cycles. The receiver subsystem shall include a control system to maintain the HP and IP turbine inlet conditions within design tolerances while being subjected to fluctuations in solar heat fluxes due to normal daily/hour variances and partial cloud transients. At those times when the solar system is not capable of meeting turbine inlet requirements, the receiver shall be maintained in standby mode.
>
> The primary and reheat receivers shall be supported by a single reinforced concrete tower structure 129.5 m in height. Above this elevation, the primary and reheat receivers shall

be supported by steel framework anchored to the top of the concrete tower. The top and base diameters of the concrete structure are 10.7 m (35.1 ft) and 18.3 m (60.0 ft), respectively. The tower is located adjacent to the existing unit.

The interior of the structure accommodates piping supports for feedwater and steam piping to the receiver. In addition, an elevator, ladders, walkways, and platforms are provided within the tower for inspection and maintenance.

5.3.2 Primary Receiver Design

The receiver design concept is based on the B&W advanced water/steam receiver technology which combines high reliability and efficient performance with ease of operation and insensitivity to partial cloud cover.

For this repowering project the basic B&W external receiver arrangement of the advanced design has been optimized and refined to minimize size, weight, and cost without compromising the performance. A general view of the receiver is shown in Figures 5.3-1 and 5.3-2.

The primary receiver consists of eight panels arranged on the periphery of a vertical cylinder with 11.6-m (38-ft) diameter, encompassing a 210-degree arc, facing north. Each absorbing surface is 15.85 m (52 ft) high with an overall panel width of 20.97 m (68.8 ft) for a total of 332 m^2 (3,577 ft^2) of absorbing surface.

5.3.2.1 Primary Receiver Conceptual Design

The fundamental approach in the design of the solar receivers was to fully utilize the existing boiler technology and manufacturing techniques with special considerations for the unique requirements of solar power. The analyses of the unique characteristics of the heat flux incident on the receiver led to the development of an external receiver design concept which can withstand the expected variations of solar insolation. Innovative ideas were used to obtain the desired performance at a low cost. The basic features of the receiver design consist of the following:

- Partial arc external receiver facing north
- Membrane wall superheater and economizer
- Screen tubes
- Pump assisted circulation

- Ribbed tubes to avoid departure from nucleate boiling (DNB)
- Three over-surfaced superheater passes
- Dual (east, west) flow paths
- Spray attemperation
- Biasing valves

Membrane Wall

As in fossil-fueled steam generators, the absorber surface of the receiver consists of membrane wall panels which provide a firm boundary capable of withstanding, safely and reliably, the thermal stresses and external loads (wind). The membrane panels are light-tight to protect the supporting structure. The superheater panels consist of 1.9-cm (0.75-in)-diameter Incoloy 800H tubes welded together with 9.5-mm (3/8-in)-wide bars about 5 mm (0.19 in) thick of the same material to form a membrane construction. The inlet and outlet headers are also of the same material (Incoloy 800H) to provide uniform thermal expansion. The steam flow in the superheater panels is upward in order to ensure positive steam flow in all tubes during fast cloud transients, when the heat flux may be expected to change from near zero to full value in 10 seconds. The panel is provided with structural steel buckstays to maintain its flat shape and to hold it to the tower structure. The panel is free to expand downward from the support grid and sideward from its north centerline.

Screen Tubes

The primary receiver design utilizes spaced screen tubes in front of the superheater panels (Figure 5.3-3) to reduce the heat flux incident on superheater tubes to an acceptable level. The screen tubes are cooled by subcooled or boiling water which absorbs the major part of the high incident heat flux. Rows of screen tubes can reduce the heat flux incident on a superheater panel by 30 to 70 percent, depending on tube size and spacing. By proper selection of screen tube sizes and spacings, it is possible to obtain an acceptably low-level, relatively uniform peak heat flux pattern on all superheater panels.

Use of screen tubes as the boiler section in front of the superheater panels also provides a significant advantage for reliable receiver operation. With this arrangement of heating surface, the superheater panels always absorb the same proportion of incident heat. Therefore, any diurnal, seasonal, and cloud shadowing variations of incident heat flux affect the boiler and the superheater in the same degree. This facilitates the steam temperature control especially during periods of partial cloud coverage.

Another benefit of the screen tubes is increased thermal efficiency of the receiver. Because the screen tubes are cooled by subcooled or boiling water, their metal temperatures are much lower than those of the superheater panels. Thus, the overall mean external metal temperature of the receiver is considerably lower than for a design without screen tubes. The major effect is a reduction of the heat losses from the receiver due to emissivity and convection to the surrounding air. Also reradiation losses from the superheater are reduced because a significant portion of the energy reradiated from the superheater is absorbed on the rear facing portion of the screen tubes.

Pump-Assisted Circulation

This feature was selected to provide maximum freedom for transitions between operating modes. The circulating pump is important to receiver reliability because of its ability to maintain the required mass velocity at all operating conditions. No orifices are required in the boiling tube. Pump-assisted recirculation eliminates possible dynamic flow instabilities during fast insolation transients. With natural circulation, a risk exists that tubes which become stagnant or have reverse flow during cloud cover will not be able to re-establish adequate mass velocities when the cloud passes. With pump-assisted circulation, the flow in the tubes remains substantially constant, independent of load or heat absorption variations.

Ribbed Tubes

Ribbed tubes with internal spirals are used for the screen tubes to avoid DNB (Figure 5.3-3). The circulating pump maintains the required mass velocity and circulation ratio (steam quality) at all predictable operating conditions, including extremes of insolation distribution. Ribbed screen tubes operating with nucleate boiling can withstand very high water-side heat fluxes without excessive thermal stresses. Accordingly, the high water-side heat transfer rate of the tubes allows the use of low alloy, low cost material (SA-213 T2) for the screen tubes.

Superheater

The superheater is divided into three separate flow passes with spray attemperation between passes. During normal operation, the incident solar energy varies considerably from panel to panel with time of day and with seasons of the year. The fraction of total radiant energy absorbed by each panel varies greatly with partial cloud cover. These variations in absorption of each panel result in different steam temperatures leaving the various panels. Multipasses permit a reduction of heat pickup per pass and decrease the temperature differentials. Also, after each pass, the steam is mixed to equalize the unbalanced temperatures.

The superheater absorbing surface is "over-surfaced" to obtain full rated steam temperature at reduced or unbalanced insolation, especially during partial cloud shading. Under normal conditions, the excess steam temperature obtained by the oversized superheater is "attemperated" by spraying feedwater to the steam. This provides very rapid and simple control of the steam temperature without degrading the cycle efficiency.

Dual Flow Path

The superheater is divided into two symmetrical flow paths, east and west, each consisting of three series passes with spray attemperation between the passes. These two flow paths with spray attemperation for each are needed to compensate for the large diurnal, seasonal, and cloud-induced variations of incident power on the west and east sides of the receiver. During the morning hours, the west side receives more insolation; in the afternoon, the east side absorbs more. During cloud transients, one side will likely absorb more than the other. The separate attemperators in each flow path control the steam temperatures.

Biasing Valves

A butterfly control valve is located at the inlet to each superheater panel to provide proper flow distribution to panels during severe cloud transients and during early morning and late afternoon operation. During normal operation the valve is throttled to approximately 70 percent open position. If the panel outlet steam temperature exceeds the allowable value, the control repositions the valve to increase the flow to this panel. If the steam temperature is below a given value, the valve is throttled to divert the flow to the other flow paths. When the valve is fully open and the steam temperature at the exit of the panel is above the allowable value, a signal is provided to the collector field control to redirect a corresponding group of heliostats away from the hot flow path.

5.3.2.2 Description of Main Receiver Configuration

The centerline of the main receiver absorbing surface is located 155 m (508 ft) above ground, facing a north collector field occupying approximately 160 degrees.

Absorber Panel Arrangement

The panel arrangement of the primary receiver is shown schematically in Figure 5.3-4. The external receiver consists of eight panels arranged symmetrically about the north-south axis; six are superheaters and two are economizers. The superheater panels are composed of steam-cooled membrane wall tubes with water-cooled screen tubes in front of the membrane wall. The active surface covers 210 degrees of the receiver circumference; the remaining 150 degrees is closed with nonabsorbing galvanized steel siding to prevent unsymmetrical wind loading of the receiver.

Panel Design

A sectional view of the basic panel design is shown in Figure 5.3-5. The superheater panels consist of small-diameter Incoloy 800H tubes, with screen tubes arranged in front of the panel to shield the panel from excessive heat flux levels. Tables 5.3-1 and 5.3-2 show the tube sizes, spacing, and other general design data for the panels. The screen tubes are always located outboard in line with the membrane so that the vibration support bar can penetrate directly through the slot in the membrane panel. The spacing of the screen tube is, therefore, always a multiple of the membrane wall tube spacing. As can be seen from Table 5.3-1, the screen tube sizes and spaces are varied from panel to panel. The variation is necessary to obtain a moderate and uniform heat flux pattern on superheater panels.

The farther away from the north of the receiver, the larger is the incident heat flux gradient. To avoid placing the hottest panel in the area with the severe heat flux gradient, the secondary superheater panel is located between the primary and the intermediate superheaters. To minimize steam temperature differences between tubes of the panel, it is necessary to use two screen tube sizes in the intermediate superheater panel.

The screen tubes originate at an inlet header on the bottom and terminate at outlet headers at the top. Water/steam flows upward through the tubes. The inlet header is supplied from the circulating pump discharge manifold. The outlet header collects the steam and water mixture of low steam mass fraction (quality) and discharges it to the steam drum.

The screen tubes are attached to the superheater panels at a distance depending on tube size. Attachments maintain the appropriate spacing and avoid vibration. The attachment device provides a sliding fit support to compensate for differential thermal growth of the screen tubes and membrane panel. The design of this vibration support, shown in Figure 5.3-6, is an investment casting made of Type 304 stainless steel and is bolted to the rear of the membrane; thus, it is not exposed to the incident heat flux. A slot in the membrane permits the penetration of the screen support bar which is welded to the screen tube. The support bar is guided through a round pin in a pair of vertical slots provided in the casting. This construction provides freedom of relative movement in the vertical direction only.

The design of the vibration support was analyzed for a variety of possible flow instabilities such as galloping, whirling, vortex shedding, turbulence, buffering and wake-induced oscillations. Whirling and vortex shedding proved to be the most dangerous instabilities. The spacing of the supports was selected to avoid critical vibration frequencies under any possible wind conditions at the receiver.

The screen tubes are assembled together with the membrane wall in the shop to form a single shipping unit. All headers and buckstays are shop-assembled. Insulation, applied at the plant site before the panel assembly is lifted into its position on the tower, is applied in two layers to a thickness of 0.18 m (7 in) with staggered joints. Calcium silicate blocks 7.6 cm (3 in) are placed next to the membrane with 10-cm (4-in) medium-temperature blocks of mineral fiber over it. The insulation is held in place by heat resistant studs welded to the back of the membrane bars. Aluminum rib sheathing is applied over the insulation.

A tee-shaped stainless steel member clipped to the membrane panel permits unrestrained lateral growth in both directions from the center, where the tee is fastened to the membrane. Brackets welded to the tee member slide along two carbon-steel I-beams, which represent the buckstay, to permit unrestricted longitudinal expansion and contraction. The I-beams are outside of the insulation and always remain cold, while the tee-shaped member is below the insulation and is hot during boiler operation. The panel is supported from the upper headers that are attached to a horizontal member, which is welded to the upper ends of the buckstays. Two lifting lugs on the horizontal member are used to lift the panel on the receiver support grid. The buckstays are attached to the horizontal trusses of the main support structure. The surface of the tubes that are exposed to solar radiation is coated with Pyromark black paint, which has a high absorptivity coefficient.

Flow Sequence Through the Receiver

The flow path through the receiver is conventional, as illustrated in Figure 5.3-7. Feedwater is admitted at a controlled rate into the two economizer panels to maintain the liquid level in the steam drum. The water is preheated in the economizer panels and is injected into the drum, where it is mixed with the saturated water discharged from the cyclone separators. Slightly subcooled liquid at about 321°C (610°F) is pumped from the drum and distributed through the bottom header to the boiler tubes. As the liquid flows upward through these tubes, it is heated, converted into approximately 25 percent quality steam, collected by the upper header, and returned to the drum. Steam is released from the upper part of the drum, passes through centrifugal separators and scrubbers, then flows into the superheater.

As mentioned before, a pump-assisted circulation is used to ensure adequate and stable flow in every screen tube for all operating conditions, with sufficient margin or reserve for transient upsets. The circulation system is shown in Figure 5.3-7. Since panel arrangement is symmetrical, only one half is shown. As shown in the figure, the circulating system for the primary receiver consists of a circulating pump with discharge manifold, supply tubes, screen tubes, risers, drum, and downcomer.

All circulation calculations are performed by using a proprietary B&W circulation balancing computer program. The input consists of all circuits geometry and heat absorption distribution with selected sizes of downcomer, supply tubes, discharge riser, pump and cyclone separators. The output yields flow rates, mass velocities, steam quality, DNB ratio, stability, etc. The output must meet the established standard acceptance criteria and limits. The results indicate that the circulating system needs one downcomer, 20 supplies, and 20 risers. The number and sizes are listed in Table 5.3-3. The calculation was further extended to the worst condition when circulating pumps stop working. In the event of pump failure, the circulation system will still work by natural circulation. However, for a solar receiver with unpredictable heat flux variation from cloud transients, it is difficult to ensure adequate flow behavior in all natural circulation circuits. There exists a risk that tubes which become stagnant are having reverse flow from cloud cover and will not be able to re-establish adequate mass velocities by the time the cloud passes. In the event of an electric power supply disruption to the recirculation pump and controls, the receiver will not be endangered if removal of incident power begins within 15 seconds and the incident heat flux on the receiver is gradually (linearly) and uniformly reduced to below 70 kW/m² within 80 seconds of the disruption. The water storage capacity in the drum, even at the low water level, is adequate to maintain circulation and to supply steam to sufficiently cool the superheater to prevent tube failures.

A glandless boiler circulating pump is used for the receiver. The glandless wet-stator design is now considered to be standard for boiler water circulation. The power requirement of the pump at normal operation is less than 40 kW with about a 57-kW peak at cold start-up. The total circulation flow rate is near 5.35 x 10^5 kg/hr (11.8 x 10^5 lb/hr), which corresponds to a circulation ratio of 4 based on rated steam generation.

The superheater is divided into two symmetrical flow paths, east and west, each consisting of three series passes. There is one panel per pass in each flow path, with spray attemperation between the passes; thus, four attemperators are provided. The two flow paths and the spray attemperation are needed to compensate for the large diurnal, seasonal, and cloud-induced variations of incident power on the west and east sides of the receiver. Butterfly control valves are located at the inlet to each superheater panel to provide for flow distribution to panels during severe cloud transients and during early morning and late afternoon operation. The biasing of the butterfly valves is needed only at extreme transients when superheater temperatures become excessive.

Moisture-free steam from the drum flows through saturated connections to the primary superheater, where it is heated to about 417°C (783°F). The output of the primary superheater is lead through two steam downcomers, one in each flow path, and attemperated and distributed into the intermediate superheater. The spray attemperator, consisting of an atomizing nozzle and a venturi sleeve, is located in each steam downcomer pipe. Additional feedwater is injected into the steam, as required, to control the final steam temperature. At the design point, about 9.3 percent spray is used and the steam temperature entering the intermediate superheater is reduced to 369°C (696°F).

The steam leaving the intermediate superheater has an average temperature of about 446°C (835°F) and passes through a second stage attemperator located in each steam downcomer. At normal operating conditions, no spray is needed at this stage. The steam is heated in the secondary superheater to the final steam temperature of 549°C (1,020°F) at the required pressure of 11.72 MPa (1,700 psia).

5.3.3 The Reheat Receiver Design

The baseline conceptual design of the reheater receiver originally followed the advanced receiver arrangement and consisted of horizontal flow panels arranged in a 4 by 4 matrix. A detail performance analysis of that configuration has indicated an excessive pressure drop. Therefore, it was necessary to change the arrangement of the reheater panels from four passes to three passes and from horizontal flow direction to vertical. Also, there was a non-absorbing transition between the primary and reheat receivers, which would require special precaution to prevent overheating. The turbine cycle requires a proper energy ratio between the primary and reheat steam supply. During cloud transients, this ratio may become upset, therefore, it may become necessary to refocus some of the heliostats from one receiver to the other. This maneuver could overheat non-absorbing surfaces.

The new design of the external reheat receiver consists of 16 vertical panels located directly below the primary receiver and arranged to prevent insolation from falling on non-absorbing surfaces. The absorbing panels are arranged on the circumference of a vertical cylinder of 14.4-m (47.5-ft)-diameter concentric with the main receiver and encompassing a 210-degree angle, and facing north. The height of the absorbing surface is 13.1 m (43 ft); the total panel width is 26.25 m (86.1 ft), and the total absorbing surface is 343.8 m^2 (3,700 ft^2).

Panel Arrangement

The panel arrangement of the reheat receiver is shown schematically on Figure 5.3-8. The panels are composed of steam cooled membrane walls, made of vertical tubes 3.8 cm (1.5 in) diameter on 5.7 cm (2.25 in) centers with 1.9 cm (0.75 in) wide membrane bars welded between them. The panels are of the type shown in Figure 5.3-9, which in general, is similar in construction to the superheater panels. The vertical panel is bent at the top and supported at the curvature on a horizontal support pipe attached to the buckstay system, which is similar to the panel support at Barstow. The function of the buckstay system is to maintain the panel shape and to hold it to the support structure while allowing for thermal growth. The junction at primary and reheat receiver is depicted in Figure 5.3-10. A distance of 1.45 m (4.75 ft) is maintained between the reheater and superheater panels to hide the headers and supports from incident radiation and to provide room for future closure door rails.

The reheater has two symmetrical flow paths east and west, with three series passes in each path and full steam mixing between passes. The first pass of the reheater is made of low alloy material SA-213 T22 and the two final passes are a Incoloy 800H material. Table 5.3-4 is a list of the solar reheater panel data. A spray attemperator is arranged at the inlet to each flow path to control the reheat outlet temperature. Each flow path is also provided with a butterfly biasing valve to restrict flow to the cold side and increase flow to the hot side.

5.3.4 Receiver Support Structure

Although the primary and reheat receivers are thermally independent and are each served by dedicated sets of heliostats, they are supported by the same structure. This structure, shown schematically in Figure 5.3-11, consists of seven columns bolted to foundation plates on the top of the tower. The columns are interconnected by trusses at the tower surface and at ten other elevations to form a rigid septagonal space frame; diagonal bracing between these elevations increases the torsional and bending rigidity of the frame. Although such a frame is redundant, it can be readily analyzed by finite element methods. Platforms, decks, component attachment fittings, stairways, etc, can be installed inside this space frame at whatever elevations the sizes of the boiler components dictate.

The major loads on the space frame consist of the receiver weight, ice load, wind load, seismic effects, and future closure doors. The receiver components and the support structure are designed to withstand UBC Zone 2 earthquake conditions and winds with a maximum speed of 45 m/s (100 mph) gusts at ground level (exponentially increased for height). The design was performed only to a level required to obtain a cost estimate.

The major vertical load on the structure is the weight of the receiver components which are fairly uniformly distributed around 210 degrees of the north side periphery. The drum weight is suspended near the center from the top grid by means of U-shaped rods. The south side 150 degrees of the periphery supports mainly the enclosure siding. The major lateral load on the support structure is caused by the winds.

The receiver is suspended from a steel grid made up of large beams attached to the vertical columns; see Figure 5.3-11. The columns are spaced on a 8.53-m (28-ft) diameter circle and are attached to the concrete tower. Circular (septagonal) trusses brace the columns at several elevations. Every bay between the columns is diagonally braced for stability and to transfer the loads to the tower. A schematic arrangement of the column and bracing is depicted in Figure 5.3-11. Figure 5.3-12 shows a typical horizontal truss in the primary receiver area with vertical hangers and intermittent diagonal bracings. Figure 5.3-13 shows a schematic arrangement of the horizontal truss in the reheat receiver area and Figure 5.3-14 shows the top support steel.

Platforms, stairs, and railing are provided around the drum, pump, headers, and valves to facilitate inspection and maintenance.

Optional Closure Doors

The operational advantages of the external main receiver could be enhanced by the use of optional closure doors. These insulating doors would reduce the cooldown rate of the pressure parts when there is no solar input.

The door consist of two curved, insulated, tambour type, sliding doors moving on trolleys over the absorber surface of the main receiver. In closed position, one door covers the east half of the receiver tubes, and the other covers the west half. The two doors move on rails attached to the receiver support structure. The door consists of panels about 18.0 m (59 ft) long, each made of standard steel joints and cross-braced for stiffness. Four panels are hinged together to form the east door, and four panels make up the west door. A trolley drive, operated by a 7.5-kW (10.0-hp) electric motor will move each door into open or closed position. The door hangs on the upper rails and is guided in the bottom rails.

5.3.5 Receiver Thermal Performance

The thermo-hydraulic analysis was performed using the B&W solar receiver computer program. The basic inputs are heat flux maps, steam conditions, and assumed panel configurations.

Heat flux distribution has the largest effect on receiver design. The heliostat aim strategy selected for both primary and reheat receivers is to provide a skewed heat flux pattern for the primary receiver with the peak in the lower half, and a nearly uniform vertical heat flux distribution with a decrease towards the bottom of the reheat receiver. The vertical peak heat flux distribution for both primary and reheat receivers at various times of the day is shown in Figure 5.3-15.

Thermal losses from the receiver include the losses due to reflection from absorber surface, convection to the surrounding air, infra-red radiation of the hot receiver surface, and conduction through the insulation and supports.

The convection loss is the most difficult one to predict because of complex geometry. The natural convection part is estimated according to Kreith's correlation. The forced convection part is calculated based on a reasonable extension of Achenbach's experimental data. The method of loss calculation of the receiver is presented in the Sandia report, SAND 79-8177, Conceptual Design of Solar Advanced Steam/Water Receiver. Ambient temperature and wind speed have a significant effect on thermal losses and, therefore, on receiver efficiency.

5.3.5.1 Primary Receiver Thermal Performance

The heat flux map for the primary receiver at the design point (at noon of winter solstice) is shown in Table 5.3-5 (the peak heat flux on the main receiver is 655 kW/m²). Based on ambient temperature equal to 13.9°C (57°F) and wind speed at receiver equal to 5.5 m/s (18 ft/s), the thermal efficiency at the primary receiver is found to be 88.45 percent. The power distribution to, and power absorbed by, receiver panels are presented in Figure 5.3-16. The summary results at design point are listed in Table 5.3-6. As can be seen, the pressure drop through the superheater is 1.93 MPa (280 psi), and the steam flow rate is 133,700 kg/hr (294,800 lb/hr), which is 3.8 percent over the required steam flow. Also shown are the highest possible unbalanced steam temperatures and upset metal temperatures caused by extreme flow imbalance due to a combination of the following reasons:

- Header maldistribution
- Tube and manufacturing tolerances
- Screen tube deflection
- Panel flux gradient
- Heat flux peaks (resulting from heliostat misalignments, etc)

The total flux upset factor (F_Q) varies in both vertical and horizontal directions along the receiver. However, the flow unbalanced factor (F_U) only changes from panel to panel and remains constant along the tube. It is estimated that the maximum heat flux upset factor is about 1.259 (+25 percent); the minimum flow unbalanced factor is about 0.93 (-7 percent) at the design point, assuming that flow control valves are not biased.

Figure 5.3-17 indicates the fluid and metal temperature profile of the primary receiver at design point. The highest upset metal temperatures are in the secondary superheater. It is seen that the fluid temperature in the economizer and superheater tubes continuously increases. However, the tube metal temperature increases and then decreases along the receiver height. This is due to the fact that the incident flux becomes small near the top of the receiver. With actuation of the biasing valves, the upset temperatures will be significantly reduced; these biasing valves are needed only for transients caused by cloud passage.

5.3.5.2 Reheater Receiver Thermal Performance

In addition to peak incident heat flux shown in Figure 5.3-15, the heat flux map for reheater receiver at the design point is listed in Table 5.3-7. As indicated on the table, the peak heat flux on the reheat receiver is 149 kW/m². Figure 5.3-18 indicates the power distribution to the reheater panels with total incident power of 25.77 MWt at the design point. Among them, 17.54 MWt is absorbed by the reheater receiver, which represents a thermal efficiency of 68.0 percent. The summary of thermal performance results is presented in Table 5.3-8. The steam is generated at a rate of 1.2 x 10^5 kg/hr (2.65 x 10^5 lb/hr) which corresponds to about 4 percent above the required steam flow, and the total pressure drop in the reheater is 0.193 MPa (28 psi).

The fluid and metal temperature profiles for both normal and upset conditions of reheater at design point are shown in Figure 5.2-19. The fluid temperature in the reheater continuously increases and, except for the first pass of the reheater, the tube metal temperature increases due to the rise of steam temperature and then decreases along the flow direction when the incident flux drops.

5.3.5.3 Overall Thermal Performance

Solar receivers' performances during winter solstice day are shown in Figure 5.3-20, which contains information about thermal efficiency, steam flow, and spray quantity during the morning hours of the day. The afternoon performance is a mirror image of the morning graphs. The dash line corresponds to the performance of the primary receiver and the solid line represents the results of the reheater receiver. Because of increasing incident heat flux from 9:00 a.m. to 12:00 a.m., the steam flow and the thermal efficiency increase for both primary and reheater receivers. The overall thermal efficiency of the two receivers at various times of the day is listed in Table 5.3-9. It is seen that overall efficiency decreases from 84.37 percent at 12:00 a.m. to 80.47 percent at 9:00 a.m., while the output drops 40 percent.

The receiver's thermal losses versus power output are presented in Figure 5.3-21. As indicated in the figure, there are four types of losses, namely, radiation, convection, reflection, and conduction. Within the range as specified in the figure, the total losses and loss of each component are linearly proportioned to the receiver power output. The reflection losses for both primary and reheater receivers are assumed to be 5 percent of the incident heat flux. It is seen that the radiation loss of the reheater receiver is higher than convection loss. The reversed trend is found for the primary receiver. This can be explained by the lower average surface temperature of the primary receiver, including boiler (screen tubes) and economizer.

The total power output, steam flow, and the thermal efficiency versus the total incident power are plotted in Figure 5.3-22. The dash lines represent the extrapolation of the present available results. The total power output of the two solar receivers is nearly a linear function of the total incident power.

The thermodynamic diagram for temperature versus enthalpy at design point is presented in Figure 5.3-23. This figure shows the temperature and the enthalpy of fluid at any stage in the receivers. This figure also provides the useful information in calculating power unit heat balance.

5.3.6 Modes of Operation and Startup

The solar receiver is capable of operating alone or in combination with the fossil boiler, with a smooth transition from one mode to the other. Because of several control provisions incorporated in the receiver design, it is also able to operate during cloud transient with approximately 60 percent cloud coverage. The receiver can be held in "standby" condition for several hours with heliostats stowed. It can be started from standby condition (receiver warm) or from cold condition in the morning or mid-day.

The preferred diurnal start-up procedure is to pre-warm the receiver before sunrise with water and/or steam from the turbine cycle or from the fossil boiler, so that all available solar power from the collector can be utilized to generate steam as early in the morning as possible. The steam is admitted through vent valves and the condensate is removed through drain traps.

Morning Startup (Receiver Cold)

The initial conditions of the receiver are near ambient temperature with a nitrogen blanket at slightly above atmospheric pressure. The warm-up procedure brings the receiver to main steam line pressure and saturation temperature by sunrise.

The most important parameter affecting the startup is the rate of drum pressure increase which must be limited to keep temperature and stress within acceptable levels. The expected trends during cold startup of pressure and temperature for the primary receiver are shown in Figure 5.3-24. The corresponding steam consumption and energy required are indicated in Figure 5.3-25. The required warm-up energy and steam consumption for the reheater is depicted in Figure 5.3-26 as a function of time. Since much less time is required to preheat the reheater than for the primary receiver, steam is first introduced into the primary receiver. The boiler section (screen tubes) is heated by use of steam sparger inductors and, when the pressure starts to rise above atmospheric (after 18 minutes), steam condensation in the cold superheater panels causes a large rise in steam consumption. After additional 5 minutes, the superheater panels reach saturation and steam condensation slows down. Now steam is introduced into the reheat receiver. After a total of 60 minutes, both receivers are at full operating pressure. The total steam flow consumption during the warm-up period is shown in Figure 5.3-27 and the total steam energy amounts to 25.4 MW/hr (86.6 x10^6 Btu). An additional solar energy of 6.3 MW/hr (21.6 x 10^6 Btu) is used to heat the panels to their full operating temperature; see Table 5.3-10.

The sequence for cold start-up is listed in Table 5.3-11.

Mid-Day Cold Startup

For start-up after sunrise when the receiver is cold, it is preferred to prewarm the receiver using the same procedures as listed in Table 5.3-11, except for a slower, controlled rate of aiming heliostats on the receiver after the required pressure is attained.

Cold Startup Using Heliostats

The receiver can be started from cold without the use of auxiliary steam for prewarming. After the drum is filled with water and the circulating pump is put into operation, selected groups of heliostats are sequentially focused on the receiver to control the metal temperature rise and temperature differentials at allowable limit.

Hot Restart

After a standby period, selective heliostat focusing is required to attain proper steam condition suitable for admission to turbine-generator. The rate of rising steam pressure and metal temperatures must be controlled within acceptable limits.

Freeze Protection

When the ambient temperature falls below 4°C (40°F) and there is no insolation, it is necessary to protect the receiver tubes and pipes from freezing. This can be done by either draining the entire receiver, or by draining only the superheater and reheater, and feeding hot feedwater through the water containing circuits (economizer and screen) and circulating the water with the boiler circulating pump.

5.3.7 Receiver Weight and Cost Estimate

An estimate of the receiver component weights is listed in Table 5.3-12. The estimate was performed using B&W experience in the design and manufacturing of steam generating equipment.

Cost estimates of engineering, materials, fabrication, and erection of the receiver components are given in Table 5.3-13. They are based on January 1982 material cost and reflect wage rates at B&W manufacturing facilities. Cost of field construction of the receiver support structure and the primary and reheat receivers, including insulation, was obtained using

B&W's expertise in construction and installation of steam generating and similar equipment adjusted for labor rate in the El Paso area.

TABLE 5.3-1

PRIMARY RECEIVER PANEL DATA

Panel Number	Width m (ft)	Screen Tubes (Boiler) No.	Spacing cm (in)	OD cm (in)	Membrane Tubes Type	No.	Spacing cm (in)	OD cm (in)
1								
	1.2535	30	8.5725	3.4925	SH1	88	2.8575	1.905
3	(4.1124)		(3.375)	(1.375)			(1.125)	(0.750)
5								
	1.2535	22	11.4300	5.0800	SH3	88	2.8575	1.905
7	(4.1124)		(4.500)	2.125)			(1.125)	(0.750)
9	1.2535	11	11.4300	4.4450				
	(4.1124)		(4.500)	(1.750)	SH2	88	2.8575	1.905
11	1.2535	11	11.4300	3.4925			(1.125)	(0.750)
	(4.1124)		(4.500)	(1.375)				
13								
	1.4989	--NO SCREEN TUBES--			ECON	80	3.8100	2.540
15	(4.9176)						(1.500)	(1.000)

NOTES:

1. Due to symmetrical arrangement, only half of the primary receiver is listed here.

2. SH1 = Primary superheater; SH2 = Intermediate superheater; SH3 = Secondary superheater; ECON = Economizer

TABLE 5.3-2

GENERAL DESIGN DATA FOR PRIMARY RECEIVER PANELS
External Type, Diameter 11.58 m (38 ft), Active Height 15.85 m (52 ft)

Membrane (Superheater)

Tube and Membrane Material	800H
Tube Wall Thickness	2.54 mm (0.100 in)
Active Tube Length	15.85 m (52 ft)
Total Tube Length	16.31 m (53.5 ft)
Membrane Thickness	4.75 mm (0.187 in)
Inlet Header OD	0.114 m (4.5 in)
Outlet Header OD	0.114 m (4.5 in)
Header Material	800H
Design Pressure	14.5 MPa (2,100 psia)

Screen Tubes (Multi-Lead Internal Ribs)

Tube Material	SA-213-T2
Tube Wall Thickness	3.76 mm (0.148 in)
Active Tube Length	15.85 m (52 ft)
Total Tube Length	16.61 m (54.5 ft)
Inlet Header OD	0.168 m (6.625 in)
Outlet Header OD	0.168 m (6.625 in)
Header Material	SA-210-C

Membrane (Economizer)

Tubes and Membrane Material	SA-210-A1
Tube Wall Thickness	3.43 mm (0.135 in)

TABLE 5.3-2 (Cont)

Active Tube Length	15.85 m (52 ft)
Total Tube Length	16.31 m (53.5 ft)
Membrane Thickness	6.35 mm (0.250 in)
Inlet Header OD	0.168 m (6.625 in)
Outlet Header OD	0.168 m (6.625 in)
Header Material	SA-106-C
Design Pressure	14.8 MPa (2,150 psia)

2 of 2

TABLE 5.3-3

PRIMARY RECEIVER CIRCULATING SYSTEM DATA

Panel No.	Screen Tube (Boiler) No.	Supplies			Risers			Downcomer		
		No.	OD m (in)	Thickness m (in)	No.	OD m (in)	Thickness m (in)	No.	OD m (in)	Thickness m (in)
1 3	30	4	0.0889 (3.5)	0.0064 (0.25)	4	0.0889 (3.5)	0.0064 (0.25)	0	—	—
5 7	22	4	0.0889 (3.5)	0.0064 (0.25)	4	0.0889 (3.5)	0.0064 (0.25)	1	0.2938 (11.75)	0.0214 (0.843)
9 11	22	2	0.0889 (3.5)	0.0064 (0.25)	2	0.0889 (3.5)	0.0064 (0.25)	0	--	--

NOTES:

1. Due to symmetrical arrangement, only half of the receiver is listed here.
2. The dimensions of the screen tubes are shown in Table 5.3-1.
3. Only one downcomer is needed for entire receiver.
4. The steam drum is 1.37 m (54 in) ID, 0.1175 m (4.625 in) thick, 3.5 m (11.5 ft) long with hemispherical heads, material SA-515.
5. Only one circulating pump is needed.
   Circulating pump = 39.3 kW at operating.
   = 56/4 kW at cold.

TABLE 5.3-4

REHEATER RECEIVER PANEL DATA

				Membrane Tube			
Panel Number	Flow Direction	Width m (ft)	Material	Type	No.	Spacing cm (in)	OD cm (in)
1		1.8776 (6.1567)	Croloy 2 1/2	RH1	65	5.715 (2.25)	3.81 (1.5)
3	upward	1.8766 (6.1567)		RH1		5.715 (2.25)	3.81 (1.5)
5		1.5692 (5.1483)	Croloy 2 1/4	RH1	28	5.715 (2.25)	3.81 (1.5)
7		1.5692 (5.1483)		RH2	27	5.715 (2.25)	3.81 (1.5)
9	downward	1.5692 (5.1483)		RH2	55	5.715 (2.25)	3.81 (1.5)
11		1.5692 (5.1483)	Alloy 800H	RH2		5.715 (2.25)	3.81 (1.5)
13	downward	1.5692 (5.1483)		RH3	55	5.715 (2.25)	3.81 (1.5)
15		1.5692 (5.1483)		RH3		5.715 (2.25)	3.81 (1.5)

NOTES:

1. Because arrangement is symmetrical, only half of the reheater receiver is listed here.
2. RH1 = primary reheater, RH2 = intermediate reheater, RH3 = secondary reheater
3. All tubes are 0.263 cm (0.105 in) minimum thickness

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TABLE 5.3-5

DESIGN POINT PRIMARY RECEIVER FLUX MAP

E N W

Sector Number

Height of Main Receiver (M)	15	13	11	9	7	5	3	1	2	4	6	8	10	12	14	16
15.93	15	35	73	105	127	138	143	150	144	151	149	134	109	83	51	20
14.48	23	67	140	179	230	267	280	280	276	260	249	235	211	167	98	33
13.03	30	93	202	286	348	384	401	417	399	402	390	364	321	250	160	48
11.58	37	114	256	385	473	507	503	504	519	493	475	459	426	339	207	71
10.13	49	139	287	417	513	571	592	580	610	589	561	538	505	423	255	92
8.69	49	154	322	457	558	617	643	657	638	632	623	597	538	435	244	96
7.24	47	175	321	479	583	638	657	660	650	643	630	611	567	457	242	86
5.79	49	142	297	447	544	592	615	651	656	602	580	556	510	432	226	79
4.34	38	129	251	386	462	507	533	542	556	537	520	479	412	340	189	68
2.90	26	81	178	270	321	355	383	401	409	378	367	344	300	245	146	49
1.45	17	51	113	167	198	222	243	256	252	237	216	197	175	142	80	28

NOTE: Map of the incident flux (kW/m^2). These values are interpolated from those presented in Table 5.2-3.

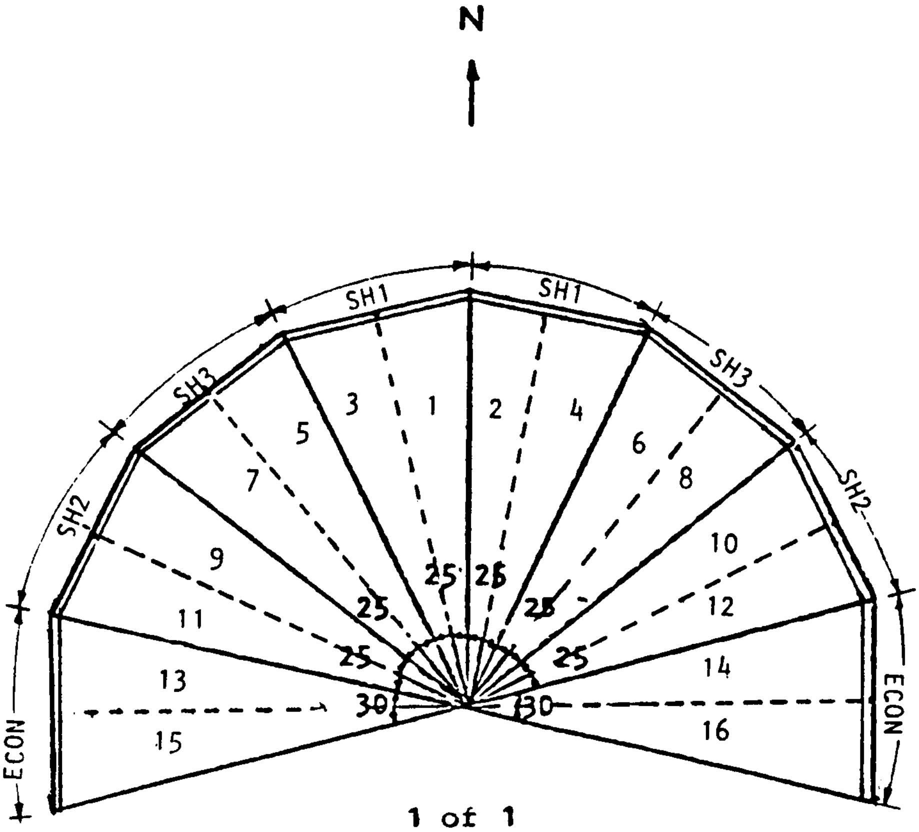


TABLE 5.3-6

PERFORMANCE OF PRIMARY RECEIVER AT WINTER SOLSTICE DESIGN POINT

Superheater Outlet			
Pressure	MPa (psia)	11.72	(1700)
Temperature	C (F)	549	(1020)
Pressure Drop Through Superheater	MPa (psi)	1.93	(280)
Drum Pressure	MPa (psia)	13.66	(1980)
Flow Rate	kg/hr (lb/hr)	133700	(294820)
Primary Superheater (or Preheater)		121600	(268200)
Spray Attemperator 1		12070	(26620)
Intermediate Superheater		133700	(294820)
Spray Attemperator 2		0	0
Secondary Superheater		133700	(294820)
% Spray		9.03	
Circulation Flow		534820	(1179280)
Circulation Ratio		4	
Circulation Pump Power	kW	39.3	
Feedwater Temperature	C (F)	236	(457)
Incident Power	MWt (MBtu/hr)	103.249	(352.492)
Radiation Loss	MWt (MBtu/hr)	2.914	(9.948)
Convection Loss	MWt (MBtu/hr)	3.332	(11.375)
Conduction Loss	MWt (MBtu/hr)	0.516	(1.762)
Reflection Loss	MWt (MBtu/hr)	5.163	(17.627)
Absorbed Power	MWt (MBtu/hr)	91.325	(311.784)
Efficiency	%	88.45	

1 of 2

TABLE 5.3-6 (Cont)

Power Absorbed by Components			
Preheater	MW (MBtu/hr)	7.696	(26.274)
Evaporator	MW (MBtu/hr)	47.215	(161.191)
Primary Superheater	MW (MBtu/hr)	14.581	(49.779)
Intermediate Superheater	MW (MBtu/hr)	10.832	(36.981)
Secondary Superheater	MW (MBtu/hr)	10.966	(37.439)
Peak Flux at Noon	kW/m² (kBtu/hr-ft²)	660	(209.22)
Average Flux at Noon	kW/m² (kBtu/hr-ft²)	308.28	(97.724)
Peak Superheater Tube OD Temperature	C (F)	590	(1094)
Peak Screen Tube OD Temperature	C (F)	374	(705)
Maximum Steam Temperature Leaving Tube	C (F)	601	(1114)
Maximum Upset Tube OD Temperature	C (F)	640	(1184)
Ambient Conditions			
Ambient Temperature	C (F)	13.89	(57)
Wind Speed at Receiver	m/s (ft/s)	5.5	(18.04)
Receiver Configuration			
Height	m(ft)	52	(15.85)
Diameter	m(ft)	38	(11.58)
Arc Angle	degrees	210	
Developed Width	m(ft)	20.97	(68.8)
Absorber Surface	m²(ft²)	434	(4673)

NOTE:

*Economizer plus Superheater plus Screen (Flat Projected)

TABLE 5.3-7

DESIGN POINT REHEAT RECEIVER FLUX MAP

	E							N								W
	SECTOR NUMBER															
Height of Reheat Receiver (m)	1	3	5	7	9	11	13	15	16	14	12	10	8	6	4	2
13.03	9	33	60	89	116	135	144	149	138	140	129	115	101	84	50	16
11.58	10	25	61	90	109	123	133	131	127	128	128	117	97	77	56	17
10.13	9	28	60	94	112	118	121	132	121	125	119	113	110	101	56	18
8.69	8	29	59	89	112	124	128	134	137	129	124	117	108	101	51	19
7.24	10	24	56	87	105	117	125	127	116	116	114	109	100	83	42	12
5.79	7	25	53	67	98	112	117	117	122	115	110	107	101	80	45	11
4.43	10	26	48	77	99	111	114	109	111	102	100	99	92	76	46	12
2.90	5	20	43	60	75	82	83	85	85	81	75	73	71	71	39	8
1.45	3	10	26	40	41	44	52	55	55	47	45	43	40	63	18	6

NOTE: Map of the incident flux (kW/m^2). These values are interpolated from those presented in Table 5.2-4.

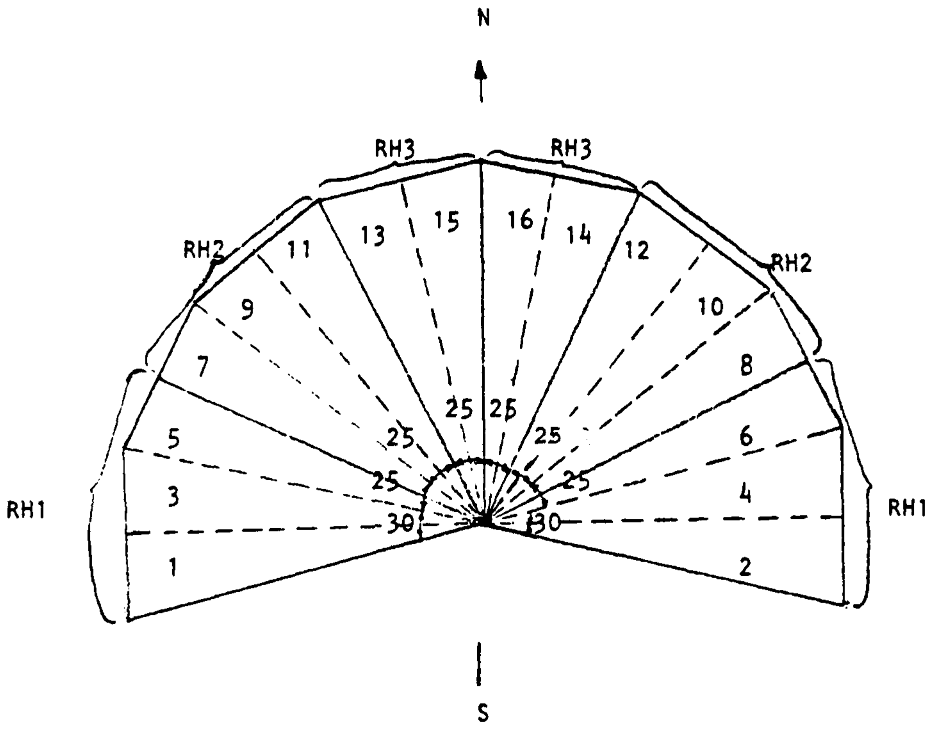


TABLE 5.3-8

PERFORMANCE OF
REHEATER RECEIVER AT
WINTER SOLSTICE DESIGN POINT

Reheater Inlet			
Pressure	MPa (psia)	3.178	(455)
Temperature	C (F)	372.8	(703)
Reheater Outlet			
Pressure	MPa (psia)	2.945	(427)
Temperature	C (F)	549	(1020)
Pressure Drop	MPa (psia)	0.193	(28)
Flow Rate			
Inlet	kg/hr (lbm/hr)	113060	(249300)
Attemperator	kg/hr (lbm/hr)	7110	(15670)
Outlet	kg/hr (lbm/hr)	120170	(264970)
% Spray		5.91	
Incident Power	MWt (MBtu/hr)	25.774	(87.992)
Radiation Loss	MWt (MBtu/hr)	4.809	(16.418)
Convection Loss	MWt (MBtu/hr)	2.013	(6.872)
Conduction Loss	MWt (MBtu/hr)	0.129	(0.440)
Reflection Loss	MWt (MBtu/hr)	1.289	(4.401)
Absorbed Power	MWt (MBtu/hr)	17.535	(59.864)
Efficiency	%	68.03	
Ambient Conditions			
Ambient Temperature	C (F)	13.89	(57)
Wind Speed at Receiver	m/s (ft/s)	5.5	(18.04)
Receiver Configuration			
Height	m(ft)	13.11	(43)
Diameter	m(ft)	14.48	(47.5)
Arc Angle	Degrees	210	
Developed Width	m(ft)	26.30	(86.27)
Absorber Surface	$m^2 (ft^2)$	345	(3710)

TABLE 5.3-9

OVERALL THERMAL EFFICIENCY AT VARIOUS TIMES

	12 Noon	10AM	9AM
Incident Power (MWt)			
Primary Receiver	103.25	87.98	66.89
Reheater Receiver	25.77	21.82	16.50
Total	129.02	109.80	83.39
Absorbed Power (MWt)			
Primary Receiver	91.33	77.06	57.32
Reheater Receiver	17.54	13.88	8.98
Total	108.87	90.94	66.30
Efficiency (%)			
Primary Receiver	88.46	87.59	85.69
Reheater Receiver	68.06	63.61	54.43
Overall Efficiency (%)	84.38	82.82	79.54

NOTES:

1. Ambient temperature is 13.89°C (57°F)

2. Wind speed at receiver is 5.5 m/s (18.04 ft/s)

TABLE 5.3-10

ENERGY REQUIRED FOR WARM-UP

			Energy Sources		
Type	Doors	Ambient C (F)	Steam MW-hr (MBtu)	Solar	Energy Required MW-hr (MBtu)
Primary Receiver	No	10 (50)	16.8 (57.3)	1.8 (6.0)	18.5 (63.3)
Primary Receiver	Yes	177 (350)	8.0 (27.2)	1.7 (5.7)	9.6 (32.9)
Reheater Receiver	No	10 (50)	8.6 (29.3)	4.5 (15.5)	13.1 (44.8)

NOTES:

1. Energy from steam is used to heat the receiver from ambient temperature to saturated condition.
2. Energy from solar is used to heat the superheater or reheater from saturation temperature to its average temperature 443°C (830°F).

TABLE 5.3-11

START-UP SEQUENCE - RECEIVER COLD
(FOR REFERENCE TO VALVE LETTERS SEE FIGURE 5.3-28)

1. Vent and fill drum to slightly above normal water level with feedwater (mix as required to match within 65°C (150°F) of bottom lower drum metal temperatures).

2. Open economizer circulation valve E, superheater drains, and trap system H. Superheater steam vent valve F remains closed until drum is warmed to saturation 100°C (212°F).

3. Start boiler circulating pumps.

4. Close nitrogen blanketing valves, open turbine end main steam stop valve, open warm-up valve B, and control prewarm-up of economizer and screen at prescribed rate. Note: This valve controls pressure and, thus, saturation temperature rate of change 5.6-3.3 C/min (10-6 F/min).

5. Stem sparger inductor valve D is used to warm up the drum, screen tubes, economizer panels, and all associated connection piping. Open valves F when the drum water reaches saturation temperature 100°C (212°F). Superheated steam is admitted through valve F into the SH, and condensation is returned through traps at H. If SH vent to atmosphere is open, close at 0.172 MPa (25 psia).

6. As volume of water in drum swells on warm-up, excess is dumped through G to maintain level slightly higher than normal set point (single-element controller).

7. When steam consumption in superheater falls below 50% of peak rate, open valves K to admit steam to the reheater. The condensation is returned through traps L.

8. At sunrise, focus heliostats on receiver.

9. Steam evaporation begins at first insolation at a rate corresponding to net power input to screen tubes and economizer. Open receiver steam valve A. Close steam sparger inductor valve D. Close superheater vent valves F and reheater vent valves K. Close drain valves G and L. Spray attemperators must be available for use.

10. Drum level dump valve G should be closed (automatically) as steam flow occurs. The feedwater flow is started when drum level drops below normal. Economizer circulation valve E is closed as this occurs. Drum level control is automatic.

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

1 of 1

TABLE 5.3-12

RECEIVER COMPONENT WEIGHTS 1,000

	kg	lb
Support Structure (plus platforms and stairs)	302	665
Primary Receiver (dry)	304	670
Reheat Receiver (dry)	150	330
Water Fill	43	95
Instrumentation and Controls	18	40
Closure Doors	91	200
2" of Ice (on Receiver and Doors)	113	250
Total Weight at Top of Tower	1021	2,250

TABLE 5.3-13

BUDGETARY COST ESTIMATE FOR RECEIVER SUBSYSTEM
(January 1982 Dollars)

Engineering		$1,200,000
Material Delivered plus Service and Supervision		7,935,000
Erection Labor		2,005,000
Total		$11,140,000
*Closure Doors Delivered	$690,000	
Erection	95,000	
	$785,000	

*Not included in direct cost estimate. These doors are considered optional.

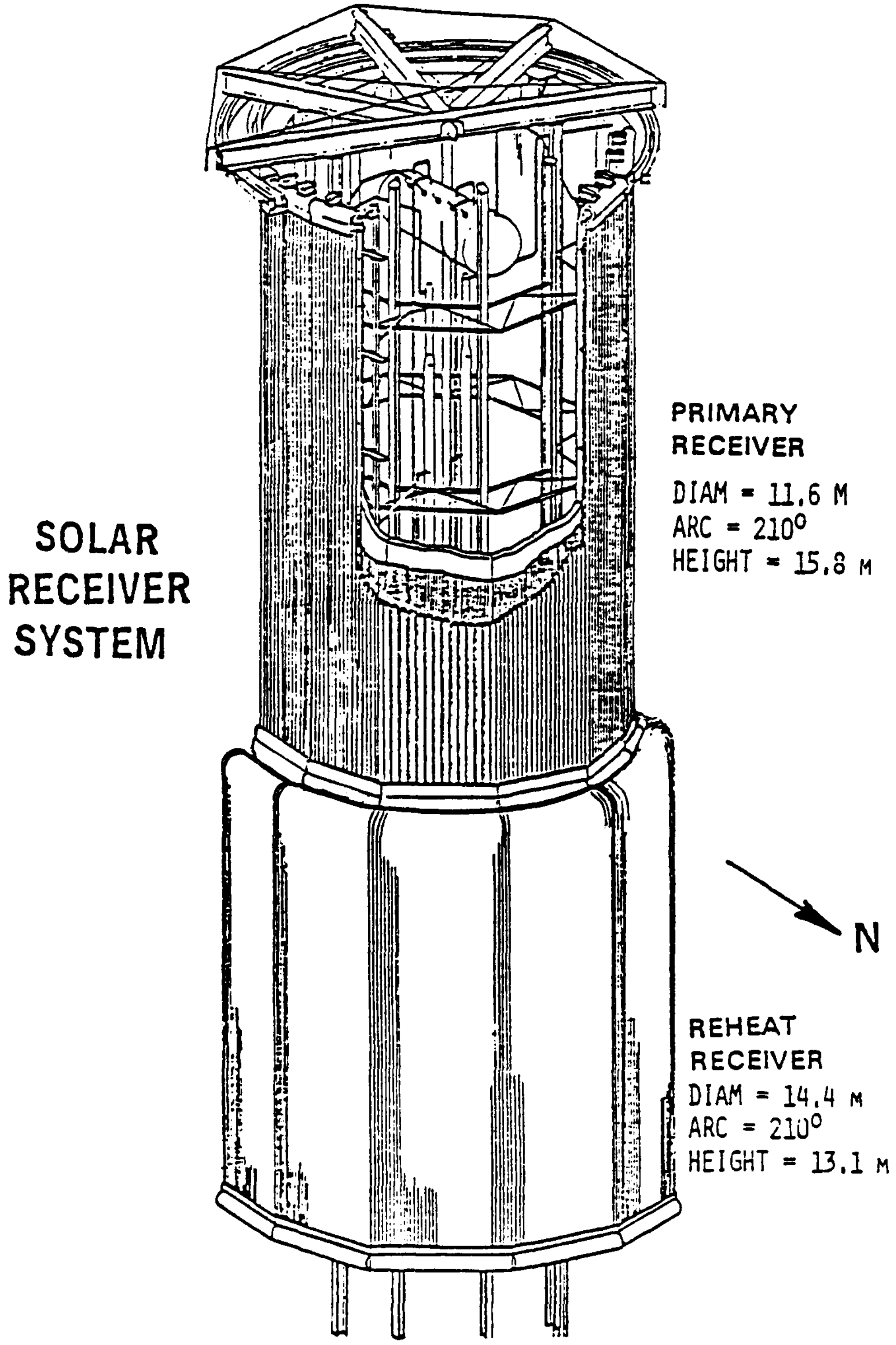


FIGURE 5.3-1
EXTERNAL WATER/STEAM
SOLAR RECEIVER SYSTEM

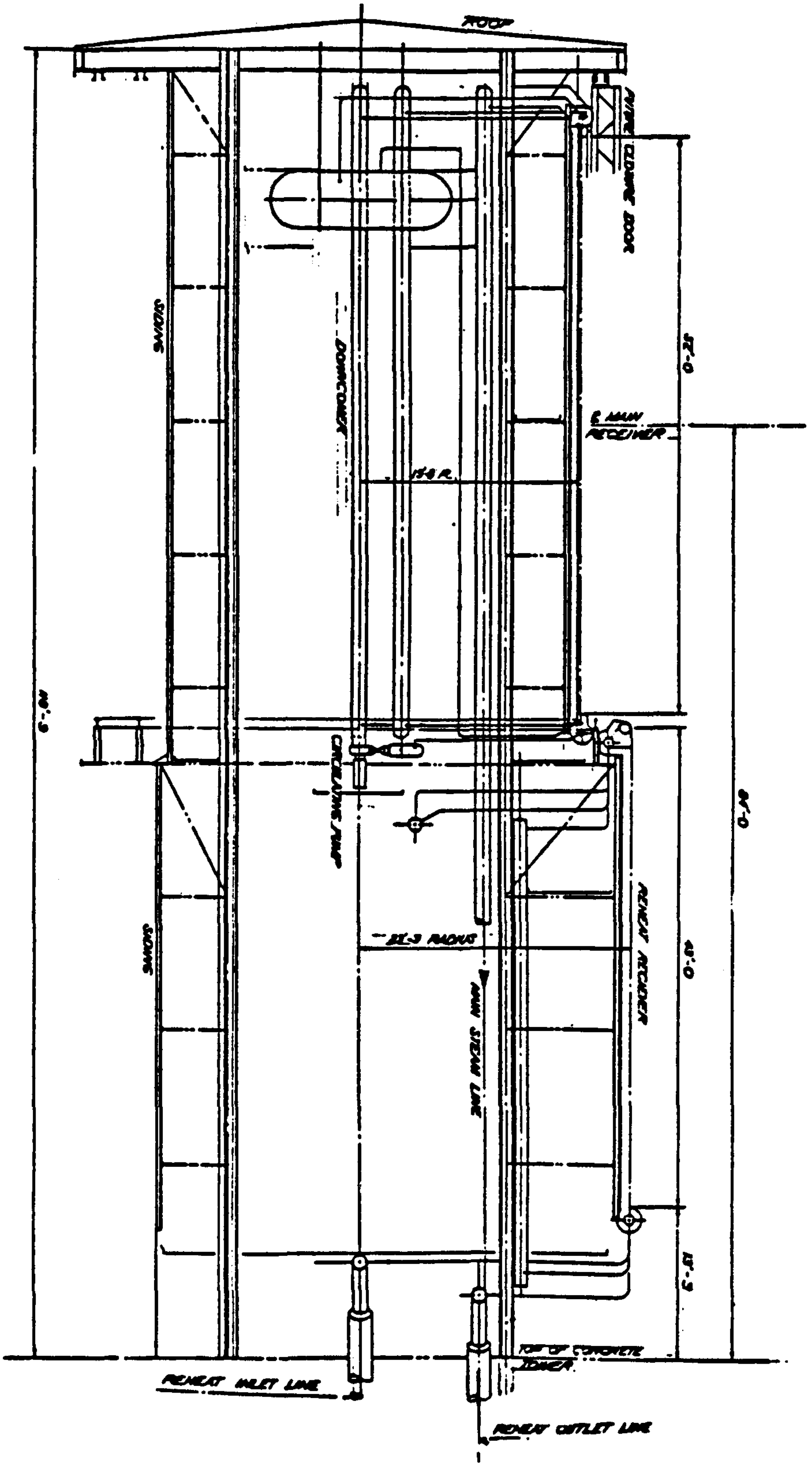


FIGURE 5.3-2
SECTION THROUGH RECEIVERS

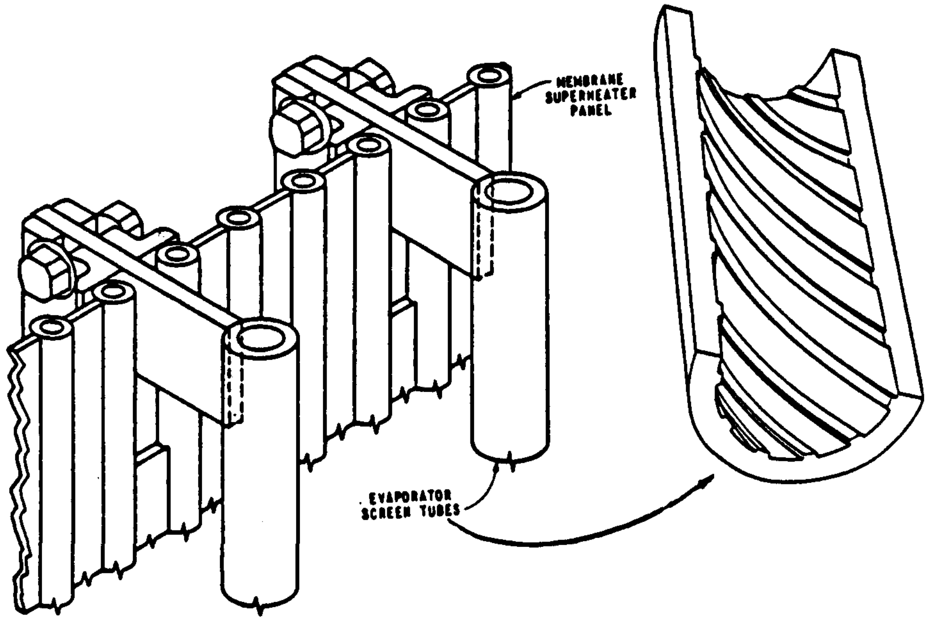


FIGURE 5.3-3
MEMBRANE WALL WITH SCREEN TUBES

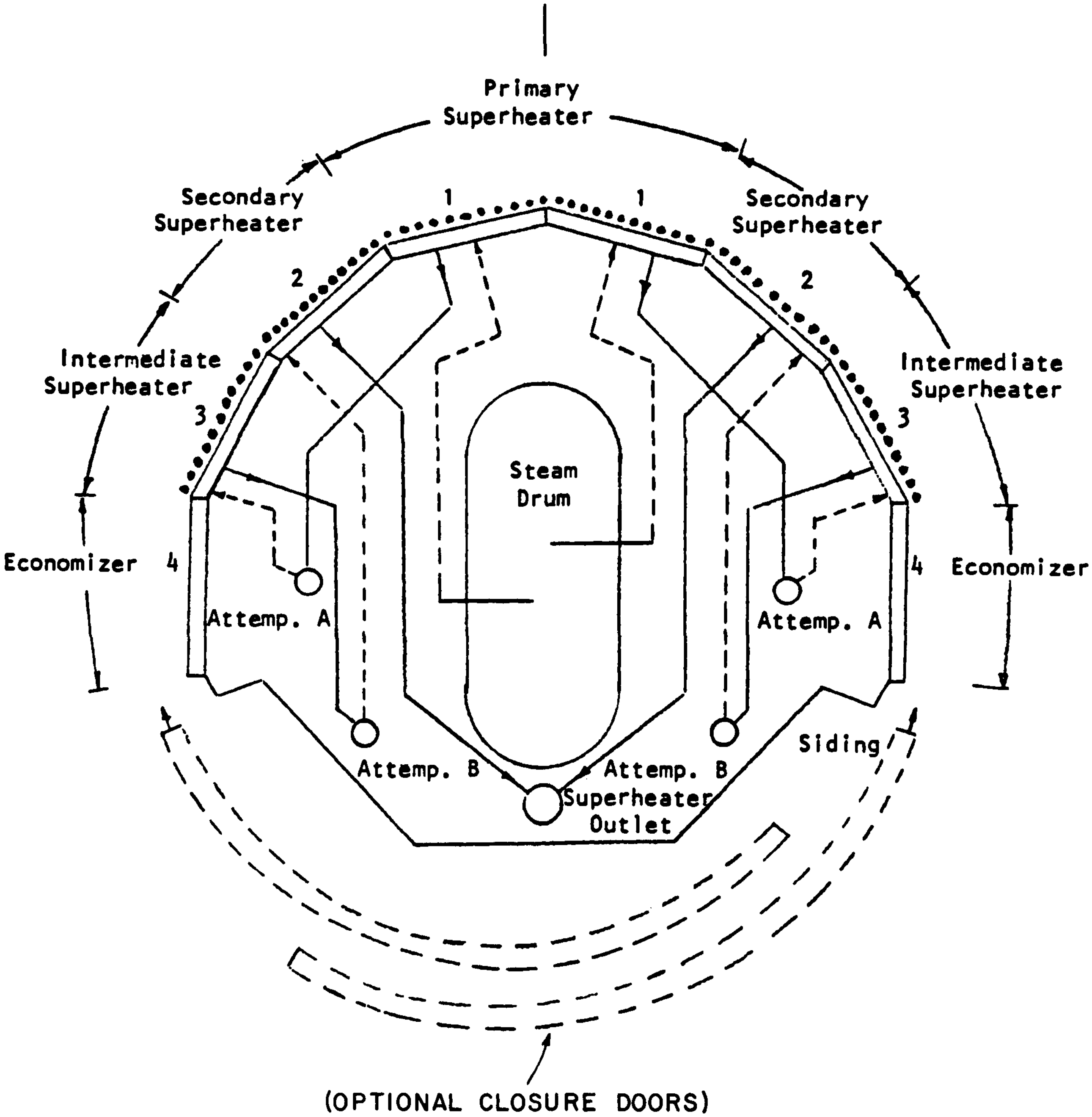


FIGURE 5.3-4
EXTERNAL RECEIVER SCHEMATIC

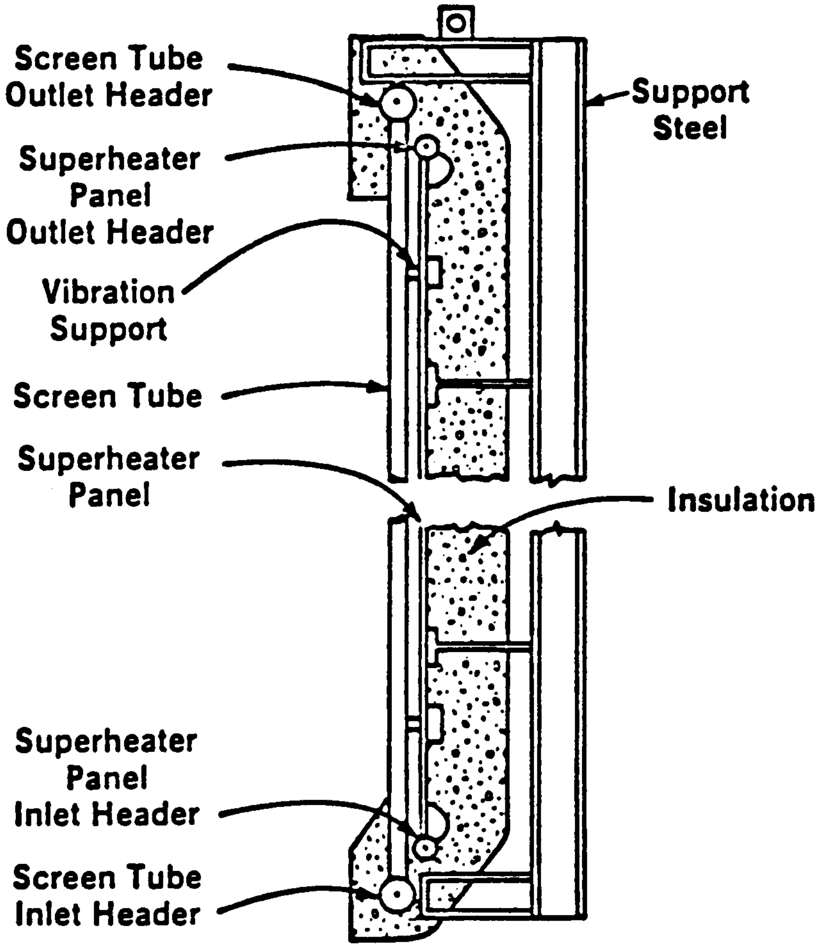


FIGURE 5.3-5
PRIMARY RECEIVER
PANEL DESIGN

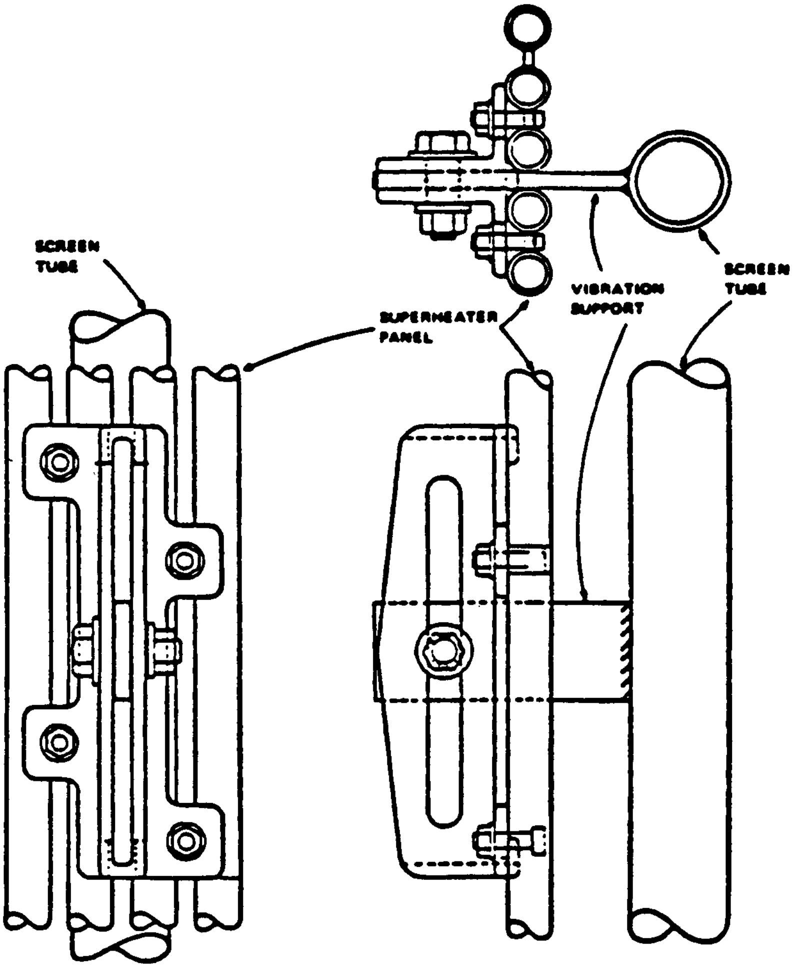


FIGURE 5.3-6
SCREEN TUBE
VIBRATION SUPPORT

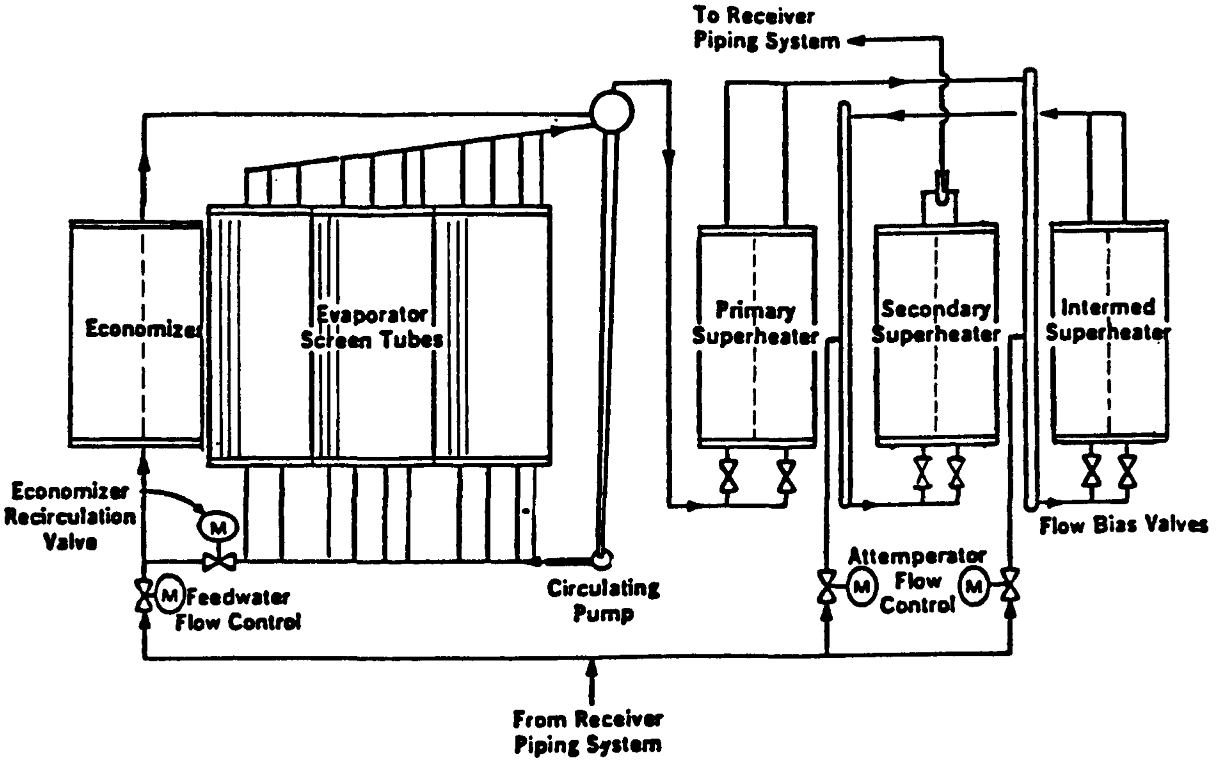


FIGURE 5.3-7
SCHEMATIC FLOW DIAGRAM
OF PRIMARY RECEIVER SYSTEM

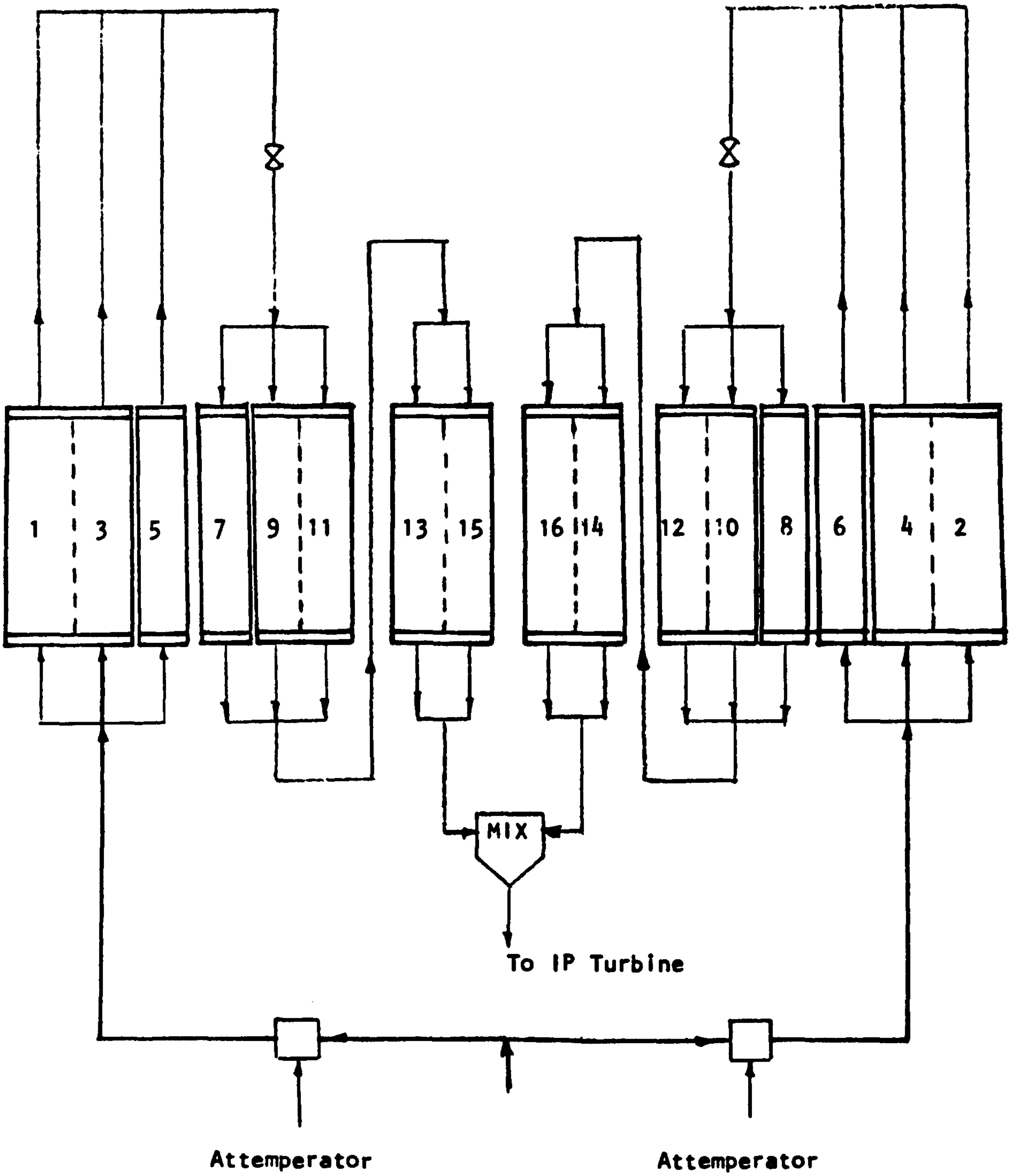


FIGURE 5.3-8
REHEATER RECEIVER SYSTEM

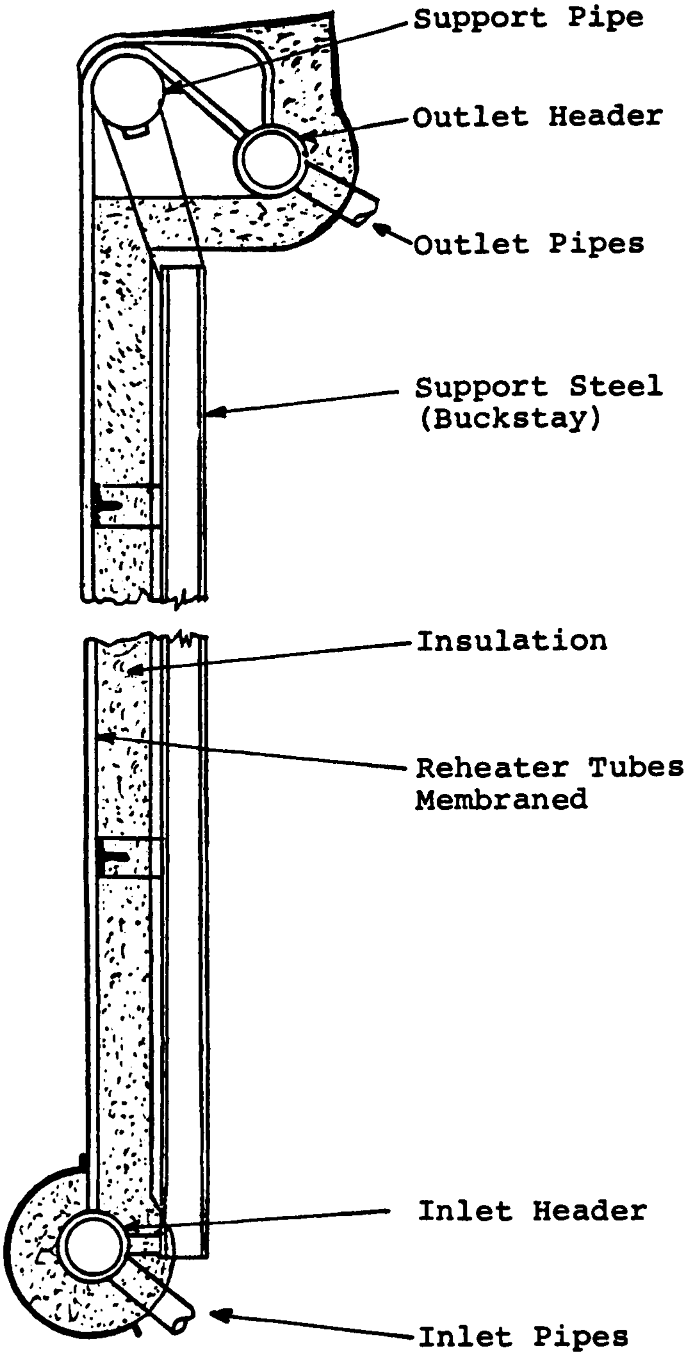


FIGURE 5.3-9
REHEATER PANEL DESIGN

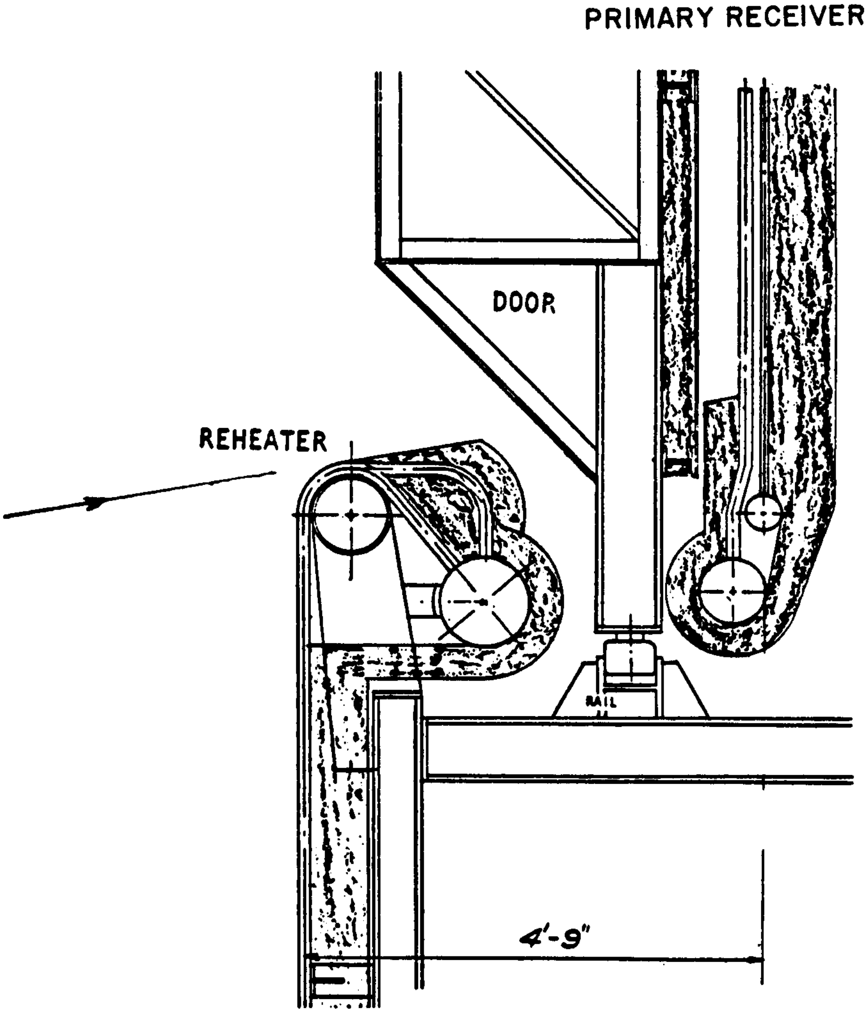
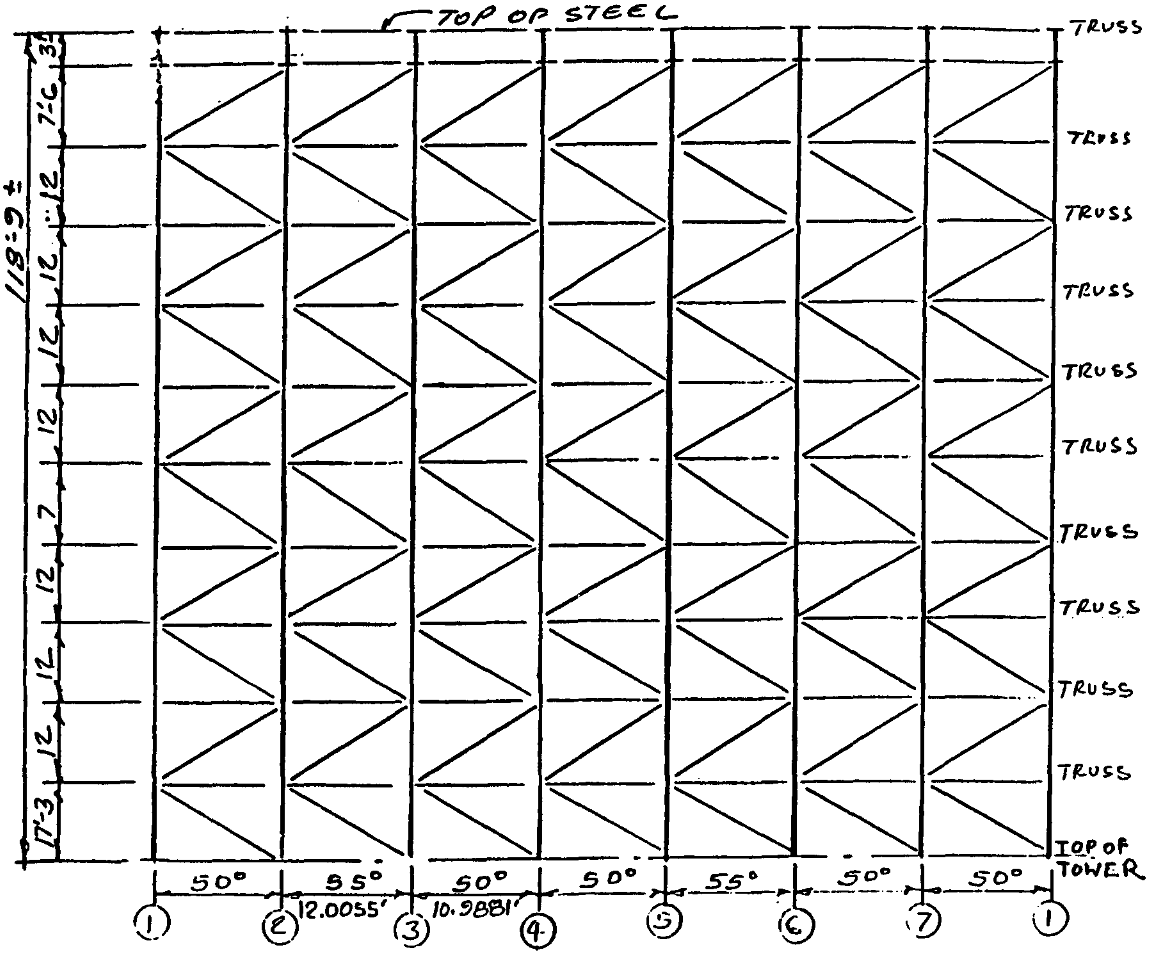


FIGURE 5.3-10
JUNCTION AT PRIMARY
AND REHEAT RECEIVER



SCHEMATIC DEVELOPED VIEW

FIGURE 5.3-11
ARRANGEMENT OF COLUMNS
AND VERTICAL BRACES

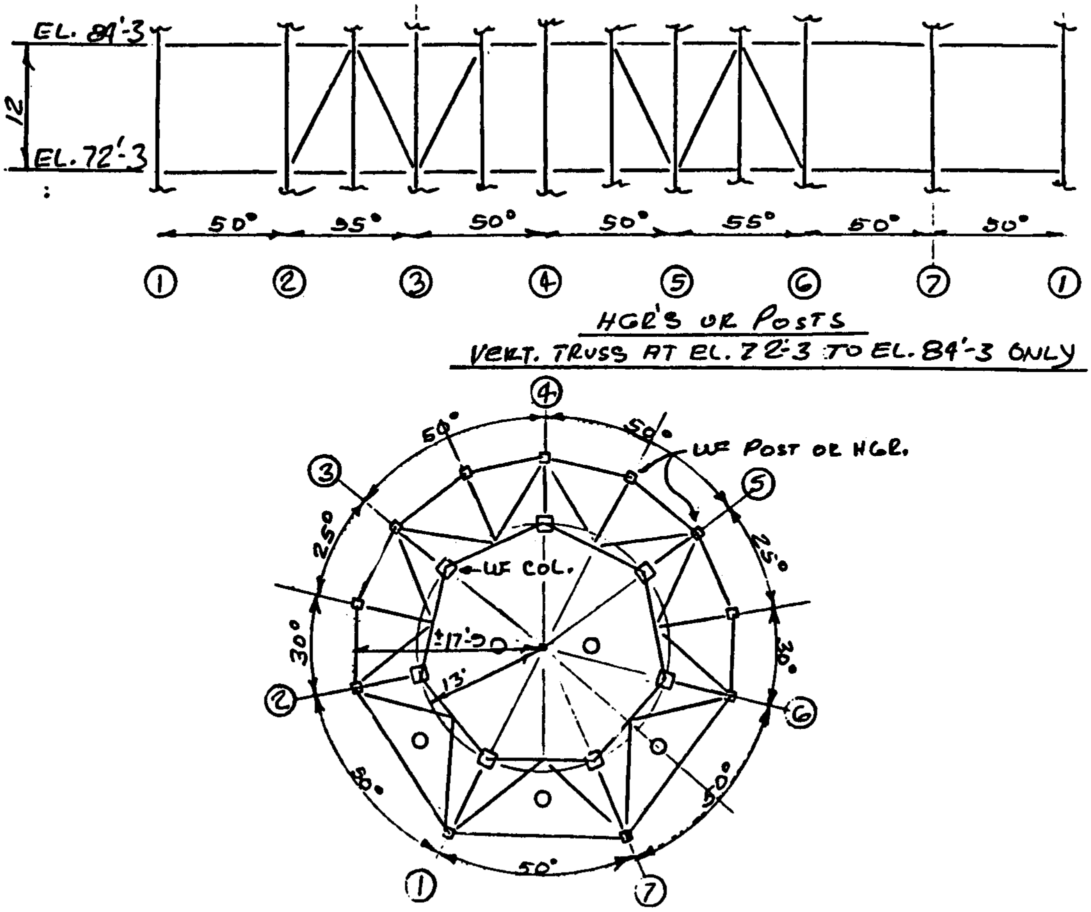


FIGURE 5.3-12
TYPICAL TRUSS IN
PRIMARY RECEIVER AREA

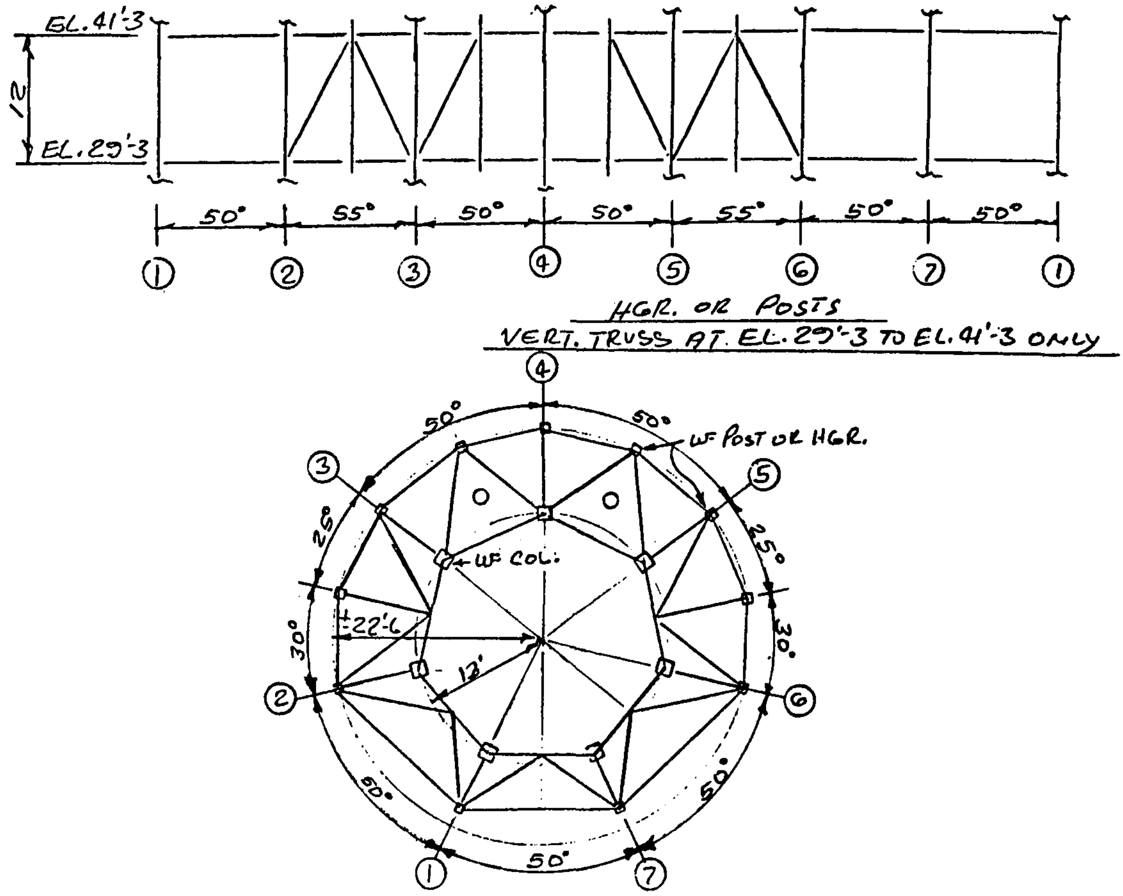


FIGURE 5.3-13
TYPICAL TRUSS
IN REHEAT RECEIVER AREA

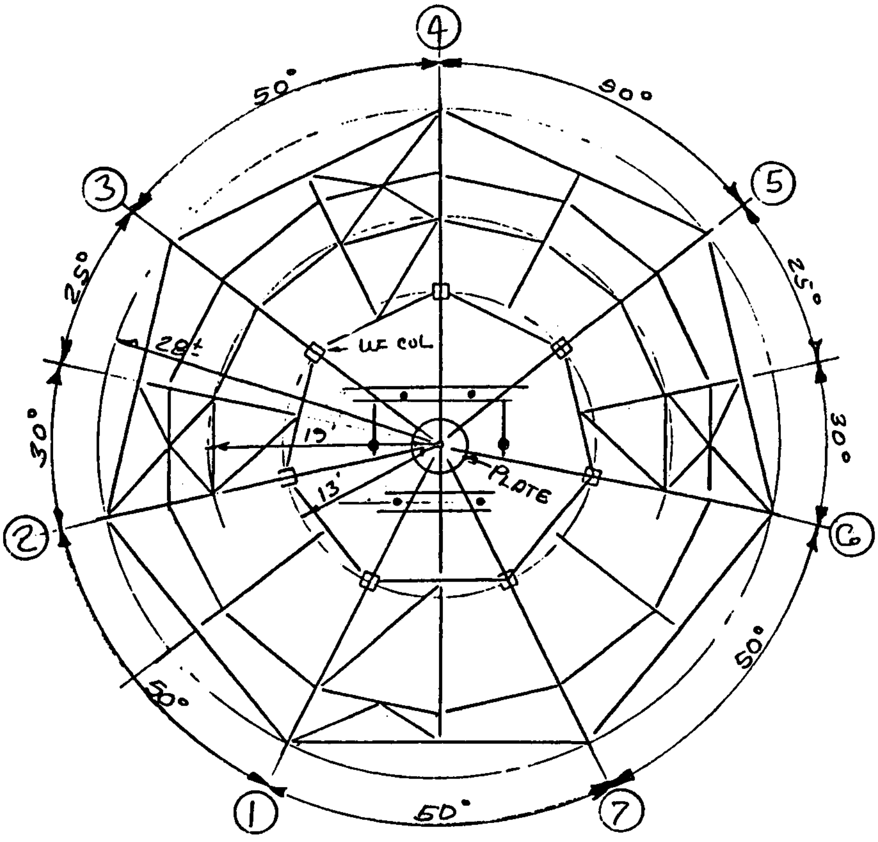


FIGURE 5.3-14
TOP SUPPORT STEEL

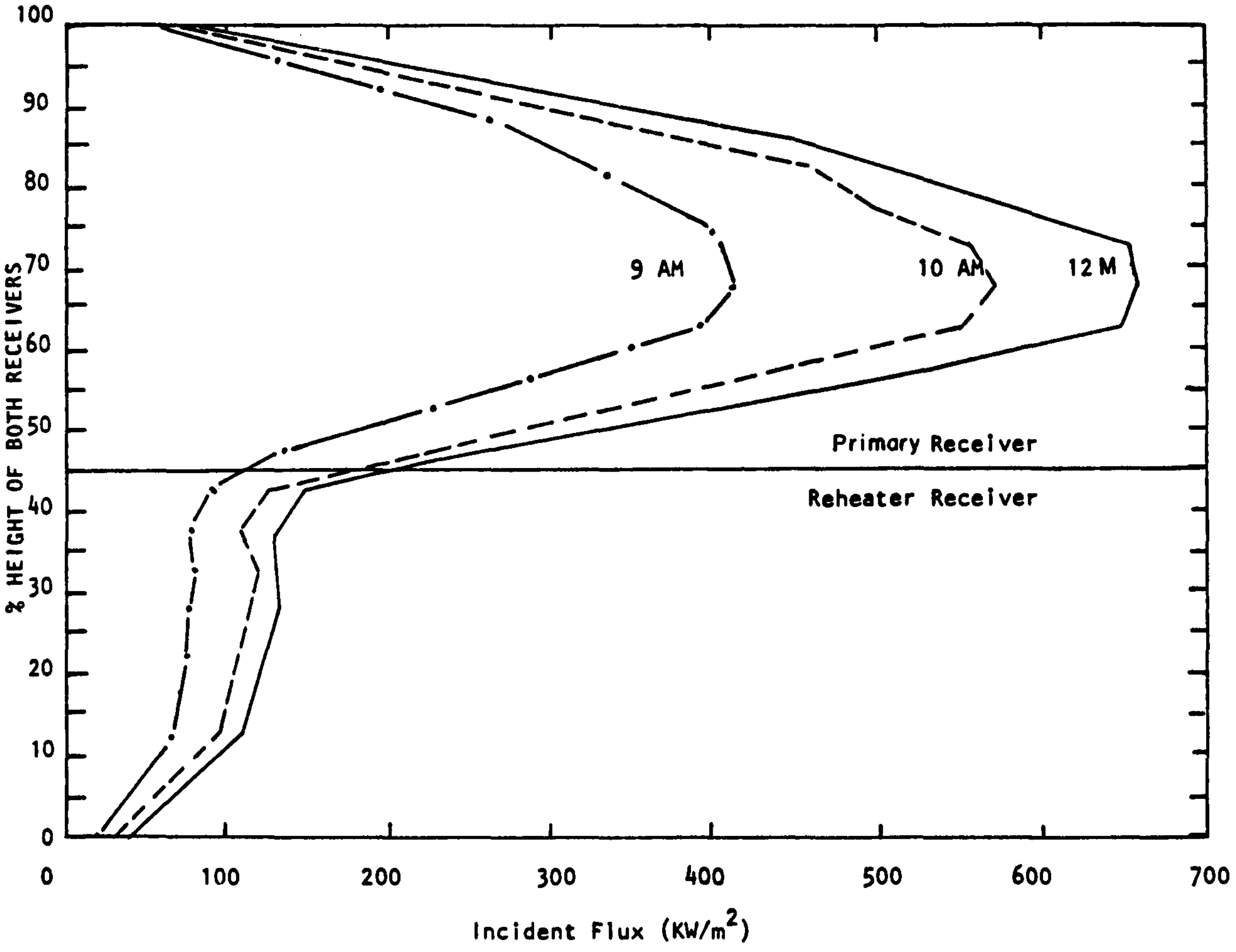


FIGURE 5.3-15
PEAK INCIDENT HEAT FLUX AT VARIOUS ELEVATIONS OF THE RECEIVER FOR 3 TIMES A DAY

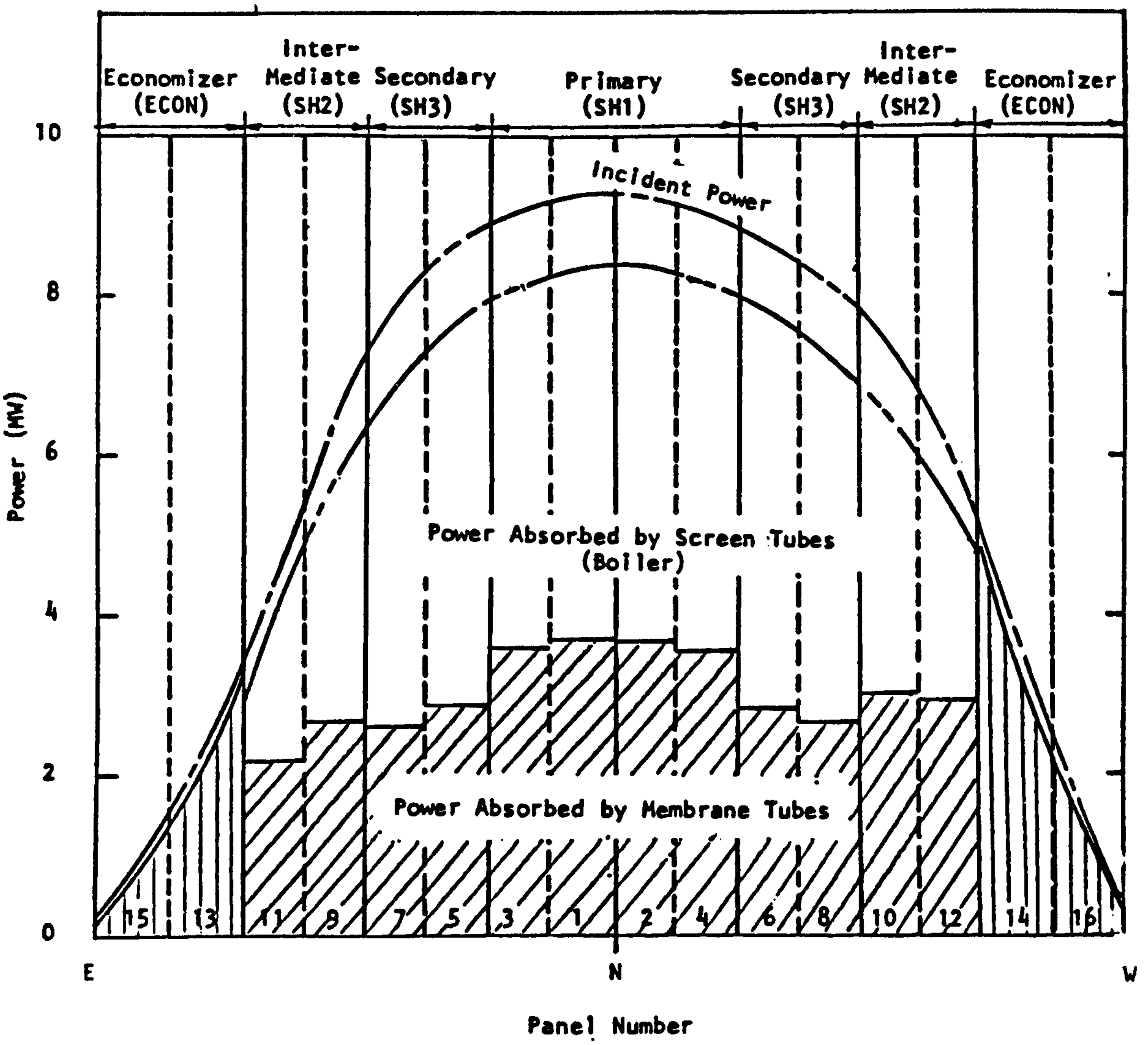


FIGURE 5.3-16
POWER DISTRIBUTION TO PRIMARY RECEIVER AT DESIGN POINT

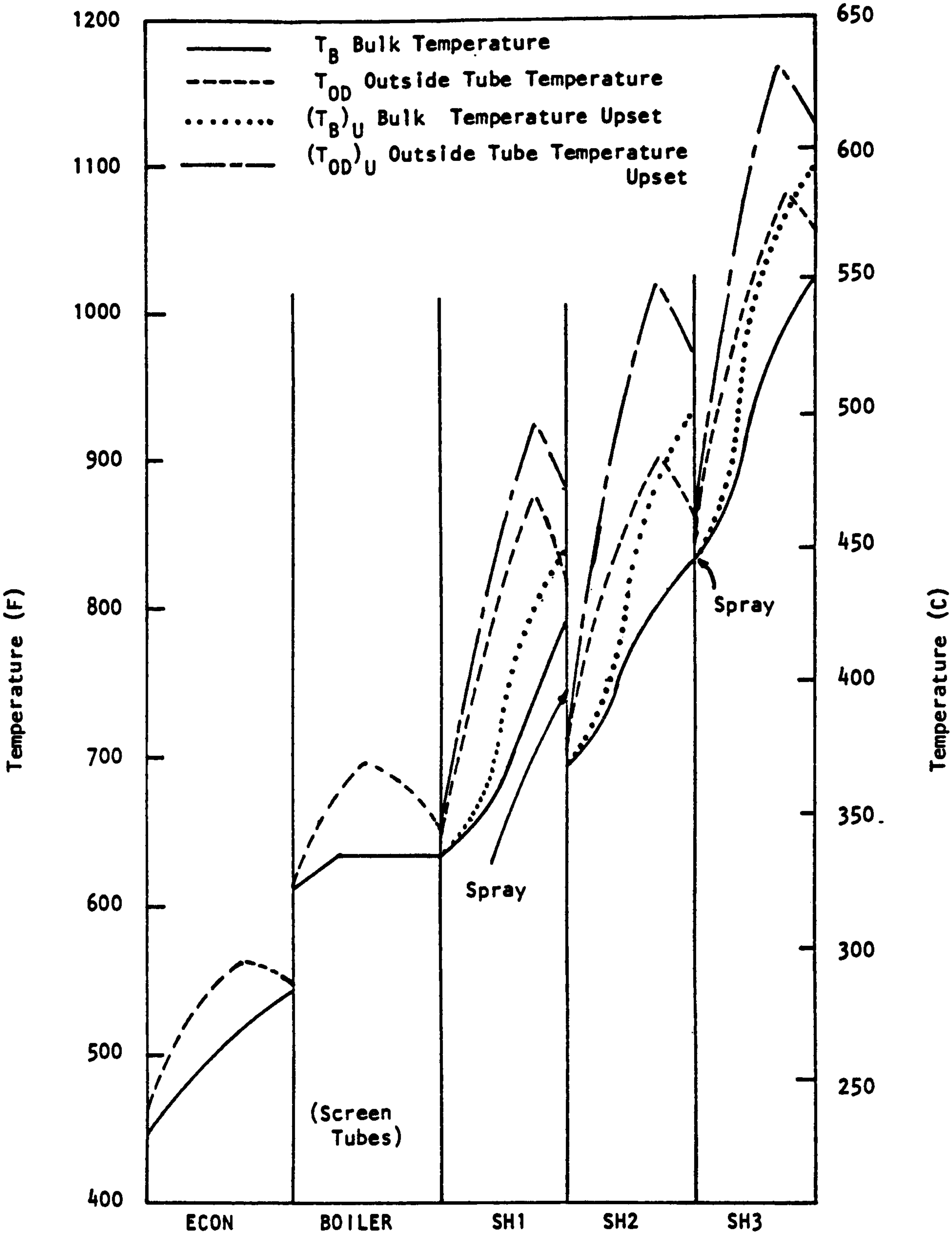


FIGURE 5.3-17
FLUID AND METAL TEMPERATURE PROFILE OF PRIMARY RECEIVER AT DESIGN POINT

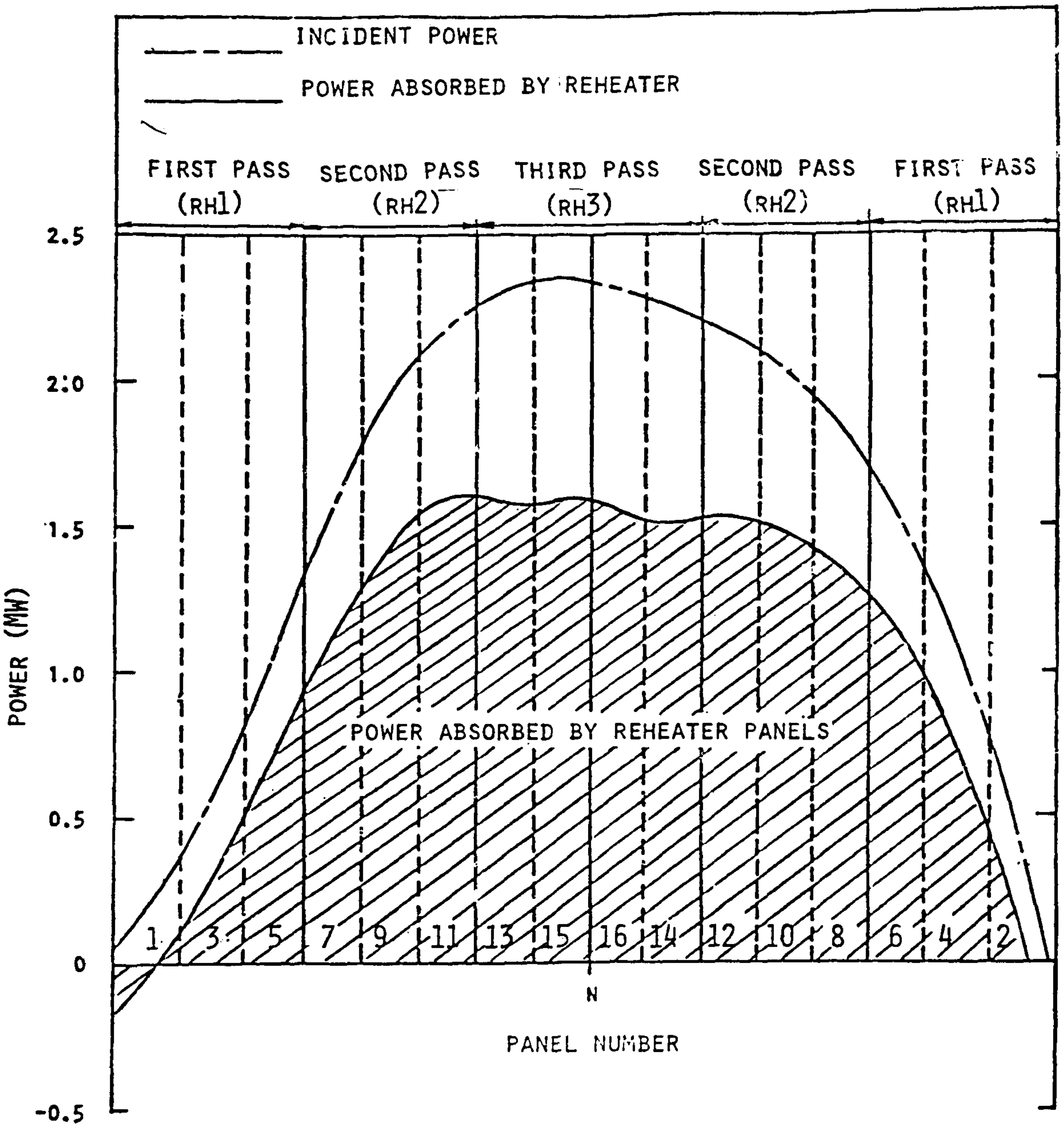


FIGURE 5.3-18
POWER DISTRIBUTION TO REHEAT RECEIVER

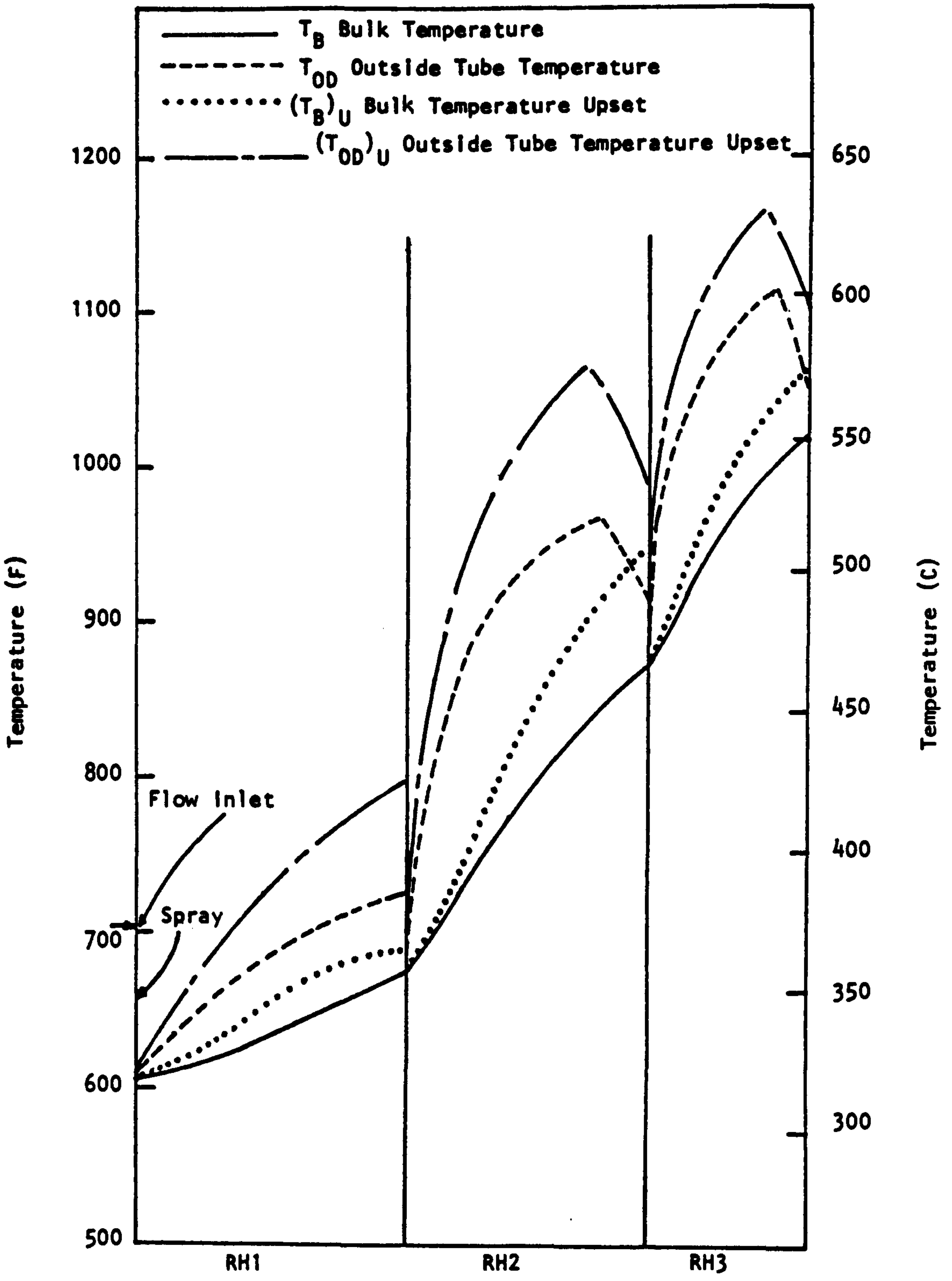


FIGURE 5.3-19
FLUID AND METAL TEMPERATURE PROFILE OF REHEAT RECEIVER AT DESIGN POINT

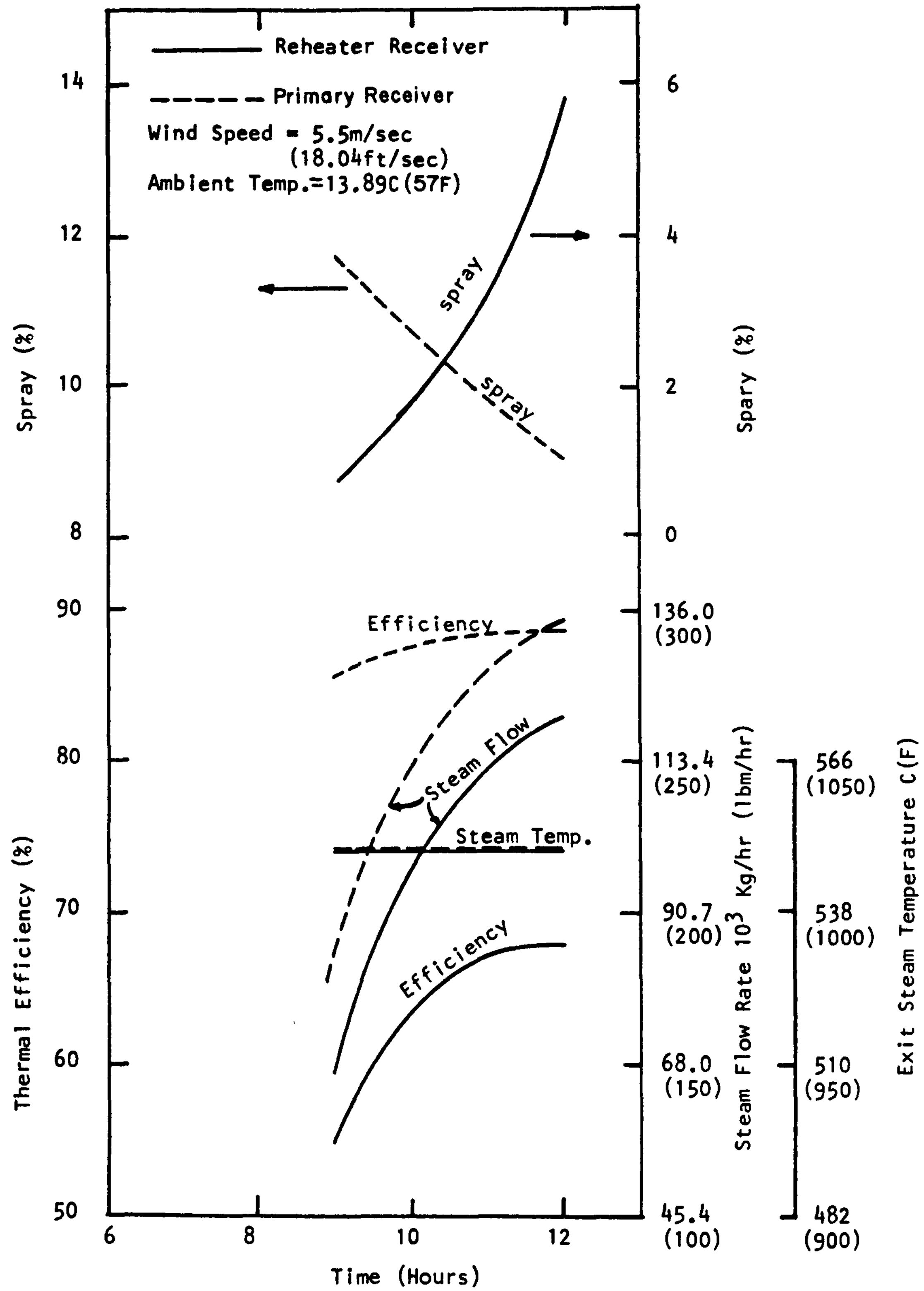


FIGURE 5.3-20
THERMAL PERFORMANCE
OF RECEIVERS DURING
WINTER SOLSTICE DAY

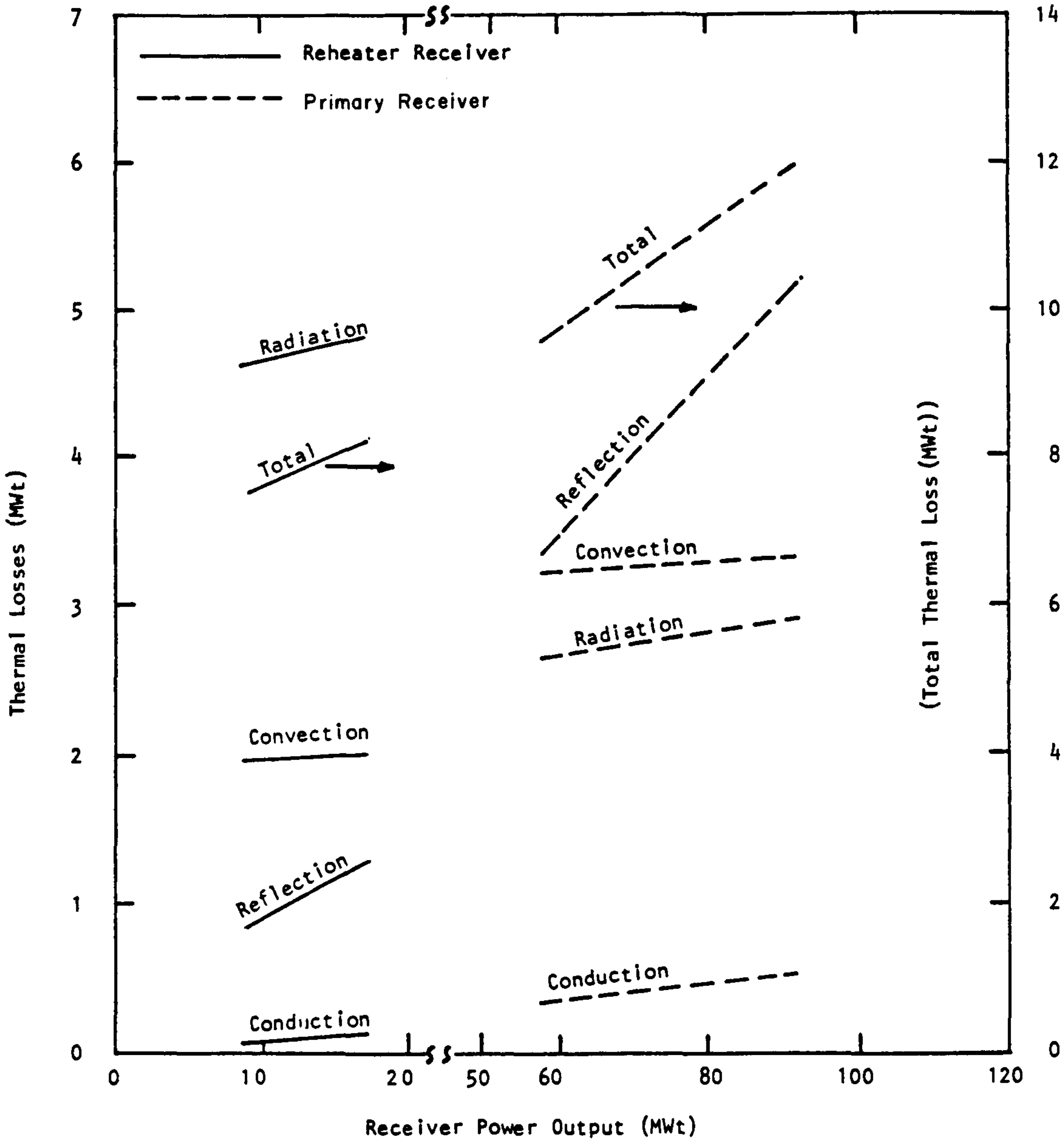


FIGURE 5.3-21
RECEIVER THERMAL LOSSES
VERSUS POWER OUTPUT

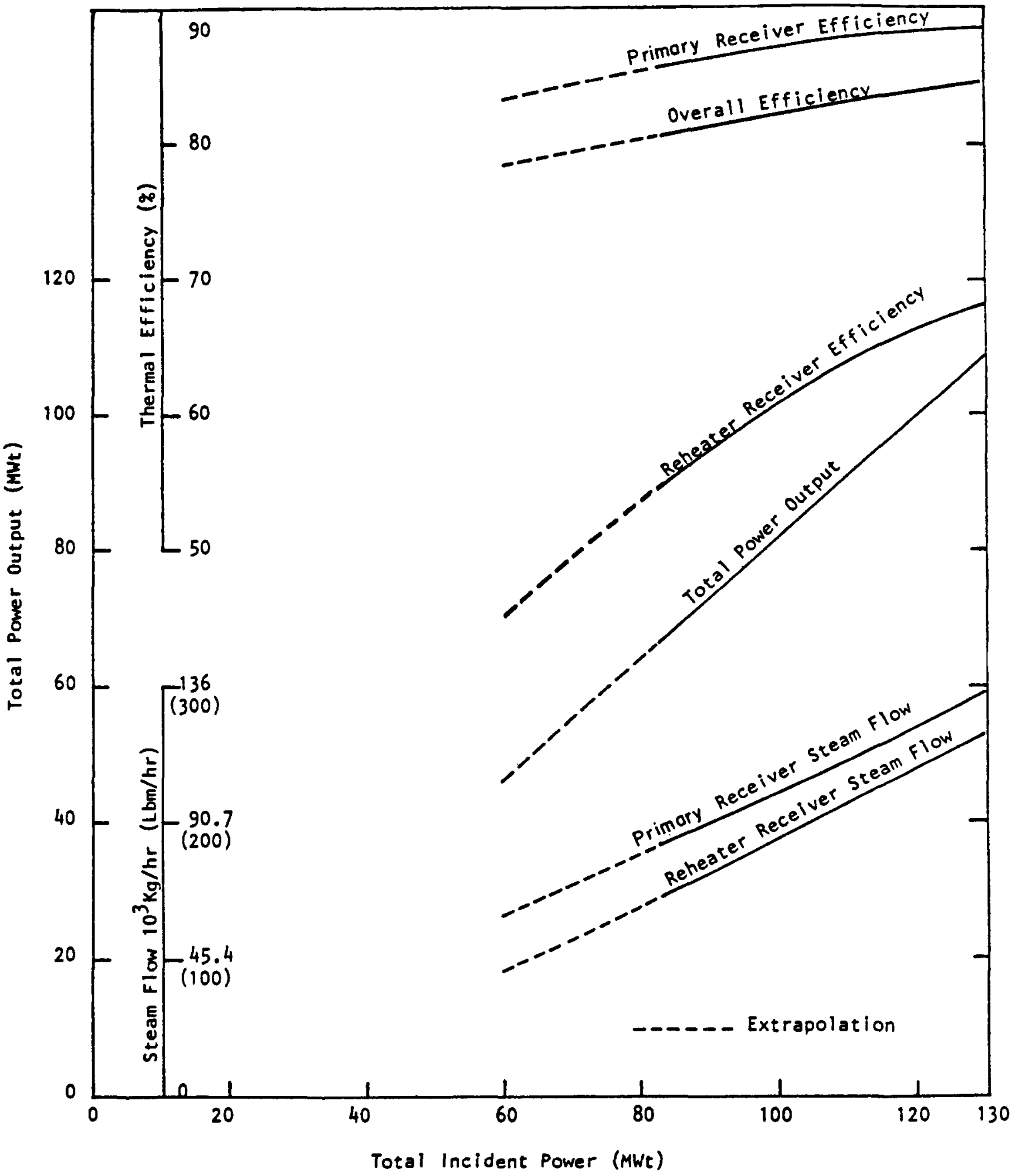


FIGURE 5.3-22
RECEIVER PERFORMANCE AS FUNCTION OF INCIDENT POWER

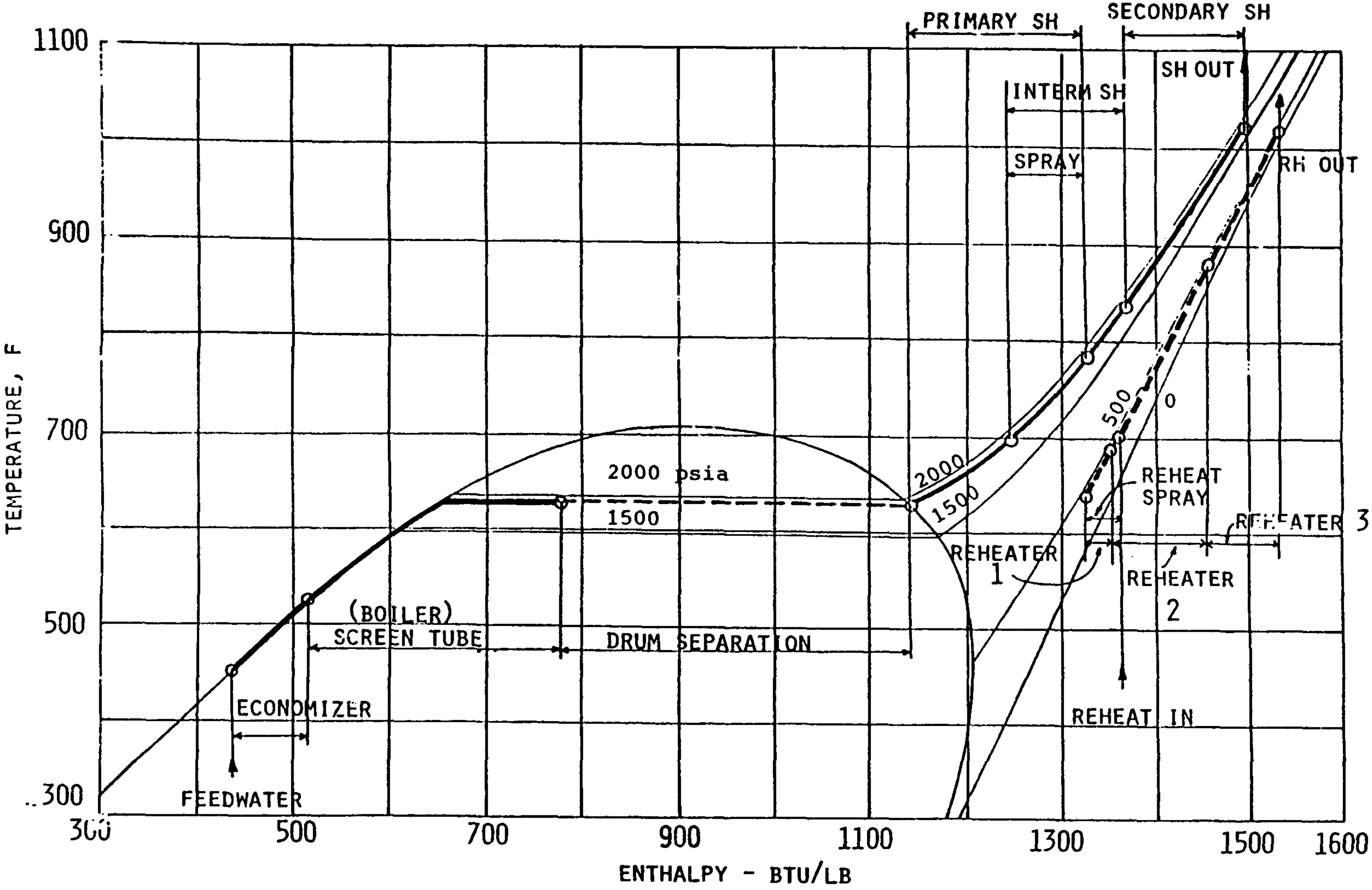


FIGURE 5.3-23
TEMPERATURE-ENTHALPY DIAGRAM AT DESIGN POINT

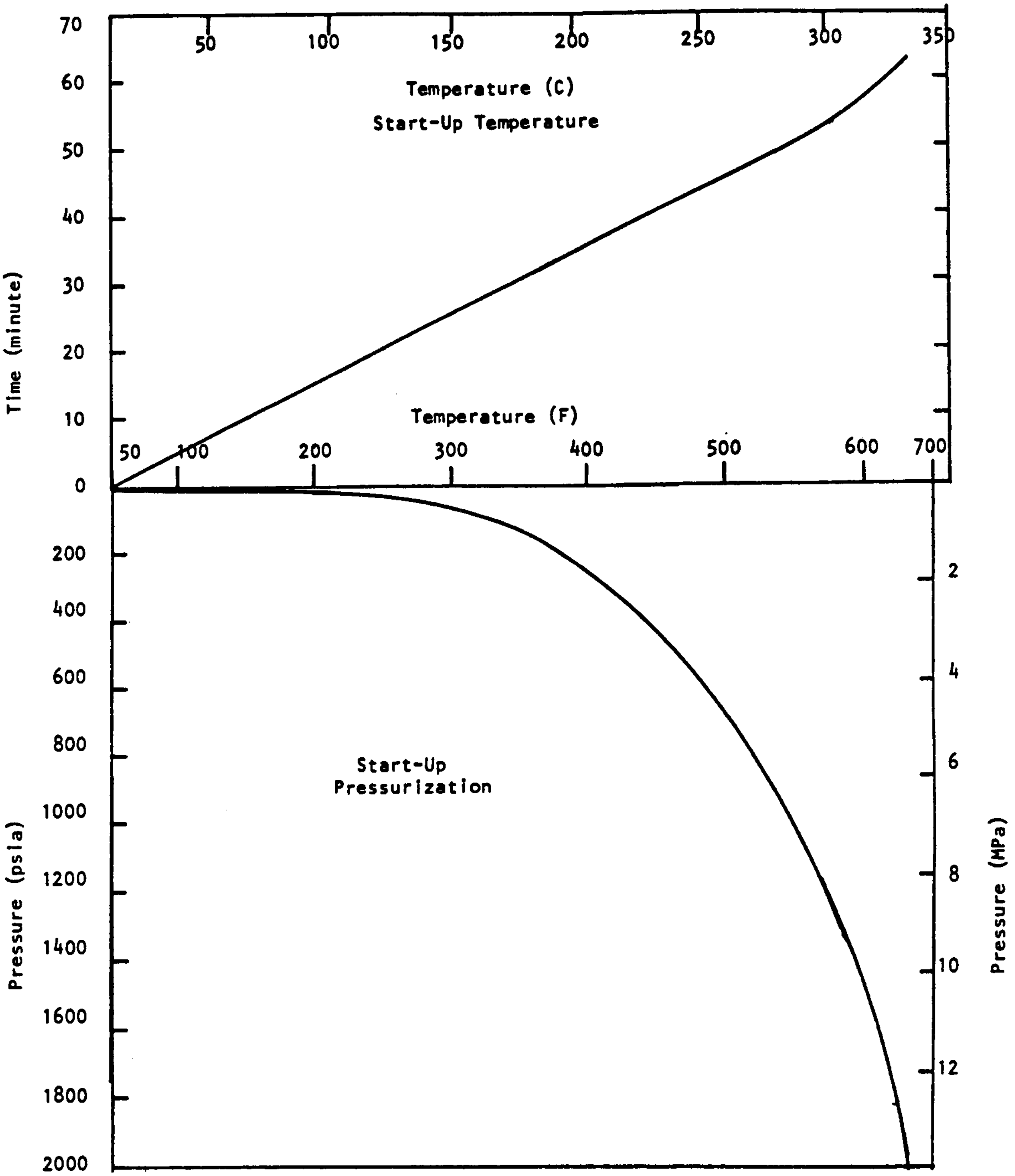


FIGURE 5.3-24
BOILER START UP

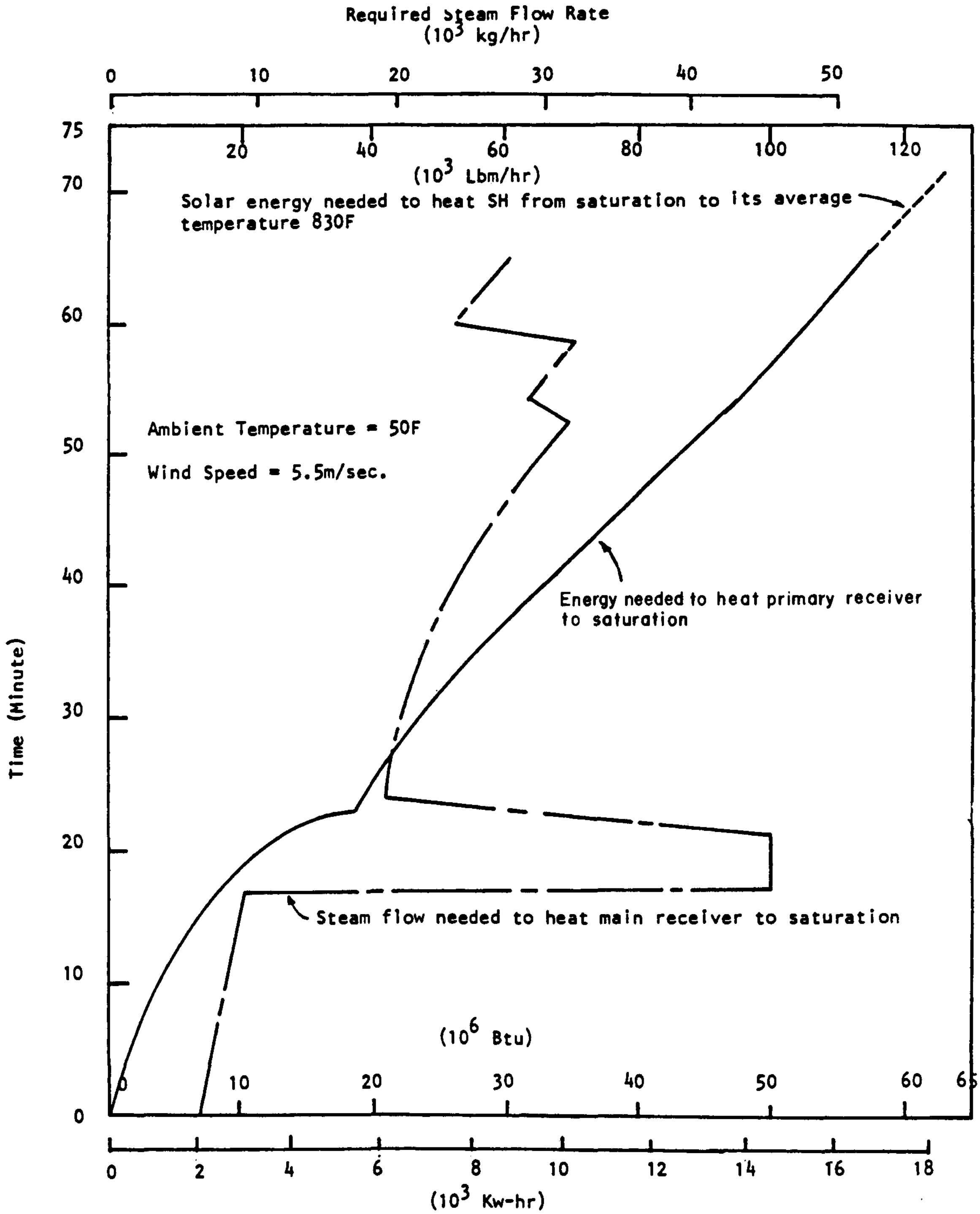


FIGURE 5.3-25
PRIMARY RECEIVER WARM-UP DATA

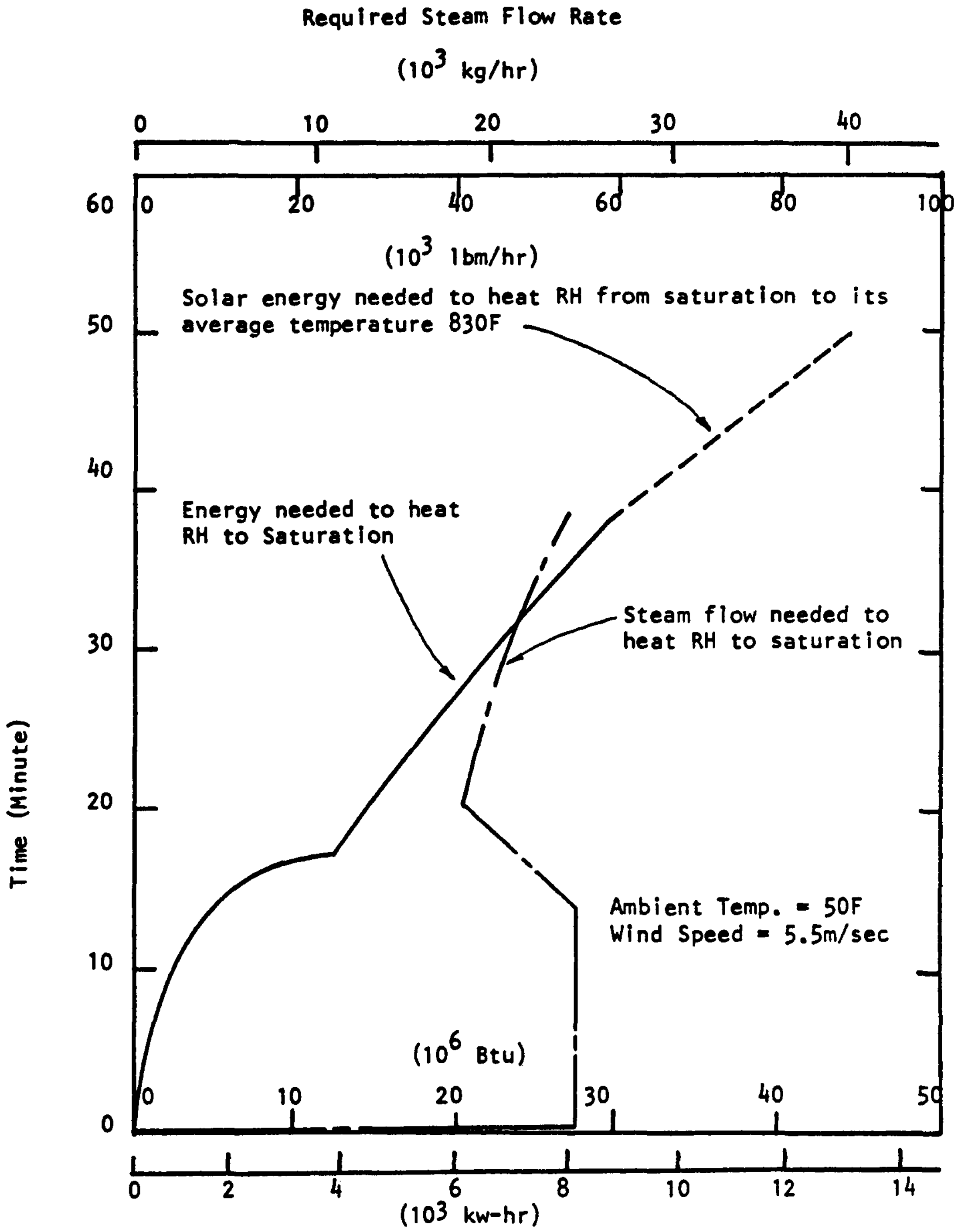


FIGURE 5.3-26
REQUIRED WARM-UP ENERGY
REHEATER WARM-UP DATA

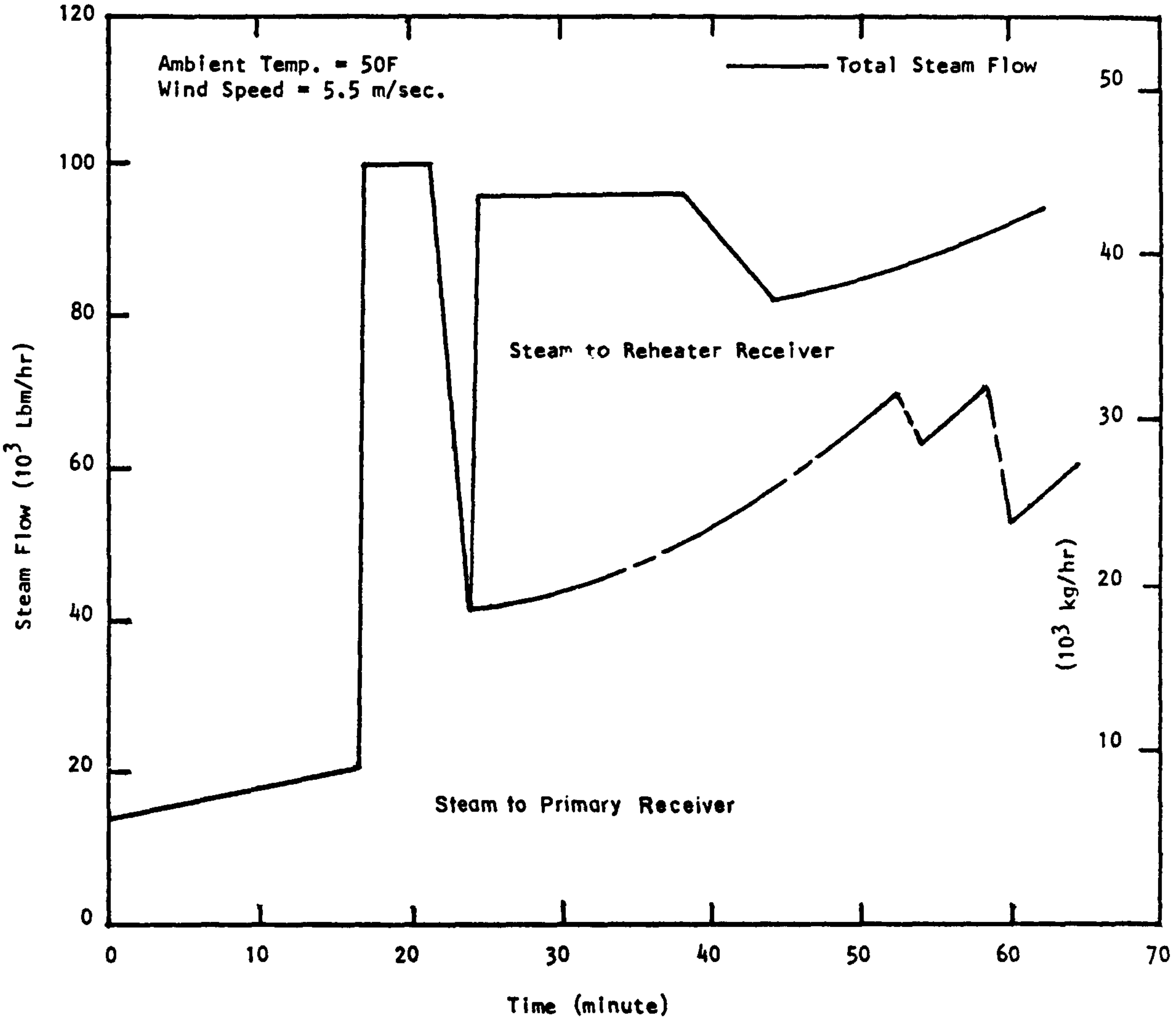


FIGURE 5.3-27
STEAM CONSUMPTION AT START UP

5.4 FOSSIL BOILER SUBSYSTEM

The fossil boiler subsystem includes the existing fossil-fueled boiler and associated boiler control system modified to provide state-of-the-art control components to improve the reliability and availability of the subsystems. The only modifications to the fossil boiler subsystem affect the combustion control, feedwater control, steam temperature control, and burner control. These modifications are discussed in Section 5.6.

5.5 ELECTRIC POWER GENERATING SYSTEM

This section describes the functional requirements, design, performance, and cost of the existing electric power generating system (EPGS) modified to include a solar repowering system. The description of the characteristics and performance of the existing EPGS is detailed in Appendix E.2.

5.5.1 Functional Requirements

The EPGS shall accept steam from either or both the solar or fossil steam supply systems. The design of the system shall permit isolation of either the solar receivers or the fossil boiler for inspection and maintenance while the unisolated steam supply equipment continues to supply steam to the turbine generator.

All modifications to incorporate a solar repowering system shall meet the operating constraints imposed by the existing EPGS as specified in Table 5.5-1.

The solar repowering system components are located close to the existing plant to provide an economical and practical arrangement.

5.5.2 Design

5.5.2.1 Major Fluid Systems

The conceptual design drawings of the solar repowered Newman Unit 1 Power Station are presented in Appendix B. The fundamental flow diagram, 14067-PID-1-1, schematically shows that the solar repowering system primarily interfaces with the existing EPGS at the feedwater, main steam, and low temperature reheat and high temperature reheat systems. Interface point for main steam piping is shown in Figure 5.5-1. Interface points for low and high temperature reheat piping are shown in Figure 5.5-2.

Flow diagram 14067-FM-9-SR details the piping, valves, controls, and instrumentation required to satisfactorily combine and operate the solar repowering system with the existing EPGS.

When the solar receivers and the fossil boilers are operating concurrently, the feedwater flow splits at the discharge of the boiler feed pumps. A new 20.3 cm (8-inch) nominal size line from the existing feedwater line conveys part of the feedwater flow through two solar feedwater heaters to the inlet of the solar feedwater pumps. The remaining feedwater is transported to the economizer of the existing fossil fueled boiler.

The feedwater entering the solar feedwater pumps is discharged through a 15.24-cm (6-inch) nominal size line to the solar primary receiver economizer panels.

Main steam from the superheater outlet of the solar primary receiver is delivered through a 30.5-cm (12-inch) nominal size main steam line to a connection at the existing main steam piping. The superheated steam from the fossil boiler is combined with the solar steam prior to admitting the steam to the high pressure (HP) turbine inlet.

Low temperature reheat steam flow exiting the HP turbine exhaust is divided and part of the steam is transported by two 35.6-cm (14-inch) branch lines that are headered into a 61.0-cm (24-inch) line to the solar reheat receiver. The remaining flow is delivered to the reheat section of the fossil boiler.

High temperature reheat from the solar receiver is returned by a 61.0-cm (24-inch) header which splits into two 35.6-cm (14-inch) lines to combine into the existing high temperature reheat piping. The solar high temperature reheat steam and the fossil boiler reheat steam are mixed prior to entering the intermediate section of the HP turbine. The design of the combustion control, feedwater control, and the reheat steam temperature control are described in Section 5.6.

EPGS motor-operated isolation valves are supplied in the feedwaters, main steam, and high and low temperature reheat piping. These isolation valves permit the operator in the control room to isolate either the solar or fossil systems.

Piping drawings for the conceptual design of the solar repowered Newman Unit 1 are included in Appendix D. Table 5.5-2 specifies the piping sizes, wall thickness and material, and the length of piping required for the solar feedwater, main steam, and high and low temperature reheat systems.

The solar feedwater pumps are two half-capacity centrifugal pumps, each rated at 0.27 m³/s (430 gpm) and at a total developed head of 36.6 m (1,200 feet). The motors are rated at 186 kW (250 hp). The pumps are designed to withstand the boiler feedpump total shutoff discharge pressure of 14.9 MPa (2,160 psig) at a temperature of 236°C (457°F).

A potential problem associated with high steam temperature, over 480°C (900°F), piping is exfoliation, which results in turbine solid particle erosion. An initial identification of the potential problem, its impact, and possible solutions is presented in order to support initial conceptual design efforts.

Exfoliation is a condition caused by the formation of an oxide scale on the surface of the ferritic alloy material that has been exposed to a steam temperature of about 538°C (1,000°F). When the material undergoes thermal cycling, the tightly bonded oxide scale separates from the base metal and is transported to the turbine by the steam where it can cause considerable damage.

As early as 1954, a utility had reported exfoliation on the inside surface of superheater tubes. Recently, a domestic turbine manufacturer has surveyed 800 turbines and reported 796 units has experienced turbine damage from exfoliation.

The main steam and high temperature reheat piping in the solar repowered Newman Unit 1 will carry 538°C (1,000°F) steam. Ferritic alloy material, 2 1/2 percent chromium/1.0 percent molybdenum, has been selected because the material is able to withstand the steam conditions and the cost of the material is lower than other suitable materials. Since the piping will undergo daily thermal cycling, and since the total surface area of the solar repowering is more than eight times greater than provided in the Newman Unit 1 power plant, exfoliation could be a greater problem than in conventional systems.

To minimize the problem of exfoliation, coatings can be applied to the piping to protect the surfaces from oxidizing. For example, Babcock & Wilcox has developed a method to coat the surfaces with a layer of enriched chromium. The coating has been shown to resist degradation after a number of years in service and reduce exfoliation significantly.

Further investigation of the exfoliation problem will continue during the preliminary design effort.

5.5.2.2 Turbine Generator Modifications

The addition of a solar repowering system to Newman Unit 1 requires the unit to be cycled daily when operating in a solar-only mode.

The existing turbine generator is designed as a baseloaded unit, requiring modifications for cycling duty. Modifications made to the turbine generator will allow the equipment to withstand the thermal stresses created in both the turbine cylinder and spindle when these parts are heated and cooled between extreme values of metal temperatures at high and low loads. The value of the stress level will depend primarily on the total temperature change, the rate of change, and the physical dimensions and geometry of the part being heated.

Daily cycling affects principally the following turbine areas:

Increased wear rate on nozzle vanes and impulse blades due to solid particle erosion.

Cracking of spindle and cylinder surfaces due to thermal cycling.

Control of internal turbine clearances during rapid differential expansion is associated with quick starting and loading.

The required turbine generator modifications permit the equipment to withstand the daily thermal cycling and any thermal transients occurring during normal operation. The modifications include a digital electrohydraulic control system (DEH) and refurbishing of critical internal components of the existing turbine generator.

The DEH system has a high pressure fluid supply system that supplies fluid to hydraulic actuators that position the turbine generator throttle, governor, and intercept valves. The DEH controls are described in Section 5.6.

The turbine generator refurbishing is accomplished by providing new radial inserts, spindle balance piston seals, nozzle chest seals, inner cylinder and low pressure dummy ring seals, grounding brush, blades for the first two rows of stationary and rotating blades after the reheat section, and seal segments for the number 2 gland.

5.5.2.3 Electrical

The electrical systems for solar repowered Newman Unit 1 tie into the existing electric subsystem for startup and normal electric power. The one-line diagram, 14067-EW-S1A-SR in Appendix D, shows the primary electric components of the solar subsystem and its tie to the existing electrical subsystem.

Existing Main System

The main electrical system is relatively unchanged except for providing the extra auxiliary power required by the solar repowered unit. This requires tapping the existing 13.8 kV generator bus, the reserve station service 2,400 V transfer bus, and increasing the size of the station service transformer supplying 480 V loads.

Auxiliary Electrical System

Solar auxiliary transformer no. 1 is rated 3,750 kVA, OA future FA, 13.8-2.4 kV, 3-phase, 60 Hz. It is the normal station power source for the solar power system and its high voltage terminals are connected to generator no. 1 13.8 kV bus through a 15 kV, 400 ampere, disconnect switch. The transformer low voltage terminals connect to the 2,400 V solar bus by cable which terminates in an air circuit breaker in the 2,400 V switchgear.

The 2,400 V solar bus is comprised of metal clad, dead front switchgear in the solar feedwater pump house.

The 2,400 V switchgear also is connected to the existing Unit 1, reserve station service transformer 2,400 V transfer bus through an air circuit breaker and a manually operated, 5 kV, 1,200 A disconnect switch. This transformer provides the startup electric power source for the solar repowering system. In the event of a loss of normal station power, automatic transfer of the 2,400 V solar bus is made to the Unit 1 reserve station service transformer 2,400 V transfer bus.

Air circuit breakers (ACBs) are rated 4.16 kV with a 156 MVA interrupting capacity and a 40,000 ampere momentary capability at 2400 V. The ACBs are electrically operated by a 125 V dc source supplied from the existing Unit 1 station battery and is controlled from a control switch on the main solar control panel.

The 2,400 V bus supplies all loads for the solar repowering system. One circuit feeds the unit substation. Four circuits feed transformers which supply power to the heliostats.

The unit substation consists of solar auxiliary transformer no. 2 rated 750 kVA, AA, 2,400-480 V, 3-phase, 60 Hz, dry type, closely coupled to drawout type air circuit breaker switchgear with both transformer and switchgear housed in a metal enclosure in the solar feedwater pump house. Feeder ACBs are rated 480 V, 225 amperes, with a 14,000 ampere interrupting capability.

The 480 V bus is connected to the transformer secondary winding through a manually operated ACB rated 480 V, 1,600 amperes.

Electrically operated, remotely controlled circuit breakers are provided for control of two 250 hp solar feedwater pumps, and one 60 hp solar receiver recirculation pump, which are fed from the unit substation. The feeders supplying outdoor lighting and other loads, including the solar motor control center supplied from this unit substation, are provided with locally controlled ACBs. All ACBs are provided with overcurrent protection.

The backup supply to the 480 V solar bus is provided by the addition of a tie between the 480 V solar bus and the Newman Unit 1 480 V station service bus no. 1. An electrically operated, administratively controlled, 1,600 ampere ACB with overcurrent protection is installed in the existing Unit 480 V switchgear for this tie. This arrangement provides a backup for solar auxiliary transformer no. 2. This backup tie requires replacement of the present Unit 1, 300 kVA, 2,400-480 V station service transformer, with one sized 750/1,000 kVA, AA/FA.

The 480 V solar motor control center is comprised of metal clad, compartmented motor starters (reversing and nonreversing), molded case breakers, and contacters as required to control small motors, motor operated valves, building and tower lighting, heating and ventilating loads, etc.

Direct current (dc) required for the solar repowered system control is supplied from Newman Unit 1. A 125 V feeder circuit is run from the existing station battery distribution panel to a 125 V dc distribution power panel in the solar feedwater pump house.

Heliostat Power Supply

Power to the heliostat field is provided by four 2,400 V circuits, two feeding four pad-mounted 150 kVA, and two circuits feeding five pad-mounted 225 kVA oil-filled, self-cooled, 2,400-480 V, 3 phase, 60 Hz, delta connected transformers, as shown on One Line Diagram 14067-EW-S1A-SR-1. Each transformer, centrally located to approximately 170 heliostats, is provided with a 2,400 V, 200 ampere, loop feed primary switch, a high side fuse, and a 480 V, 3-wire 6-circuit, 400 ampere main, outdoor distribution cabinet. Power for the heliostat field perimeter lighting is also supplied from the 2,400 V heliostat feeders.

The 2,400 V power is supplied by 5 kV cable installed in buried heavy gage plastic conduit encased in concrete to protect it from vehicular traffic. Pulling handholes are provided at necessary intervals.

Lighting and Receptacles

Fluorescent lighting fixtures, locally switched, are provided in the solar feedwater pump house together with 120 V receptacles and a distribution cabinet to supply the lighting and receptacle loads.

Fluorescent lighting fixtures are provided in the base of the solar receiver tower and enclosed, gasketed, incandescent lighting fixtures are provided in the upper levels as required. A distribution cabinet is provided to supply the lighting loads and 120 V receptacles which are located at the different levels through the the solar tower.

Metal halide lighting fixtures are provided in the heliostat maintenance building. A distribution cabinet is provided to supply the lighting load and the 120 V receptacles in this building.

The roadway and heliostat field perimeter lighting consists of 51 wood poles, 9.1 m (30 feet) high, each with a 480 V, 250 W high pressure sodium lamp, and an individual photoelectric control. The poles are spaced at 76.2-m (250-foot) intervals. The horizontal illumination level at ground level is an average of 5.4 lux (0.5 foot-candles).

Lighting power is supplied by 2,400-480 V, 3-phase transformer fed from the 2,400 V solar bus.

Solar tower external lighting conforms to FAA requirements. Two levels of high intensity strobe lights, with power fed from the distribution cabinet and a controller located in the base of the tower, are provided.

Grounding

A no. 4/0 bare copper cable is buried around the solar feedwater pump house and the solar tower. Solar electric equipment and building steel in each of these structures are tied to the buried ground cable. A minimum of two no. 4/0 copper cables ties the solar tower and solar feedwater pump house grounding into the existing station ground grid.

The transformer in the heliostat field is tied to the solar pump house and tower grounding grids by no. 4/0 bare copper cable buried a minimum of 0.8 m (30 inches) below ground surface in proximity to the concrete encased duct line supplying power to the transformers in the heliostat field. Ground rods are driven at regular intervals and bonded to this buried ground cable.

The portion of the heliostat perimeter fence which runs parallel to the 345-kV and 115-kV transmission lines is attached to ground rods driven at 6 to 15-m (20- to 50-foot) intervals along the fence. This reduces induced voltages to a negligible value.

Lightning Protection

Depending upon final tower design, one or more air terminals are bonded to the steel in the tower roof and upper steel structure which extend to a point below the reheat receiver. The air terminals are 1.9-cm (0.75-inch) diameter solid stainless steel and extend 0.6 m (2 feet) above the highest part of the roof. Two no. 4/0 bare copper cables, located diametrically opposite each other, are bonded to the upper tower structural steel below the reheat receiver and run down the outside of the tower. The cables are fastened to the concrete structure by anchors located on approximately 1.8 m (6 foot) centers and bonded to the tower grounding system.

No side stroke protection is included. This requires a special study when the tower design is finalized. No lightning protection is planned for the heliostat field.

Switchyard and Transmission Facility

A section of the Alamogordo and Caliente 345 kV and the two 115 kV transmission lines emanating from the present switchyard are rerouted to avoid crossing over the heliostat field.

5.5.3 Performance

The solar repowered Newman Unit 1 performance at various net electrical unit loads is specified in Table 5.5-3. The percent of rated main steam flow, auxiliary power, and net station heat rates for the solar and fossil systems are provided in this table. Figure 5.5-3 shows solar and fossil-supported EPGS efficiency as a function of overall unit load.

Adding the solar repowering system to the existing EPGS has no significant effect on the performance of the existing unit when the unit is operating solely on the fossil boiler subsystem. Inserting a reheat flow control valve into the existing reheat system increases slightly the reheat system pressure drop by 10.3 kPa (1.5 psi), which increases the station heat rate by approximately 4.2 kJ/kWh (4 Btu/kWh). A study will be conducted during the preliminary design phase to evaluate the cost of increasing the size of the existing reheat piping versus accepting the pressure drop penalty on the station heat rate.

Table 5.5-4 describes the effect on unit output and net unit heat rate when varying the main and reheat steam temperatures and the reheat pressures at the inlets of the turbine generator.

The solar repowering system provides additional flexibility which is normally unavailable in a fossil fueled boiler system. When at low loads, the fossil boiler is unable to maintain the reheat temperature at 538°C, the Newman Unit 1 boiler reheat temperature decreases to 527°C (980°F) at approximately 28 percent rated electrical output based on actual plant performance. The net station heat rate, at low unit loads, can be improved by biasing a greater amount of the low temperature reheat steam flow to the solar reheat receiver which reheats the steam to 538°C. When the solar and fossil reheat steam flows are recombined, the temerature entering the turbine is higher than 527°C (980°F). During the preliminary design phase a detailed analysis will be conducted to determine the effect of biasing reheat flow.

5.5.4 Cost

The cost of modifying the EPGS (Account 5800) is estimated at $5.64 million in 1982 dollars. These costs include replacing the existing turbine generator mechanical hydraulic controls with a digital electronic hydraulic control system (DEH); all pumps, valves, piping, and related equipment between the receivers and the existing feedwater and steam lines at the turbine building; and electrical equipment.

The DEH modifications are estimated at $1,186,000 in 1982 dollars.

Piping, valves, pumps, and related equipment are estimated at $3,798,000 in 1982 dollars.

Electrical equipment provided to support electrical power requirements is estimated to cost approximately $655,000 in 1982 dollars.

The costs of modifications to the existing turbine-generator for cycling operation are not included, as the modifications will be made regardless of any solar repowering of Newman Unit 1.

TABLE 5.5-1

OPERATING CONSTRAINTS OF EPGS

Operating constraints imposed by the existing EPGS are as follows:

1. Maximum gross electric output	85.8 MWe
2. Rated main steam flow for guaranteed output	257,000 kg/hr (567,000 lb/hr)
3. Main steam rated temperature	538°C (1,000°F)
4. Reheat steam rated temperature	538°C (1,000°F)
5. Main steam rated pressure	10.1 MPa (1,465 psia)
6. Rated reheat pressure drop	255 kPa (37 psi)

7. Steam temperature limitations (at turbine main stop valve):
   - a. Average over 12 months not to exceed 538°C (1,000°F)
   - b. 552°C (1,025°F) for not more than 400 hours for 12 months
   - c. 566°C (1,050°F) for up to 15 minutes, not more than 80 hours/year
8. Steam pressure limitations:
   - a. 10.1 MPa (1,465 psia) at rated output
   - b. 10.6 MPa (1,541 psia) as turbine approaches zero output
   - c. 13.0 MPa (1,901 psia) momentarily, not exceeding 12 hours/year
9. Load limitations
   - a. Rate of load change is limited by metal temperatures in critical areas of turbine.
   - b. Normal turbine load change rates are limited to about 5 MWe/minute.
   - c. Faster load changes will require careful monitoring of metal temperatures.

TABLE 5.5-2

SOLAR REPOWERED SYSTEM PIPING

	Nominal Pipe Size cm (in.)	Wall Thickness cm (in.)	Material	Approximate Total Length of Piping m (ft)
Feedwater				
at Pump Inlet	20.3 (8)	1.27 (.50)	c.s.	37 (120)
	15.2 (6)	1.42 (.56)	c.s.	4.6 (15)
at Pump Outlet	10.2 (4)	As Req'd	c.s.	15 (50)
	15.2 (6)	As Req'd	c.s.	213 (700)
Main Steam	30.5 (12)	3.33 (1.31)	CR/MO	238 (780)
Low Temperature Reheat	35.6 (14)	1.50 (.59)	c.s.	21 (70)
	61.0 (24)	2.46 (.97)	c.s.	210 (690)
High Temperature Reheat	35.6 (14)	1.50 (.59)	CR/MO	21 (70)
	61.0 (24)	2.46 (.97)	CR/MO	229 (750)
Extraction Steam	15.2 (6)	0.71 (.28)	c.s.	16.7 (55)
	15.2 (6)	0.71 (.28)	CR/MO	16.7 (55)
Heater Drains	6.4 (2 1/2)	0.51 (.203)	c.s.	29.0 (95)

NOTES:

c.s. - carbon steel
CR/MO - Chromium Molybdenum

1 of 1

TABLE 5.5-3

STATION HEAT RATES

Operational Mode	Net Generation, MWe Fossil/Solar	Auxiliary Power, MWe	Net Station Heat Rate 10^3 kJ/kWh (Btu/kWh)	
			Fossil	Solar
Fossil/Solar	41.0/41.0 (Design Pt)	3.78	10.9(10,310)	9.1(8671)
Fossil/Solar	20.5/41.0	3.51	11.0(10,440)	9.3(8790)
Fossil/Solar	30.75/30.75	3.53	11.0(10,452)	9.3(8790)
Fossil/Solar	61.5/20.5	3.83	10.9(10,303)	9.2(8673)
Fossil/Solar	20.5/20.5	3.23	11.7(11,065)	9.8(9317)
Fossil/Solar	46.1/15.4	3.53	11.0(10,457)	9.3(8792)
Fossil/Solar	30.75/10.75	3.22	11.7(11,075)	9.8(9312)
Fossil only	82.0/-	3.56	10.8(10,250)	-
Fossil only	61.5/-	3.27	11.0(10,400)	-
Fossil only	41.0/-	2.95	11.6(11,000)	-
Fossil only	20.5/-	2.30	13.7(13,000)	-
Solar only	-/41.0	3.04	-	9.8(9,271)
Solar only	-/20.5	2.42	-	11.6(11,010)

NOTE:

Net station heat rate is calculated based on net electricity generated per unit heat introduced to the boiler/receiver. No comparison should be made between the existing and the solar repowering station heat rates because solar receiver efficiencies (accounting for receiver reflected energy and thermal losses) are not included and the solar main receiver blowdown rates are assumed to be zero for all loads. Cycle efficiencies are based on original plant design heat balances which assume reduced steam temperatures for the partial load cases. Actual heat rates are expected to be lower if steam temperatures are maintained at 538°C at partial loads.

TABLE 5.5-4

EFFECT OF STEAM TEMPERATURE AND REHEAT PRESSURE DROP VARIATION ON UNIT HEAT RATE

				Increase in Net Unit Heat Rate kJ/kWhr (Btu/kWhr)	
Main Steam Temperature °C (°F)	Reheat Steam Temperature °C (°F)	Reheat Pressure Drop kPa (Psi)	Decrease In Net Unit Output (MWe)	Solar Operation	Fossil Operation
538 (1,000)	538 (1,000)	255 (37)	0	0	0
		345 (50)	0.59	24 (23)	28 (27)
		414 (60)	1.03	43 (41)	52 (49)
		483 (70)	1.47	61 (58)	74 (70)
510 (950)	510 (950)	255 (37)	3.42	142 (135)	169 (160)
		345 (50)	3.98	168 (159)	199 (189)
		414 (60)	4.41	186 (177)	223 (211)
		483 (70)	4.83	206 (195)	245 (232)
482 (900)	482 (900)	255 (37)	6.83	296 (281)	352 (334)
		345 (50)	7.38	323 (306)	383 (363)
		414 (60)	7.79	343 (325)	406 (385)
		483 (70)	8.20	363 (344)	430 (408)

<u>NOTE</u>:

All other operating conditions consistent with full load operation shown on heat balance for 83 MW in Section 5.1.

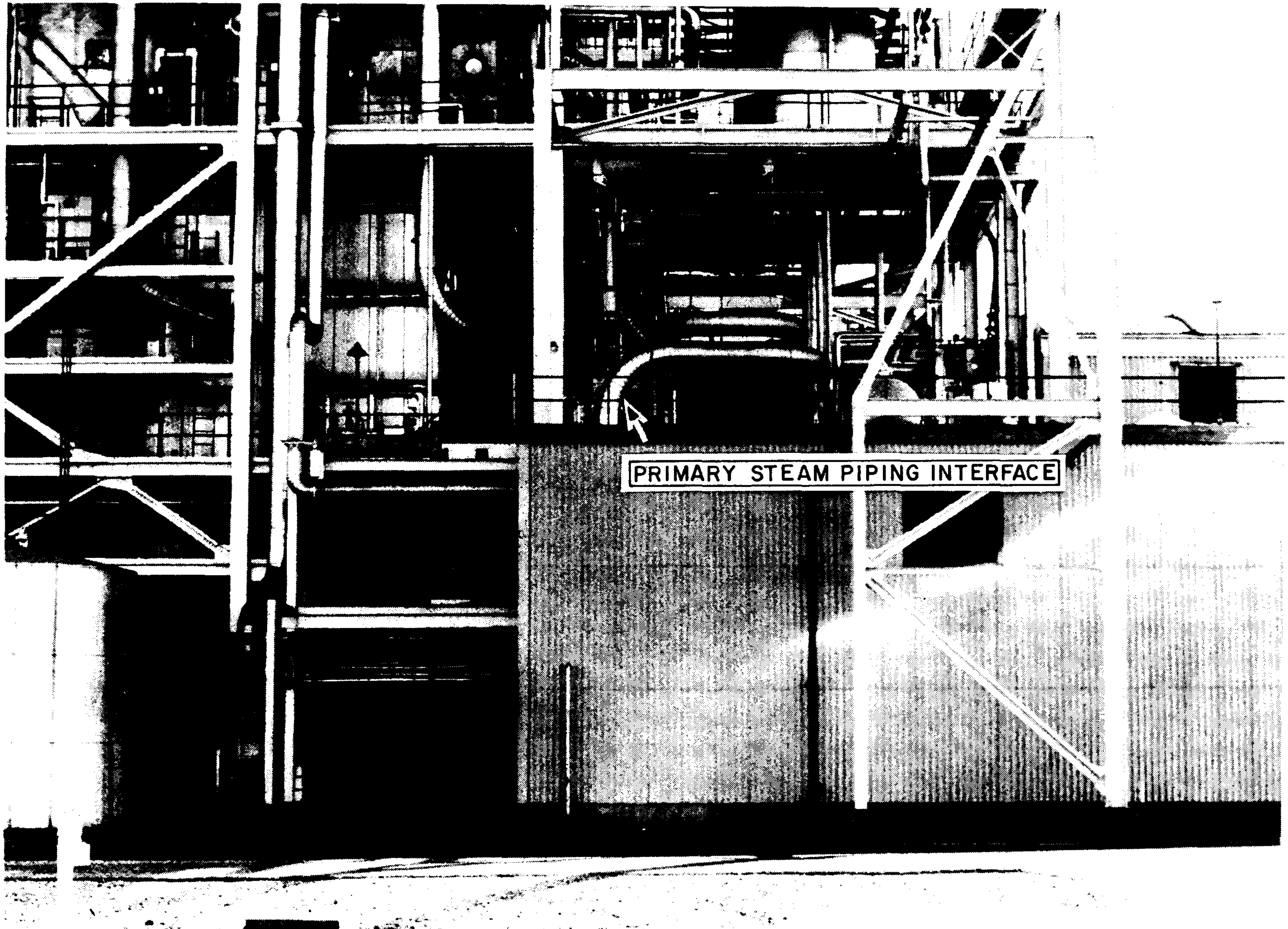


FIGURE 5.5-1
PRIMARY STEAM
PIPING INTERFACE

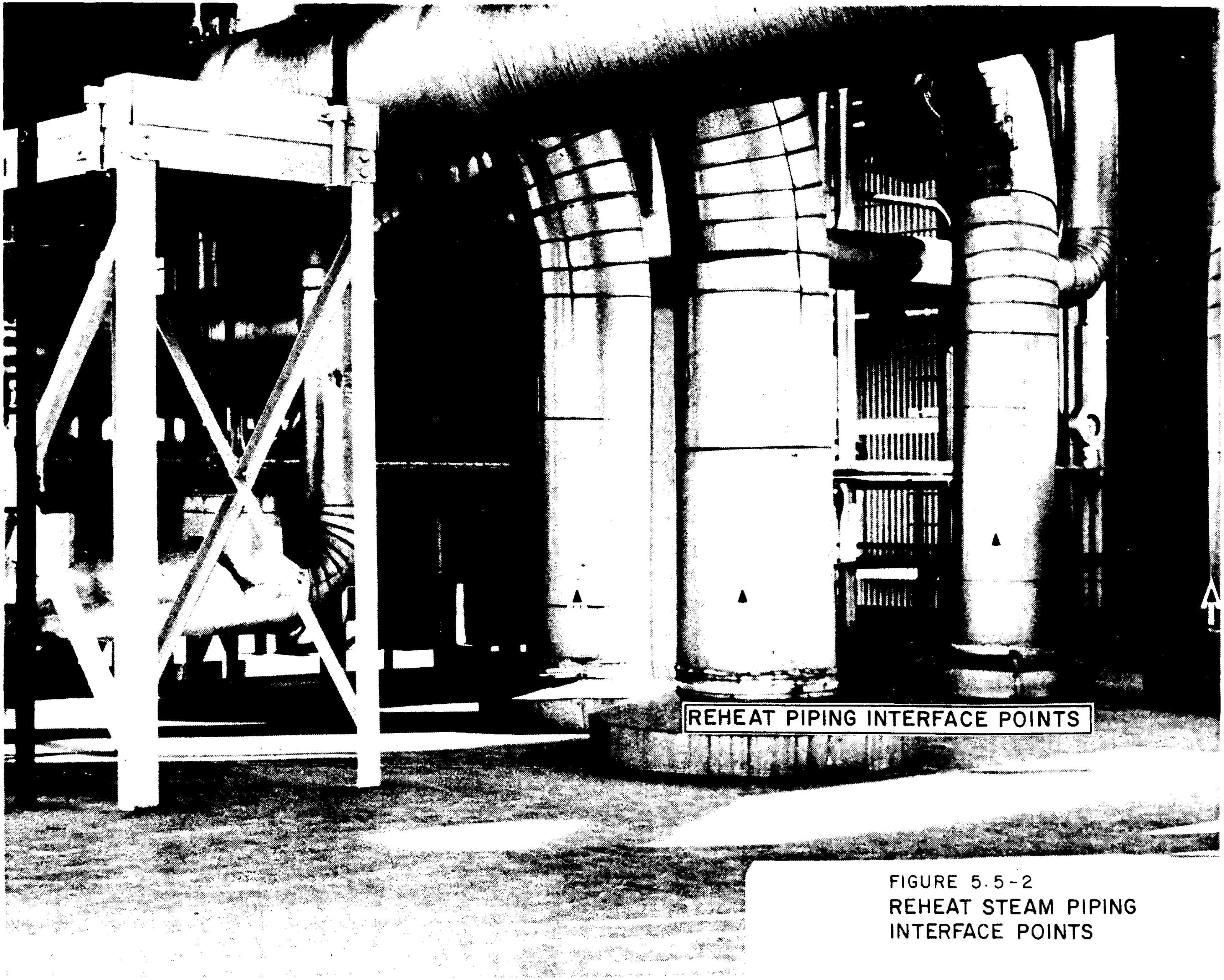


FIGURE 5.5-2
REHEAT STEAM PIPING
INTERFACE POINTS

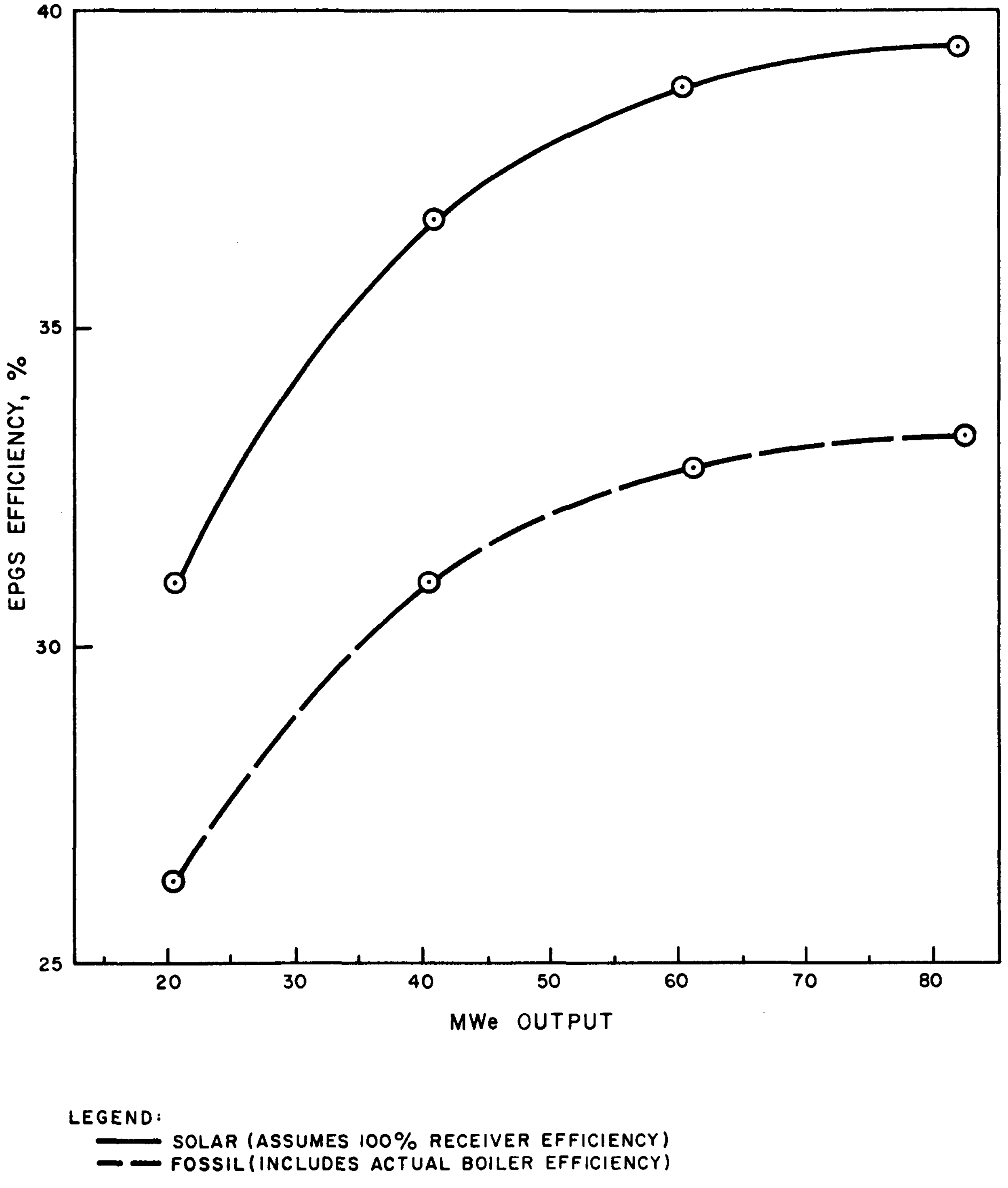


FIGURE 5.5-3
EPGS EFFICIENCY

5.6 MASTER CONTROL SUBSYSTEM (MCS)

This section discusses general design requirements of the control system for solar repowered Newman Unit 1, and describes the process control system, operator/plant interface, collector controls, receiver controls, fossil boiler controls, and plant control room modifications.

5.6.1 General Functional Requirements

The Newman Unit 1 control system and existing power plant equipment shall be modified to provide for daily cycling of the unit and to utilize fossil and solar energy for generation of electrical power. The MCS shall control the solar steam supply system and the existing unit equipment in a safe and reliable condition under all modes of operation.

The MCS shall permit the operator to select one of three unit operating modes: fossil, solar, or combined solar/fossil.

The MCS shall operate the unit under all conditions including startup, shutdown, transient, steady state, and emergency operation.

5.6.1.1 Design Criteria

In order to satisfy the general design requirements, the MCS shall meet the following design criteria:

High Availability

High component/circuit reliability employing the latest solid-state technology and conservative designs.

Major control systems and components shall have full redundant backup.

Modular architecture to enhance fault detection and maintenance.

Self-diagnostic capability wherever possible.

Redundancy

The MCS will include full system redundancy where feasible. A failure of one central processing unit (CPU) will not cause a reduction in control, monitoring, display, or other required unit control function.

Comprehensive Operator/Plant Interface

Cathode ray tube (CRT) displays are provided for the following:

- Process monitoring
- Trouble identification
- Operator guidance
- Interactive communications
- Status information
- Historical review
- Main control board with conventional analog displays, control stations, alarms, etc, provide the operator with a familiar operation/process interface.

Flexibility

All control logic functions and control algorithms are implemented in comprehensive direct digital control (DDC) software. The system is programmed in a simplified basic language which allows changes to be made simply and quickly.

System Modifications

Existing control systems will be modified or replaced only where necessary. The following criteria will be used:

- Direct interface with MCS.
- Significant enhancement of the repowered unit's ability to meet the design requirements.
- Ability of the equipment to function properly for the required 30-year lifetime.

In general, the instrumentation that will be replaced meets two or more of the above criteria.

5.6.1.2 Design Philosophy

Solar repowering Newman Unit 1 presents complex and unique control problems which require a flexible control system with extensive control capabilities that can be easily reconfigured.

To accomplish this the controls for the major unit systems and overall unit control are incorporated in a centralized, minicomputer-based MCS; the heart of which is the process computer system (PCS). The PCS employs redundant CPUs with a proven history in the power industry.

A centralized MCS has the following advantages:

Provides full system redundancy. A failure of one CPU will not cause a reduction in control, monitoring, display, or any other required unit control function.

Reduces the number of interfaces with other control systems, thus simplifying plant design, operation, maintenance, and personnel training.

Enhances system response by reducing communication problems.

Provides flexibility for control system design.

Is easy to reconfigure.

The backup CPU is a powerful tool and can be used to run additional performance evaluations, programs, perform program debugging tasks, or other program/processing functions.

Provides a comprehensive operator/process interface:

CRT displays for the following:

- Processing monitoring
- Trouble identification
- Operator guidance
- Interactive communications
- Status information
- Historical review

Interfaces with conventional analog displays, control stations, alarms, etc, providing the operator with a familiar operator/process interface.

5.6.2 Process Computer System (PCS)

The purpose of the PCS is to integrate, supervise, and coordinate the operation of all major systems and subsystems of solar repowered Newman Unit 1, including:

Collector Subsystem
Beam Characterization System
Receiver Subsystem
Fossil Boiler Subsystem
EPGS Turbine-Generator
Balance of Plant

The PCS consists of two central processor units (CPUs). One CPU is used for primary unit control, monitoring and display functions while the other CPU provides backup. The backup CPU has complete software and active data base so that it can quickly take over unit control whenever the primary CPU is not operational.

5.6.2.1 Process Computer System Capabilities

The PCS shall have the capability to perform the following:

Direct digital control
Data acquisition, storage, analysis, and retrieval
Comprehensive equipment and unit performance calculations
Displays, monitor, and alarm
Trend logs, trip logs, and operations journals
Contact sequential events recording and logging
Analog trending of points using trend pen recorders

5.6.2.2 Process Computer System Hardware

The PCS hardware configuration is shown schematically in Figure 5.6-1. This configuration is typical of commercially available computer and support hardware used in numerous power plant applications.

The components of the PCS are as follows:

Two central processor units (256 K, 32-bit word, core memory).

One operator's console, with color graphic CRT and control functions keyboard.

One engineer's/programmer's console, with color graphic CRT and control functions keyboard.

A programmer's terminal with keyboard.

Three medium speed printers associated with above consoles and terminals.

One alarm printer, one-line printer, and a general purpose printer.

Computer-driven trend strip chart recorders.

Three color graphic CRTs mounted on the main control board for alarm, DEH control, graphic display, etc. Information displayed on any CRT is operator selectable.

Magtape unit for programming.

Two drum/disc units for bulk storage.

Analog and digital I/O multiplex cabinet with all required hardware to read, condition, amplify, compensate and digitize process signals (such as flows, temperatures, pressure levels and contact closures supplies included).

Relay and logic cabinet to interface the PCS with the final control elements

Interface cabinets

5.6.2.3 Process Computer System Software

The PCS includes a process software package that has been used in many power plant applications. This software includes the following:

Operating system
Programming support/languages, i.e., Fortran, etc
Data base management
Data acquisition and validation
Real time variable calculations
Data analysis and alarming
Operator/engineer communications
Color graphic display
Unit operations displays/records

In addition to the above, the PCS includes a comprehensive direct digital control (DDC) software system. The DDC system performs conventional analog control algorithms as well as the more complex application programs necessary for supervisory control and plant integration. The system also performs sequential control for burner management on the fossil boiler and other applications previously accomplished using relay logic.

A considerable amount of the application software includes untried control algorithms and will be developmental. The production and checkout of this software will have an important impact on the schedule for engineering and construction for the repowering project.

5.6.3 Operator/Unit Interface

5.6.3.1 Control Levels

The unit can be operated at no less than three levels of control with the operator's responsibilities varying with each level.

Automatic

At the automatic level the PCS is providing overall unit control and subsystem integration and coordination. The PCS optimizes operation by evaluating many environmental, unit, system, and component variables, characteristics, and responses. The operator simply monitors the performance and status of the unit, systems, and components.

Semi-Automatic

At this level the PCS automatically controls each subsystem with the operator providing the supervisory control and subsystem integration/coordination function. The operator accomplishes this by adjusting the setpoints on the subsystem master control stations or initiates control logic sequences associated with the individual subsystems.

Manual

In the unlikely event that both CPUs fail or during startup/shutdown, the operator can operate the unit manually by directly positioning final control elements.

For critical variables, the operator is provided with hard-wired indicators and annunciators (bypasses the PCS) to assist with unit shutdown.

The portion of the emergency trip and interlock system necessary for operating safely employs solid-state logic and functions automatically at all levels of control.

5.6.3.2 Main Control Board

The solar repowered Newman Unit 1 is designed for the operator to control and monitor the unit from the main control board (MCB).

The MCB is a free-standing board with a bench section that incorporates conventional control devices, i.e., switches, control stations, indicators, recorders and annunciators, in addition to color graphic CRTs, keyboards, and operator's communication console. The MCB design is illustrated in Figure 5.6-2.

5.6.3.3 Operator/Engineer Communication

Operators and engineers communicate with the system through two I/O CRT communication consoles, illustrated in Figure 5.6-1. The operators' console is mounted in the main control board and the engineers' console is in the results room. Operators and engineers will have the capability of using their CRT consoles to:

Request information from the system.
Enter information into the system.
Initiate or cancel system services.

The system provides for identical and complete capability on the two I/O CRT communication consoles. However, each console also has a keylock switch for locking out a subset of the console functions without affecting the other console. It is possible to designate any console function as lockable and to change these designations in the field.

The engineers' I/O CRT communication console serves as a backup to the operators' I/O CRT communication console.

The I/O CRT communication capability provided performs the following:

Displays any analog input.

Capacity to change the value or state of any parameter.

Displays a calculated real variable.

Displays a contact input or calculated logical variable.

Controls group CRT displays.

Controls trend logs.

Controls trend pens.

Capability to restart the control system (boot system in from bulk memory).

Start-stop programs.

Controls output device status and function.

Displays or prints DDC loop status.

Displays or prints various summaries.

Monitors or changes the control system's tuning parameters or control logic.

Interfaces with the collector control system and the beam characterization system.

5.6.3.4 CRT Displays

There are four 19-inch, graphic CRT displays on the main control board (MCB). One CRT is dedicated to the turbine digital electro-hydraulics (DEH) control system and the three remaining are associated with the MCS.

The three MCS CRTs have the following general functions:

One CRT is an I/O CRT dedicated to the operator's communication console and is used to perform the function described in Section 5.6.3.3.

Alarm CRT - In addition to all alarms being logged on a printer, an output CRT is dedicated to displaying alarms.

Trend/Graphic - One of the output CRTs may serve as a trend/graphic CRT. Its functions would be to display the values of the operator-selected analog, logical, and calculated variables to display a trend of any group in the system, or to display system flow diagrams or other graphic displays.

The CRTs are dedicated to specific functions. However, for the purposes of backup and operating flexibility, the functions of the CRTs are assignable and interchangeable.

5.6.3.5 Graphic Display Capability

Graphic display capability to present flow diagrams, etc to the operator/engineer is provided including dynamic updating of analog input values and the capability of making a hard copy of a graphic display on the line printer. A software package is provided for generating CRT graphics on the off-line, backup computer.

5.6.4 Collector Controls

This section describes a typical collector subsystem control design which may change pending selection of a specific heliostat manufacturer. The collector controls are composed of the following major components:

Heliostat Controllers (HC)
Heliostat Field Controllers (HFC)
One Heliostat Array Controller (HAC)

The design for the collector field controls is based on reliable and currently available hardware through a three-level distributed computer system network. The heliostat controls use an open-loop sun-tracking concept with an accurate 15-bit encoding resolution of elevation and azimuth positions. Position command is closed loop, calculated by the microprocessor that directs the motors to keep the position error at zero based on encoder feedback.

A block diagram in Figure 5.6-1 depicts the collector control configuration.

5.6.4.1 Heliostat Controller (HC)

Each heliostat has one 16-bit microprocessor that is the heart of the heliostat controller (HC). The microprocessor is a single chip device with programmable or erasable and programmable read only memory (PROM or EPROM) as well as random access memory (RAM). Additional components of the HC include the communication programmable control chips and various interface/line driver elements. The HC receives azimuth and elevation angles from the heliostat position encoders and then delivers appropriate signals to the azimuth and elevation drive motors for the required pointing angles. Heliostat control commands and sun vectors are received from the respective heliostat field controller (HFC). The HC delivers requested data to the HFC upon command.

5.6.4.2 Heliostat Field Controller

Each of the four HFCs handles a field of 28 or 29 HCs by means of a single serial communication line composed of twisted shield pair operating at 9,600 bauds. All HCs are "multidropped" from the same line that can be as long as 3,050 m (10,000 feet) without requiring communication modems.

The heliostat field has been divided into four sectors to handle the required number of 2,998 heliostats.

Each sector contains up to 750 heliostats which are controlled by 26 HFCs.

Each HFC, in turn, is "multidropped" from a single twisted pair operating at 9,600 bauds that links it with the respective interface unit at the heliostat array controller (HAC).

The HFC computer hardware is similar to the HC hardware. The only differences are a larger random access memory (RAM) and the existence of a bubble (non-volatile) memory unit at the HFC. The bubble memory has a minimum 48,000 byte size while the RAM array is capable of storing a minimum of 32,000 bytes. Two serial communication I/O ports enable command linkages to all HCs and the HAC interface unit, respectively. Each HFC unit is housed on a chassis having approximate dimensions of 12 by 8 by 5 inches.

5.6.4.3 Heliostat Array Controllers

There are two HACs: one for normal operation and the other multiprocessor coupled for 100-percent backup capability for the entire array. The HAC is a minicomputer system with disc unit, 256,000 byte resident memory, CRT displays, line printer, real time hardware, and one communication interface with each sector. Each interface communicates serially with a respective sector. Communications within each sector occur simultaneously for all sectors. In order to further increase the flexibility of the collector array, the control system is designed to operate without the HAC with respect to the main modes of operation. Each of the four HAC is needed only to coordinate certain maintenance and alignment operations (it directs, for example, a given heliostat to track its beam onto the calibration target) and to update or modify the normal control sequence for any sector, field, or single heliostat as desired by the operator. Since the HAC fully interfaces with the process computer system (PCS), the above functions can, at the request of the operator (or automatically), be initiated at the HAC or be relayed to and from the PCS. The beam characterization system (BCS) has its own interface at the HAC to provide the necessary heliostat data and control for beam quality and accuracy measurements.

5.6.4.4 Beam Characterization System (BCS)

The BCS as shown in Figure 5.6-1 consists of a BCS computer, two TV cameras located in the collector array, and two calibration targets positioned below the reheat receiver. Purpose of the system is to permit automatic real time evaluation of quality of the beam and pointing accuracy provided by any heliostat. The whole operation is under software control and requires no operator intervention. At any one time, two heliostats, one from each half of the array, are directed to deflect their beams from the receiver to their respective calibration target. Beam size, shape, centroid, flux distribution, and power are then measured for each heliostat. This is a passive process made possible by use of video cameras aimed at the calibration targets. Their output is digitized, calibrated, and processed. Software modules detect any abnormality and provide the operator or maintenance personnel, through the interface with the PCS, with data necessary to perform any eventual heliostat beam adjustment. Such operation will have to be performed at the heliostat by correcting, as necessary, canting of mirror facets. Pointing information is delivered to the HAC for automatic realignment.

Each camera, permanently installed in the field, is remotely controlled. Temperature stabilizer, environmental enclosure, and camera filters are part of the field installation.

Calibration targets, each approximately 9.1 by 9.1 m (30 by 30 feet), have a Lambertian high temperature surface paint and remotely controlled pyrheliometers for absolute flux measurements. The output of the sensors is transmitted to the BCS computer. Camera output is also transmitted to the BCS computer where a video switch selects each camera in turn. Central processing units, CRT displays, keyboards, printers, video digitizers, and data recorders are utilized to extract needed data. Meteorological data and solar irradiance data are also delivered to the BCS computer to close the loop on evaluation of heliostat beam characteristics.

The BCS computer and the HAC work in direct communication, under PCS supervision, in selection of the heliostats to be aligned and calibrated. Once a heliostat is selected, the BCS gives the instructions to the HAC to direct the heliostat beam from the receiver to the standby position and then to the calibration target to perform the measurements. The operator can intervene at any time to modify or take active part in the operation. The BCS is capable, however, of operating on its own, without the connection to the PCS, in its basic interactions with the collector system through the HAC. Total failure of the HAC or the BCS computer interrupts the beam characterization process. Since BCS failure does not immediately affect the actual performance of the repowering units (the heliostats are capable of functioning without the BCS), no redundant BCS system is required. The unit operator is simply notified so that he can take necessary action to restore normal conditions.

5.6.4.5 Collector Control Operation

All detailed control algorithms for operation of the heliostats during the various modes are stored in the bubble memory of the HFC. Execution of these algorithms is controlled by loading them from the bubble memory into the RAM section. It is possible to modify or update the routines from the HAC by downloading new routines through the same communication network utilized for control of the array. Status of each heliostat or set of heliostats is available at all times at the request of the HAC operator. The HC has the necessary software, stored in the programmable read only memory (PROM) of the microprocessor chip, to execute any command.

Heliostat control arrangement is designed to achieve intended performance at all levels with very little human intervention. All modes of operation, including startup, normal tracking, synthetic tracking, maintenance shutdown, emergency operation, and contingency operation, can be selected by a single operator by controlling the execution of appropriate instructions or set of routines, which are permanently stored in the computer software. Although operation routines are permanently stored, they can be modified or updated at any time using the standard computer system software without affecting the hardware. Provisions are included, however, to enable manual intervention in any function by the operator.

One of the principal concerns associated with design of the operations control strategy is to minimize the impact of malfunctions, occurring at any level, on the performance of components not directly affected by the malfunction. Abnormal conditions are relayed through the communication network to the MCS.

Alignment will take place on a continuous basis under the control of the HAC utilizing calibration targets located below the reheat receiver. The PCS and the BCS take part in this operation through their respective interfaces with the HAC.

Alignment data and control commands for heliostats undergoing alignment are exchanged with the BCS while the entire procedure occurs under the PCS supervision. One heliostat from each half of the field is commanded in sequence to reflect the sun's image onto the assigned calibration target. Heliostat beam pointing data from the BCS are transmitted through the HAC to the HFCs serving the applicable heliostats. At the same time the HAC selects the field of heliostats (served by one HFC) that must undergo alignment. The HFC then produces necessary commands to verify correct aiming at the calibration target and to make necessary adjustments for each heliostat under its control. Any biases necessary to make the calibration signal satisfy the alignment requirements are stored in the bubble memory on the HFC and are used in subsequent operation to correct the heliostat pointing. The HFC notifies the HAC that alignment of its set of heliostats has been completed so that the HAC can switch to the next set of heliostats. The entire procedure is under software control with provisions for manual operator intervention.

5.6.5 Receiver Control

5.6.5.1 General

The purpose of the receiver controls during normal operation are to maintain superheat and reheat steam temperature within specified limits, and to maintain drum level through the feedwater control.

The receiver controls are composed of five main independent controls:

Superheat steam temperature control
Panel bias valve control
Reheat steam temperature control
Feedwater control
Economizer recirculation control

Receiver control is implemented in the PCS. Process measurements are transmitted to the PCS for processing according to the control algorithms programmed into the PCS. The output from the control algorithms forms the analog demand signal which is transmitted to the final control element (valve, damper drive, etc.) to complete the control loop.

5.6.5.2 Process Overview

Figure 5.6-3 shows a simplified flow diagram of the solar receiver indicating the locations of control valves and measurements. Feedwater flow to the receiver is provided by two 50 percent capacity solar feedwater pumps. Feedwater flow is controlled by a single flow control valve. One 100 percent capacity recirculating pump is provided. The superheater is divided into two parallel flow paths, east and west. Two stages of water attemperation are used to control superheater steam temperature of each path. In addition, each of the superheater panels has an inlet bias valve to restrict flow to a cold panel and increase flow to a hot panel. The reheater has two separate flow paths (east and west) with a single stage of water attemperation in each path to control reheater outlet temperature. Each reheater flow path has a butterfly control valve to bias the flow when the incident power is significantly different in the two paths due to diurnal affects or cloud pattern. Excessive reheat temperature requires a defocusing of the mirrors from the reheat panels.

5.6.5.3 Solar Receiver Superheat Steam Temperature Control

The secondary superheater outlet temperature of each flow path is independently controlled by two stages of attemperation. (See Figures 5.6-3 and 5.6-4.)

One attemperator is located between the primary and intermediate superheater section and the other attemperator between the intermediate and secondary superheater sections.

The secondary superheater outlet temperature for each flow path is compared to an operator-selected setpoint and the resulting error signal, in conjunction with a feed-forward function from the steam flow, generates the attemperating water demand signal.

A maximum attemperator flow limit signal is developed, based on the steam flow through the flow path and the primary superheater outlet temperature, to prevent the first stage of attemperation from overspraying such that the outlet steam contains moisture. This limit signal is based on preventing the attemperator outlet temperature from dropping below preset limits.

Initially, the total attemperation flow is through the first stage attemperator. When this stage is at its maximum, additional attemperation is done with the second stage attemperator. A degree of overlap in the operation of the two attemperators is necessary to provide positive control when transferring between one and two stages of attemperation. During transients, both attemperators may move in parallel to minimize the temperature swing.

The demand for each attemperator is compared to its measured flow to develop the demand for each attemperator flow control valve. A block valve associated with each attemperator control valve is interlocked to close whenever its control valve is demanded to close.

5.6.5.4 Panel Bias Valve Control

Each of the 12 superheater panels has a bias valve at its inlet controlled by deadband proportioned control as shown on Figure 5.6-5. Panel bias valve control logic is shown in Figure 5.6-5. These valves under normal, steady-state conditions are throttled to approximately 70 percent open. If, during a transient, the outlet temperature of any panel deviates from the average of the four panels by the amount established by the deadband, the valve is repositioned to divert flow away from a cold panel or increase flow in a hot panel. If the demand for panel bias opening exceeds a predetermined amount, a signal is generated for directing some heliostat groups away from the hot flow path.

The two-stage superheat temperature control system and the panel bias control system provide stable and responsive control of superheat steam temperature over a wide load range and during system transients.

5.6.5.5 Solar Reheater Steam Temperature Control

The reheat outlet steam temperature of each of the two flow paths is controlled by a single stage attemperator at the inlet in combination with a flow biasing butterfly control valve. In addition, heliostat defocusing is used when the attemperation or flow bias is out of the control range (see Figure 5.6-3). Reheater outlet temperature of each flow path is compared with the setpoint and the resulting error is used to develop a demand for reheater attemperator flow. The flow control valves are 70 percent open at steady state conditions and are biased when the spray quantity ratio falls outside a 3 to 1 range.

The solar reheat receiver is designed with excess surface and with as high a reheat temperature spray flow as the existing turbine can handle. The turbine can accommodate 8 to 9 percent reheat spray at maximum design reheat steam flow. This is done to provide reheat temperature control over as wide a load range as possible.

When the reheat attemperator reaches its upper flow limit and the flow control valves are at their extreme positions, a sufficient number of heliostats are refocused from the reheater and onto the main receiver to reestablish the attemperator within its control range.

5.6.5.6 Solar Feedwater Control

The feedwater flow required to maintain proper drum level is controlled using a three-element feedwater control system (see Figure 5.6-7).

Measured main steam flow less attemperator flow signal is used to establish feedwater flow demand. The measured drum level is compared to a setpoint in the proportional plus integral controller which is used to correct the feedwater flow demand. The corrected demand signal is compared to measured flow and applied to a proportional plus integral controller to position the feedwater control valve.

During startup and shutdown when there is little or no steam flow from the receiver, a single element feedwater flow control based on only drum level is used. Also, a high-level dump valve on the drum is used to assist in controlling drum level swell during startup. If drum level exceeds a high-level setpoint, a proportional controller is used to position the dump valve to limit the drum level rise.

5.6.5.7 Economizer Recirculation Valve Control

The economizer recirculation valve is automatically closed when feedwater is flowing to the receiver or when no recirculating pump is in service. The valve is automatically opened when no feedwater is flowing in the associated path and a recirculating pump is in service in that flow path. Feedwater flowing requires that a feed pump be running.

5.6.6 Fossil Boiler Control

Fossil boiler subsystem includes the existing fossil-fueled boiler and associated boiler controls as described in Section 5.2.

The fossil boiler subsystem will be modified with state-of-art control components to improve the reliability and availability of the subsystem. Modifications affect the combustion control, feedwater control, steam temperature control, and burner control.

5.6.6.1 Combustion Control

The existing Bailey Meter Company pneumatic combustion control is working satisfactorily at this time; however, it has been decided to replace it for the following reasons:

> The existing controls will be 27 years old and are not expected to function properly for many of the additional 30 years for which the repowered unit will be designed. Bailey Meter Company is no longer manufacturing this line of instrumentation nor the spare parts to keep it operating.
>
> The combustion controls have a major control and monitoring interface with the PCS.
>
> In order to limit effects of solar transients on the turbine-generator, the fossil unit dynamic response must be as fast as possible within design limitations of the existing unit.

The new combustion controls employ new electronic components and state-of-the-art control concepts.

New combustion control logic includes cross-limiting of fuel/air, feed-forward, and other techniques that will provide improved dynamics response, stability, and safety (see Figure 5.6-8). This logic is implemented in PCS software. This approach greatly simplifies the interface, improves response, and provides added control and monitoring capability.

The basic combustion control consists of three-elements: 1) fuel flow, 2) steam pressure, and 3) air flow. Final control elements for this unit are the gas valve which controls the fuel and the forced draft fan damper which controls the air. All final control elements will be retained if they are working properly.

5.6.6.2 Feedwater Control

The present Bailey Meter feedwater pneumatic control employs a three-element feedwater control concept to maintain proper drum level. (See Figure 5.6-9.)

Like the combustion control system, feedwater controls instrumentation will be replaced by electronic equipment, but will retain the three-element control concept. Control logic is implemented in the PCS.

Final control is through two pneumatic control valves. Each receives an electronic signal which is converted to a pneumatic signal through a current-to-pneumatic converter (I/P).

5.6.6.3 Steam Temperature Control

The present three-element Bailey Meter pneumatic superheat and two-element reheat steam temperature control components will be replaced by an electronic system. Although the control concept will be retained, control logic is implemented in the PCS. (See Figure 5.6-10.)

Better superheat steam temperature at low load is obtained by interlocking the superheat control with the new burner control and bringing in new rows of burners when attemperation has reached its low limit.

Reheat steam temperature can also be maintained at low loads by diverting a portion of the fossil boiler reheat steam to the solar reheat receiver.

5.6.6.4 Balance of Plant (BOP)

The following comprise the BOP equipment:

Generator

Instrument Air/Service Air Compressor
Heater Drains
Deaerator Level
Condenser Hotwell
Condensate Pumps
Makeup and Treating Water System
Chemical Treatment System
Turbine Auxiliaries
Fire Protection
Service Water System

All the above systems are interfaced with and monitored by the PCS. Information from components of the BOP communicate with the PCS through its I/O system.

In general, the present BOP controls are retained; however, new control switches, pushbuttons, control stations, indicators, recorders, and lights are provided on the new main control board.

5.6.7 Plant Control Room Modifications

5.6.7.1 General

An evaluation was performed to establish the impact of solar repowering on the existing controls and facility. The new control room design is illustrated in Figure 5.6-11. The resulting room is the primary area for personnel to perform such functions as programming, calculations, heat balances, debugging, tuning, and system reconfiguration. This room houses the engineer/programmer's console, a programmer's terminal, two medium speed printers, one line printer, and magnetic tape unit. In addition, discs, printers, and CRTs associated with the BCS and HAC are located in this room.

Referring to Figure 5.6-11, adjacent to the results room is the computer room which houses the CPU for the PCS, the DEH, the HAC, and BCS, together with all peripheral and support cabinets. This room is segregated from the relay room (also in this figure) to avoid noise pickup originating from relay or other electromagnetic equipment.

Provisions are made to add suitable HVAC equipment, located on the results center level (above the existing control room), to supply the proper environment for personnel comfort and operation of the computer and other electronic equipment.

Evaluation has led to modification, addition, and/or change in the following major areas:

Control Room
Results Center
Control Board
Boiler Controls

Turbine Controls
Burner Controls
Instrumentation

5.6.7.2 Control Room

Existing control room is presently shared by Newman Units 1, 2, and 3. Due to additional controls associated with the solar unit, space allocated for Newman Unit 1 is not sufficient to house the new control board, master control subsystem, and associated cabinets and peripherals. Therefore, the existing control room area will be expanded by moving the north wall 2.3 m (7.5 feet) to house the new control board, an alarm printer, and utility printer. The new control room will also include a battery room for backup power.

5.6.7.3 Results Center

In addition to expansion or the existing control room, another floor level will be required to house all the I/O cabinets, computer equipment, etc associated with the MCS. The new floor level will be located above the existing control room and is called the results center.

The results center is composed of three major areas:

Relay Room
Results Room
Computer Room

The relay room is used to house the multiplexing, interface, and relay logic cabinets. In this area, a properly designed air conditioning system is part of the HVAC equipment. The system features chemical and particulate filters to remove airborne particles and corrosive or hazardous gases.

The HVAC equipment maintains the results center under a slight positive pressure to keep dust or gases from entering the building when the doors are opened.

Other features of the results center are a conference room, a maintenance and spare parts storage room, and facility rooms.

Dimmer switches are provided to reduce illumination levels of the individual areas.

Fire protection equipment with automatic extinguishers using Halon 1301 or 1211 gas are provided.

5.6.7.4 Control Board

A study of the present control board of Newman Unit 1 showed that it will not be possible to retain the present operating board.

Considering the rework necessary to remove all existing pneumatic lines, wires, instruments, and controls associated with the control board and to implement the new electronic controls for the fossil/solar hybrid unit it will be more cost-effective to provide a new control board.

The new control board will be shop-fabricated and prewired/preassembled to the greatest possible degree. Control signals from the PCC, the DEH, boiler controls, and BOP to the control board will be through prefabricated multi-conductor cables.

The proposed control board design is shown in Figure 5.6-2. The computer/control board interface is illustrated in Figure 5.6-12.

5.6.7.5 Fossil Boiler Controls

As part of the repowering program, all pneumatic instrumentation presently used in the combustion control, steam temperature control, and feedwater control shall be replaced with solid-state electronics. The benefits of this change are:

Improved transient response
Simplied PCS interface
Improved reliability
Reduced maintenance

Analog signals originating from the new electronic instruments are fed to the PCS where all the necessary control functions are provided in software for each of the following:

Combustion controls (Figure 5.6-8)
Burner controls
Steam temperature controls (Figures 5.6-4 and 5.6-10)
Feedwater controls (Figures 5.6-7 and 5.6-9)

The combustion control philosophy follows present state-of-the-art approach, e.g., cross-limiting with a feed-forward load indicator and using steam pressure as the master. The system interfaces with the turbine to establish the required signals to operate the unit in a boiler-follow or a turbine-follow mode. Steam temperature controls (superheat and reheat) and feedwater controls also follow the present state-of-the-art approach.

All final control elements such as valves and unit drives are retained provided they are working properly. Analog signals from the MCS to final controlled elements are through I/P converters.

5.6.7.6 Turbine Control

The present Newman Unit 1 Allis-Chalmers turbine requires some engineering redesign of the existing mechanical-hydraulic system to allow the turbine to operate in a turbine-follow mode. In addition, a digital electro-hydraulics (DEH) control system will be implemented.

Due to expected cyclic operation of the fossil/solar hybrid unit, it is important to avoid excessive thermal stresses during rapid transients and, at the same time, reduce startup times under all operating conditions. The implementation of a DEH control system greatly facilitates operator interface and minimizes the margin for error.

Some of the important benefits of implementing a DEH are:

Automatic turbine startup (ATS) from turning gear to synchronous speed.

Measures shaft eccentricity, vibration, and metal temperatures.

Calculates rotor stresses and adjusts turbine speed accordingly. Self-diagnostic features to evaluate the validity of control information

Executes load runback based on command from the control system.

The ATS normally has two operating modes:

Automatic
Supervisory

In the Automatic mode, an ATS program adjusts turbine speed and acceleration to the digital reference.

In the Supervisory mode, guide messages inform the operator to adjust turbine speed and acceleration manually.

The turbine DEH system is composed of a dedicated digital computer in the computer room which receives analog and digital information from turbine sensors and transmits control signals to the electrohydraulic system that controls the turbine throttle valves.

The DEH is interfaced with the process computer system through a data link. The PCS coordinates turbine operation to match load requirements of solar repowered Newman Unit 1 under the fossil only, fossil/solar, and solar only modes.

Communication between the operator and the DEH system is through a dedicated console with its corresponding keyboard and dedicated CRT for color graphic display and program status.

5.6.7.7 Burner Control

The present Forney Engineering Company burner controls are working properly. However, they require a great deal of manual operation.

The burner control system is old and would require extensive work to be upgraded sufficiently to provide the response necessary to meet the repowered unit requirements. Therefore, it will be necessary to provide a new burner control system.

The new burner control system will respond faster to unit transients, will increase fuel safety, and will operate automatically from the main control board under all operating conditions.

The new burner control system consists of a panel insert on the new main control board with pushbuttons and switches to provide the operator interface and comply with the latest OSHA and NFPA-85B requirements.

The control logic and interlocks for burner operation, purge, prelight, fuel safety, etc are implemented in the PCS software. In addition, sufficient hard-wired solid state logic is provided so the operator can safely shut down the fossil boiler in the unlikely event that both PCS CPUs fail. Also, remote local controls are provided to control individual burners whenever they are required.

5.6.7.8 Instrumentation

New electronic process measurement transmitters are used to replace the existing pneumatic Bailey Meter instruments and to add new process measurements required by the new solar receiver and fossil plant.

These new transmitters are field rack mounted where feasible and measure the different parameters associated with the fossil/solar repowering unit as part of the PCS. The major parameters measured by the new instruments are:

Pressure and Differential Pressure
Temperature
Flow
Level

The new transmitters are of a simplified and compact design with external span and zero adjustment, with modular construction and plug-in circuit boards to aid troubleshooting and reduce parts inventory.

Solid-state strip chart records driven by the computer are mounted on the main control board to record and trend any abnormal condition encountered during load excursions, transients, and system failures.

Also, new vertical indicators, ammeter and voltmeter control switches, and pushbuttons of a compact design are mounted on the main control board.

In addition, new orifices, flow nozzles, thermocouples, control valves, recorders, local pressure gages, pressure, temperature, flow switches, etc are provided where necessary to support the PCS data acquisition and control requirements of the solar repowered unit.

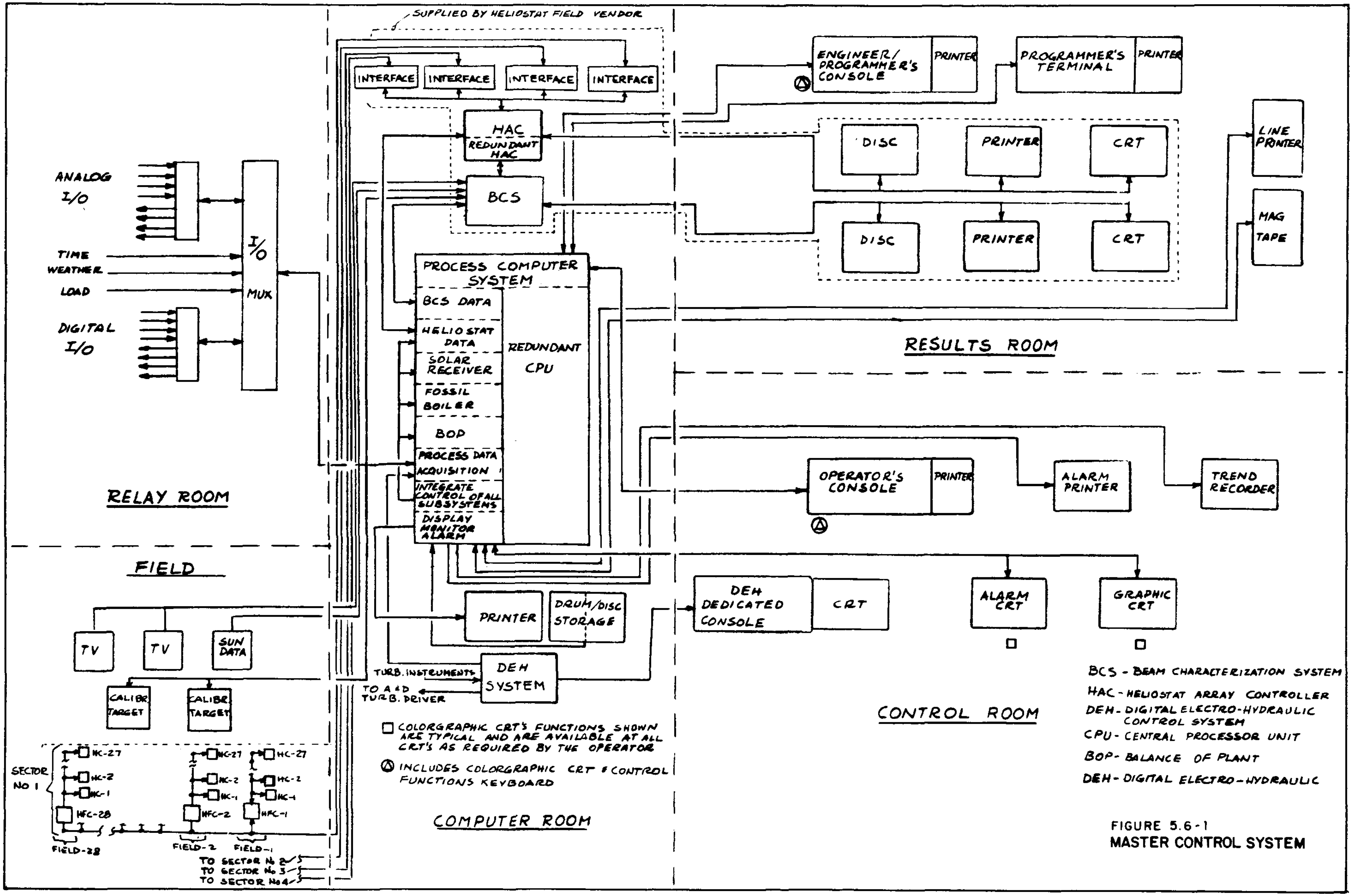


FIGURE 5.6-1
MASTER CONTROL SYSTEM

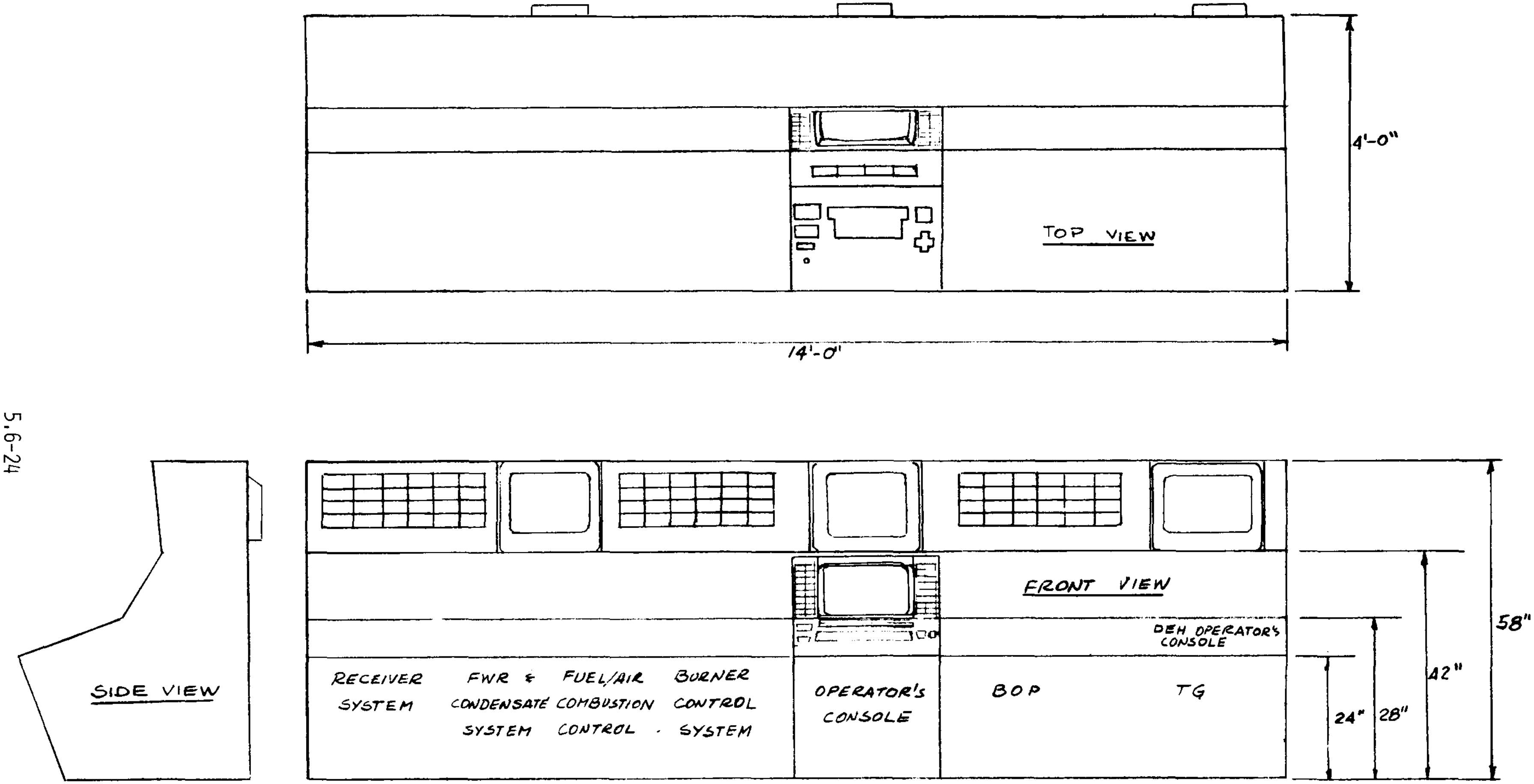


FIGURE 5.6-2

MAIN CONTROL BOARD

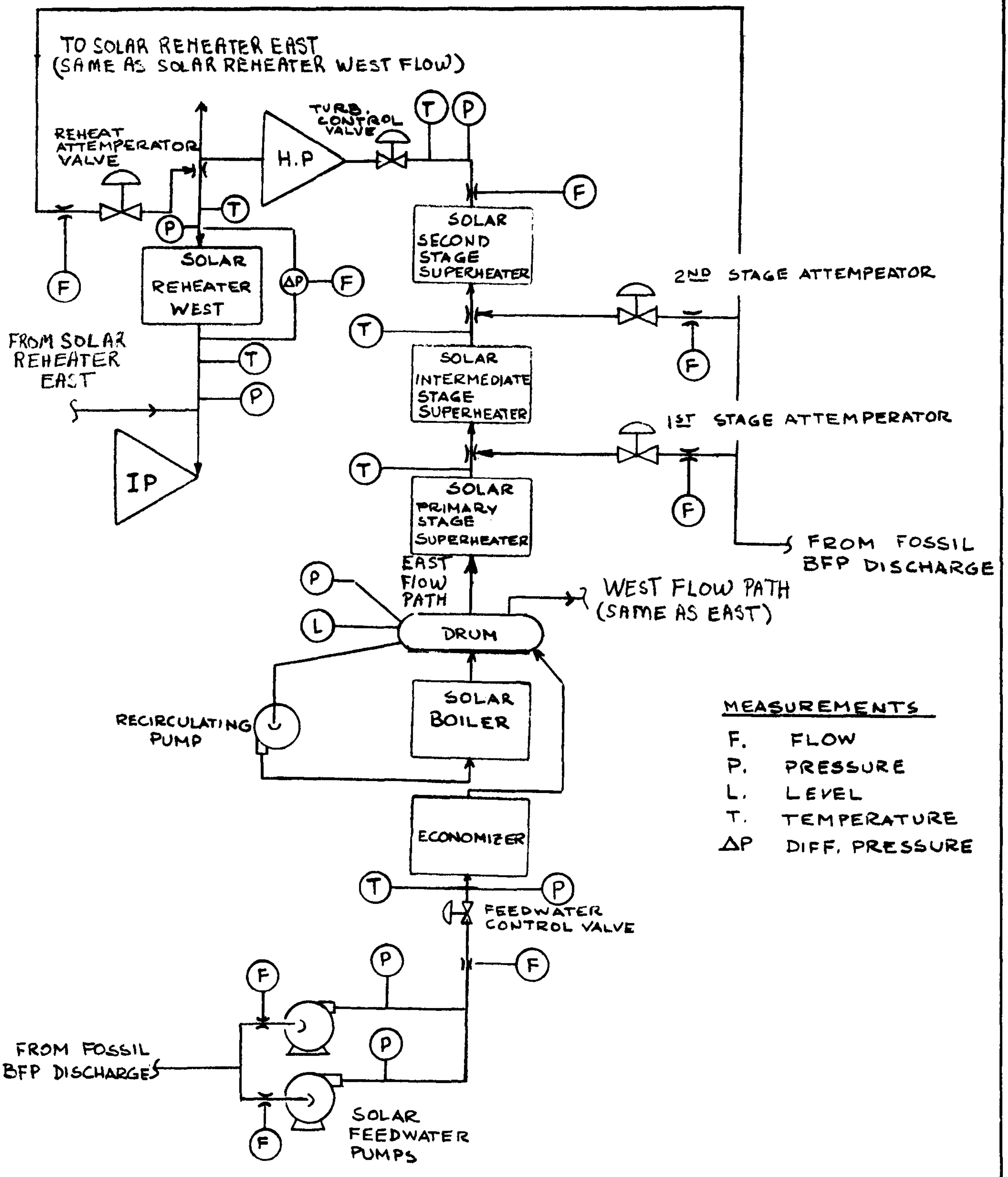


FIGURE 5.6-3
RECEIVER SIMPLIFIED
FLOW DIAGRAM

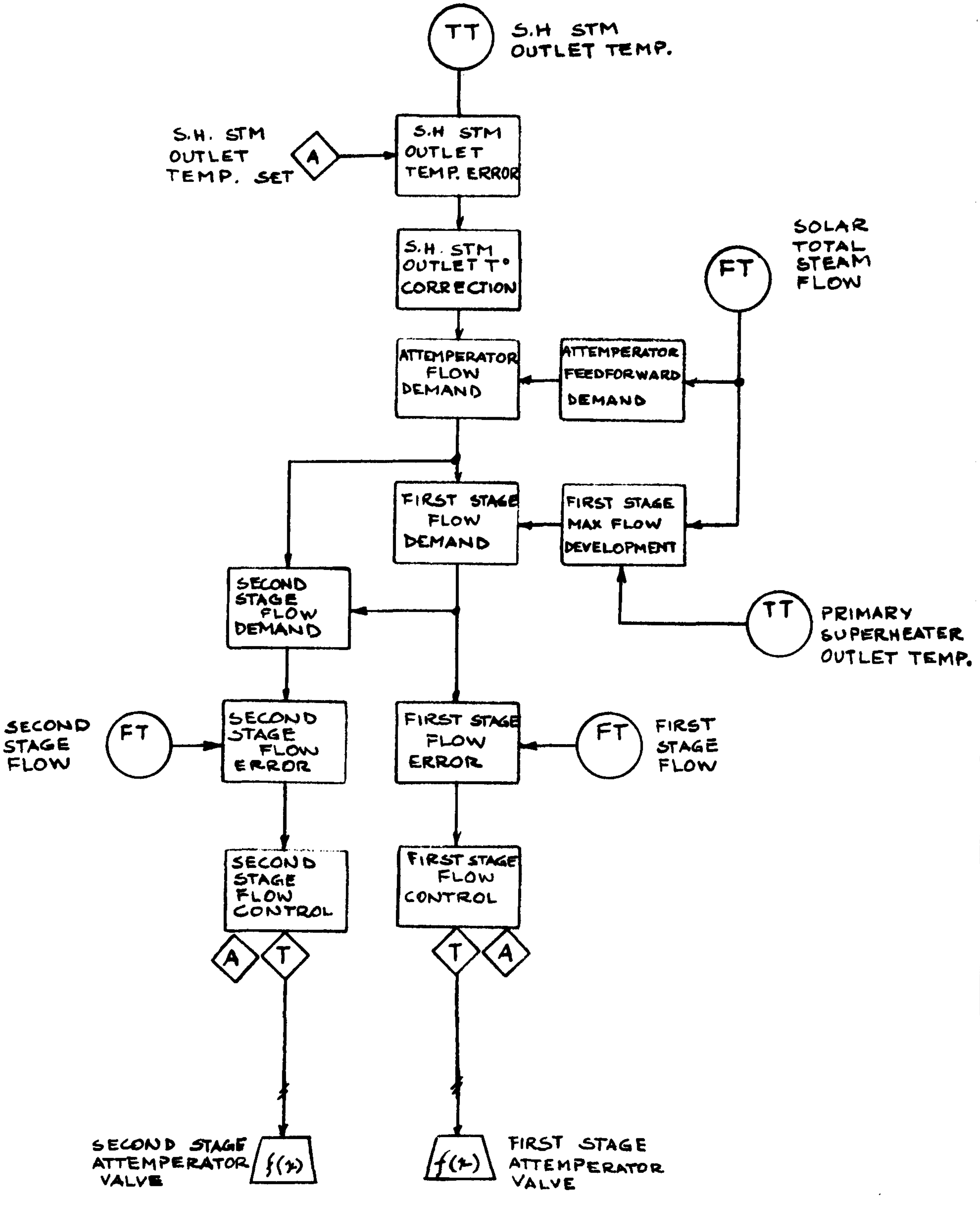


FIGURE 5.6-4
SOLAR RECEIVER SUPERHEAT
STEAM TEMPERATURE CONTROL

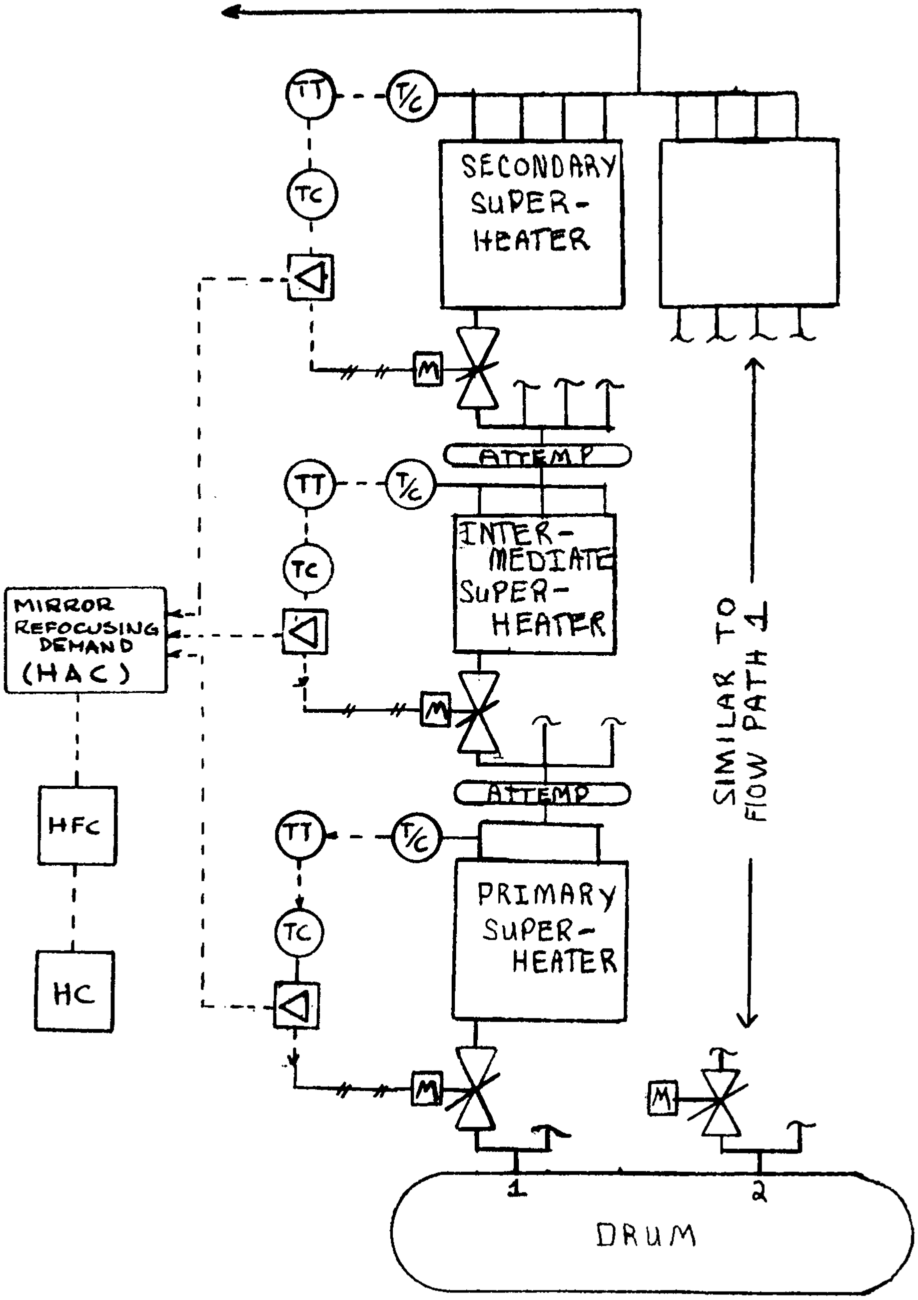


FIGURE 5.6-5
BIASING VALVE CONTROL

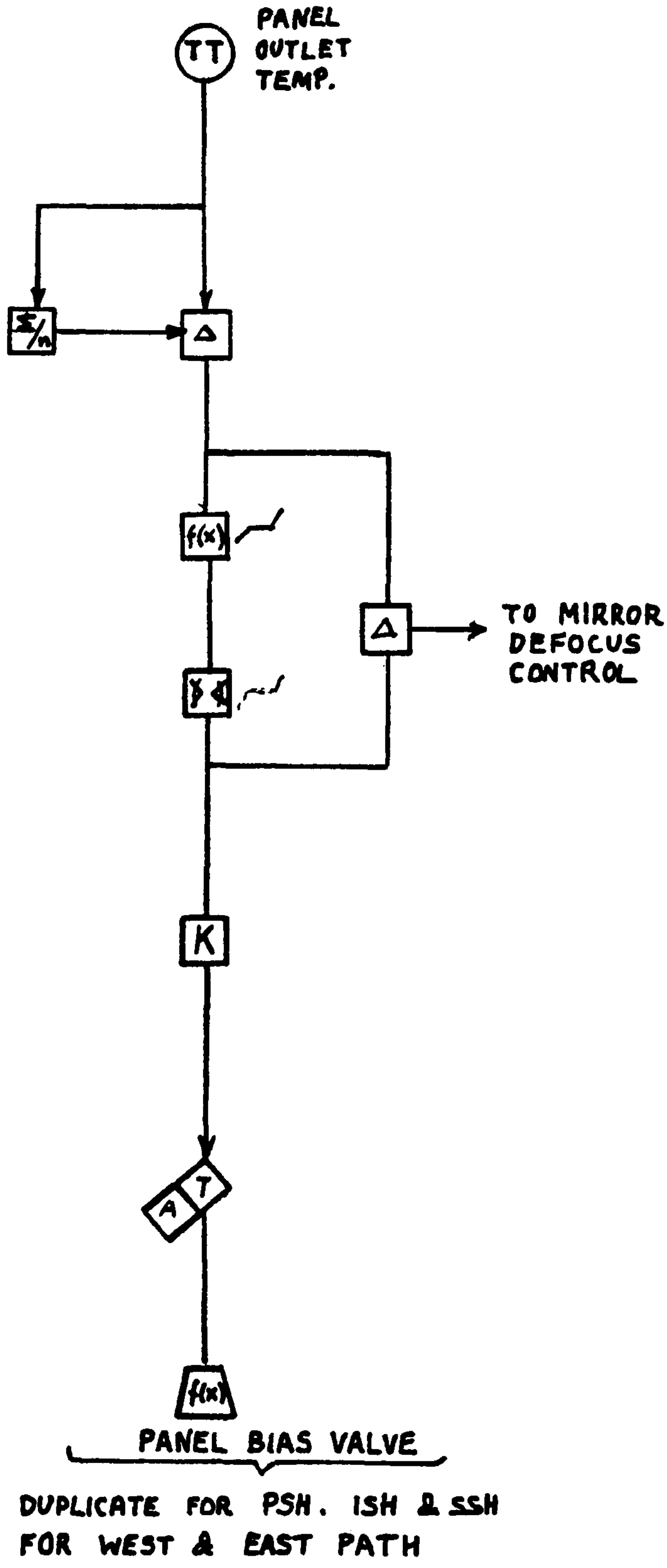


FIGURE 5.6-6
PANEL BIAS VALVE CONTROL

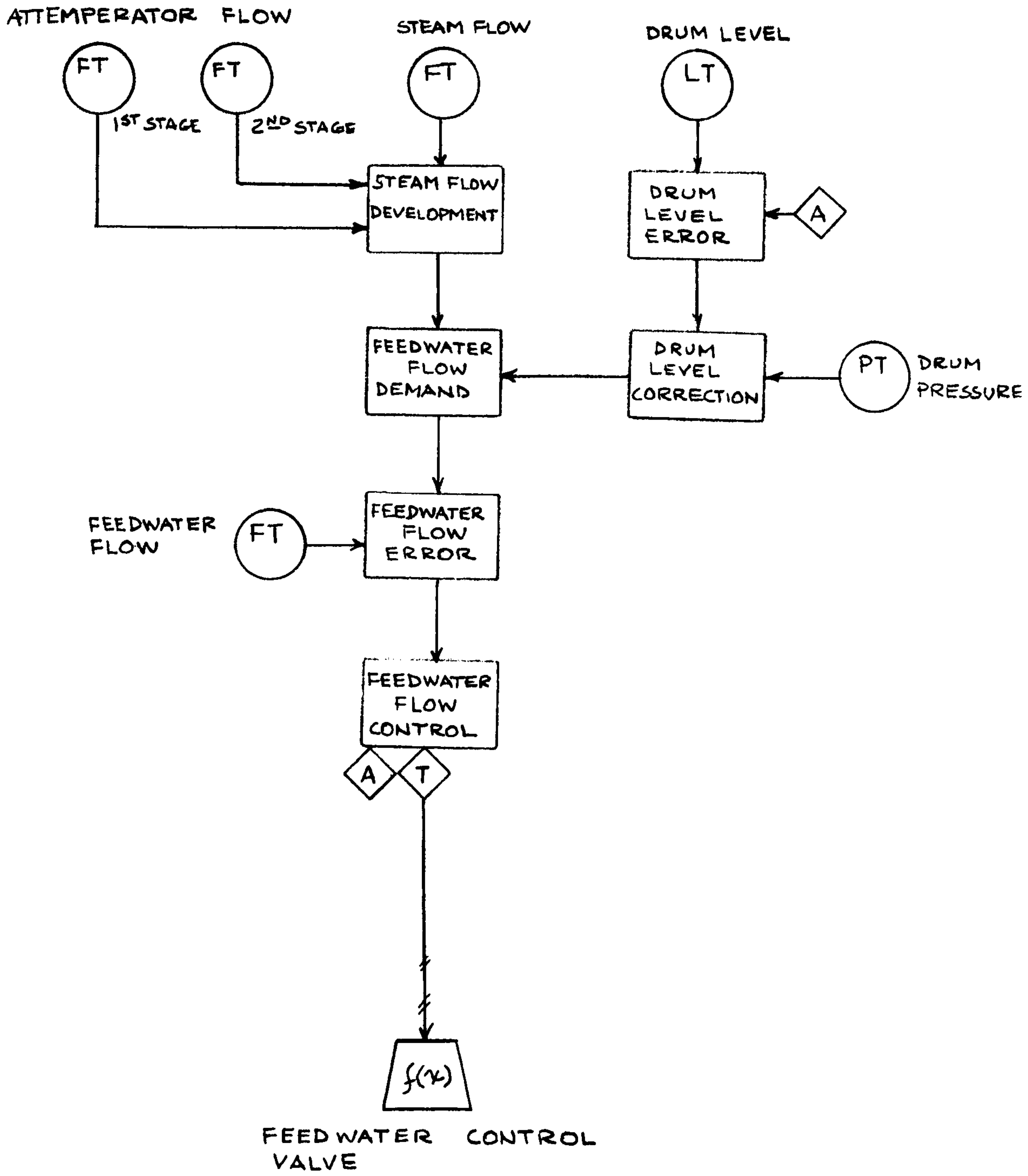


FIGURE 5.6-7
SOLAR FEEDWATER
CONTROL SYSTEM

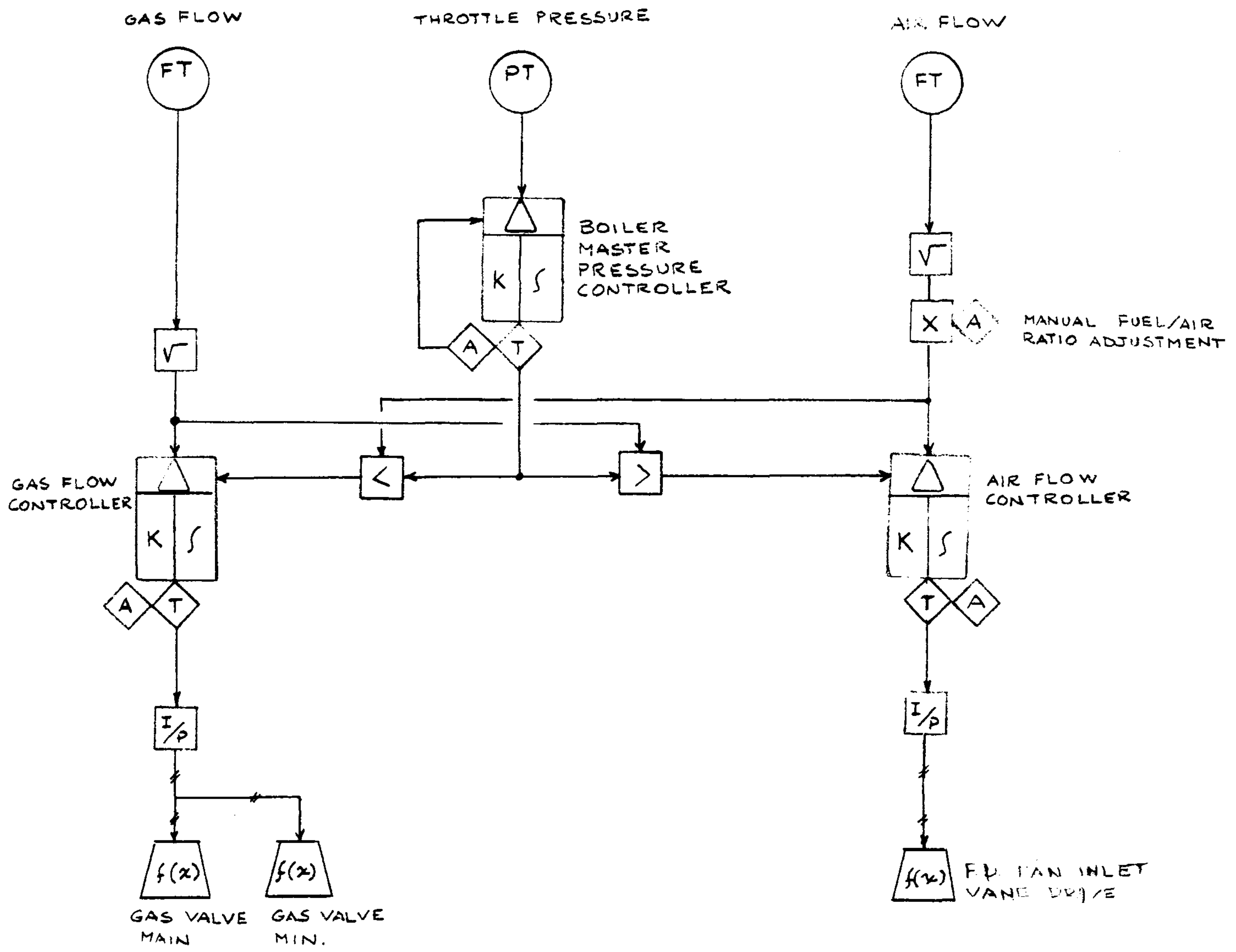


FIGURE 5.6-8
COMBUSTION CONTROLS WITH MANUAL FUEL / AIR ADJUSTMENT

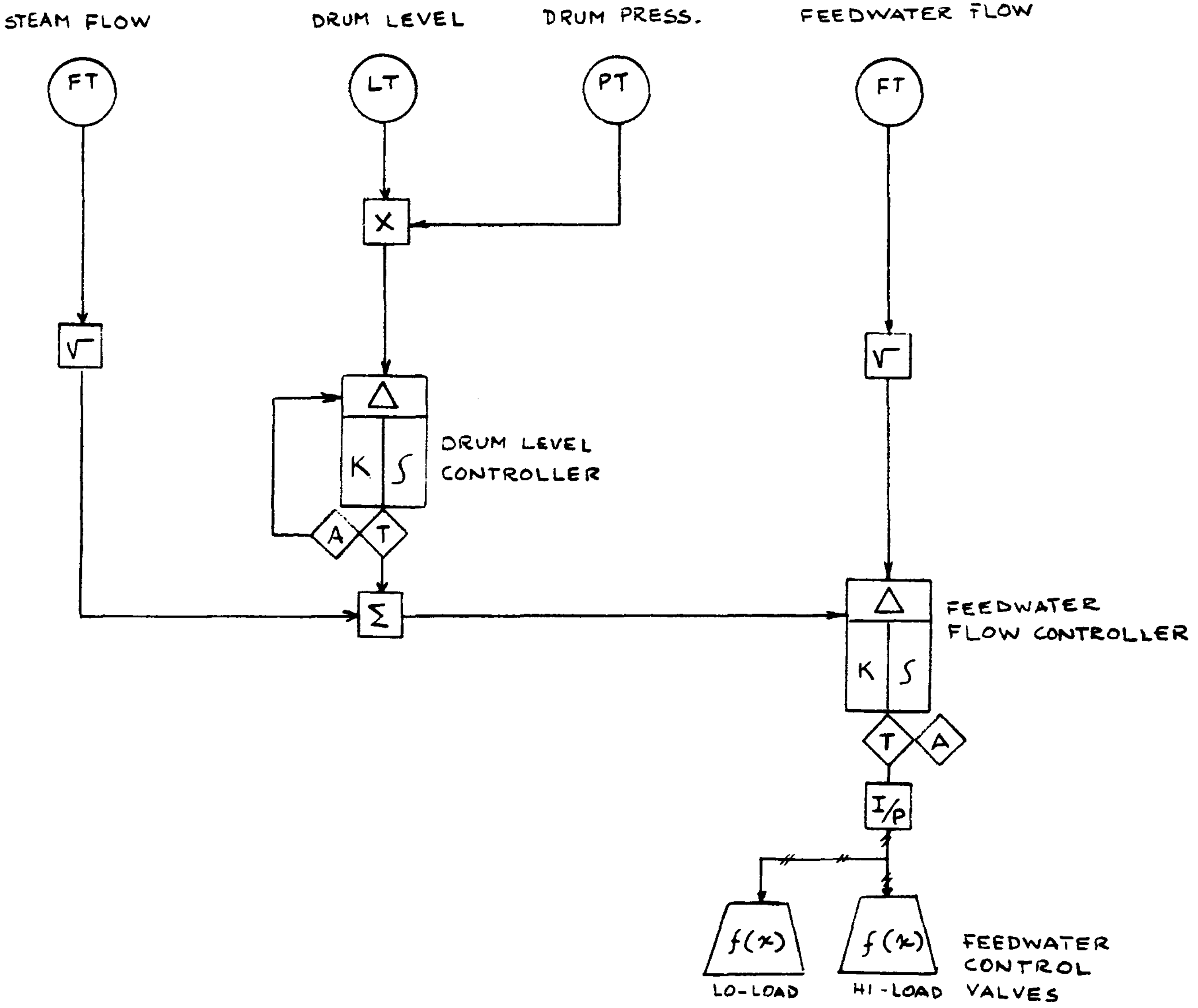
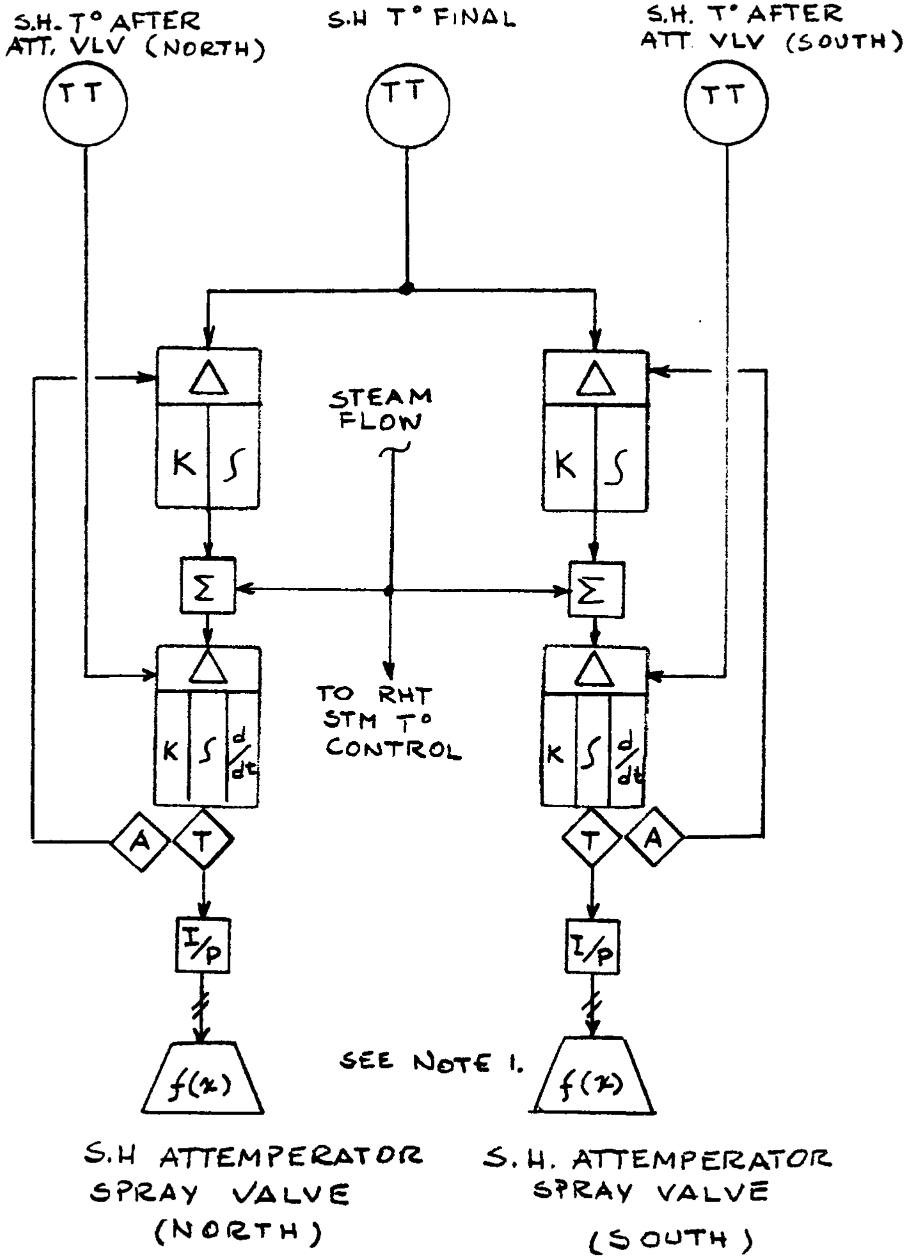
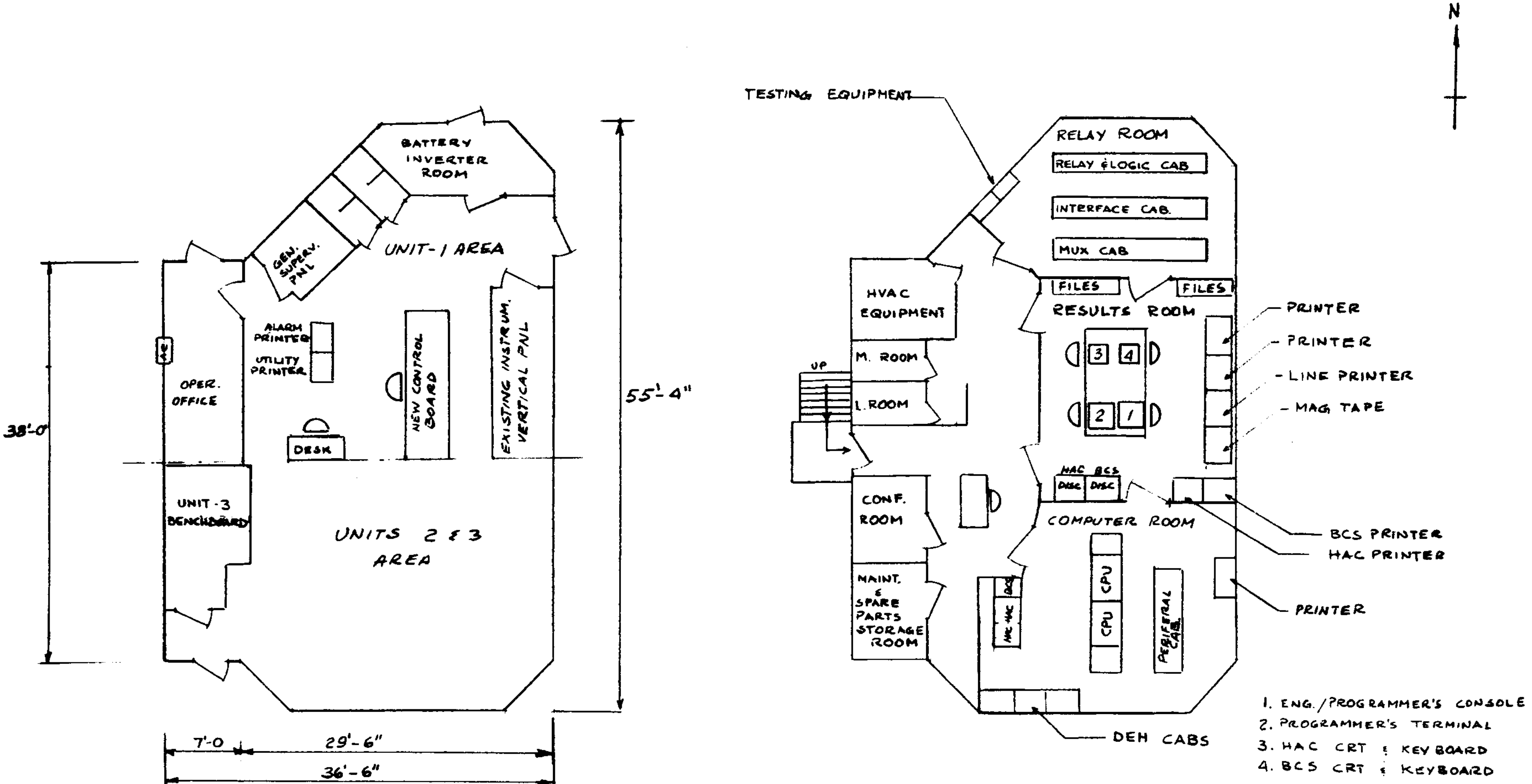


FIGURE 5.6-9
FEEDWATER CONTROL SYSTEM



NOTE 1. SUPERHEAT STEAM TEMP. CONTROL SHOWN
REHEAT STEAM TEMP SIMILAR

FIGURE 5.6-10
STEAM TEMPERATURE CONTROL SYSTEM



CONTROL ROOM

RESULTS CENTER

FIGURE 5.6-11
CONTROL & RESULTS ROOM

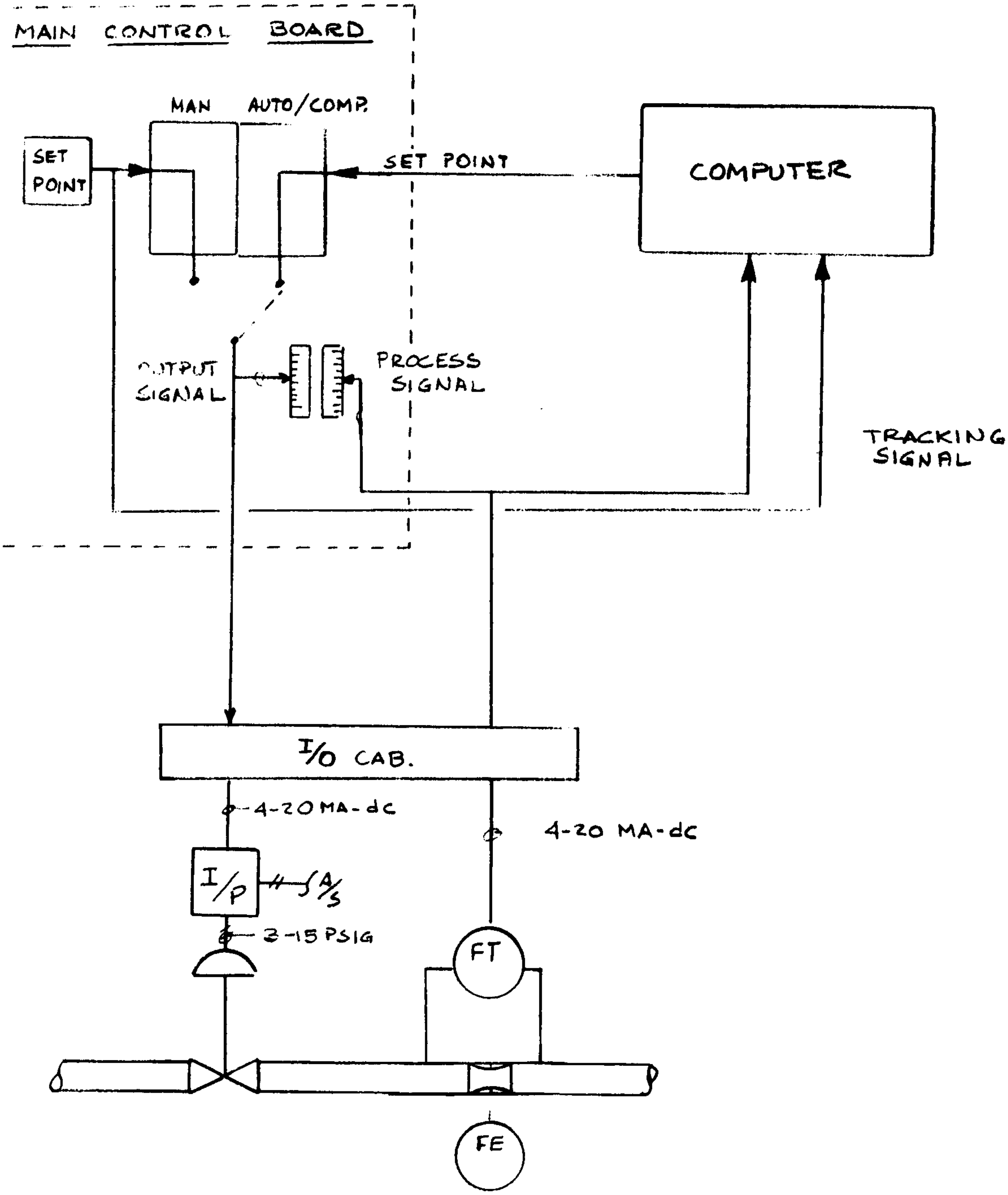


FIGURE 5.6-12
COMPUTER/CONTROL BOARD INTERFACE

5.7 SITE PREPARATION

The Newman site is nearly flat with a downward slope of approximately 2 degrees from west to east. The solar collector field is graded with access to the heliostats for inspection and maintenance from a 9.1 m (30 feet) wide asphalt paved perimeter road. A 2.4 m (8 feet) high fence along the perimeter road is provided to discourage unauthorized access to the heliostats. The Farm to Market Road 2529 that crosses the east-west part of the proposed field terminates outside the solar collector field boundaries. A new 3.2 km (2 mile) long highway is provided to reroute traffic north of the solar collector field site.

Arroyos ranging from surface erosion near the center of the site to 2 m (6 ft) washes near the War Road west of the site are diverted north of the collector field. The diversion channel extends east across a 36.6 m (120 feet) wide natural gas line right-of-way (ROW). Rainfall in the field will be channeled by several north-south shallow ditches, 0.6 m (2 feet) deep with a 3.0 m (10 feet) bottom width covered by 5.1 cm (2 inches) of crushed stone. The shallow ditches discharge into collection ditches of 0.9 m (3 feet) deep and 6.1 m (20 feet) bottom width along the field's east-west perimeter road. Ten culverts are provided under the perimeter road to drain water away from the field area. The approximate location of the drainage and collection ditches and the culverts are shown in Figure 5.7-2.

Exclusion areas in the collector field allow access to existing piping. A 36.6 m (120 feet) wide ROW located in the eastern part of the field is provided for underground natural gas lines. A 12.2 m (40 foot) wide ROW running in the east-west direction is provided for water and gas/lines at the Newman Station. In addition, a 61 m (200 foot) wide exclusion area is provided on the east, north, and west sides of the heliostat field to provide room for turning trucks and reducing the likelihood of vandalism.

Existing transmission lines in the proposed field location will be rerouted and future transmission line ROWs are provided to meet El Paso Electric Company expansion plans. Rerouted and future transmission rights-of-way will occupy the adjacent area to the north of the planned 345 kV switchyard addition (see Figure 5.7-1).

North of the Newman Station site, an irrigation spray system, using water from the Newman Station evaporation pond, irrigates land for cattle grazing. The irrigation system will be moved to a new location in order to use the land for the solar collector field.

The total cost of the site preparation is \$1.9 x 10^6. The site preparation costs are itemized in Table 5.7-1 and include the costs for cleaning the land, minor grading, surface preparation with 5.1 cm (2 inch) crushed stone, roads, and fencing.

TABLE 5.7-1

SITE IMPROVEMENT COSTS

Clearing and Grubbing	$ 500,000
Diversion Channel and	130,000
Drainage Ditches	260,000
Roads and Fencing	1,010,000
Total (1982 dollars)	$1,900,000

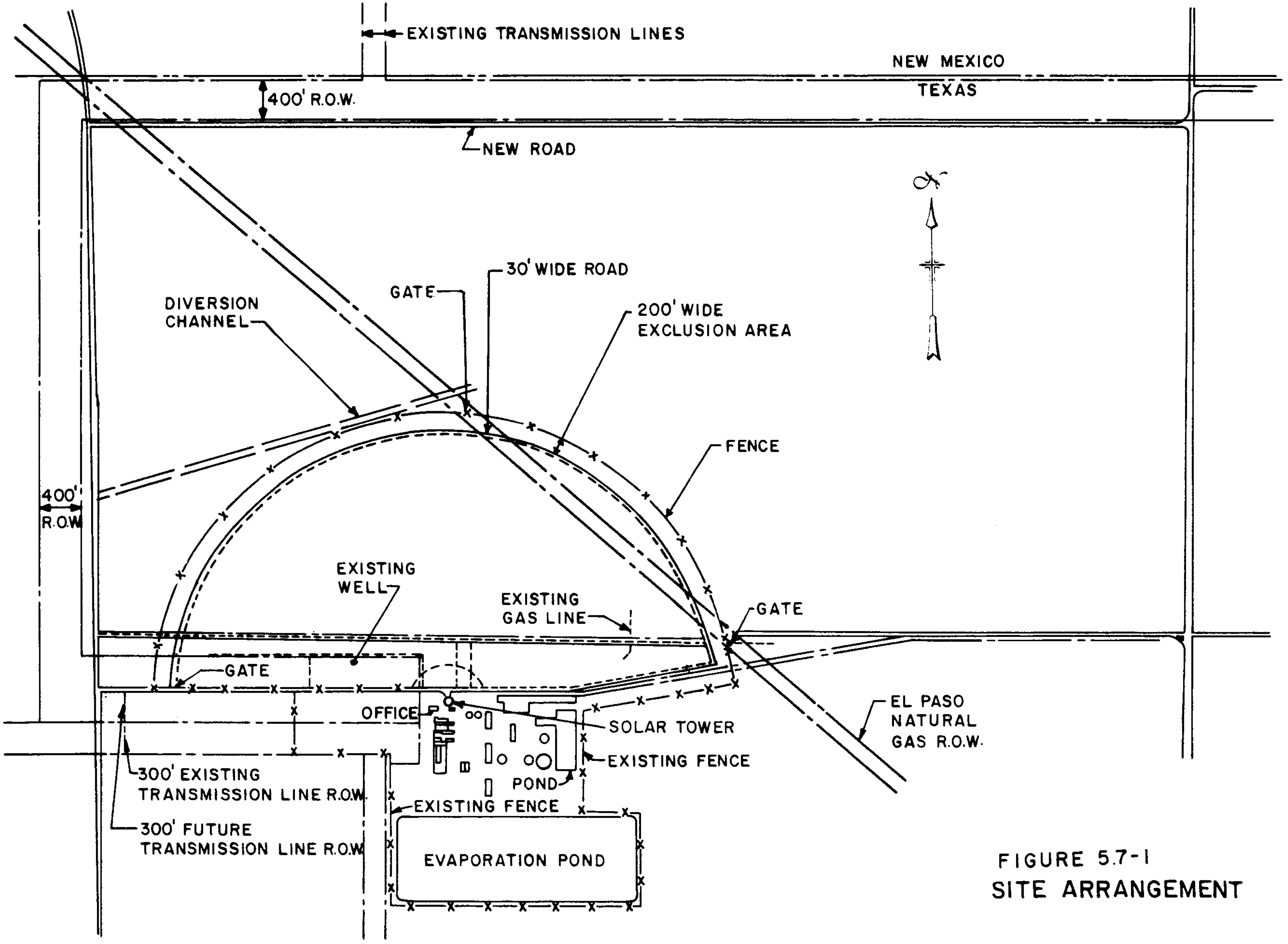


FIGURE 5.7-1
SITE ARRANGEMENT

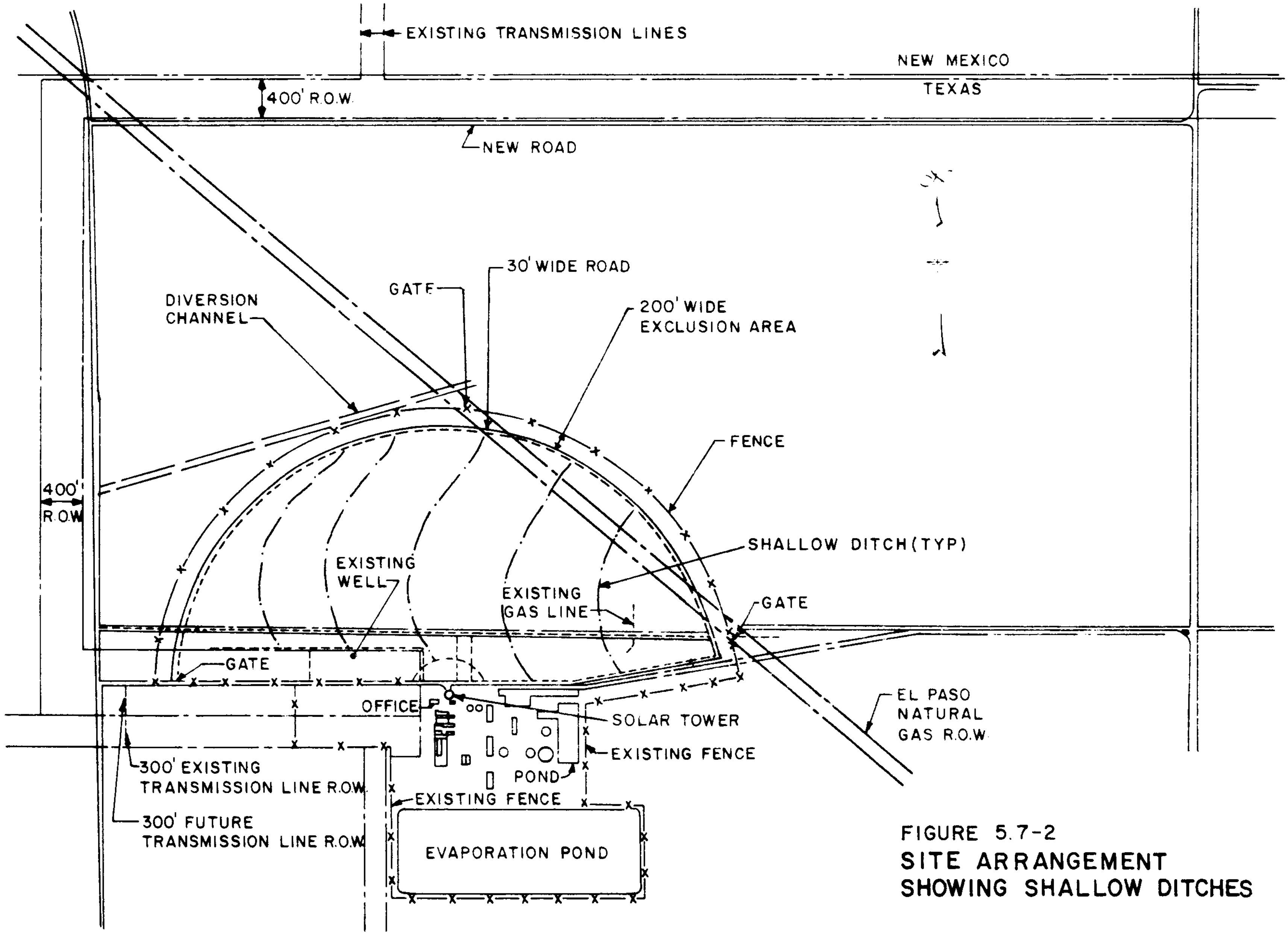


FIGURE 5.7-2
SITE ARRANGEMENT SHOWING SHALLOW DITCHES

5.8 SITE FACILITIES AND STRUCTURES

New site facilities and structures associated with the solar repowered Newman Unit 1 Station include a modification to the existing control room, a new solar feedwater pump house, and an extension to the existing maintenance building. Detail conceptual design drawings included in Appendix D have been developed to show the locations of the new site facilities.

5.8.1 Functional Requirements

The control room will require a second level to house the solar repowering electronic equipment. The extended control room areas shall be air conditioned to maintain the correct ambient temperature for the new computers and associated equipment. The second level will require new toilet facilities. An addition to the maintenance building will be required to enable plant personnel to repair and test complete heliostat assemblies. Additional cooling and ventilating equipment will be required to circulate fresh air through the maintenance area.

The solar feedwater pump house will be required for the solar feedwater pumps and the solar repowering equipment switchgear.

The existing fire protection system must be extended to protect the new site facilities. Hydrants and hose stations will be necessary for the heliostat field and around the solar feedwater pump house and maintenance area. Hose stations shall be provided at the various levels inside the solar receiver tower.

Outdoor lighting shall be provided along the solar collector field perimeter road and at the base and upper levels of the tower.

5.8.2 Design

The solar repowering system computer equipment, relay equipment, and associated consoles for the operators and programmers are located in a second level over the existing control room as shown on Figure 5.6-1. The second level is approximately 17 m (56 feet) by 11.0 m (36 feet), air conditioned, and includes an engineering office, spare parts storage room, conference room, and personnel toilet facilities. An addition to the existing control room extends the north side of the room approximately 2.3 m (7.5 feet) to provide floor space to combine the solar repowering system control panel with the Newman Unit 1 boiler control panel.

A new air-conditioned equipment room will be provided just below the top of the concrete tower to house receiver instrumentation and control equipment.

The solar feedwater pump house is an 11 m (36 foot) by 15.2 m (50 foot) sheet-metal enclosure located next to the solar receiver tower. The pump house includes two half-capacity solar feedwater pumps/motors and associated equipment and a switchgear area for the solar repowering electrical equipment.

A 12.2 m (40 foot) by 18.3 m (60 foot) maintenance area is connected to the existing warehouse. The new maintenance area has adequate space to assemble and test a heliostat unit prior to field installation. Existing fire protection underground mains are extended to cover new fire protection requirements for the solar repowering facilities. Hydrants and hose stations are located at strategic points in the solar collector field, around the maintenance area, and solar feedwater pump house. A fire water booster pump is located at the base of the solar receiver tower, and hose stations are provided at the tower upper levels.

5.8.3 Cost

The total direct cost for new site facilities and structures (Account 5200 - Administrative Areas) is estimated at $586,000.

SECTION 6

ECONOMIC ANALYSIS

This section presents the detailed economic analysis of the solar repowered Newman Unit 1 operating on the EPE system. The analysis is based on the advanced conceptual design of the repowered unit described in Section 4.

The intent of the analysis is to realistically assess the economics of the "first" repowered unit using present cost data for a limited production level for the solar hardware. The results therefore are not indicative of the economic potential of solar repowering, but rather only of the economics of the "first demonstration" unit; the future economic potential of solar repowering is addressed in Appendix A.

This section of the report includes a summary description of the methodology used for the analysis, a brief description of the repowered unit including the operating strategy, a description of the EPE system, a discussion of the economic bases for the analysis, and the results and conclusions of the analysis.

6.1 METHOD

The integration of solar repowered units into electric utility systems raises a number of questions as to the value of the repowered units, problems they may introduce, and requirements that should be placed upon them. In addition to technical feasibility, economic and reliability impacts are major concerns to El Paso Electric Company. These involve the cost of repowering, the quantity of fossil fuels displaced, a potential capacity credit for unit life extension, and the reliability of the solar repowered unit.

A cost/value analysis was performed to evaluate solar repowering of Newman Unit 1 on the EPE system. The analysis was performed utilizing the methodology developed by Westinghouse as part of EPRI Contract RP 648-1 entitled "Requirements Definition and Impact Analysis of Solar Thermal Power Plants." The following general assumptions were made for analyses:

1987 Initial full year of commercial operation

EPE system expansion plan modeled

Solmet weather data for El Paso/typical meteorological year

Solar plant model developed as part of EPRI RP-648

Newman Unit 1 operated to maximize the benefit of solar repowering following the 6-month test and engineering evaluation period

Newman Unit 1 operated for either solar, fossil, or a combination of solar/fossil energy

Day's insolation profile and load demand known in advance

Thirty year operating life

For the proper assessment of the prospective value and impact of the solar repowered unit upon the EPE system, detailed modeling of the operation of such a unit is required. This modeling must involve the interactive dispatch of the solar unit with other generation units on the utility system.

The methodology includes a system of computer models and economic procedures specifically integrated to perform solar unit concept assessment and economic impact analysis. The framework of the specific methods employed involves the following sequence of analysis (Figure 6.1-1):

Develop hourly projections for year and utility system of interest.

Simulate the operation of conventional units on utility system for that year, producing incremental operation cost tables.

Use incremental cost tables, hourly system loads, and hourly insolation to dispatch solar unit, subtracting solar unit electrical power production from the load profile.

Use hourly load reduction to calculate solar unit capacity credit and conventional capacity displacement.

Simulate again the operation of conventional generating units with reduced system load.

Use economic precedures to calculate resulting solar unit value.

This framework allows the evaluation of the solar repowered unit in different operating and insolation environments. It also provides a vehicle for assessing the value of either a single solar unit or a number of solar units, independent of their cost projection.

The basis of the evaluation models is a set of Westinghouse Electric Corporation utility planning computer programs and a model for solar repowered unit dispatch. The utility models include a production costing model that simulates the operation of the balance of the utility system in bi-hourly increments. Capacity credit is calculated using a loss-of-load probability model capable of accepting a probability distribution for the availability of the solar plant.

The methodology implemented for economic and system reliability impact assessment relies heavily upon utility system simulation. The Load Projection, Load Statistical Analysis, Reliability Analysis, and Detailed Production Cost blocks (Figure 6.1-1) are separate existing Westinghouse models (computer programs) that are routinely used to analyze utility systems. These models have had minor modifications to allow them to interface with the Solar Thermal Unit Model. This latter model is a modified version of the one developed by Westinghouse as part of EPRI Contract RP 648-1. The projected hourly system and site weather data are input to the solar unit model, which simulates the operation of the solar unit with outputs for further analysis of the remaining load to be served. The solar unit model uses incremental operating cost data for the balance of the utility system to guide its dispatch. This is particularly important for the optimum conservation of fossil fuel.

A dispatch routine that recognizes balance of utility system incremental costs, turbine efficiency variations, and insolation projections is implemented using considerations shown in Table 6.1-1. The approach assumes a foreknowledge of the full day's insolation and load profile at the beginning of each day. It also uses information as to the incremental operating cost of the utility system at various load levels using various fuels along with the various solar subsystem efficiencies.

For realism in the modeling of the operation of the repowered unit, the items shown in Table 6.1-1 include fossil fuel consumption to bring the boiler up to temperature, accounting for both fuel consumption and the time required. Operating scenarios where the boiler heat is maintained in a warm (standby) condition overnight is an option in the program.

Logic requiring fossil energy to buffer the turbine during insolation transients is also incorporated. The skycover conditions are sampled hourly from the insolation tape to determine when insolation transient conditions apply.

To prevent excessive cycling of the turbine, the unit is fired to run through what otherwise would be a brief shutdown period. When wind speeds exceed the input design limits, the heliostats are assumed stowed and no solar energy is collected for that hour. Both boiler and turbine-generator part-load efficiency curves are incorporated in the solar repowered model.

When the insolation is not sufficient to operate the turbine at its minimum level and a specified insolation threshold is exceeded, the boiler is fired to provide enough supplemental energy to salvage the insolation and operate the turbine-generator.

The incremental cost of competing conventional plants is tested hourly to establish whether additional fossil firing of the solar repowered unit is economical. A test is also made to determine whether it is economically advantageous to start the boiler during each cloudy day, or to leave the boiler at standby and thus not recover the electric power production potential of the solar subsystem. The proper boiler shutdown hour is also established on an economic dispatch basis.

The economic methods developed use conventional Revenue Requirements analysis, recognizing both the time value of money and independent escalation of various cost elements. These methods are consistent with electric utility practice and provide the needed flexibility. The Revenue Requirements methodology is also consistent with the EPRI economic evaluation guidelines stipulated in the August 1977 EPRI "Technical Assessment Guide." The principal economic measures of solar units implemented in this methodology are shown in Table 6.1-2.

Because of the uncertainty of the costs of certain portions of the solar unit, particularly under mass production conditions, the economic value of the solar unit is assessed independent of its costs. The value arises potentially from both operating cost savings and capital cost savings to the balance of the utility system. The operating cost savings are derived from reduction in fuel consumption and variable operating and maintenance costs. The capital cost savings arise from reduced conventional capacity requirements and a potential shift in the mix of conventional units.

The operating value of the solar repowered unit results from a reduction in energy production by the balance of the electric utility system. The reduction in conventional unit operation saves fuel and variable operating and maintenance (O&M) costs on the most costly (operating cost) units that would have been operating at the time the solar repowered unit is producing power. Since the solar repowered unit operates during different times of the day and throughout the year, the highest cost conventional unit being displaced at any hour changes. Thus the operating credit varies with the EPE system chronological load shape and the mix of available generation, as well as with many other parameters. The major parameters affecting the operating value of a solar repowered unit are shown in Table 6.1-3.

Capacity credit can be interpreted as the megawatts of conventional generating capacity not required to be installed due to the presence of the solar repowered plant or in terms of the dollars represented by this saved capacity. The capacity credit can be taken only for those years of operation of the repowered unit beyond its normal retirement date. From an analysis standpoint, megawatt savings may be considered first and then converted to dollars. In general, for a solar repowered unit, 100 percent capacity credit can be considered for those years of operation beyond the normal retirement date due to the presence of the fossil boiler.

The busbar energy costs are functions of solar unit cost and electric energy production. The net economic impact of a solar unit upon the EPE system is calculated by subtracting the solar unit value from its estimated costs.

The cost/value ratio is calculated by dividing the present worth of solar unit lifetime costs (revenue requirements) by the present worth of its lifetime value.

Since the inclusion of unit value as well as unit cost is considered in determining the economic choice, the cost/value ratio is selected as the primary evaluation criterion.

As the solar repowered unit operates during different times of the day and throughout the year, the highest cost conventional unit being displaced is not constant. For example, during reduced-load periods of the day or on weekends, the solar repowered unit may occasionally displace energy normally provided by a baseload unit. On the other hand, the solar repowered unit will displace a peaking unit on the days in which the load is high. The operating credit varies with the utility system chronological load shape and the mix of available generation, as well as with many other parameters.

Displacement of baseload energy partly occurs due to the EPE philosophy of keeping some minimum generation level on at its local (in El Paso area) stations at all times as a reliability consideration.

TABLE 6.1-1

DISPATCH CONSIDERATIONS IN SOLAR REPOWERING MODEL

Fossil Startup Logic
Fossil Buffer for Insolation Transients
Closeup Potential Shutdown Windows
High Wind Speed Solar Shutdown
Boiler Efficiency Corrections
Fossil Recovery of Low Insolation
Economic Fossil Fuel Dispatch
Hot Standby (Option)
Economic Shutdown at End of Day
Cost/Value of Daily Fossil Fuel Use

RECOGNIZING

Foreknowledge of Day's Insolation Profile

Foreknowledge of Day's Load Profile

Utility System Incremental Cost Curve

Fossil Boiler Limits and Efficiency

Turbine-Generator Limits and Efficiencies

Insolation High Transient Conditions

Operational Wind Limits

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TABLE 6.1-2

SOLAR UNIT ECONOMIC MEASURES

- Solar Plant Value
    - Operating Cost Savings
    - Capital Investment Displacement
- Solar Plant Busbar Energy Cost
    - Plant Capital Cost
    - Plant Operating Cost
    - Energy Produced
- Utility System Cost Impact
    - Solar Plant Costs
    - Utility Differential Costs
- Solar Plant Cost/Value Ratio
    - Solar Plant Lifetime Costs
    - Solar Plant Lifetime Value

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TABLE 6.1-3

OPERATING VALUE FACTORS

Insolation Characteristics

Utility System Load Shape

Utility Mix of Generating Units

Fuel Cost and Escalation Projections

Conventional Unit Heat Rates

Variable O&M Cost and Projections

Plant Collector Area

Penetration of Solar Hybrid Repowered Plants

Present Worth Discount Rate

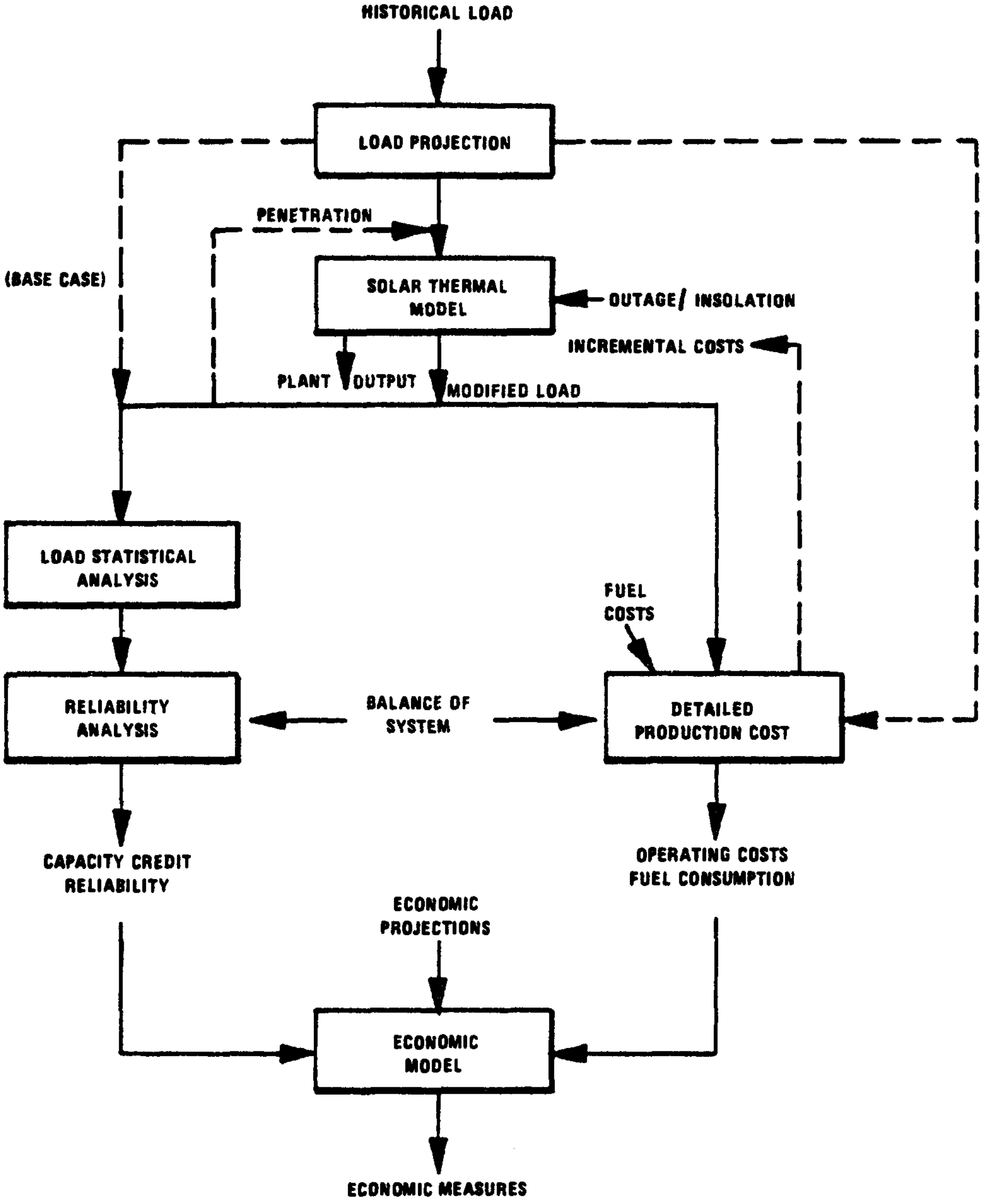

FIGURE 6.1-1
ECONOMIC MODEL FLOW DIAGRAM

6.2 UNIT OPERATING DESCRIPTION

A reference solar repowered unit for Newman Unit 1 is defined in Table 6.2-1 for the purpose of performing the unit economic analysis. The reference unit is based on the conceptual design presented in Section 4 and utilizes the solar hardware and technology being developed as part of the Second Generation Heliostat Development Program and the Advanced Water/Steam Central Receiver Development Program. The capital cost data for this unit are given in Section 4.6 and the anticipated operating and maintenance costs in Section 4.7. The solar subsystem is sized to provide 41 MWe net (50 percent repowering) at noon winter solstice based on an insolation level of 1000 watts/m^2.

The ability to operate on fossil fuel has been maintained in the repowered unit. The unit can therefore operate and produce up to 82 MWe using steam generated from the fossil boiler or a combination of both the fossil boiler and the solar receivers. It is assumed that the unit will always operate on fossil fuel only or a combination of solar and fossil produced steam during cloudy days - a cloudy day for the purpose of the unit economic analyses is defined as a day during which the sky cover exceeds 0.5 for two or more consecutive hours (see Appendix A).

The operating scenario for the fossil boiler is important in assessing the economic benefit of solar repowering. Since the solar repowered Newman Unit 1 is a "first-of-a-kind" demonstration unit, an operating strategy for the fossil boiler has been selected to permit operator confidence and experience to be obtained with the solar subsystem without jeopardizing the integrity of the existing equipment or the ability of the unit to produce power. Although this strategy penalizes the initial economics of the solar repowered unit because of additional fuel consumption, considerations of successful demonstration and reliability are paramount. EPE would not expect so severe a constraint on future units. The operating strategy consists of:

Unit operation initiated January 1987

1/87 to 2/87, the fossil boiler produces 41 MWe minimum when the unit is operating on solar; the unit is also economically dispatched on fossil.

3/87 and 4/87, the fossil boiler produces 23 MWe minimum when the unit is operating on solar; the unit is also economically dispatched on fossil.

Beyond 4/87, the fossil boiler operates only when required to offset solar insolation transients on cloudy days or when economical to dispatch on fossil fuel, otherwise it is maintained in a warm standby condition.

After six months of engineering test and evaluation, the solar repowered unit will be dispatched, in a manner similar to conventional fueled units making maximum use of the available solar energy. This operating strategy assumed Newman Unit 1 to be a "first-of-a-kind" demonstration unit. The 10 MW(e) Barstow Pilot Plant, however, is a water/steam unit similar to Newman Unit 1. The operating strategy for the Pilot Plant, which is currently being finalized, includes six months of operating mode checkout/acceptance testing, two years of restrictive unit operation during which time additional tests are being performed, and three years of operation in a conventional utility mode. During this period, EPE personnel plan to carefully follow SCE's experiences with Barstow; including, locating a team of EPE operating personnel at Barstow approximately six months to one year prior to initiating acceptance testing at Newman Unit 1 to obtain "hands-on" experience in operating a solar unit. Since the Barstow Unit has more operating modes due to the use of a thermal energy storage subsystem than contemplated for the solar repowered Newman Unit 1, and since both units will have similar control systems for the heliostat field and receiver, EPE's planned operator training at Barstow will be directly applicable to Newman Unit 1. The fossil boiler will be cycled daily; i.e., the fossil boiler is only shut down to a cold condition for routine or forced maintenance - three cold starts are anticipated throughout the year. During cloudy days when the plant is operating from solar generated steam, the fossil boiler is maintained in the minimum automatic firing condition (28 percent of rated load) throughout the cloudy day. The boiler firing rate is increased if it is economical to supplement the steam produced by the solar receiver (when compared to generating the equivalent power using units on the balance of the EPE system) or if it is required to overcome severe insolation transients in order to maintain steam conditions at the turbine inlet. At the end of the day, however, the boiler may be banked (pending economic dispatch considerations of the unit on fossil fuel) and maintained in a hot standby condition overnight. The boiler will also be banked during clear days or when it is not economical to operate the plant in either solar or fossil modes. No fossil energy will be required to maintain the Newman Unit 1 boiler in a hot standby condition for periods as long as several days; for longer periods the boiler must be intermittently fired. The boiler can achieve 28 percent of rated output from the hot standby condition in approximately 1 hour.

The fossil boiler at Newman Unit 1 is able to operate using either natural gas or fuel oil. El Paso Electric Company currently has gas supply contracts extending into the 1990's. Between 1985 and 1990, the Newman Unit 1 boiler will burn natural gas. After 1990, it is assumed the unit will also burn gas; it is anticipated that the National Fuel Use Act of 1978 prohibiting the burning of natural gas for utility units beyond 1990 will be permanently repealed.

TABLE 6.2-1

SOLAR REPOWERED NEWMAN UNIT 1

Unit Type	Reheat Steam Turbine
Unit Rating	82 MWe
Solar Repowering Percentage	50 percent
Plant Operating Scenario	Maximize solar benefit Fossil operating full time and only on cloudy days Economic dispatch fossil energy
Collector Subsystem	
Field Configuration	North field (160° arc)
Field Area	370 acres
Heliostat Area	171,000 m^2 (effective)
Number of Heliostats	2,998
Primary Receiver	
Type	External (pumped, recirculation boiler/screened tube concept)
Size	11.6m dia x 15.8m long (210° arc)
Outlet Temperature	549°C (1,020°F)
Reheat Receiver	
Type	External
Size	14.5m dia x 13.1m long (210° arc)
Outlet Temperature	549°C (1,020°F)
Tower Height	
Number of Towers	1
Primary Receiver C/L	155 m
Reheat Receiver C/L	140 m
Electric Power Generation Subsystem	
Cycle	Steam Rankine (reheat)
Net Unit Efficiency	39 percent (at full load)
Turbine Inlet	10.1 MPa/538°C
Heat Rejection	Wet cooling tower
Fossil Boiler	
Type	Gas/oil
Rate Load Efficiency	84.4 percent
Minimum Load	28% of rated Flow - 23 MWe
Startup Energy	106 x 10^6 kJ
Warm Standby	15.8 x 10^6 kJ/startup

NOTE:

* Based on an insolation level of 1000 watts/m^2

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6.3 EPE SYSTEM DESCRIPTION

The detailed economic evaluation of the solar repowered Newman Unit 1 is based on a model of the EPE system. This section describes the system model used for the economic evaluation. The model constructed is representative of the EPE system expansion plan as of April 1980; however, as is customary in the utility industry, the expansion plans are continuously reviewed as load forecasts and projected fuel costs change. The expansion plan and the system model summarized below, therefore, are at best "representative" of the future EPE system and should not be interpreted as the plan that EPE tends to implement.

6.3.1 EPE System Expansion Plan

The EPE system currently has a total generating capacity of 974 MWe. Approximately 89 percent of the existing system generating capacity is provided by gas- and oil-fired units located at the Copper, Rio Grande, and Newman Stations; the remaining 11 percent is supplied by remote coal. EPE is a summer peaking system with most of the peak load demand resulting from air conditioning requirements during June and July.

The solar repowered Newman Unit 1 will be operational by January 1987; the operating scenarios for the unit are described in Section 6.2. The EPE system expansion plan (March 1982) was modeled for the years 1987 through 2000. During this time frame, most of the planned capacity additions are in the form of nuclear (Palo Verde) and coal plants. In 1987, approximately 43 percent of the generating capacity is coal and nuclear and by the year 2000 this will increase to 68 percent. The solar repowered unit will therefore displace some baseload energy (and thus not be as economically attractive) during the winter months. For modeling purposes beyond the year 2000, the dispatch of the system in terms of unit priority is assumed identical to the dispatch during the year 2000.

6.3.2 Load Forecast

The peak load forecasted for 1987 is 995 MWe and by the year 2000 the system load is expected to increase to 1,594 MWe. These data are used in conjunction with the EPE hourly load shape for a typical year for the economic evaluation. It has been assumed for the analysis that the hourly load shape for a typical year is representative of the years 1987 to 2016.

6.4 ECONOMIC ASSUMPTIONS

The methodology used for the economic impact analysis of the solar repowered unit is described in Section 6.1. The economic principles applied are based upon revenue requirement analysis requiring the application of escalation rates, present worth discounting, and capital fixed charge rates. In order to carry out this analysis it is necessary to make assumptions for the solar repowered and conventional unit capital costs, operation and maintenance costs, and fuel costs as well as the escalation of these costs for 30 years into the future.

The capital cost estimate for the solar repowered unit and estimate for the operation and maintenance costs are given in Sections 4.6 and 4.7,respectively. A schedule maintenance period of three weeks for the solar repowered unit plus an equipment related forced outage rate of 10 percent is included in the analysis.

Table 6.4-1 presents the economic scenarios developed by EPE for the analysis. Two EPE scenarios are presented; the first scenario is based on EPE's current projection of natural gas and fuel oil escalation rates . Because of the uncertainty in the long term escalation rates for these fuels, a second scenario is also considered in the economic evaluation presented in Section 6.5 which is based on a 10 percent escalation rate for gas and oil beyond 1989. The discount rate used in the analysis for both scenarios is 15.7 percent with a fixed charge rate of 16.1 percent.

TABLE 6.4-1

EPE ECONOMIC SCENARIOS (1987)

	Scenario A	Scenario B
Present Worth Discount Rate (%)	15.7	15.7
Fixed Charge Rate (%)	16.1	16.1
Capital Cost, $/kWe (c-t/c-c/coal/nuc)	400/700/1600/1800	400/700/1600/1800
Fuel Cost ($/MBtu) (Gas/Oil/Existing Coal/New Coal/Nuc)	8.77/14.2/1.1/2.77/0.87	8.77/14.2/1.1/2.77/0.87
Fuel Escalation Rate (%) (Gas/Oil/Coal/Nuc)		
1987	8/13.6/8/8.2	8/13.6/8/8.2
1988	8/9.3/8/6.9	8/9.3/8/6.9
1989	8/10/8/5	8/10/8/5
Beyond 1989	7/7/8/7	10/10/8/7
Capital Escalation Rate (%)	8	8
O&M Escalation Rate (%)	7	7

6.5 ECONOMIC ANALYSIS RESULTS

The economic impact of the solar repowered unit on the EPE system is summarized in this section. The results presented here are based on the assumptions given in Sections 6.2 and 6.3 and were obtained utilizing the methodology described in Section 6.1. In order to more accurately determine the economic impact of the particular solar repowered unit on the EPE system, a multi-year analysis was performed. Changes in the solar repowered unit's operating strategy and EPE system configuration over time required detailed modeling of multiple years. A total of seven individual years of solar repowered unit operation were modeled. This multi-year analysis supplied valuable information concerning yearly production costs and savings incurred by the solar repowered unit. A lifetime cost/value ratio was derived from the yearly operations.

6.5.1 Multi-Year Results Summary

The annual operating costs and savings incurred by the solar repowered unit on the EPE system are shown in Table 6.5-1. Gas was assumed burned in the repowered unit during the entire study period. The numbers presented in the table are in millions of 1982 dollars. The operating savings were calculated from the annual displacement of conventional fuels and O&M by the solar repowered unit. The operating costs included those costs incurred from both economic dispatch and supplemental fossil fuel consumption in the solar repowered unit along with its required annual O&M. The net annual savings were obtained by subtracting the operating costs from the operating savings.

Table 6.5-1 shows a yearly increase in net savings from 1987 through 1990. During this time frame the EPE system generating configuration remains constant. As the system load increases, the amount of energy generated as a result of the economic dispatch of the fossil boiler in the repowered unit increases, thus resulting in a larger yearly net savings.

After 1990 coal units are added to the EPE system. Because of lower coal operating costs, the economic dispatch of the fossil boiler in the repowered unit decreases. This decrease in usage results in lower net savings, as is shown in the table.

Shown at the bottom of Table 6.5-1 is the 30-year total present worth operating costs and savings. In order to obtain these numbers, the operation of the solar repowered unit was assumed constant in years 1991 through 1994, 1995 through 1999, and 2000 through 2016. The lifetime net operating savings of the solar repowered unit is $18.97 million dollars(1982 dollars). This is for the total electrical production of 3,538,100 MWh on Newman Unit 1.

Table 6.5-2 summarizes the lifetime cost and value found from the multi-year analysis. The components of cost and value were determined for both EPE economic scenarios (A and B). For details on these two economic scenarios, see Section 6.3. The numbers shown in this table are present worth of revenue requirements expressed in 1982 millions of dollars. The cost/value ratios were 2.27 and 2.08 for economic Scenarios A and B, respectively. Also shown in the table are the levelized busbar energy costs in 1982 dollars.

A change in gas escalation rate after 1989 from 7 to 10 percent (B) resulted in larger lifetime fuel value and fuel cost, as expected. The majority of fuel displaced by the solar repowered unit was gas; therefore it follows that, if the price of gas is higher, the value of the displaced fuel is greater. However, this larger gas escalation rate also results in a higher lifetime fossil fuel cost. The net impact is a slightly greater total value because of the more efficient use of the gas burned in the solar repowered unit.

The energy output of the solar repowered unit given in Table 6.5-3 on a year-by-year basis is graphically displayed in Figure 6.5-1. The total energy, given in gigawatt hours electric, is shown divided into three components: solar, fossil for economic dispatch, and fossil for solar support operation. Support dispatch is the firing of the fossil boiler to allow for optimal use of the solar energy. Economic dispatch is the use of fossil side of the unit when it is more economical than competing fossil units. This figure shows a somewhat higher energy contribution from the support fossil operation in 1987 because of the adopted operating strategy of the repowered unit during the first four months. The amount of solar energy produced was relatively constant. Slight variations were due to a difference in the number of days the fossil boiler was used.

Even though the same solar insolation was used for each year of the analysis, the amount of solar thermal energy directed to the turbine-generator varied slightly from year to year because of its dependence on fossil boiler operation (e.g., augment solar with fossil to bring unit up to minimum output level) which is in turn dependent upon system incremental costs.

Figure 6.5-2 shows the conventional energy, in 10^{12} Btu (millions MBtu), displaced by the solar repowered unit. The solar repowered unit saves the equivalent of approximately 3 million barrels of oil over the 30-year lifetime. The lifetime reduction in future revenue requirements for fuel is approximately 350 million dollars for the EPE economic scenario. As was expected, the bulk of the energy displaced by the repowered unit was gas. The total lifetime energy displaced is about 30 million MBtu of gas and about 7 million MBtu of coal. Very little oil is displaced (0.1 million MBtu) because only a small amount of energy is produced from the oil burning units during the time frame of the study. The solar repowered unit will consume about 12 million MBtu of gas over its life including economic dispatch. Thus, the net energy displaced will be about 11 million MBtu of gas and about 7 million MBtu of coal.

6.5.2 Solar System Startup Impact

An area of concern in the operation of the solar repowered unit is the source of the energy needed to achieve normal receiver operating conditions during startup. One approach is to assume the daily startup energy is supplied by the solar receivers themselves from the early hours of solar insolation. The alternative is to use the fossil boiler to supply the same needed energy. A one year simulation was performed in the previous study to determine the economic impact of each strategy. The operation of the solar repowered unit was modeled with the startup energy equal to 15 MWHt in one case (solar) and 0 MWht in the other (fossil).

The lifetime revenue requirements for both cases were calculated. Only a slight difference in total value resulted between the two cases. Little change occurred because the solar startup energy (15 MWht) represented a small percentage of the total daily solar energy output. The fact was verified from the relative small difference in total yearly energy output (176.0 vs 179.5 GWhe), for solar and fossil startup, respectively.

Therefore, it is concluded that the strategies employed in starting the solar portion of the unit should be determined from design operating points of view and perhaps from design criteria. The economic advantage of either strategy appears to be minimal.

6.5.3 Economics and Cost Sensitivity

Due to the future uncertainty of many economic factors which have a great impact on the economic worth of the solar repowered unit, a sensitivity analysis was performed. Two of the factors reviewed were the solar repowered unit costs and future oil and gas costs. The results of the cost sensitivity analysis are presented in this section. The sensitivity of future gas costs was shown in Table 6.5-2.

Because of the methodology employed, variations in solar repowered unit costs can be analyzed easily. Table 6.5-4 shows the impact on the cost/value ratio of two alternate solar plant costs (low and high). The heliostat cost was assumed to be \$150/m² and \$350/m² for the low and high cases, respectively. This is compared against \$198/m² used in the base cases. The numbers were developed employing the EPE A economic scenario and are expressed in 1982 millions of dollars.

6.5.4 Typical Solar Plant Operations

The operation of a solar repowered unit on a utility system varies throughout the year. The operation is dependent on solar insolation, load level and daily load shape, and available conventional capacity. A number of curves displaying the typical operation of the solar repowered Newman Unit 1 on the EPE utility system are shown in this section. The typical operation curves were obtained from the 1988 solar simulation and are intended only to graphically demonstrate the operation of the unit. Typical summer and winter daily operations of the solar repowered unit are displayed in Figures 6.5-3 and 6.5-4, respectively. The total output of the solar repowered unit over the entire day is shown in these graphs. The unit net output is represented by the solid line. The dashed line enclosed within the solid line represents the amount of solar-only contribution. The amount of energy produced from direct solar is thus the area under the dashed line. The area above the dashed line and below the solid line is the energy produced from the fossil boiler, both support output and economic dispatch.

Figure 6.5-3 shows solar electrical output first appearing in hour 8 and lasting until hour 17. The maximum solar contribution during the day is about 36 MWe (hours 12 and 13). The graph shows a large amount of energy produced from the fossil boiler due to economic dispatch. In hours 8 through 21, fuel is burned to bring the output of the unit up to its maximum level, 82 MWe. An examination of the summer day's hourly skycover percentage indicates it to be a cloudy day; therefore, the fossil boiler is started and maintained at the standby level (23 MWe) beginning with the first solar insolation hour (hour 6). No solar electric output is produced in hours 6 and 7 because the solar thermal energy available in those hours is used to start the solar receiver.

The winter day shown in Figure 6.5-4 is also a cloudy day; therefore, the fossil boiler is again used to augment solar output during the buffering period (hours 8 through 16). In addition, because the fossil boiler is economically dispatched in hour 19, the fossil boiler is maintained at its standby level in hours 17 and 18. The total electrical energy produced in this winter day is much less than that produced in the summer day because of lower solar insolation and system incremental costs.

How the daily operation of the solar repowered unit adjusts the original system loads is shown in Figures 6.5-5 and 6.5-6. The original load is represented by the solid line. The dashed line represents the original load adjusted by the total solar repowered unit contribution. Conventional units are operated to meet this adjusted load.

Overlayed on these daily load shapes are the capacities of those conventional units which can be expected to operate to meet the system loads. The base capacity region shown on these curves is made up of nuclear (Palo Verde) and coal (Four Corners) units, along with the purchased power available from the to-be-built 100 MWe transmission line. The gas region represents all four Newman units and the Copper unit. The Rio Grande Station makes up the oil region. As can be seen from these figures almost all of the displaced energy is gas, with only a small amount of oil being displaced on the summer day.

Figures 6.5-7 and 6.5-8 graphically display typical summer and winter weeks of repowered unit operation. Again, the solid line represents the unit output, and the dashed line is the solar contribution. The fossil boiler was economically dispatched every day of the summer week except the first day because of high system loads. Conversely, only one day of the winter week had loads great enough to economically dispatch the fossil boiler. This can be seen in Figures 6.5-9 and 6.5-10 which display the original and adjusted EPE system loads for the same week. The solar repowered unit displaces almost entirely gas during both of these weeks, with only small amounts of oil being displaced the third day of the summer week and base loaded energy the first day of the winter week.

The original and adjusted EPE system annual load duration curves are shown in Figure 6.5-11. The area between the two curves represents the total yearly energy output of the solar repowered unit. From this graph, it is evident that a solar repowered unit would have a positive impact on the EPE system by reducing peak load period requirements.

TABLE 6.5-1

ANNUAL OPERATING COSTS AND SAVINGS
(1982 M$)

	Savings		Costs		
Year	Fuel	O&M	Fuel	O&M	Net Savings
1987	8.34	0.06	5.83	0.89	1.68
1988	8.02	0.05	5.53	0.82	1.72
1989	9.25	0.04	6.58	0.76	1.95
1990	10.03	0.04	7.21	0.07	2.16
1991	6.68	0.04	4.62	0.65	1.45
1995	3.10	0.04	1.87	0.09	1.18
2000	0.85	0.03	0.29	0.06	0.53
30 Years Total PW	81.36	0.85	52.51	10.73	18.97

TABLE 6.5-2

MULTI-YEAR COST/VALUE SUMMARY
1982 M$ PWRR

	Economic Scenario*	
	A	B
Solar Plant Cost		
Capital	72.1	72.1
O&M	10.7	10.7
Total Cost	82.8	82.8
Solar Plant Value		
Fuel Value	81.4	89.2
Variable O&M	0.8	0.8
Fuel Cost	-52.5	-57.0
Capacity Credit	6.8	6.8
Total Value	36.5	39.8
Net Value	-46.3	-43.0
Cost/Value Ratio	2.27	2.08
Levelized Busbar Energy Cost (mills/kWh)	104.7	108.1

NOTE:

*Economic Scenario A and B are identical except for oil and gas escalation rates beyond 1989:

	A	B
Gas	7%	10%
Oil	7%	10%

TABLE 6.5-3

ELECTRICAL ENERGY OUTPUT SUMMARY
(GWh/Year)

Year	Total Unit	Solar Output	Fossil Support	Fossil Economic
1987	190.2	59.6	33.6	97.0
1988	193.1	59.6	15.9	117.6
1989	231.8	61.0	15.1	155.7
1990	262.6	61.8	14.4	186.4
1991-1994	198.3	60.3	19.3	118.7
1995-1999	133.4	57.7	15.8	59.9
2000-2016	70.6	54.1	9.9	6.6

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TABLE 6.5-4

SOLAR PLANT COST SENSITIVITY
(1982M$ PWRR - A Economic Scenario)

	Low	Normal	High
Solar Plant Cost			
Capital	64.4	72.1	96.7
O&M	9.6	10.7	14.4
Total Cost	74.0	82.8	111.1
Solar Plant Value			
Fuel Value	81.4	81.4	81.4
Variable O&M	0.8	0.8	0.8
Fuel Cost	-52.5	-52.5	-52.5
Capacity Credit	6.8	6.8	6.8
Total Value	36.5	36.5	36.5
Net Value	-37.5	-46.3	-74.6
Cost/Value Ratio	2.03	2.27	3.04

<u>NOTE</u>: Heliostat Costs ($\$/m^2$)

Low	150
Nominal	198
High	350

1 of 1

FIGURE 6.5-1
SOLAR REPOWERED UNIT ENERGY OUTPUT

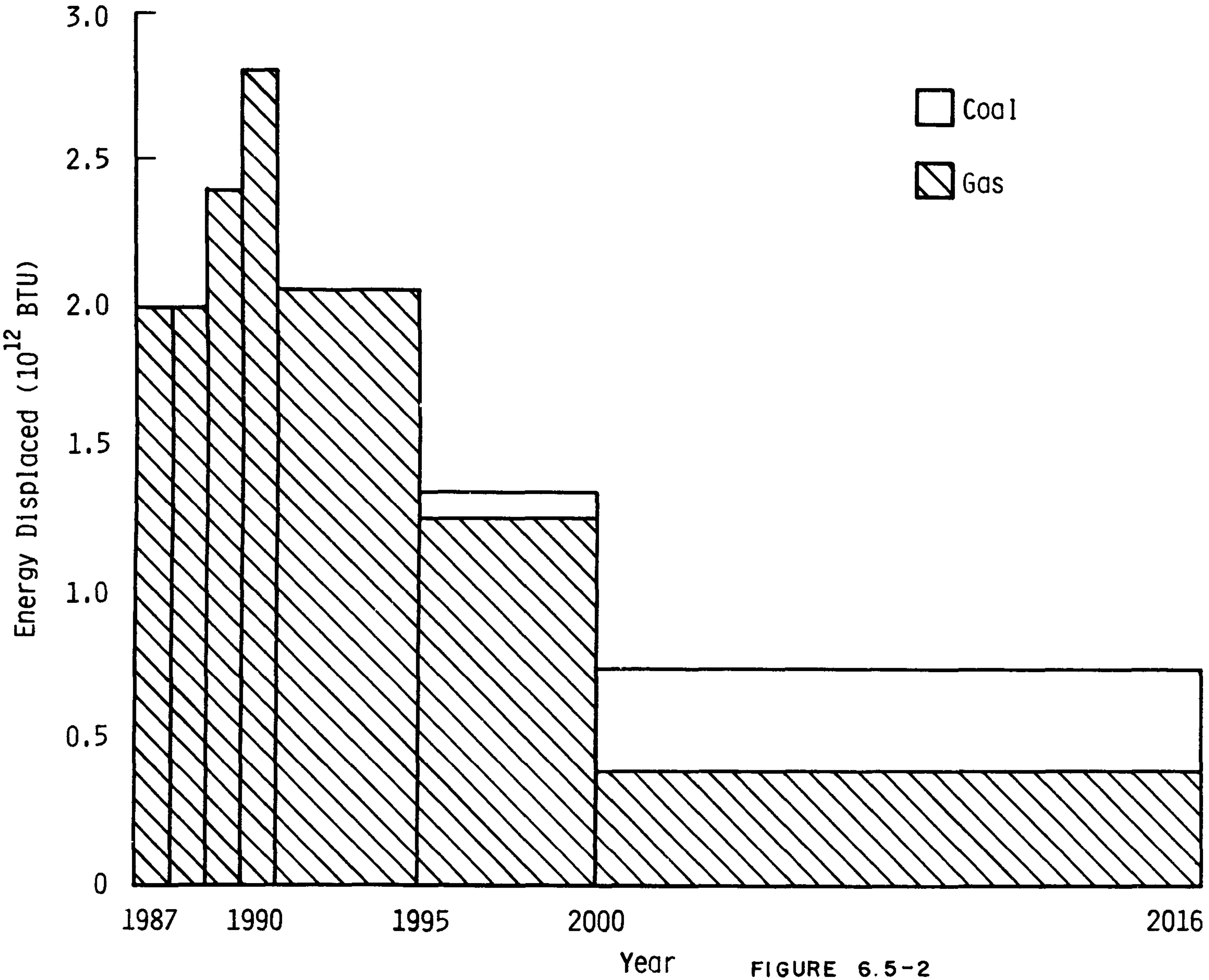

FIGURE 6.5-2

CONVENTIONAL ENERGY DISPLACED BY SOLAR REPOWERED UNIT

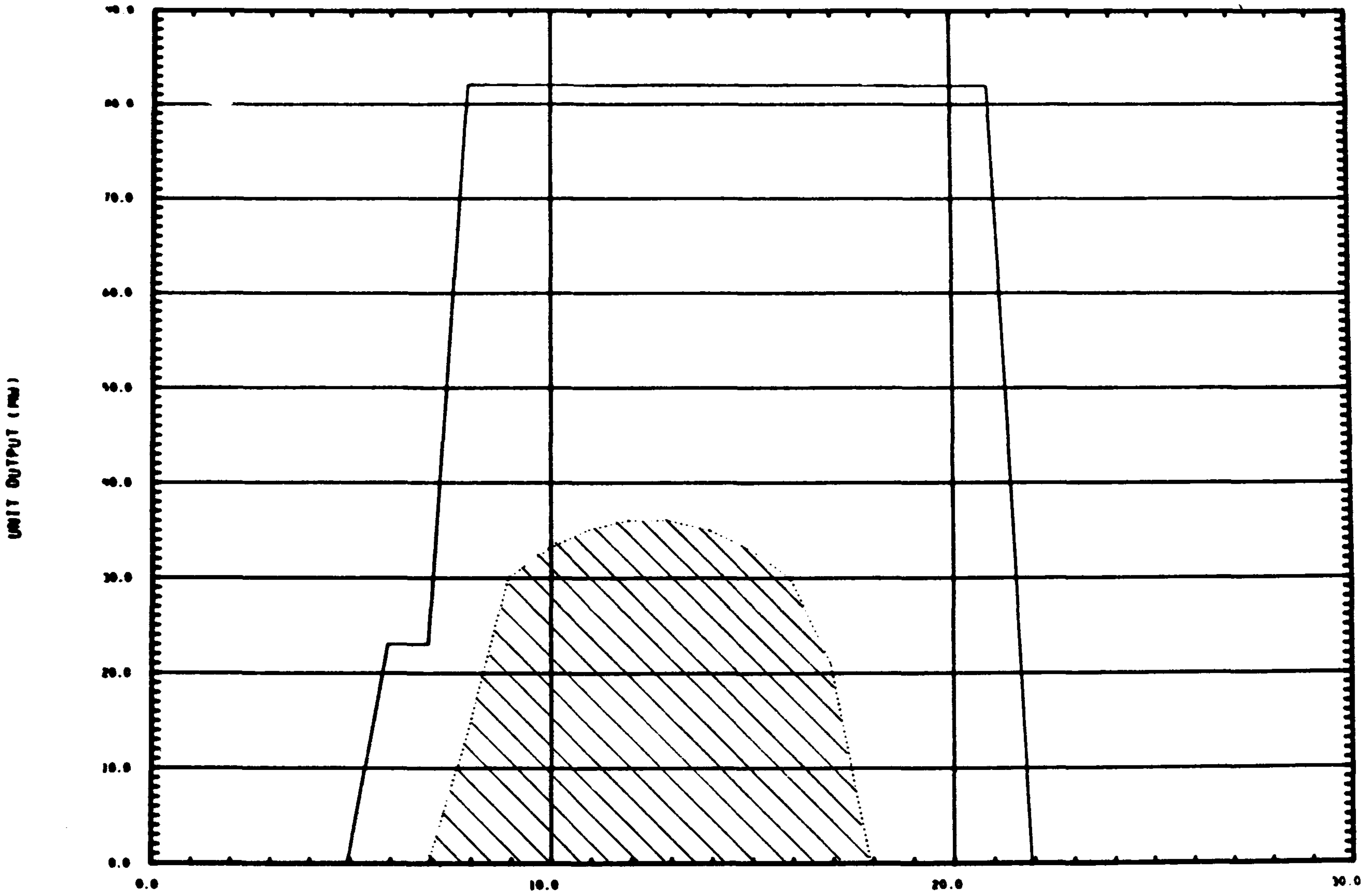

FIGURE 6.5-3
DAY 174 (SUMMER DAY)
TOTAL UNIT OUTPUT AND SOLAR OUTPUT

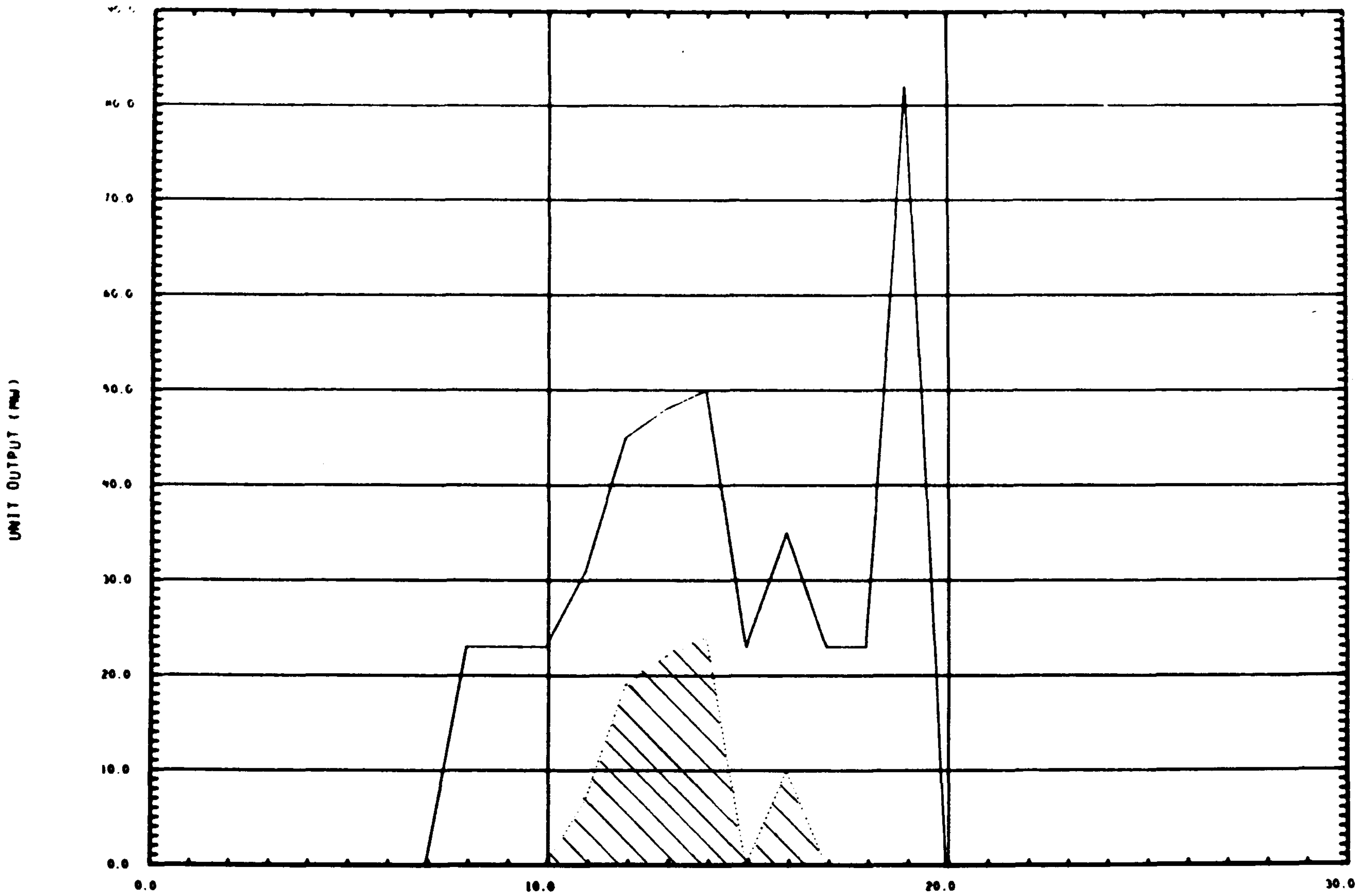

FIGURE 6.5-4
DAY 334(WINTER DAY)
TOTAL UNIT OUTPUT AND SOLAR OUTPUT

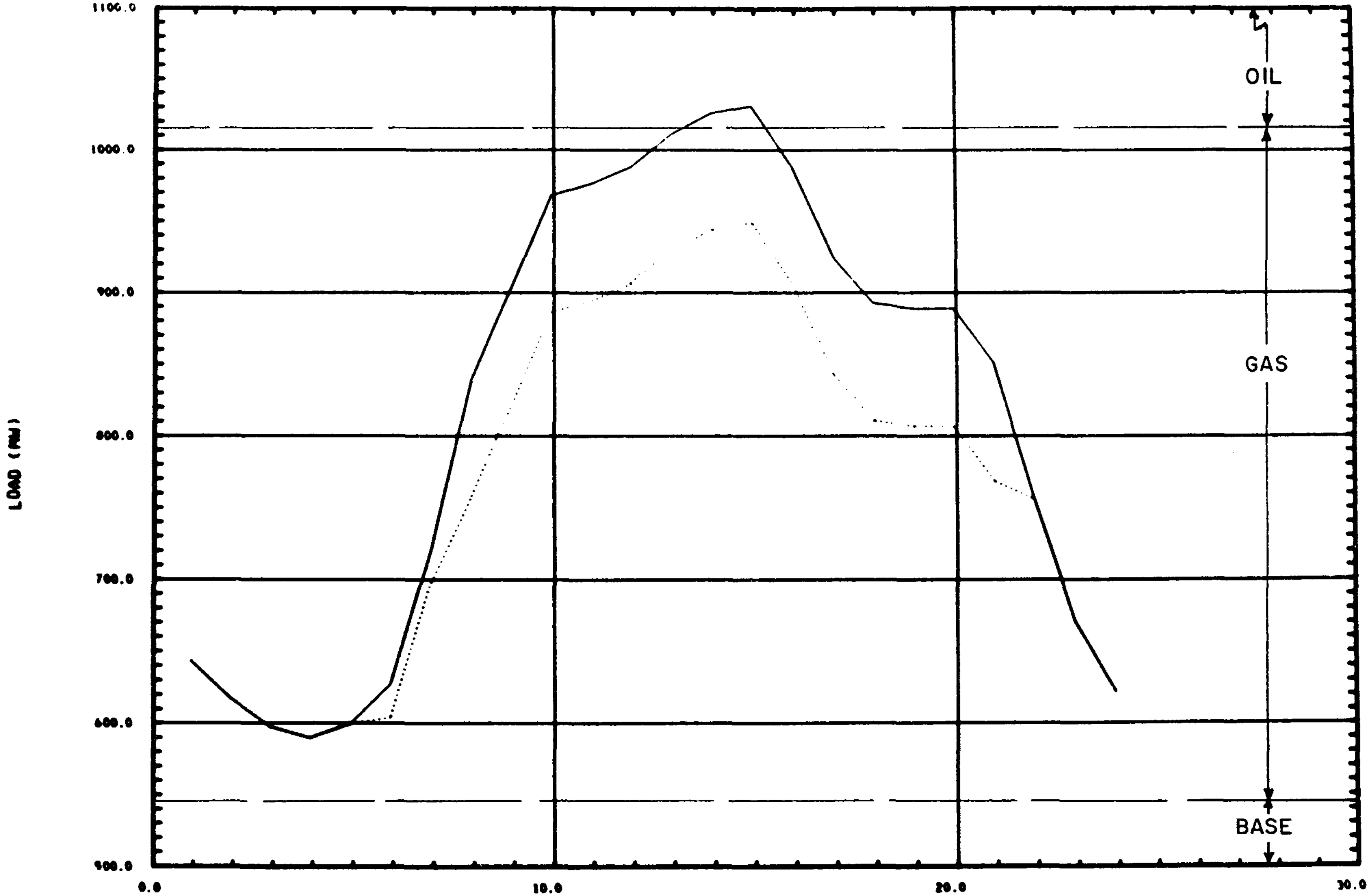

FIGURE 6.5-5
DAY 174 (SUMMER DAY)
ORIGINAL SYSTEM LOAD AND ADJUSTED LOAD

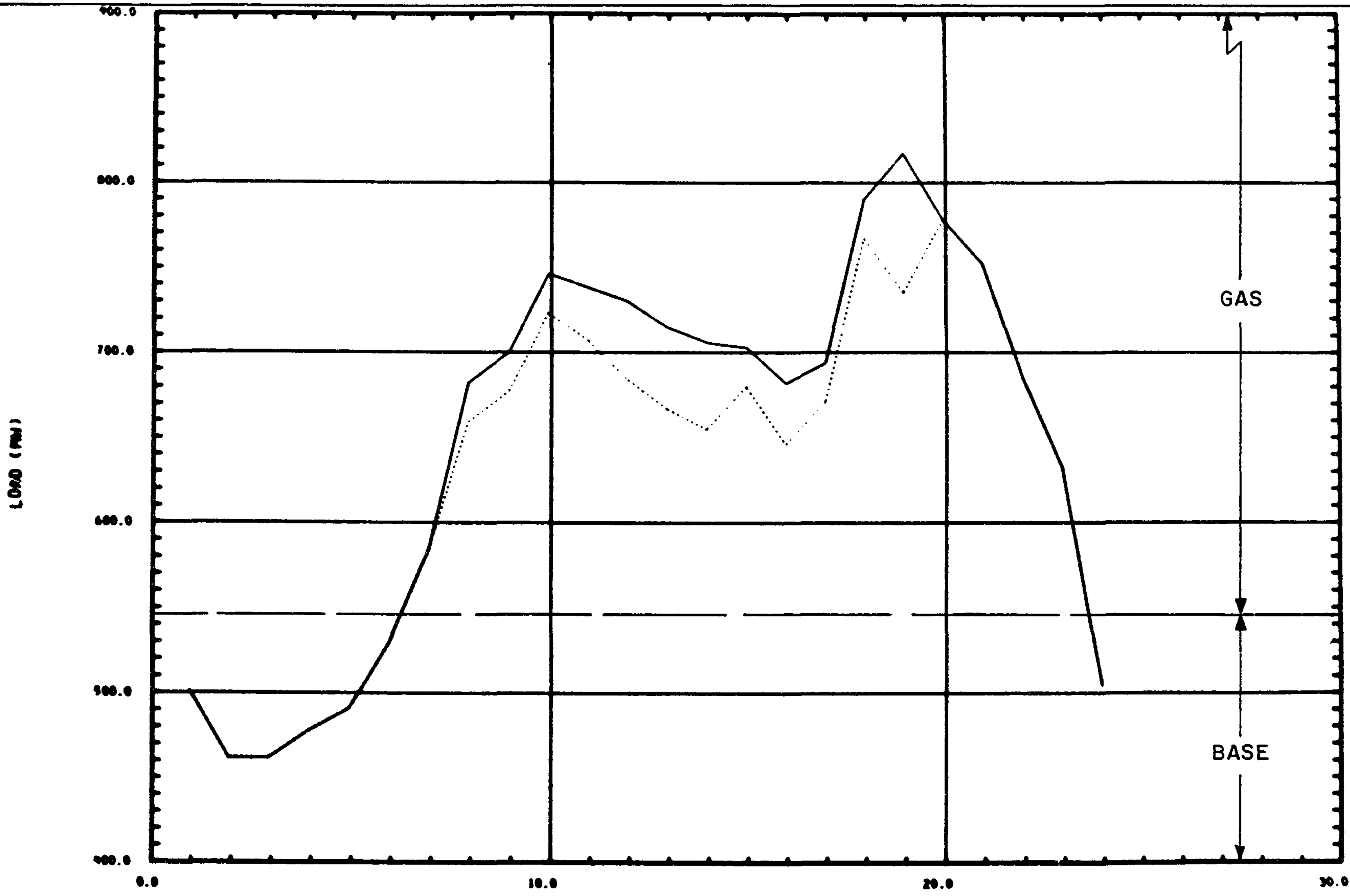

FIGURE 6.5-6
DAY 334 (WINTER DAY)
ORIGINAL SYSTEM LOAD AND ADJUSTED LOAD

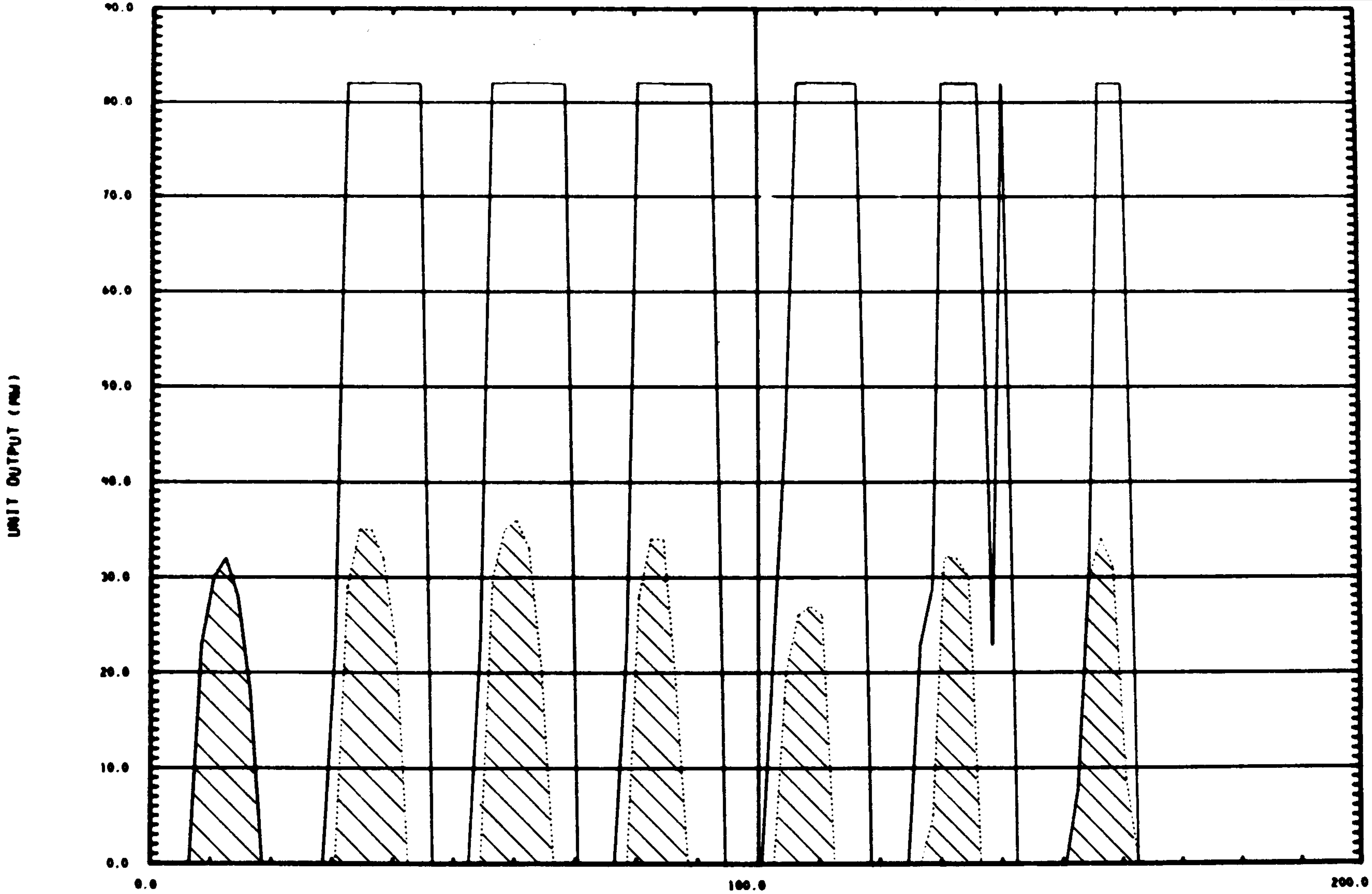

FIGURE 6.5-7
WEEK 25 (SUMMER WEEK)
TOTAL UNIT OUTPUT AND SOLAR OUTPUT

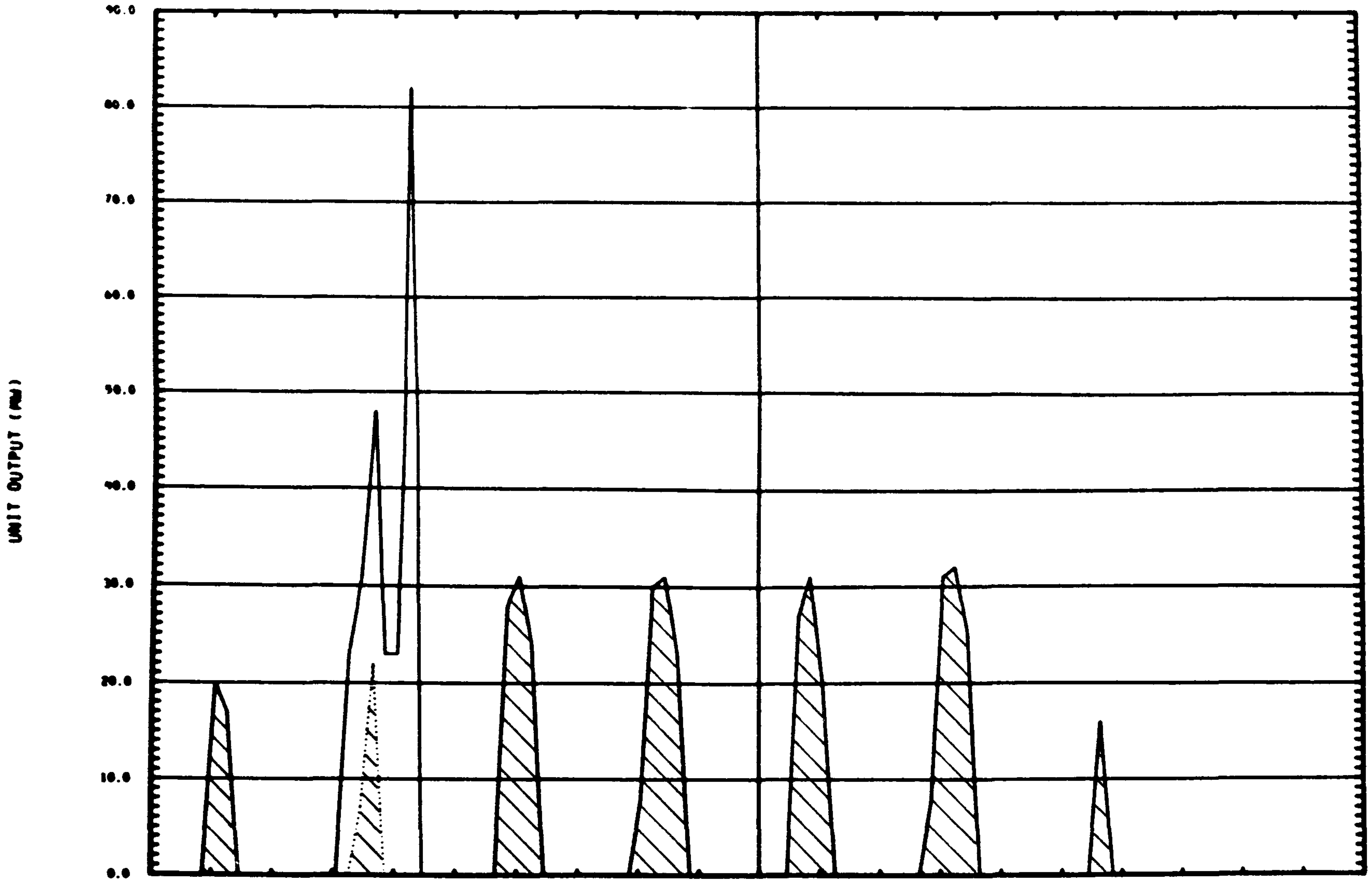

FIGURE 6.5-8
WEEK 48 (WINTER WEEK)
TOTAL UNIT OUTPUT AND SOLAR OUTPUT

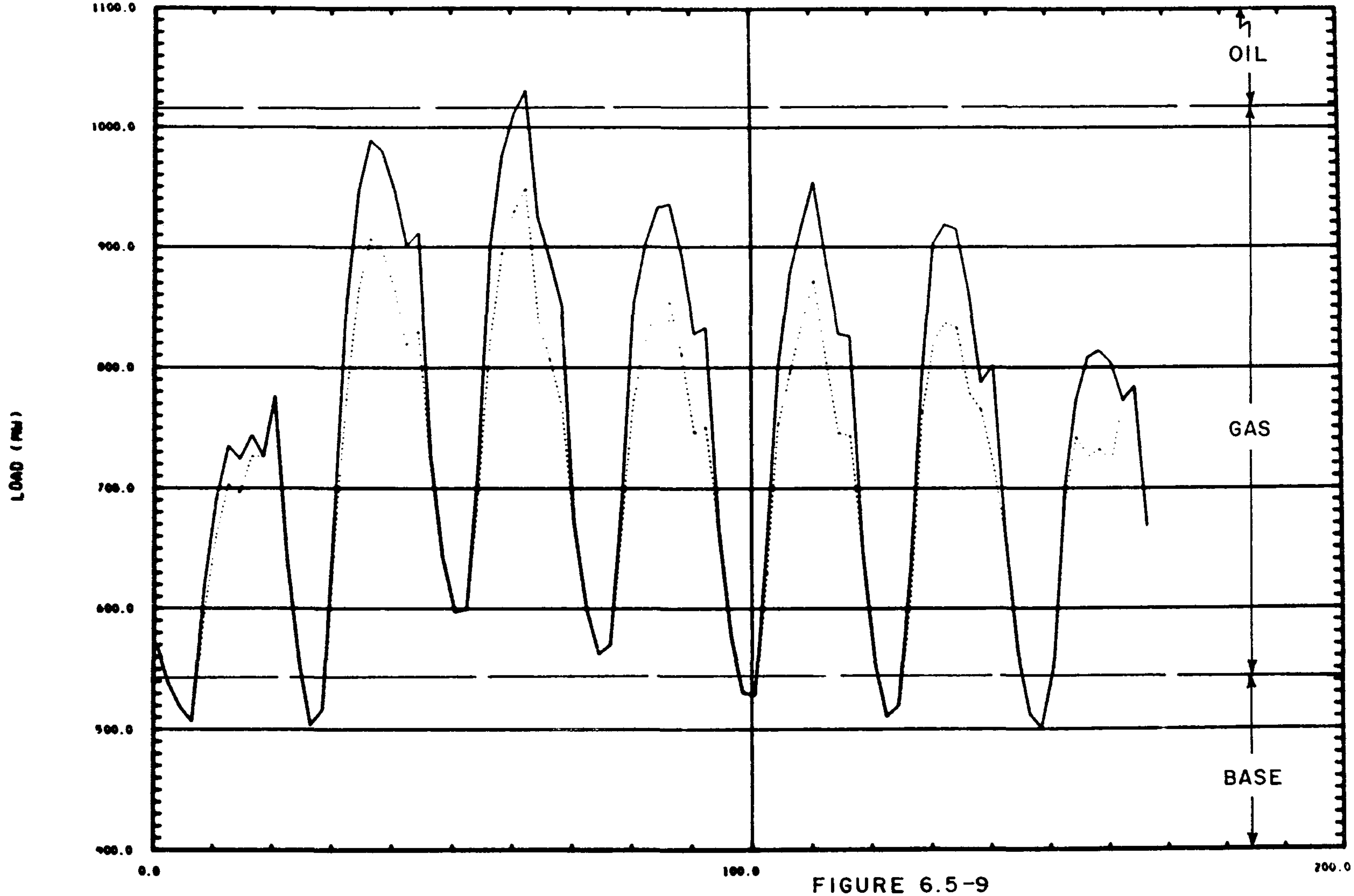

FIGURE 6.5-9
WEEK 25 (SUMMER WEEK)
ORIGINAL SYSTEM LOAD AND ADJUSTED LOAD

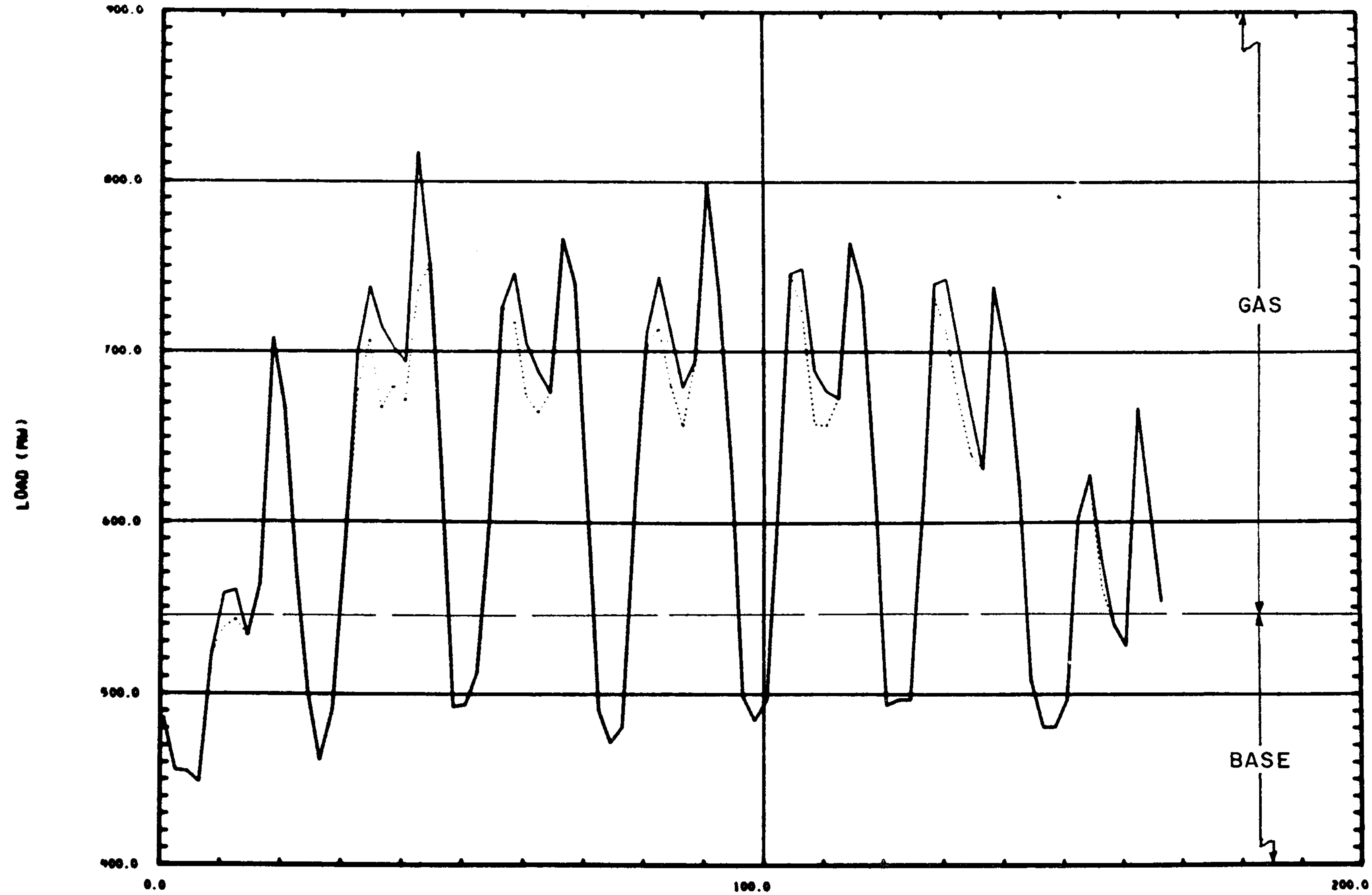

FIGURE 6.5-10
WEEK 48 (WINTER WEEK)
ORIGINAL SYSTEM LOAD AND ADJUSTED LOAD

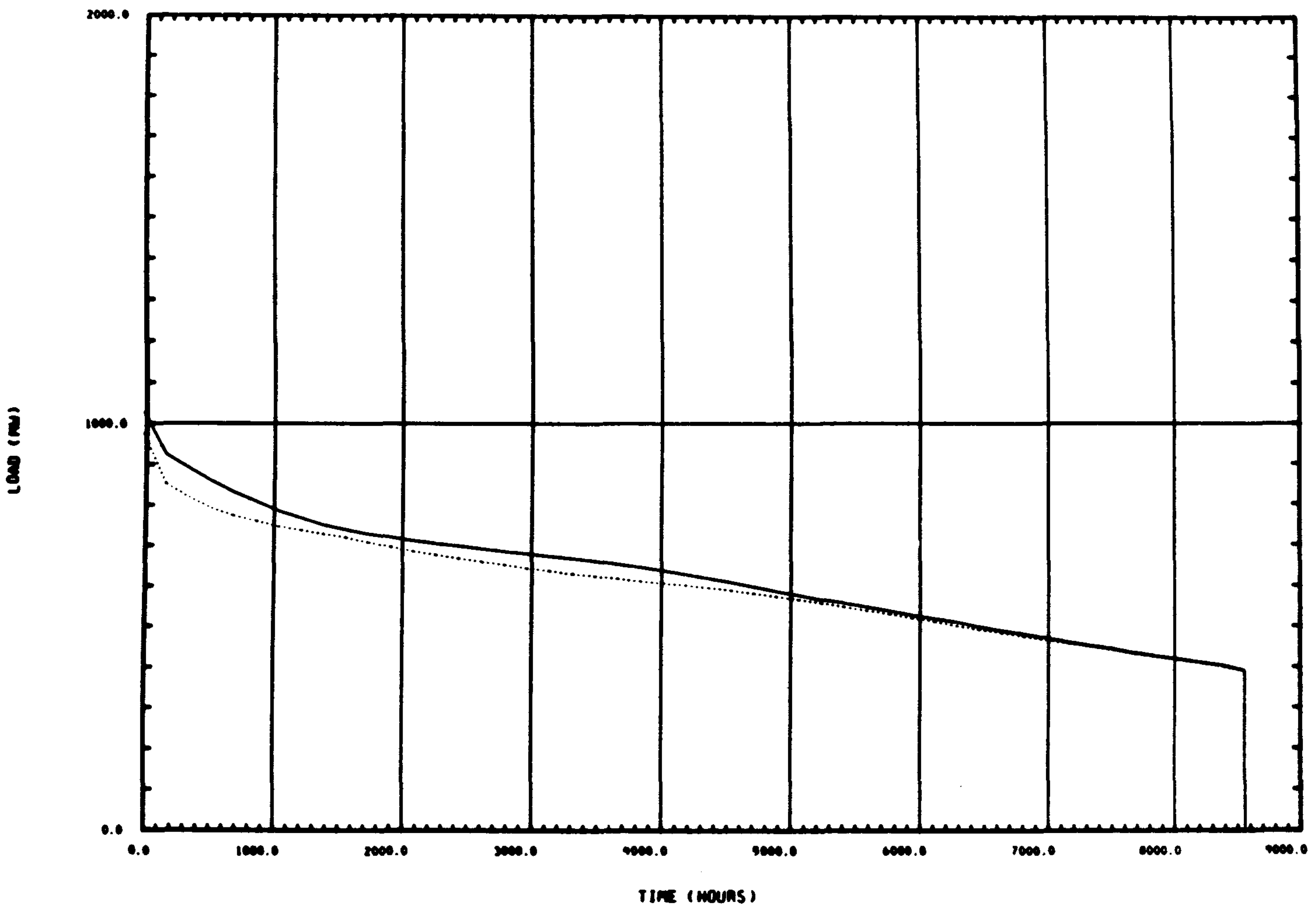

FIGURE 6.5-11
1988 ORIGINAL LDC AND ADJUSTED LDC

SECTION 7

DEVELOPMENT PLAN

The steps required to proceed from the advanced conceptual design through the conclusion of a demonstration project include design, procurement, construction, checkout, startup, performance validation, and commercial operation. Each phase is described in this section in order to evaluate the feasibility of providing a plant capable of operation by late 1986. The major areas of activity occurring over a 7-year period beginning in late 1982 are addressed.

7.1 DESIGN PHASE

The design phase encompasses several activities that focus on the development of more detailed engineering information, procurement of long lead time hardware, and revisions of design information based on vendors' data to support construction. These activities are discussed in the following sections.

7.1.1 Preliminary Design

Conceptual design data and drawings resulting from the current study will be utilized as a starting point for refining unit design descriptions and requirements to the level of detail necessary for preparation of bid packages for major hardware procurements and major construction subcontracts. Bid responses will be used to prepare a preliminary project estimate.

Preliminary design phase activities will include detailed planning and scheduling through construction, securing land required for the collector field and relocating transmission facilities, onsite insolation data monitoring, preparation of an environmental impact statement and safety analysis report, and performance testing of the existing boiler and turbine-generator.

Development of preliminary design information and bid packages for procurement of collector and receiver equipment will receive major emphasis since these subsystems will have a major impact on overall project schedule. Also, selection of equipment manufacturers for the collector subsystem will have a major impact on detailed design of the system. Tower design, heliostat foundations, heliostat locations, and electrical requirements are examples of important design areas that will require vendor data inputs.

Detailed control system design will require a thorough transient analysis. Specific control logic interfaces between the new master control system and the solar and fossil subsystems, and existing balance of plant will be completed.

7.1.2 Procurement

Procurement of major equipment and construction subcontracts represents an important activity that will have considerable impact on system detailed design, performance, cost, and overall project schedule. Procurement will be by competitive bidding for material, equipment, and construction. Major procurement activities include bidders list approval, preparation of specifications, cost and performance evaluation, vendor selection, and purchasing/contracting. Major equipment procurements, including heliostat and receiver equipment, will be ready for release for fabrication shortly after the preliminary design phase.

7.1.3 Final Design

Final design information will be developed based on information provided by equipment manufacturers. Final drawings for equipment and facilities construction will be prepared.

7.2 CONSTRUCTION PHASE

Construction work at the site is scheduled to begin approximately 27 months after initiation of Preliminary Design work. However, construction personnel will assist engineering staff in developing an economical and constructible design, and in developing detailed specification and subcontract documents.

Onsite construction activities will include overall subcontractor direction, coordination and evaluation; cost and schedule control; processing of invoices in conjunction with headquarters contract administration; site safety and security programs; technical direction from engineering and manufacturers' representatives; and contact with governing or regulatory agencies.

The first construction activity will be site preparation, followed closely by erection of the tower and heliostat foundations.

Next, modification of existing plant and unit facilities that do not constrain plant operation are initiated, such as extensions to the maintenance building. The bulk of new controls and instrumentation can be assembled prior to hookup to minimize unit downtime.

Heliostats are installed over approximately a 1-year period.

Receiver erection will begin following completion of the tower structure, and require about 1 year. Structural components and the drum will be raised inside the tower. Next, work can proceed in installing piping, platforms, and other equipment inside the tower. Receiver panels will be raised outside the tower using a hoist at the top of the receiver structure.

Newman Unit 1 will be shut down approximately 6 months in early 1986, primarily as a result of extensive turbine modifications required for installing the new digital electrohydraulic controls. All interfacing components, such as steam lines, electricals, controls, and instrumentations will be hooked up during this period.

7.3 SYSTEM CHECKOUT AND STARTUP PHASE

System checkout and startup are scheduled to begin approximately 36 months following initiation of the Final Design Phase. The purpose of checkout and startup testing is to systematically verify the proper installation and operation of the unit and all support systems, and to confirm the design intent.

A detailed plan for system checkout and startup will be developed during the Final Design Phase. This plan will address component and subsystem checkout and initial operations, followed by system startup and performance testing.

7.3.1 Component and Subsystem Checkout

Procedure documents will be developed for electrical checkout and testing, instrument checkout and testing, control verification, pressure tests, and checkout and testing of the receiver and collector equipment.

Startup and service engineers will be provided by the receiver, heliostat, and computer manufacturers.

EPE personnel will perform instrument calibration and supervise checkout and testing of new relay and switchyard equipment.

The most significant activity is the checkout of the large number of heliostat power drives, power supplies, and position sensors. Initial positioning and adjustment of each heliostat will be required prior to system startup.

7.3.2 System Startup

Procedure documents will be developed for system testing and startup.

Initial system testing and startup will involve partial load steam generation by the receiver, with limited amounts of steam vented directly to the condenser. Initial tests will verify the ability of the control system to maintain flux on the receiver, and maintain boiler drum level during variations in steam flow. Additional tests at progressively increasing loads will lead to full-load operation with steam flow to the turbine.

7.4 SYSTEM PERFORMANCE VALIDATION PHASE

After the initial startup and component system checkout tests, the solar repowered facility will operate on-line and produce power to the grid in the EPE electrical supply network. Since this plant is a first-of-a-kind demonstration of solar repowering, there will be an extended period of operation in which a number of unique tests will be performed to validate the system operation and performance. A preliminary review of the required tests will be completed; the tests identified to date encompass verification of normal steady state and transient operation and performance and abnormal operations to fully "shake down" the facility capabilities. During this period of time, the fossil boiler will be maintained in operation at all times to provide backup capability. A detailed test plan will be prepared during the next phase to identify the test scope and schedule for this verification phase. This test plan will include, in part, the following types of tests:

Demonstration tests to confirm safety of personnel, plant, and facility including demonstration of instrumentation and control systems adequacy to handle normal and emergency transients.

Demonstration tests to confirm adequacy of data acquisition to produce required data for analyses.

Demonstration tests to validate and/or modify computer simulation models and operation, maintenance, and test manuals and directives.

Demonstrations to verify unit performance.

Normal operational performance tests as a function of time of day, season, weather conditions, equipment status, direct operation, and load demand.

Transient operational performance tests as a function of startup, shutdown, cloud passage, storm impacts, dust and other environmental impacts, and grid power flow.

Component and subsystem operational performance tests, including determination, weather and other environmental impacts, off-design operating conditions, trends such as degradation, and maintenance requirements.

7.5 JOINT USER/DOE OPERATION PHASE

The operation phase will be defined in detail during the preliminary design phase of this program. However, the operation task of the program has been considered in sufficient detail to permit estimates of manpower requirements to summarize the efforts needed during the initial program phases. It is envisioned that extended utility operations will be evaluated jointly by EPE and DOE for approximately 60 months.

Preparation of the preliminary operating and maintenance plans will be initiated in the preliminary design phase to establish requirements for the design of the solar system and support facilities. A control document will be established that consists of a set of operating objectives along with descriptions of the data to be obtained and the format in which these data are reported. This document will become the basis for defining requirements for detectors, computer, and equipment in the preliminary and detailed design phases. Manuals for operation, maintenance, and crew training will be finalized in the detailed design phase as designs become finalized.

Personnel for the operation and maintenance crews will be selected, utilizing a thorough screening and testing process. Participation and support are required from the solar equipment suppliers in correctly adapting this process to solar equipment requirements. EPE has extensive experience in crew selection and training for the MCS and BOP portions. The test engineering team, a necessary requirement during the operations phase, will be selected from personnel having extensive backgrounds in the startup and testing of solar and conventional equipment. Training of supporting EPE personnel will be an objective of the team effort.

Operation, maintenance, and testing crews will be given thorough training and testing before the startup phase in preparation for their responsibilities. They will be given thorough exposure to the construction, fabrication, and erection activities to provide familiarity with the actual equipment and as-built drawings. They will also receive actual operating experience at the Barstow Pilot Plant. Equipment manuals will be supplied by the equipment vendors and operating and maintenance manuals will be prepared, with input from the crews, to provide the basis for training of crew personnel and initial startup and checkout.

Operating and maintenance crews will work with the construction, installation, and erection crews as components and subsystems are completed and operated in their respective checkout modes. Hence, as larger subsystems become operational and as the total demonstration unit is being carried through the checkout and startup procedures, the operating crew will be assuming greater responsibility and acquiring familiarity with their assignments.

Pertinent data will have been generated during the startup and checkout activities, and these data will be recorded, analyzed, and reported. A detailed operating plan will be finalized during this period that will be executed during the operation phase. These plans will include tests and operations to verify operation on a grid and to generate data to promote technology transfer, public relations, and other functions that enhance the commercialization efforts.

Test and operational plans must be flexible to respond to a wide spectrum of steady state and transient conditions that will be typically imposed on a solar powered unit as a result of the uncontrollable variation in environmental conditions. Unpredictability of occurrence of environmental phenomenon will further complicate planned operations. The operation plan must therefore account for all actions possible to maintain plant readiness and to operate whenever environmentally permissible.

The operation and test plans will be executed during the operation phase. Upon completion of a predefined period of joint utility/DOE operation, a Final Operations Report will be prepared to summarize the results of the operation phase. It will include technical data, definition of design and operational problem areas, and recommendations for future design and operations.

7.6 SCHEDULE AND MILESTONE CHART

Approximately 51 months are required between initiation of the preliminary design phase and full operation of solar repowered Newman Unit 1.

Figure 7.6-2 summarizes the major milestones that would occur following initiation of preliminary design work in October 1982.

Figure 7.6-1 provides a more detailed schedule showing activities during the design, construction, checkout, and startup phases.

Construction work is started approximately 27 months after contract award. When construction is 18 months into field work, system checkout and startup commences. The plant will be operational by approximately December 1986. At this time, solar repowered Newman Unit 1 will operate on-line and produce power to the grid.

Lead time for design, fabrication, installation, and checkout of collector and receiver hardware will have a major impact on the overall project schedule. Preliminary estimates of schedule requirements for these activities were provided by potential vendors.

Figure 7.6-3 summarizes an estimated schedule for heliostat design, fabrication, installation, and checkout. Similarly, Figure 7.6-4 summarizes the time required for engineering, fabrication, and erection of the receivers. An 8-month procurement cycle was assumed for each of these major procurements. Any major variation in these two schedules would have a significant impact on the completion date for this project. However, since unit operation can begin with a partial heliostat field in place, the collector subsystem installation schedule is less critical than receiver installation.

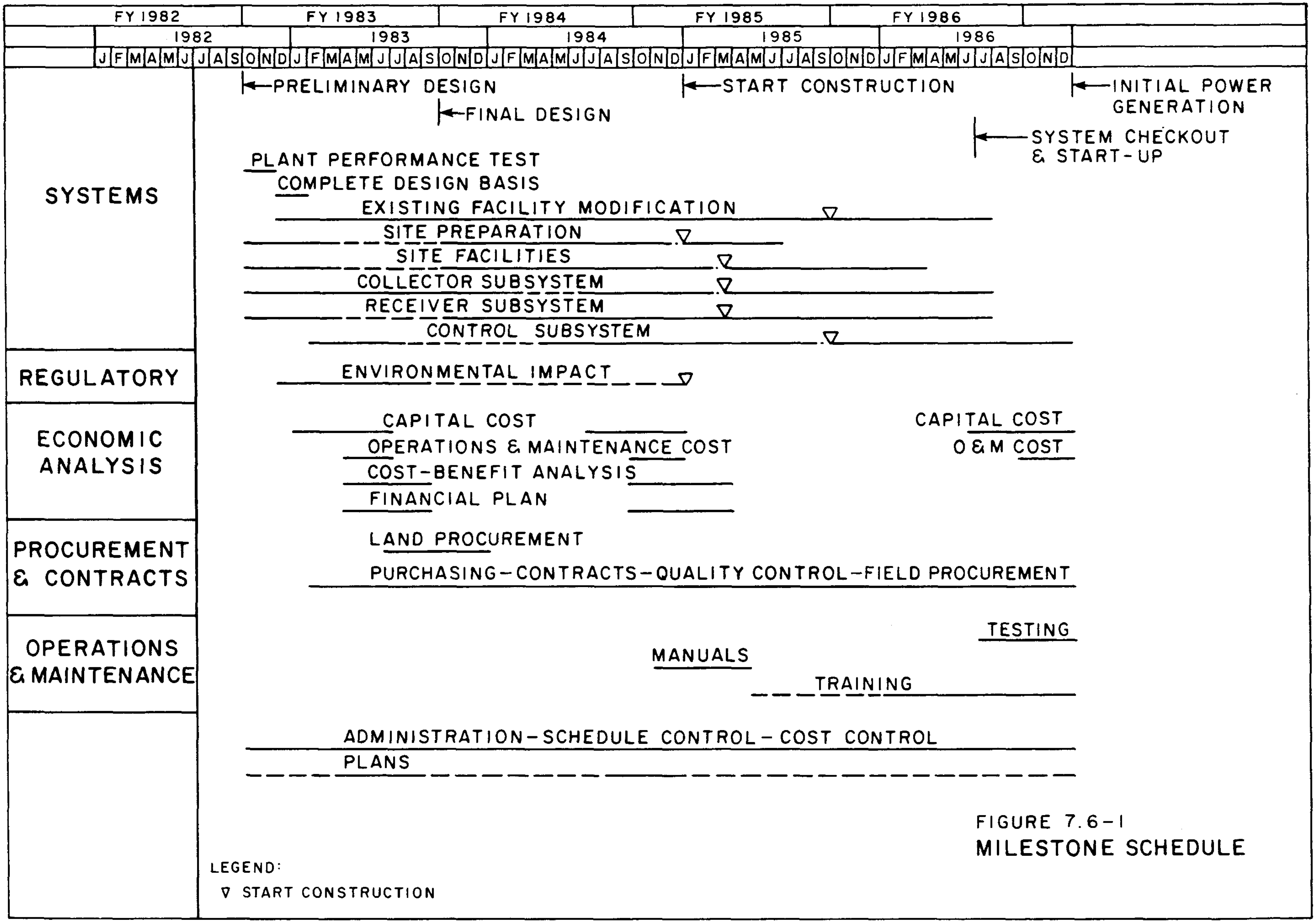

FIGURE 7.6-1
MILESTONE SCHEDULE

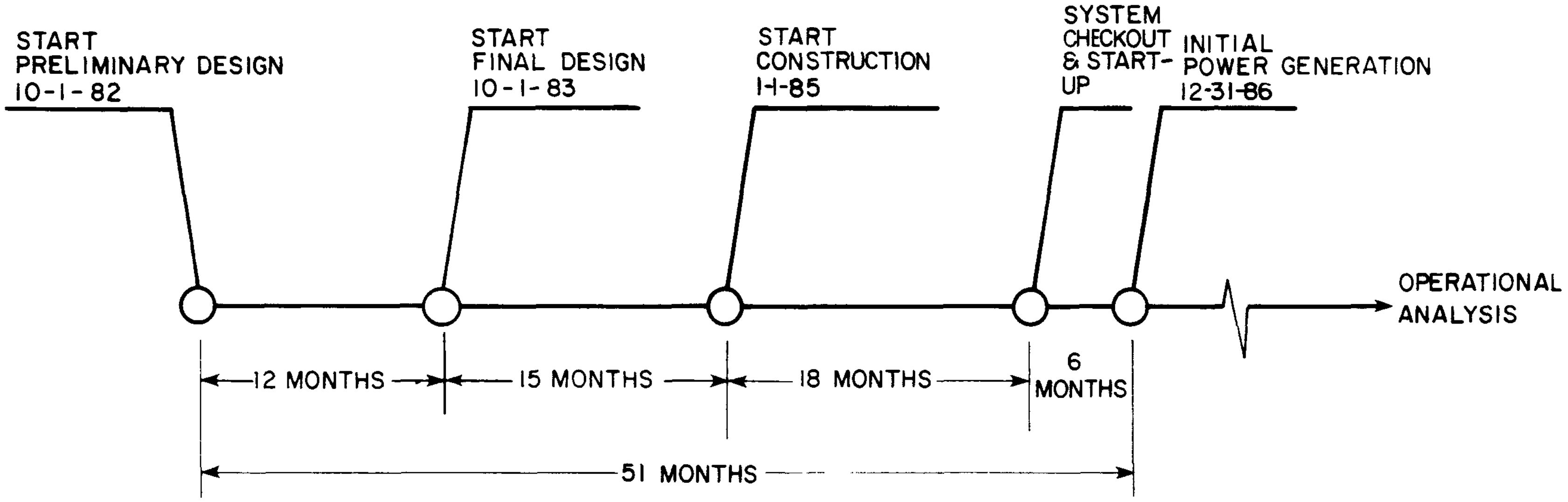

FIGURE 7.6-2
PROJECT SUMMARY MILESTONE SCHEDULE

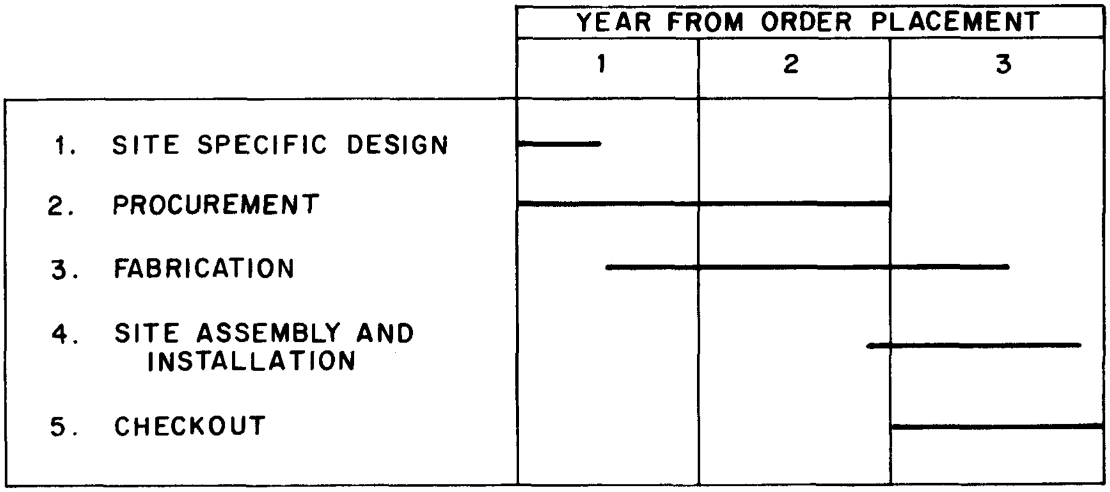

FIGURE 7.6-3
HELIOSTAT SCHEDULE

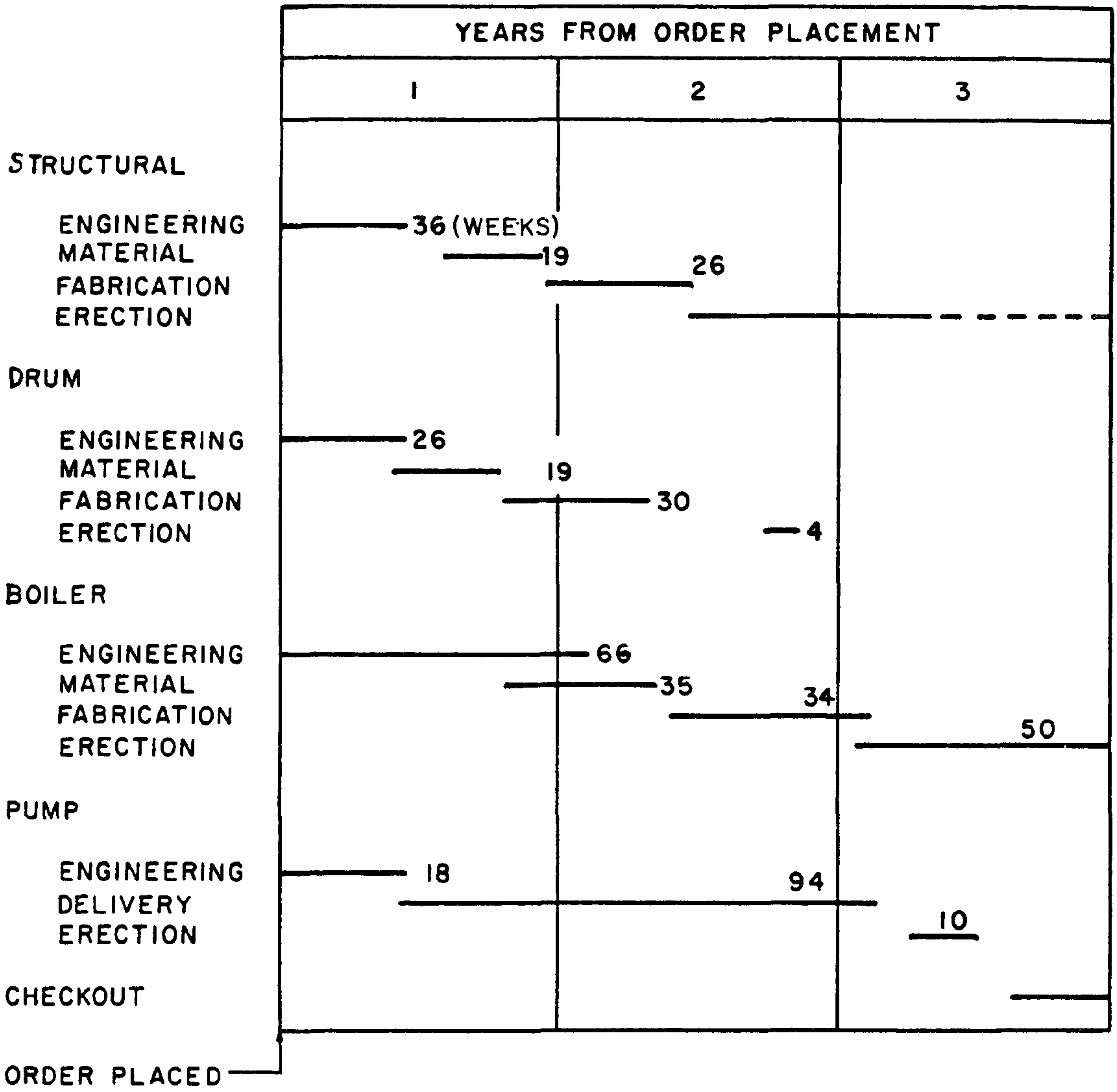

FIGURE 7.6-4
RECEIVER SCHEDULE

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