DOE/SF/10740-1(Vol.1)

NEWMAN UNIT I SOLAR REPOWERING

Final Report, Volume 1

July 1980

Work Performed Under Contract No. AC03-79SF10740

El Paso Electric Company
El Paso, Texas

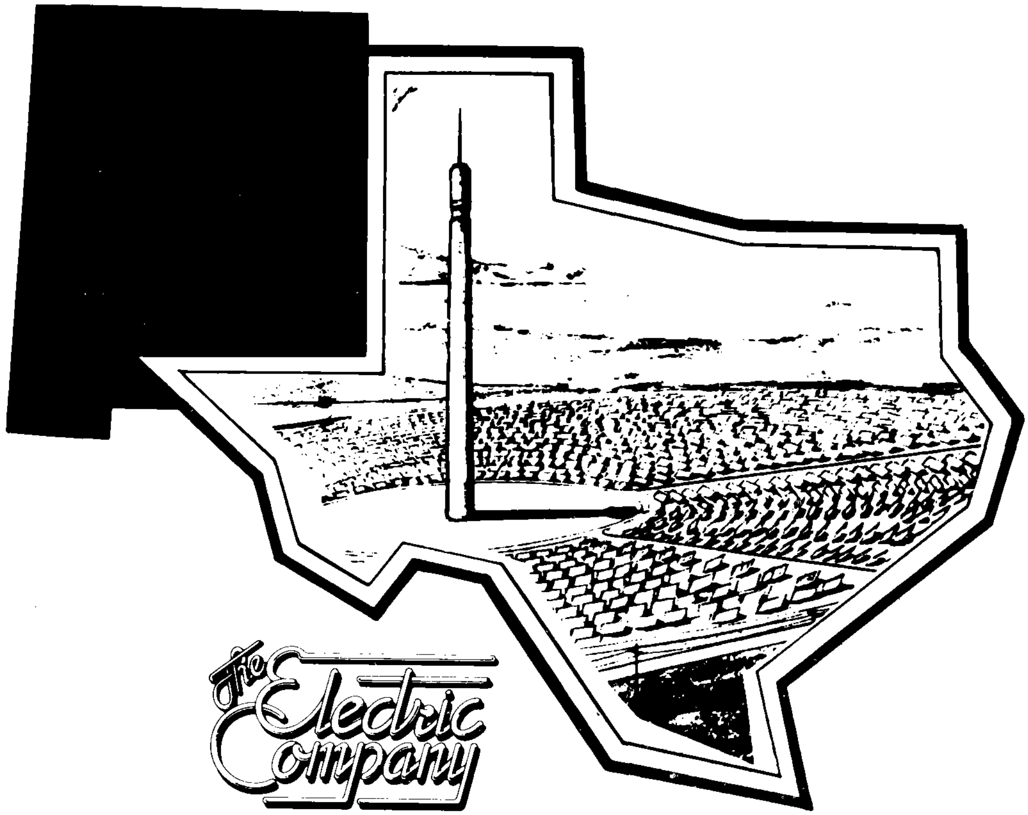
U.S. Department of Energy

Solar Energy

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

Price: Paper Copy $20.00
Microfiche $3.50

DOE/SF/10740-1(Vol.1)
Distribution Category UC-62



EL PASO ELECTRIC COMPANY

Newman Unit I Solar Repowering

Final Report Volume I

prepared for
Department of Energy as part of
Contract No. DE-AC03-79SF10740

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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 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 the overall goal of providing the technological and industrial base that is required to support 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.

The Newman Unit 1 Solar Repowering Program was funded by DOE for the period of September 30, 1979 to July 15, 1980. The principal objective was to develop a conceptual design and cost estimate for solar repowering Newman Unit 1 that has the potential for construction and operation by 1985, makes use of available solar thermal technology, and provides the best economics for this application.

An artist's concept for solar repowering Newman Unit 1 is shown in Figure 1.1-1. Solar repowering consists of modifying existing units 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 (boiler), 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 or at night. The potential for conventional electric power generation is retained, thus eliminating the need for costly energy storage systems.

The Solar Repowering Program objectives were accomplished using a work breakdown structure defining seven major tasks as follows:

- Task 1100 - System Requirements Specification
- Task 1200 - Selection of Site-Specific System Configuration
- Task 1300 - Plant Conceptual Design
- Task 1400 - Plant Performance Estimates

Task 1500 - Plant Cost Estimates and Economic Analysis
Task 1600 - Development Plan
Task 1700 - Program Plan and Management

EPE, 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 (S&W) and Westinghouse Electric Corporation (WEC).

S&W provided architect/engineer services that included the conceptual design of solar repowered Newman Unit 1, cost estimating in support of the economic analysis and demonstration program, environmental impact assessment, and construction planning for the subsequent demonstration program.

WEC's Advanced Energy Systems Division was responsible for project integration and systems engineering, solar system and subsystem design and analysis, economic and network impacts and assessments, safety evaluations, and program planning for the demonstration phases 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-Livermore Laboratories 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 and the Regional Development Division, Office of the Governor of Texas, both of which provided assistance in identifying and defining the institutional barriers and public issues associated with solar repowering. In addition, EPE formed the Southwest Solar Repowering Utility Advisory Council consisting of 32 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.

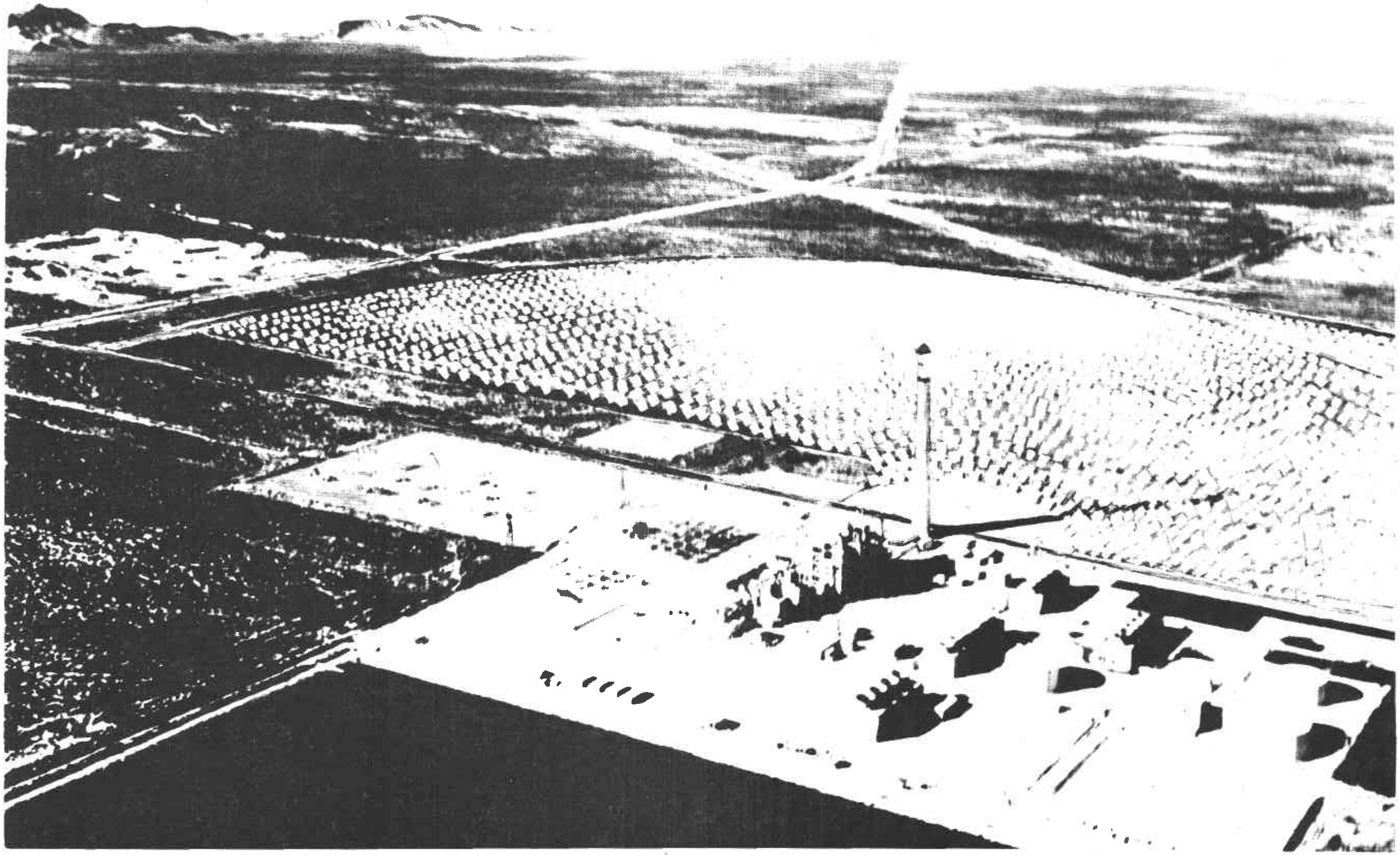


FIGURE 1.1-1
SOLAR REPOWERED NEWMAN UNIT 1

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 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 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/sec (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 highlighting the proposed collector field area.

Newman Station consists of four electric generating units rated at a total of 498 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 1979 capacity factor was 46 percent. Figure 1.2-3 is a photograph of Newman Units 1-4.

The Newman site, surrounded by 14.2 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.

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 V or larger on the Modified Mercalli 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 plant. A railway siding is located 9.6 km (6 miles) to the southeast. Newman 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 plant 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.

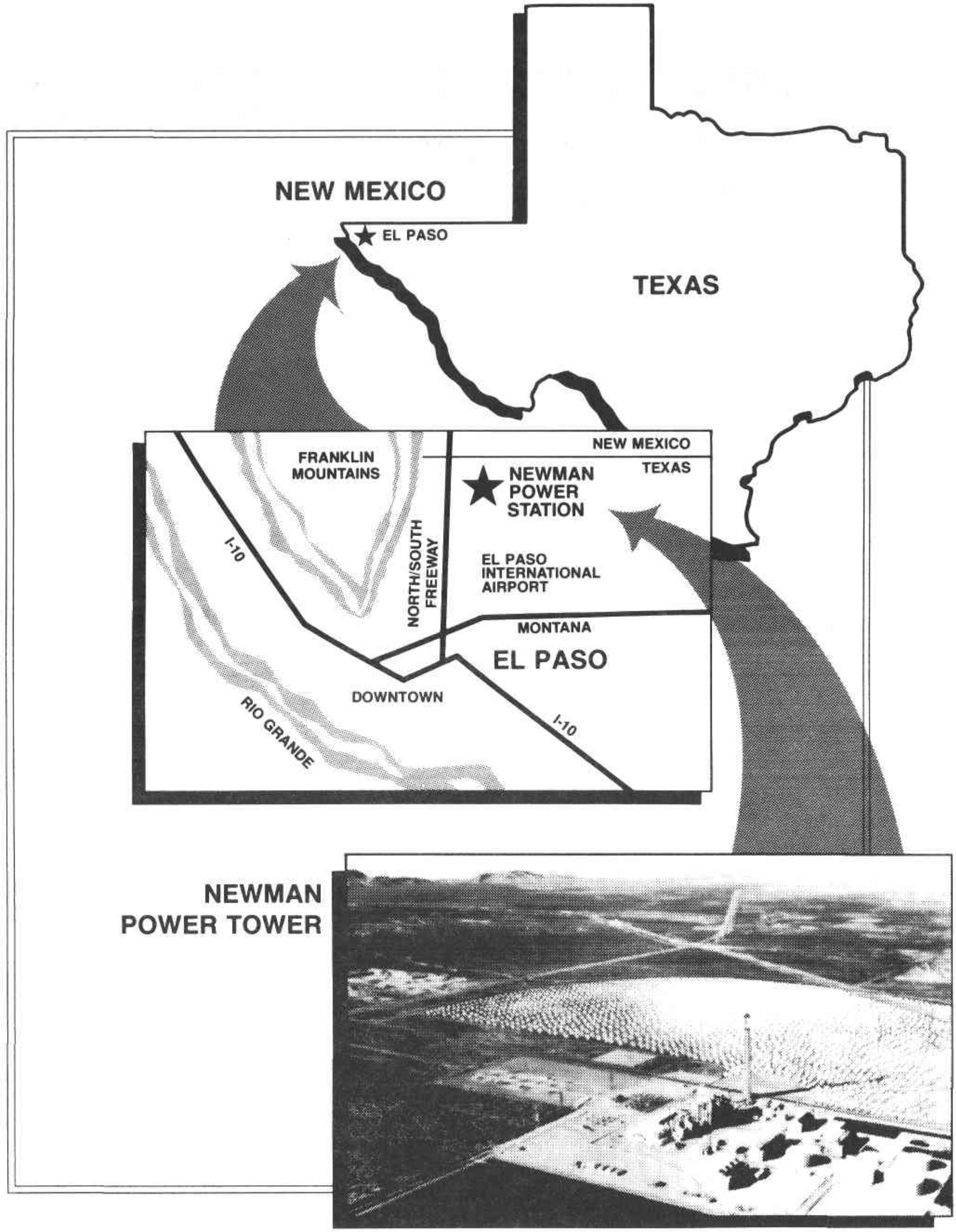


FIGURE 1.2-1
LOCATION OF NEWMAN STATION

The Electric Company
El Paso Electric

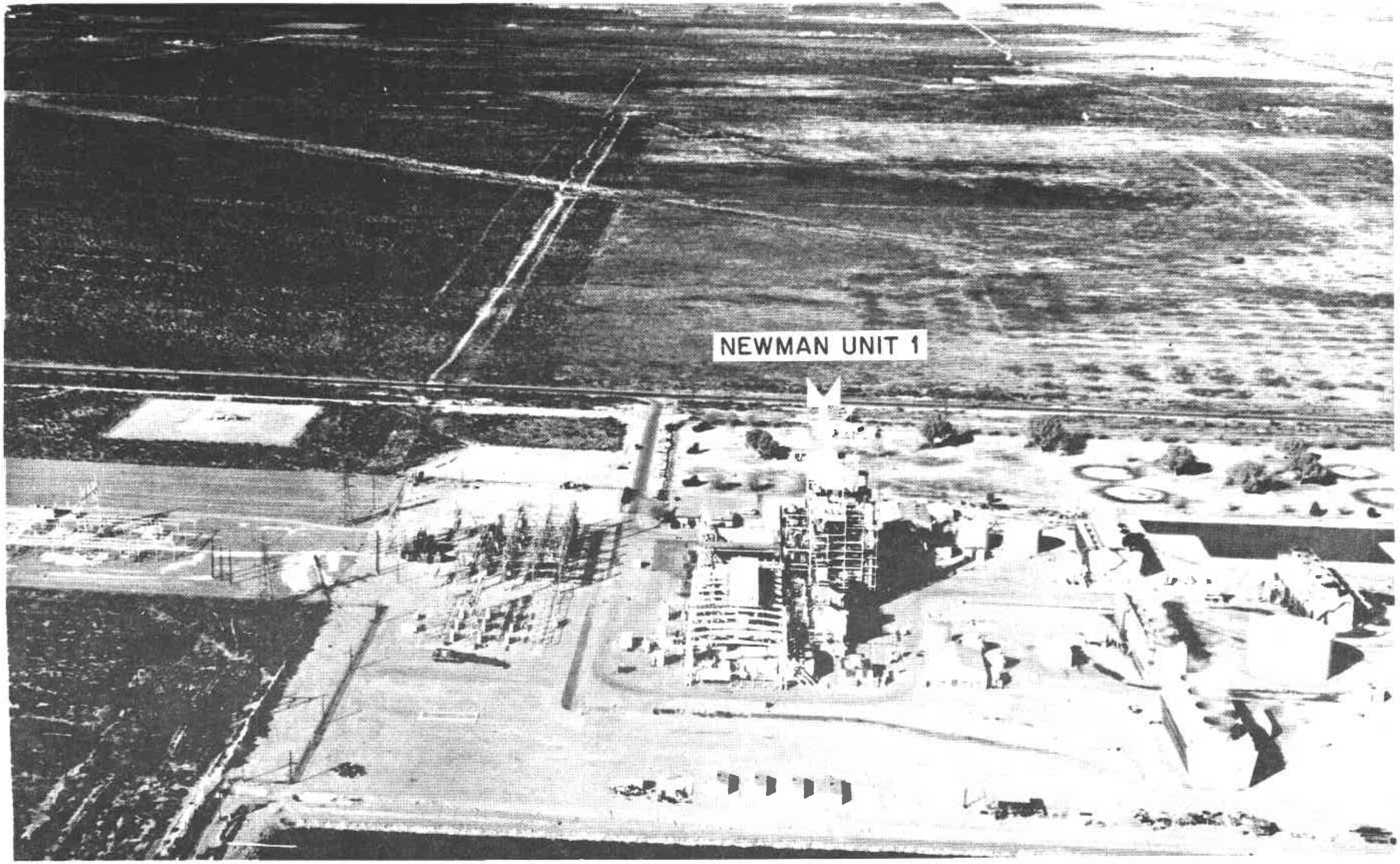


FIGURE 1.2-2
NEWMAN STATION SITE AND SURROUNDINGS

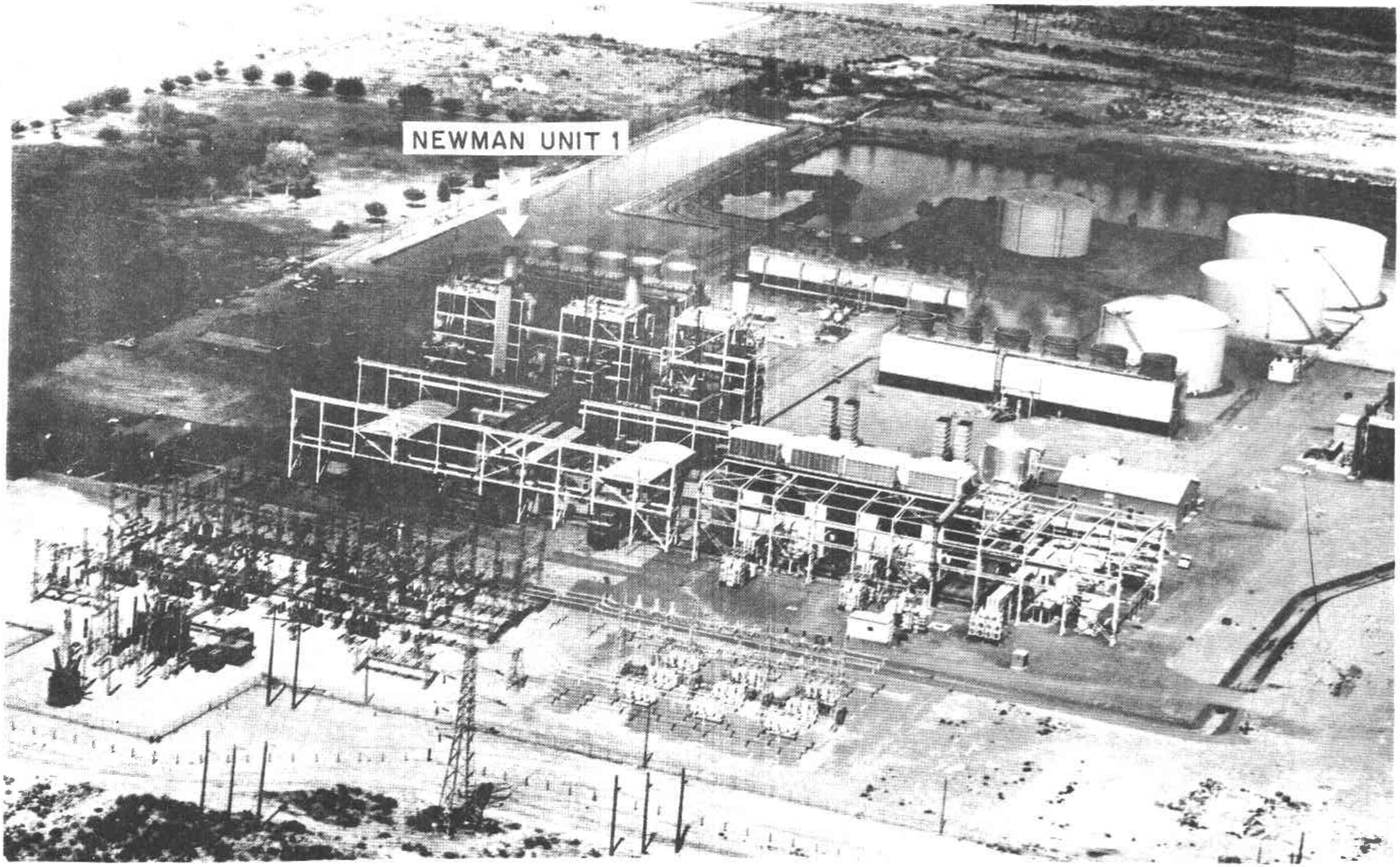


FIGURE 1.2-3
NEWMAN STATION UNITS 1-4

1.3 PROJECT SUMMARY

The principal objective of the Newman Unit 1 Solar Repowering Program was to develop a conceptual design and cost estimate for solar repowering Newman Unit 1 that has the potential for construction and operation by 1985, makes use of existing solar thermal technology, and provides the best economics for overall plant application.

Specific objectives were to: (1) prepare a System Requirements Specification for solar repowering Newman Unit 1, (2) select a preferred configuration and prepare a conceptual design, (3) establish the performance and economic attractiveness of the solar repowering design, and (4) prepare a development plan for a demonstration program at the Newman Station.

El Paso Electric Company (EPE), in a 100 percent DOE-funded program, has selected a preferred concept, developed a conceptual design, analyzed the performance, evaluated the economics, and prepared a development plan for solar repowering its existing, gas-fueled Newman Unit 1. Support has been provided by Stone & Webster Engineering Corporation (S&W), Westinghouse Electric Corporation (WEC), the Texas Energy and Natural Resources Advisory Council (TENRAC), the Regional Development Division of the Office of the Governor of Texas, and the Southwest Solar Repowering Utility Advisory Council consisting of 34 members representing investor-owned, municipal, state, federal, district, and rural electric cooperative systems.

The EPE system has a total generating capacity of 1,033 MWe which includes Copper Unit 1 put into service in June 1980. There is sufficient land available to apply solar repowering to all EPE gas and oil-fired units, which represent 922 MWe or 89 percent of the total system. EPE selected 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 km^2 (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 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 alternative 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 psi/1,000°F) reheat steam to the intermediate stage. The Babcock & Wilcox 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 Preferred Configuration for solar repowering Newman Unit 1 is illustrated in Figure 1.1-1. This design utilizes 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 when solar energy is not available.

EPE selected a solar repowering fraction of 50 percent for this demonstration unit as the minimum 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 summer solstice based on a direct insolation level of 950 watts/m². A 160° north heliostat field consisting of 2,776 Westinghouse Second Generation Heliostats is utilized in the design. A single tower housing the primary and reheat receivers, total height of 173 m (567 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 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 horizontal 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 is modified to permit cyclic duty operation consistent with peaking requirements.

The capital cost for this "first-of-a-kind" demonstration unit is estimated at 164 million dollars (1985 dollars) with anticipated operating and maintenance costs for the first year of 3.3 million dollars. Discounting this capital cost to 1980 using a 12 percent discount factor results in a cost of $93.1 million in 1980 dollars. The initial operation of the unit can commence in 1985 assuming a typical utility-oriented design and construction program is initiated by mid-1981.

The solar repowered unit will displace the equivalent of 133,000 barrels of oil per year and will yield a cost/value ratio of 1.5 to 2.3 for fuel oil escalation rates of 12 and 8 percent, respectively, for the "first-of-a-kind" demonstration unit. Based on mass-produced heliostat costs of $65/m², a commercial unit is expected to have a cost/value ratio of approximately 0.8.

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 design utilizes conventional water/steam technologies familiar to the utility industry in general and to plant operators of existing water/steam units specifically. El Paso Electric Company is convinced that demonstrating the feasibility or 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 Preferred Configuration (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 (1,450 psi/1,000°F), and reheat steam to the intermediate stage, 2.97 MPa/538°C (425 psi/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 when solar energy is not available. 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 between the fossil and solar subsystems, and (4) power supply interface to the heliostat field, primary and reheat receivers, valves, and pumps.

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 generated steam ensures that the temperatures are maintained within turbine design limits. Solar generated steam is used for most of the flow, with fossil steam generation to replace any steam flow reduction due to intermittent cloud cover and for economic dispatch when solar energy is nonavailable.

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 1.4-2 shows a site arrangement of the Preferred Configuration. 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. 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 heliostats employed in the collector field are the Westinghouse Second Generation Heliostats (Figure 1.4-3) which have a glass reflective surface area of 81.8m^2 (880 $feet^2$), an aspect ratio of 1.5:1, and a weight of 3,725 kg (8,200 lb). This heliostat concept was selected as representative of the class of configurations that will be available in 1985 for solar repowering applications.

The receiver subsystem provides a means of transferring the incident radiant flux energy from the collector subsystem into superheated steam. The receiver sybsystem consists of primary and reheat receivers (Figure 1.4-4) to intercept the radiant flux reflected from the collector subsystem, a single 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 being developed by DOE. 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 operation, startup, shutdown, and standby.

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 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 (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 thermal output from the receiver and the chemical energy in fossil fuels from the fossil energy 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 the solar steam supply system.

The estimated construction cost for solar repowered Newman Unit 1 is approximately $164 million dollars (1985 dollars). This estimate assumes plant operation by the end of 1985, and includes direct costs, indirects, distributables, escalation, contingency, allowance for funds used during construction, and owner 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 $3.3 million per year in 1985 dollars, or about 2 percent of the total capital cost.

TABLE 1.4-1

CONCEPTUAL DESIGN SUMMARY TABLE

1. Prime Contractor:

    El Paso Electric Company

2. Major Subcontractors:

    Stone and Webster Engineering Corporation

    Westinghouse Electric Corporation

3. Site Process:

    Electric power generation

4. Site Location:

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

5. Design Point:

    Noon summer 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)

    Output Fluid Pressure:

        Primary receiver: 10.1 MPa (1,450 psig)

Reheat receiver: 2.93 MPa (425 psia)

Size:

Primary receiver: 15.7m long x 12.6m diameter x 240°

Reheat receiver: 15.7m long x 12.6m diameter x 210°

7. Heliostats:

Number:	2,776
Effective Glass Area:	211,000 m^2
Direct cost:	\$48,600,000(1980 dollars) based on heliostat costs of \$230/m^2 utilized by DOE as a realistic value for a demonstration project
Type:	Westinghouse Second Generation Heliostat
Field Configuration:	North field/160° angle

8. Storage:

None

9. Total Project Cost:

\$164,000,000 (1985 dollars)

\$ 93,100,000 (discounted to 1980)

10. Construction Time:

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

11. Solar Plant Contribution at Design Point:

41 MWe

TABLE 1.4-1 (Cont)

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

    68 percent

13. Annual Fossil Energy Saved:

    4×10^6 barrels crude oil equivalent over 30 year period. Amount of energy displaced varies substantially from year to year; the average annual value is 133,000 barrels.

14. Type of Fuel Displaced:

    67% Gas and Oil

    33% Coal

15. Annual Solar Energy Produced: 206,800 MWht

16. Ratio $\frac{\text{Annual Energy Produced}}{\text{Total Heliostat Mirror Area}}$: 0.098 $\frac{\text{MWht}}{\text{m}^2}$

17. Ratio of Capital Cost $\frac{\text{(discounted to 1980 dollars)}}{\text{Annual Fuel Displaced}}$: \$397./MWht

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

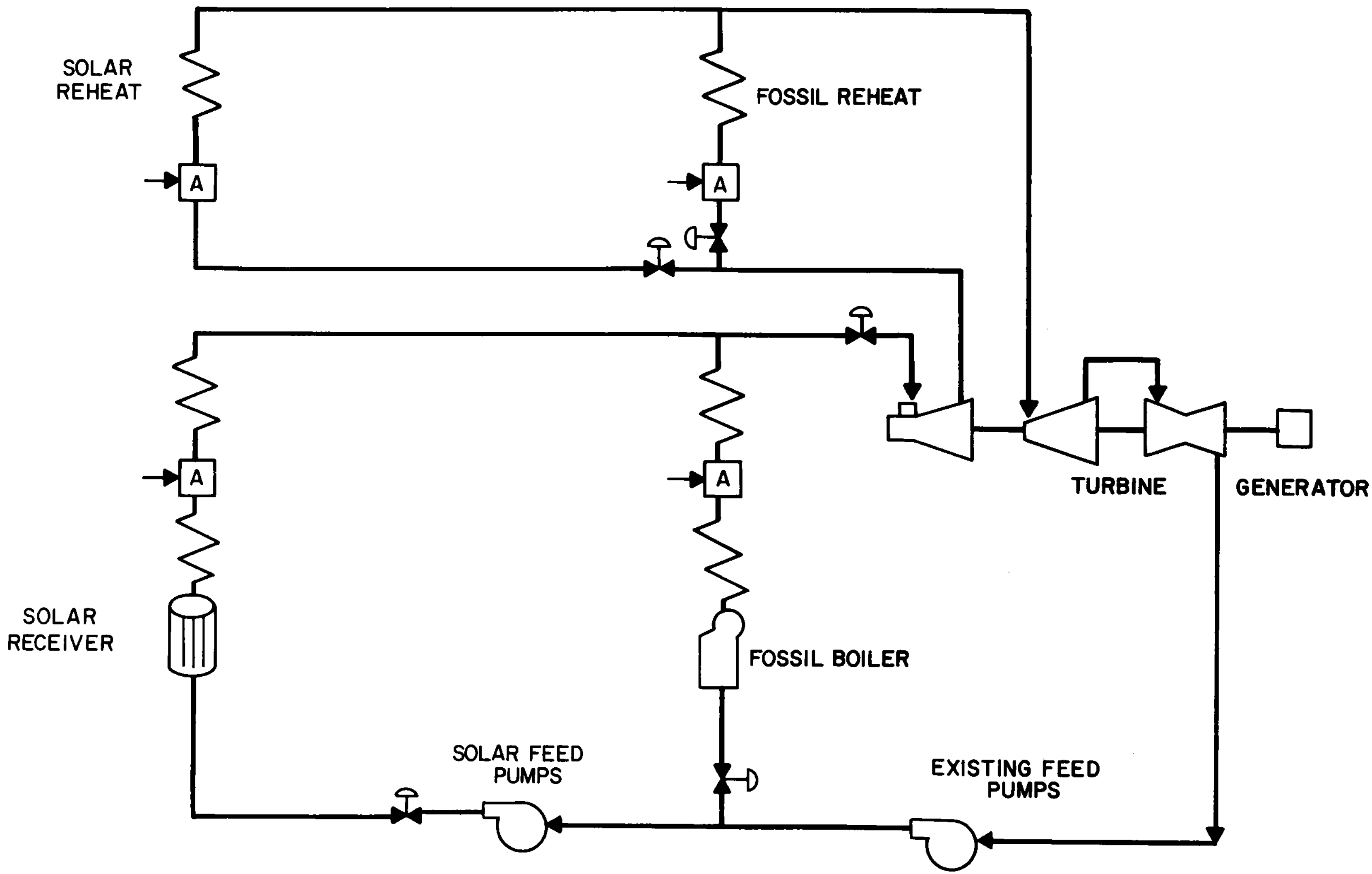


FIGURE 1.4-1
SIMPLIFIED FLOW SCHEMATIC

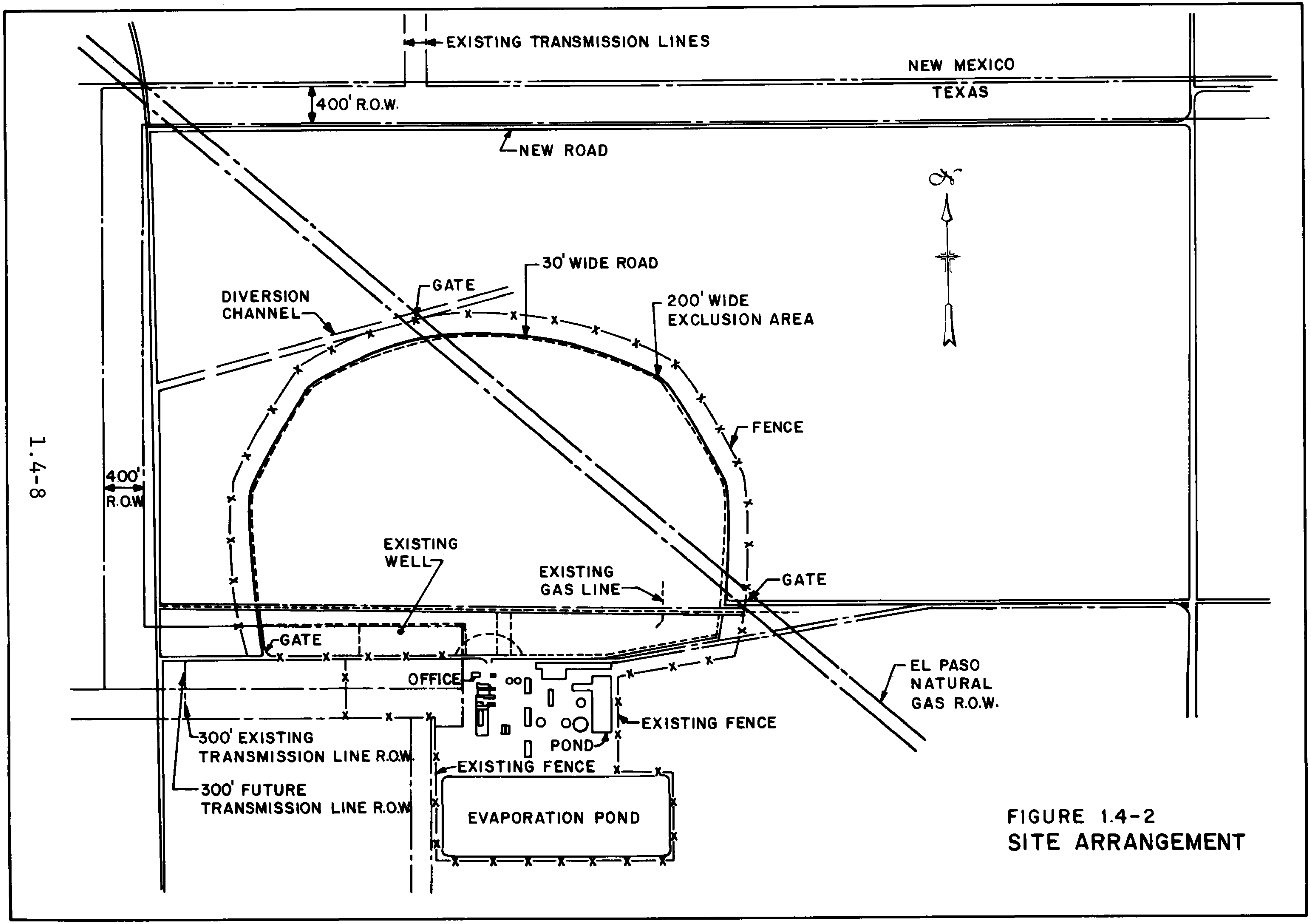
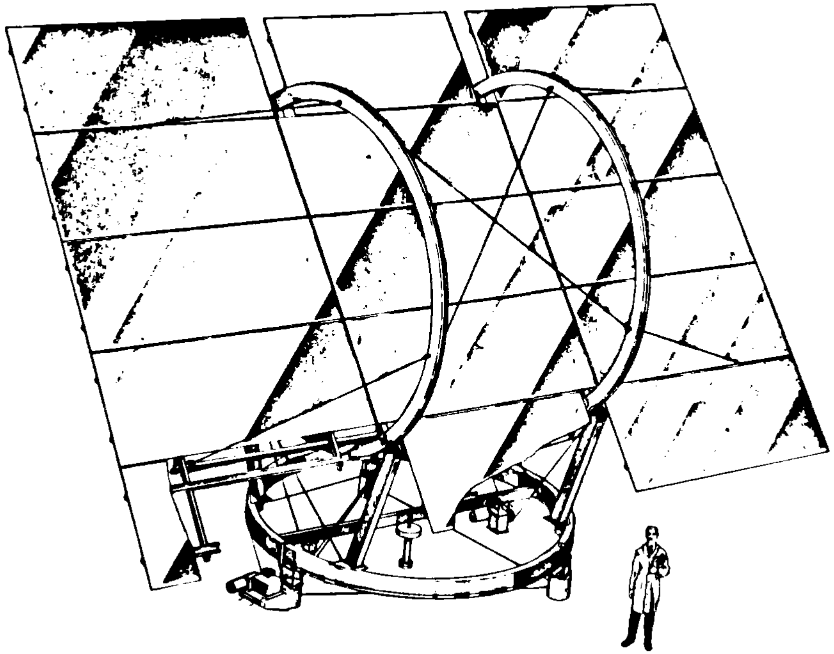


FIGURE 1.4-2
SITE ARRANGEMENT

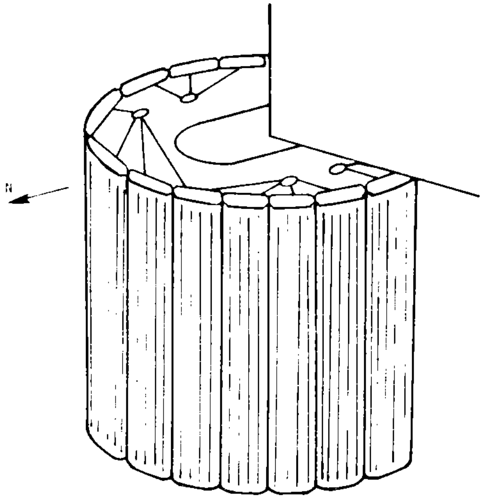


HELIOSTAT CHARACTERISTICS	
ASPECT RATIO	1.5:1 (7.6M x 11.0M)
MIRROR AREA	81.8M^2
MIRROR PANEL	LAMINATED GLASS PANELS
ELEVATION WHEELS	4.9M DIA.
AZIMUTH RING	4.57M DIA.
WEIGHT	3725KG

FIGURE 1.4-3
HELIOSTAT DESIGN

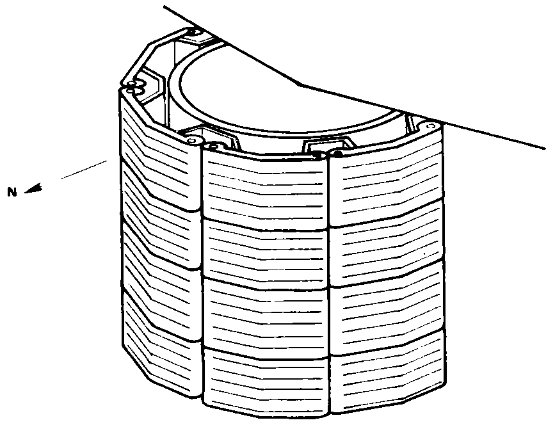
CONFIGURATION: EXTERNAL CONFIGURATION
FORCED RECIRCULATION
SCREENED TUBE CONCEPT
1 TOWER WITH PRIMARY AND REHEAT RECEIVER
160° NORTH FIELD

PRIMARY RECEIVER



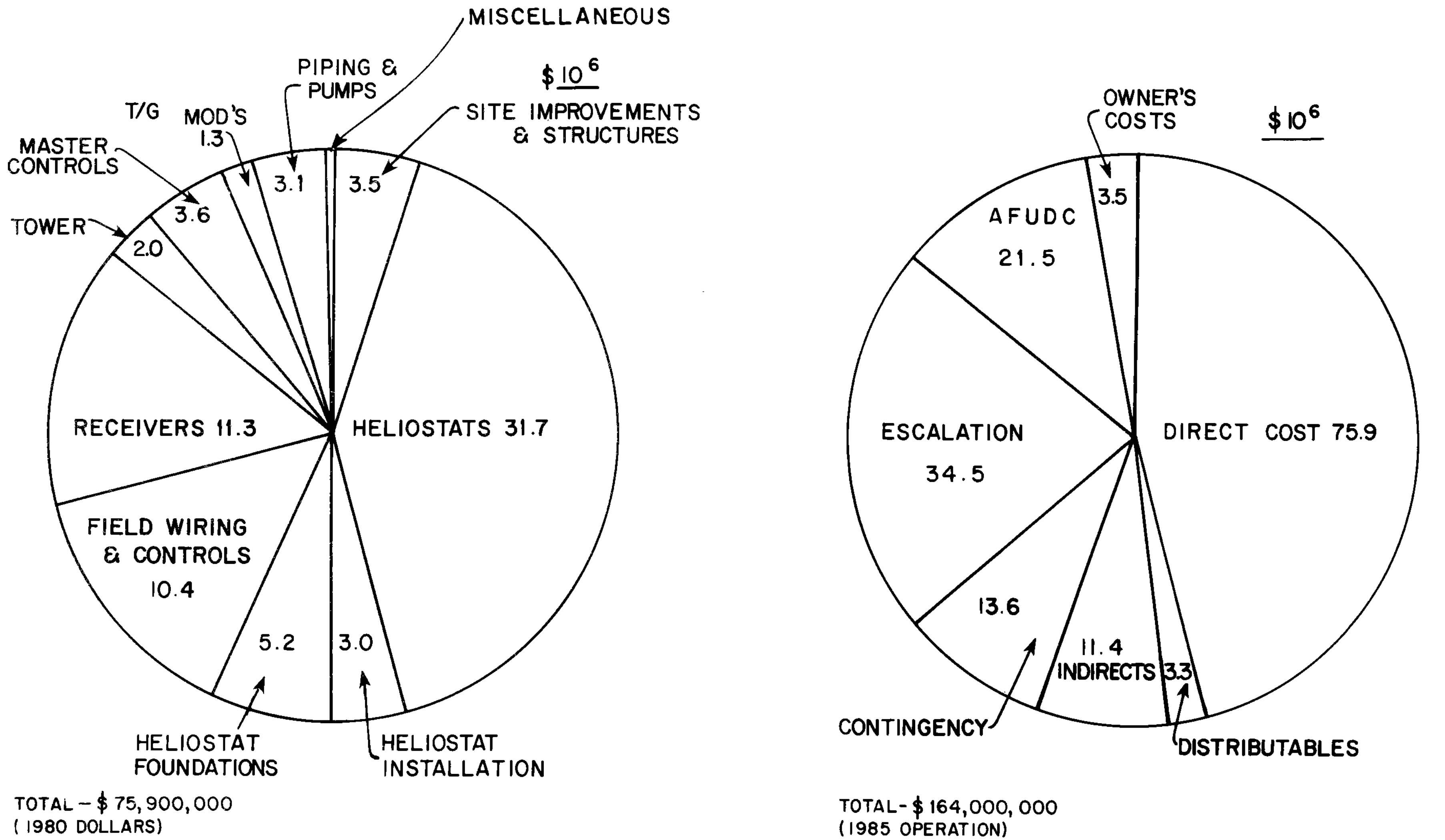
ABSORBED POWER = 92 MW (50% REPOWER)
MAXIMUM HEAT FLUX = 0.60 MW/m^2
OUTLET TEMPERATURE = 549°C
OUTLET PRESSURE = 10.8 MPa
PRESSURE DROP = 1.72 MPa
LENGTH = 15.7 m
DIAMETER = 12.6 m
ENCLOSED ANGLE = 240°
PANELS = 16
CENTERLINE ELEVATION = 155 m

REHEAT RECEIVER



ABSORBED POWER = 13 MW (50% REPOWER)
MAXIMUM HEAT FLUX = 0.14 MW/m^2
OUTLET TEMPERATURE = 549°C
OUTLET PRESSURE = 2.97 MPa
PRESSURE DROP = 0.172 MPa
LENGTH = 15.7 m
DIAMETER = 12.6 m
ENCLOSED ANGLE = 210°
PANELS = 16
CENTERLINE ELEVATION = 138 m

FIGURE 1.4-4
RECEIVER CONCEPTUAL DESIGN



DIRECT COST BREAKDOWN

CONSTRUCTION COST BREAKDOWN

FIGURE 1.4-5
CONSTRUCTION COST BREAKDOWN

1.5 SYSTEM PERFORMANCE

The 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. In this cycle, feedwater is split and delivered to 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 (1,450 psig) 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) when operating in the combined solar/fossil mode (82 MW net total output) at the design point of noon summer solstice. The collector subsystem design is based on an insolation of 950 W/m^2.

The solar repowered unit performance characteristics are summarized in Table 1.5-1 for the nooon summer solstice design point. These data are also representative of annual average conditions. Figure 1.5-1 is a stair step system efficiency chart at the design point that identifies the various components and their respective efficiencies which contribute to the heat rate. The energy output of solar repowered Newman Unit 1 is shown in Figure 1.5-2.

The dynamic response characteristics of the solar subsystems, the fossil boiler subsystem, and the EPGS were evaluated for a variety of cloud cover sizes and velocities. Transient analyses were performed for cloud cover sizes that represent insolation losses of 10, 50, and 100 per 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 transient analyses have 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
Intermediate Turbine Inlet	2.93 MPa/538° C
Main Steam Flow	257,000 kg/hr
Collector Subsystem	
Power Incident on Primary Receiver	105 MWt
Power Incident on Reheat Receiver	25 MWt
Efficiency (including cosine, reflectivity, blocking, atmospheric attenuation, spillage)	64%
Receiver Subsystem	
Power Absorbed in Primary Receiver	92 MWt
Primary Steam Outlet Conditions	129,000 kg/hr
Peak Heat Fluxes on Primary Receiver Water Cooled Surfaces	0.60 MW/m^2
Power Absorbed in Reheat Receiver	13 MWt
Reheat Steam Outlet Conditions	115,400 kg/hr 2.97 MPa/549°C
Overall System Efficiency (kWhe net output per kWht energy incident on heliostat reflective surface)	0.20

NOTE:

* Based on an insolation level of 950 $Watts/m^2$.

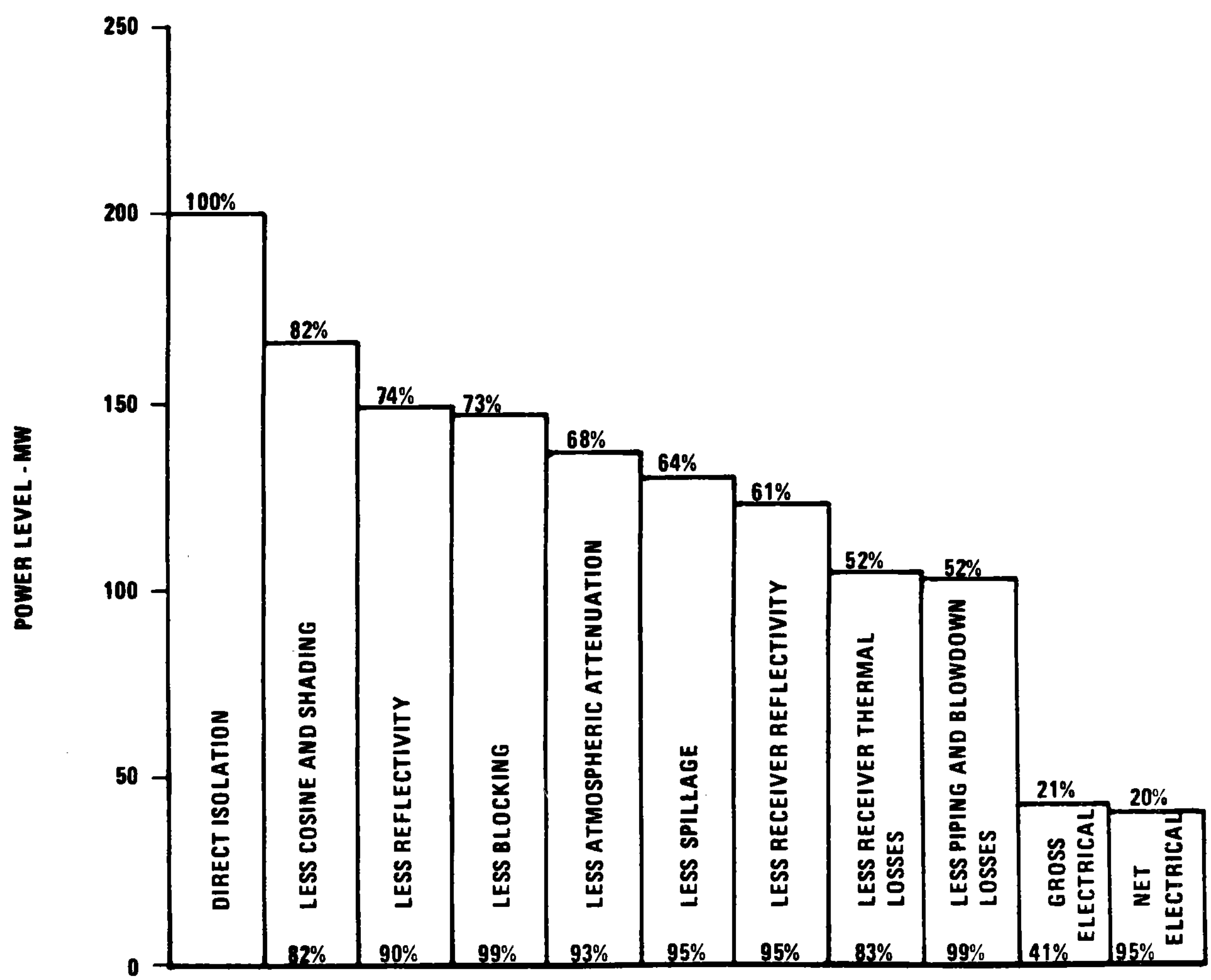


FIGURE 1.5-1
SOLAR REPOWERING NEWMAN
UNIT 1 EFFICIENCY CHART
(DESIGN POINT –
NOON SUMMER SOLSTICE –
950 W/M^2 INSOLATION)

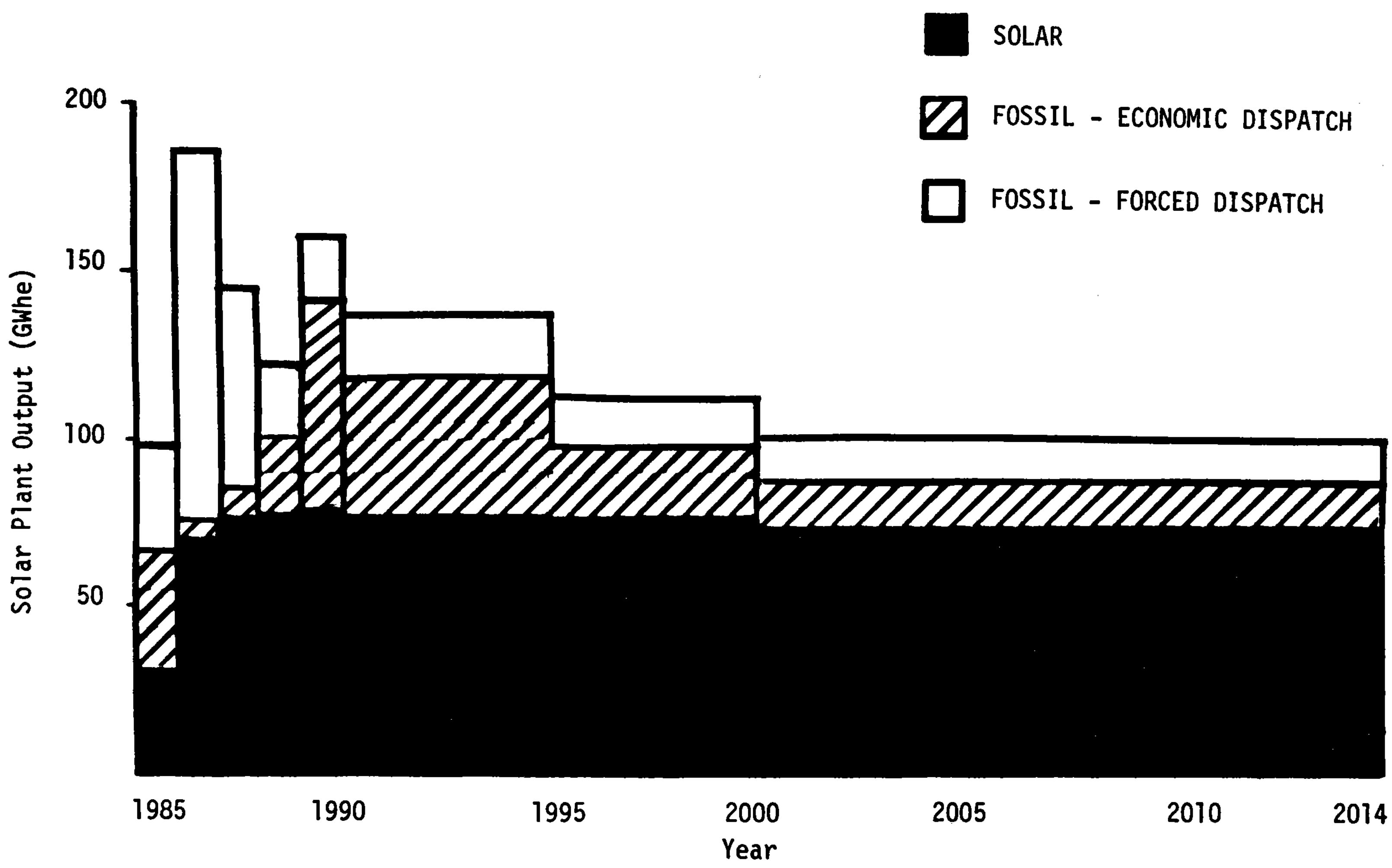


FIGURE 1.5-2
SOLAR REPOWERED UNIT ENERGY OUTPUT

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 impact is a major concern to the El Paso Electric Company. This involves the cost of repowering, the quantity 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 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 intent of the cost/value analysis is to realistically assess the economics of the "first" repowered unit using present cost data based on a limited production level for the solar hardware. The results therefore are not indicative of the true economic potential of solar repowering 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 task to select the Preferred Configuration and resulted in cost/value ratios of 0.8 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 164 million dollars (1985 dollars) with anticipated operating and maintenance costs for the first year of 3.3 million dollars. The solar subsystem is sized to provide 41 MWe (50 percent repowering) at noon summer solstice based on an insolation level of 950 watts/m^2.

The fossil boiler at Newman Unit 1 will operate using either natural gas or fuel oil. EPE currently has gas supply contracts extending into the 1990's. Between 1985 and 1990, the Newman Unit 1 boiler is projected to burn natural gas. It is assumed that after 1989 the unit will burn oil. Other gas-fired units on the EPE system, for the purpose of this economic evaluation, are also assumed to burn oil after 1989.

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, a conservative 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. The operating strategy consists of:

Solar operation initiated August 1985

8/85 to 12/85, the fossil boiler produces 41 MWe minimum when the unit is operating on solar; the unit is also economically dispatched on fossil fuel.

1/87 to 12/87, the fossil boiler produces 23 MWe minimum when the unit is operating on solar; the unit is also economically dispatched on fossil fuel.

Beyond 1987, the fossil boiler operates only when required to offset solar insolation transients on cloudy days or when economical to dispatch on fossil fuel.

After 29 months of engineering test and evaluation, the solar repowered unit is dispatched, as noted above, in a manner similar to conventional units.

EPE selected this conservative initial operating scenario of 29 months duration due to the limited data currently available on solar power plants. The "forced" burning of natural gas during the early years results in penalizing the economic attractiveness of the solar repowered unit. Within the next 2 years, solar plant operating characteristics will be better defined through experience gained with the 10 MWe Pilot Plant currently under construction at Barstow, California. It is likely that once this experience is available, a more progressive approach which shortens the duration of the initial operating period can be utilized with corresponding economic benefits.

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 April 1980. Approximately 90 percent of the existing system generating capacity is provided by gas- and oil-fired units; however, by 1985 EPE anticipates that 55 percent of their generating capacity will be provided by coal and nuclear units and that this will increase to 83 percent by the year 2000. The system peak load forecasted for 1980 is 712 MWe, and by the year 2000 the system peak load is expected to increase to 1834 MWe.

A detailed multi-year analysis was performed for the solar repowered unit operating on the EPE system. A total of eight 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 using a typical year simulating the operation of the repowered unit.

Table 1.6-1 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 of 10 and 8 percent, respectively. Because of the uncertainty in the long term escalation rates for these fuels, a second scenario is also considered in the economic evaluation which is based on an escalation rate of 12 percent. The discount rate used in the analysis for both scenarios is 12 percent with a fixed charge rate of 16 percent. The economic scenarios are consistent with a long term general inflation rate of 7 percent. In addition to the EPE economic scenarios, the DOE defined a set of capital, and fuel cost, and fuel escalation rate assumptions. The DOE assumptions are also given in Table 1.6-1. EPE assumptions for the discount rate, fixed charge rate, capital, and operation and maintenance escalation rates are assumed for the DOE scenario.

The lifetime cost and value found 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) and for the economic scenario supplied by DOE. The numbers shown in this table are present worth of revenue requirements expressed in millions of 1980 dollars. The base economic scenario (A) resulted in a cost/value ratio of 2.27. The total lifetime energy displaced is approximately 2.95 x 10^4 MJ (28×10^{12} Btus) of gas/oil and 0.84×10^4 MJ (8×10^{12} Btus) coal. The solar repowered unit consumed about 1.27×10^4 MJ (12×10^{12} Btus of gas/oil over its life. Thus, the net energy displaced is 1.69×10^4 MJ (16×10^{12} Btus) of gas/oil and 0.84×10^4 MJ (8×10^{12} Btus) of coal.

All costs presented in Table 1.6-2 are discounted to 1980 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 and oil burned at solar repowered Newman Unit 1 both to support the solar operation of the unit on cloudy days and for economic dispatch of the unit. Capacity credit is the value of new genertaing capacity that will no longer be required due to extending the life of Newman Unit 1 beyond its normal retirement date of 2000.

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 0.8. The higher cost/value ratios are due to higher costs for solar components (such as heliostats) and restricted plant operation in the early years (due to testing and establishment of operating mode confidence/experience).

TABLE 1.6-1

ECONOMIC SCENARIOS (1985)

	EPE Scenarios		
	A	B	DOE Specified Data
Present Worth Discount Rate	12%	12%	12%*
Carrying Charge Rate	16%	16%	16%*
Capital Cost, $/kWe (c-t/c-c/coal/nuc	300/600/1400/1600	300/600/1400/1600	90/360/860/1000
Fuel Cost, $\$/10^6$ Btu (gas/oil/coal/nuc)	4.5/12/1.5/1.0	4.5/12/1.5/1.0	2.50/4.00/1.25/0.85
Fuel Escalation Rate (%) (gas/oil/coal/nuc)	10/8/7/7	10/12/7/7	11/12/10/9
Capital Escalation Rate	7%	7%	7%*
O&M Escalation Rate	7%	7%	7%*

NOTE:

* EPE data used

TABLE 1.6-2

MULTI-YEAR COST/VALUE SUMMARY
1980X10^6\$ PWRR

	Economic Scenario		
	A	B	DOE
Solar Plant Cost			
Capital	119.6	119.6	119.6
O&M	28.6	28.6	28.6
TOTAL COST	148.2	148.2	148.2
Solar Plant Value			
Fuel Value	98.3	154.4	57.0
Variable O&M	3.6	3.6	3.6
Fuel Cost	-45.6	-69.3	-25.0
Capacity Credit	8.9	8.9	5.7
TOTAL VALUE	65.2	97.6	41.3
Net Value	-83.0	-50.6	-106.9
Cost/Value Ratio	2.27	1.52	3.59

* Present worth of revenue requirements

1.7 DEVELOPMENT PLAN

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

The steps required to develop the 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 was assumed that preliminary design work will be initiated in June 1981.

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

Construction work is planned to start 31 months after contract award and require an estimated 18 months to complete. The existing unit is removed from service to complete the modifications required for solar repowering during the first half of 1985. The repowered unit is again available for fossil fueled operation during the third quarter of 1985 and for intermittent duty on solar energy as part of the system startup and checkout operations. The unit is completely operational by December 1985.

During the first 29 months of operation, the operating scenario for the fossil boiler assumes continuous boiler firing during solar operation as indicated in Section 1.5. 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 other utilities. Transferring this experience to other potential industrial and utility users will be a prime objective of the demonstration program.

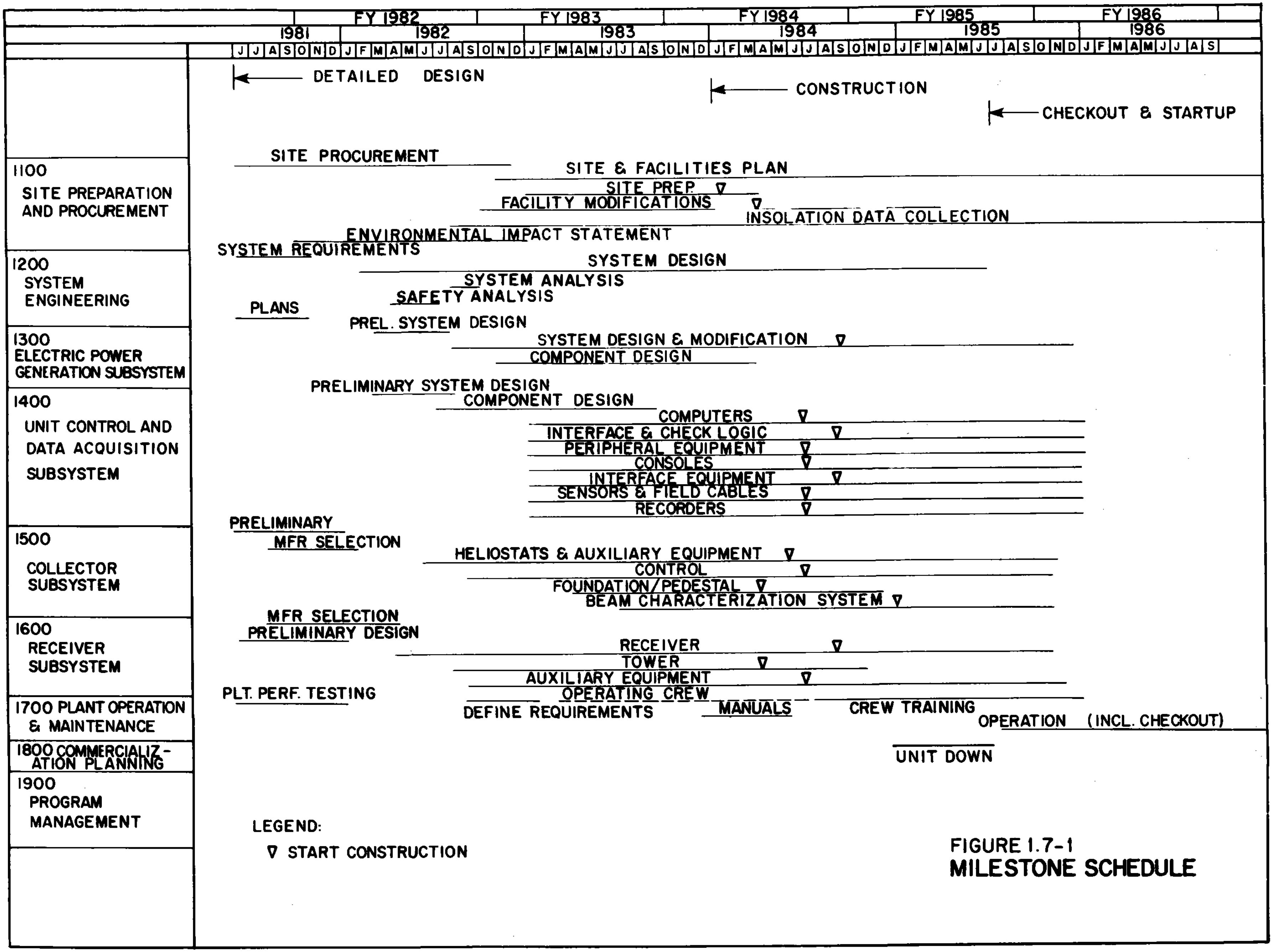


FIGURE 1.7-1
MILESTONE SCHEDULE

1.8 SITE OWNER'S ASSESSMENT

EPE, as site owner and program manager for the "Newman Unit 1 Solar Repowering" contract, has technically directed each of the seven tasks described earlier. EPE is pleased with and supportive of the 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 central receiver solar thermal 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 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 ultimate system design may not, but that is no cause for delay. 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 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 the solar industry, the business community will need to invest substantial capital in production facilities and raw materials. 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 will be reluctant to undertake large capital obligations to support commercialization.

EPE evaluates promising alternative sources of electrical generation in a manner consistent with its historical assessments of conventional generation systems. 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 intial investment capital can be obtained at a reasonable cost.

EPE has approached its analysis of solar repowering on this same basis and is comfortable with its estimated cost/value ratio of 2.3 for a first-of-a-kind demonstration for solar repowering Newman Unit 1. This ratio was calculated using EPE's projected economic factors, the most significant of which was an oil escalation rate of 8 percent. A cost/value ratio of 2.3 essentially says that a site-specific and system-specific repowering of Newman Unit 1 with solar energy has a cost which is double the 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 1985.

It utilizes a cost of $230/m^2$ for heliostats which has the potential to be reduced two-fold given future market economies and research advancements in heliostat related technologies. (Heliostats and their associated subsystems comprise 66 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/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.

EPE's projection of an 8 percent oil escalation is somewhat conservative when compared to many other projections which range to 12 percent and higher.

It shows a substantial reduction in the use of oil as a boiler fuel with an excellent potential for oil-free operation.

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.

Expanding on the technical risk issue, an unfavorable solar repowering demonstration may imply that solar is not an acceptable generation alternative for the 1990's. In EPE's opinion, the system chosen for an initial demonstration must have a high probability of successfully being constructed and operated within schedule and budget, widely integrated into electric utility systems, and satisfies 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. 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.

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.

EPE's economic analyses utilized an initial O & M cost equivalent of 2 percent of the capital costs, and this was escalated by 7 percent each year. This appears to be a realistic projection of O & M costs; 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 20 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 a 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. Safety aspects will be further minimized through the utilization of a water/steam working fluid as compared to sodium and molten salt applications. 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.

The Newman Unit 1 site is also located such that public access is quickly and easily accomplished through an excellent system of roads. It is situated relatively near a major airport. The El Paso community, 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 oil 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. The benefits that accrue to the local communities and electric rates payers is recognized by EPE, and its senior management has expressed a willingness to cost-share with the government to the greatest extent possible.

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, 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 standard business sense, but cost-effectiveness should not be an overriding concern in an R & D demonstration. Future commercial applications of this technology are expected to be extremely 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. Pre-demonstration O & M estimates appear reasonable, but subsequent actual data from a future demonstration may lower projections for this significant cost item, thus enhancing 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 Solar Repowering Program." The period of performance was September 30, 1979 to July 15, 1980. The programmatic data pertaining to this contract are:

Contract Number	-	DE-AC03-79SF10740
Contract Cost	-	$496,381
Prime Contractor	-	El Paso Electric Company P.O. Box 982, El Paso, TX, 79960
Principal Investigator	-	James E. Brown (915-543-5816)

The conceptual design developed during this program for solar repowering Newman Unit 1 is technically feasible for a 1985 demonstration of the concept. This concept uses conventional water/steam technology 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 energy option.

2.1 STUDY OBJECTIVE

The principal objective of this study was to develop a conceptual design and cost estimate for solar repowering Newman Unit 1 that has the potential for construction and operation by 1985, makes use of existing solar thermal technology, and provides the best economics for this application. Specific objectives were: (1) to prepare a systems specification for solar repowering Newman Unit 1, (2) to select a preferred configuration and prepare a conceptual design, (3) to establish the performance and economic attractiveness of solar repowering design, and (4) to prepare a development plan for a demonstration program at Newman Station.

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 Solar Repowering Program was divided into seven major tasks:

Task 1 - System Requirements Specification
Task 2 - Selection of Site-Specific System Configuration
Task 3 - Plant Conceptual Design
Task 4 - Plant Performance Estimates
Task 5 - Plant Cost Estimates and Economic Analysis
Task 6 - Development Plan
Task 7 - Program Plan and 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 task-by-task basis.

The foundation of the program was Task 2 - Selection of a Site Specific System Configuration complemented by Task 1 - Systems Requirements Specification that is designed to guide the performance of all subsequent tasks.

2.2.2 Selection of Newman Unit for Solar Repowering

The EPE system has a total generating capacity of 1,033 MWe and has sufficient land available neighboring its local Copper, Rio Grande, and Newman Stations to solar repower all 13 of its existing gas- and oil-fired units, which represent 922 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:

<u>Widespread market potential for solar repowering reheat steam turbines similar to Newman Unit 1</u> - 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(1,450 psig/1,000°F).

Availability of unencumbered, flat land - More than 14.2 km^2 (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 13 existing gas- and oil-fired units on the EPE system, the net heat rate for Newman Unit 1 is better than 9 of the units and comparable to 3. 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 recently performed 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 19 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.

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 (1,450 psig/1,000°F), and reheat steam to the intermediate stage 3.0 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, 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/m^2) can be achieved with a 1.4 km^2(350 acre) field north of the unit.

The performance and economic attractiveness of the Baseline Configuration were assessed against several Alternative Configurations during the 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 were also assessed as part of these trade studies. The trade studies focused on the solar/non-solar interface complexity versus the economic advantage, in terms of cost/value ratios, to be gained from more complex systems. The output from these trade studies was the selection of a specific system configuration for performing the conceptual design and detailed economic evaluations during subsequent program tasks. Criteria were developed and reviewed with DOE to guide the selection of the system configuration. Prior to initiating the trade-off studies, a list of the studies to be performed were prepared including the assumptions and the limits the parameters were to be varied.

A conceptual design was prepared for the system configuration selected in Task 2. The 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. 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 program as summarized above provides a utility user-oriented evaluation of the technical feasibility and economic attractiveness of solar repowering reheat steam turbine units using water/steam technologies. This approach provides EPE and other utilities with the technical and economic data necessary to support a decision to cost-share a demonstration program, or to initiate a commercial solar repowering program using water/steam technologies.

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 plant. A railway siding is located 10 km (6 miles) to the southeast. Newman is not directly beneath a Federal airway, although some aircraft fly over and south of the site.

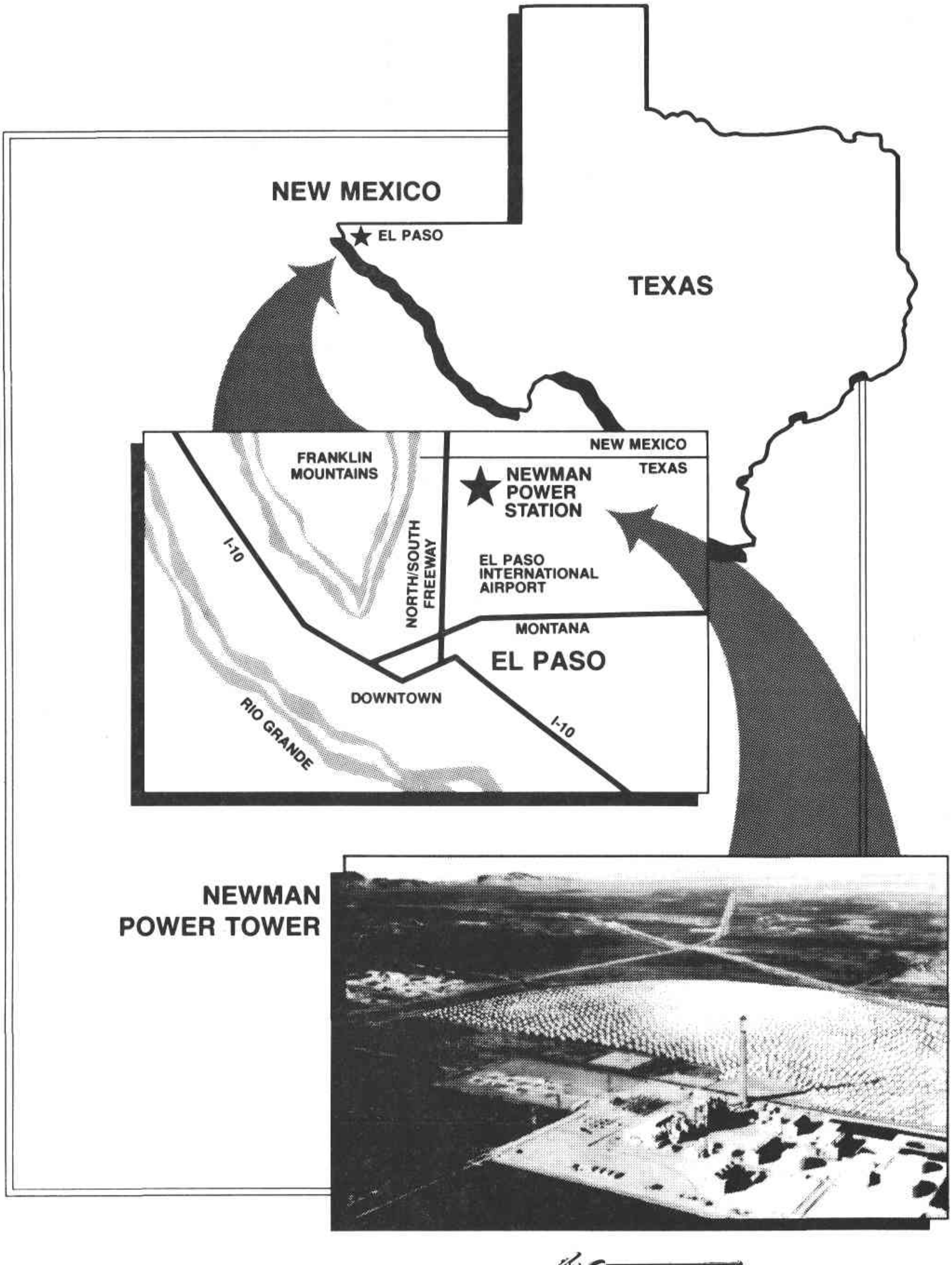


FIGURE 2.3-1
LOCATION OF NEWMAN STATION

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 V or larger on the Modified Mercalli 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 plant, Farm Road 2529 adjacent to the existing plant on the north side, McCombs Road to the east, and the large evaporation pond south of the plant. 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 is somewhat better due to its 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	0.4 km^2 (100 acres)
Latitude	31° 59'N
Longitude	106° 25'W
Elevation	4,069 feet (above mean sea level)
Owner	El Paso Electric Co.
Collector Field Site	
Location	North of Existing Site
Land Area	1.5 km^2 (370 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.

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 (one-half 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 teens. 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 a 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.

The air quality of El Paso is in violation of ambient air quality standards for several pollutants based on monitoring conducted in downtown El Paso. However, the air quality at the Newman site is somewhat better due to its location away from the city.

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)	107 (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.

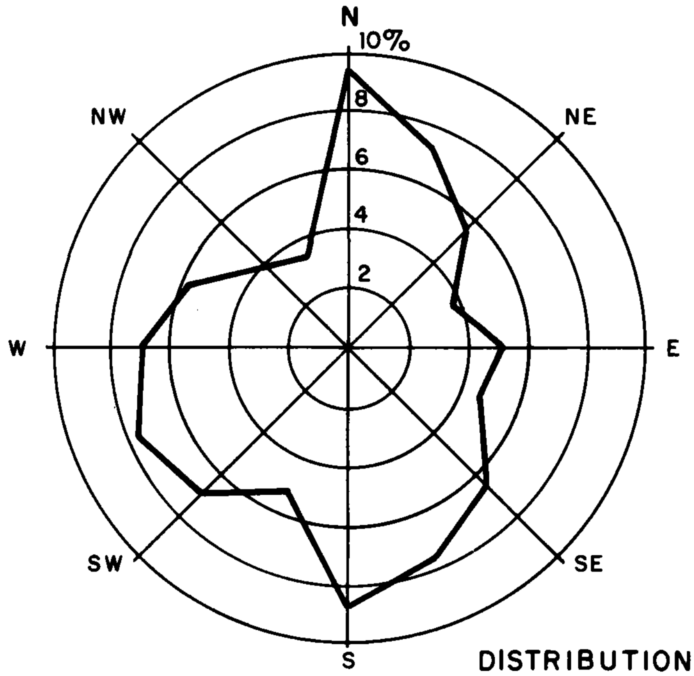
** T refers to trace

TABLE 2.5-2

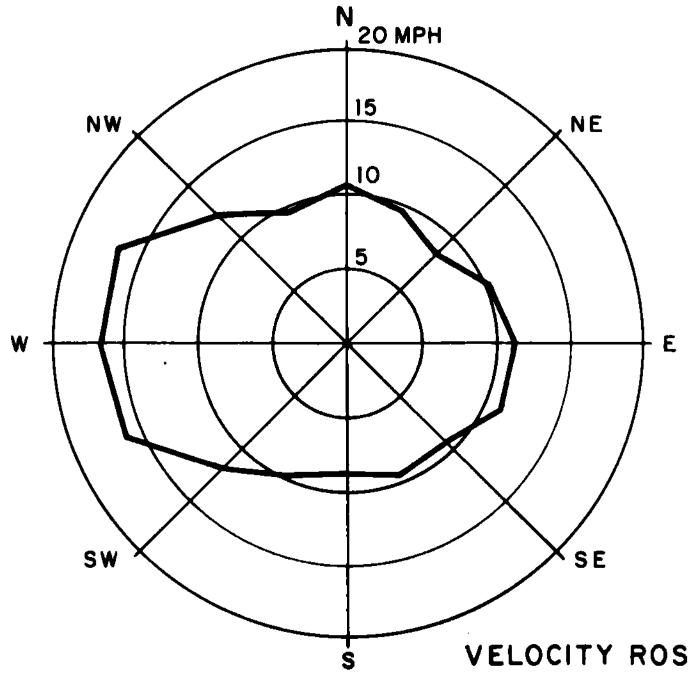
CLIMATOLOGICAL EXTREMES*

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 (70 mph)	May 1950

NOTE:



DISTRIBUTION ROSE
(CALM 1.4%)



VELOCITY ROSE

FIGURE 2.5-1
EL PASO WIND ROSES

2.6 EXISTING UNIT DESCRIPTION

This section reviews the most important characteristics of the Newman Unit 1 boiler, turbine-generator, and control systems that could be modified when a solar repowering system is added to an existing unit. Other pieces of equipment and systems are discussed as appropriate. Figure 2.6-1 illustrates the existing Newman Station. Construction of the unit was completed in 1960.

2.6.1 Boiler

Boiler design and operating constraints are summarized in the following sections.

2.6.1.1 Boiler Design

The existing boiler at Newman Unit 1 has a pressurized water-cooled radiant furnace, a two-stage drainable type superheater, and a drainable reheater and was fabricated by Babcock & Wilcox. The steam generator is designed to burn natural gas. The boiler was refitted in 1962 to allow residual fuel oil firing for limited periods of time under manual control. Experience with operating the unit on oil has been very limited, and further modifications will be required to allow operating on oil as a primary fuel. Water is circulated in the boiler by natural convection.

The nominal full load superheater steam flow conditions are 254,000 kg/hr (560,000 lb/hr) with 10.5 MPa (1,510 psig) and 538°C (1,000°F) at the superheater outlet and 538°C (1,000°F) at the reheater outlet. The steam generator is capable of a maximum continuous superheater steam flow of 257,100 kg/hr (567,000 lb/hr).

The two-stage superheater has a total effective heating surface of 1,227 m^2 (13,205 ft^2). Water spray attemperators for final steam temperature control are located in the connecting pipes between the two stages. Superheater temperature is controlled by selection of burners and by attemperation at high loads.

The reheat section has a total effective heating surface of 644 m^2 (6,930 ft^2). Spray type attemperators are located in each low temperature reheat steam line just upstream of the reheat inlet header connections. Reheat temperature is controlled by varying excess air and by attemperation at high loads.

The economizer has a total effective heating surface of 1,519 m^2 (16,350 ft^2) to absorb heat from the flue gas as it leaves the superheater primary section.

The boiler design is illustrated in Figure 2.6-2.

2.6.1.2 Boiler Operation

Boiler operation is discussed in terms of temperature, pressure, load variations, startup, and banking.

2.6.1.3 Steam Outlet Temperature

Boiler performance has exceeded predicted design values for steam temperature at partial unit loads.

The boiler was designed to maintain a superheat steam temperature of 538°C down to about half-load 510°C (126,980 kg/hr steam flow). Based on design data, a temperaure of 510°C can be attained at 40 percent load (104,310 kg/hr); and a temperature of 482°C can be attained at 26 percent load (86,170 kg/hr).

Based on design information, reheat steam temperature can be maintained at 538°C down to about two-thirds load (169,160 kg/hr). A reheat temperature of 510°C can be attained at 55 percent load (140,590 kg/hr). A reheat temperature of 482°C can be attained at 48 percent load (122,450 kg/hr).

However, EPE plant operating personnel estimate that the full superheat temperature (538°C) can be maintained down to turbine-generator minimum load (automatic control) through burner selection and increased excess air.

2.6.1.4 Steam Pressure

Required steam pressure at the turbine steam throttle valves is maintained in accordance with steam demand by the pneumatically operated combustion control system which proportions the amount of air and fuel for maximum combustion efficiency. Changes in main steam flow to the turbine are accompanied by changes in steam pressure. Following an initial steam pressure change, the master pressure regulator automatically restores the steam pressure to the set value of 10.1 MPa (1,450 psig) by appropriately adjusting the furnace firing rate with proper pneumatic signals to the forced draft fan inlet vane control drive and the fuel gas (or oil) control valve.

A safety valve mounted on the main steam piping is set to blow at 11.1 MPa (1,590 psig) and reseat at 10.8 MPa (1,545 psig) to protect the superheater and main steam piping. Safety valves are located upstream and downstream of the reheat section. The outlet header safety valve is set to blow at 3.7 MPa (517 psig) and reseat at 3.5 MPa (500 psig).

2.6.1.5 Boiler Startup and Load Change Capability

According to estimates by EPE operating personnel at Newman Unit 1, the maximum boiler ramp rate (percent per minute rate of increase or decrease in steam flow, measured as a percent of rated steam flow) above minimum load (23 MWe) is estimated to be about 10-20 percent per minute.

The boiler should only be ramped at the 20 percent/minute rate during emergency conditions, but up to 10 to 20 occurrences per year are considered acceptable.

The boiler is capable of a maximum continuous superheater steam flow of 257,140 kg/hr (567,000 lb/hr). The minimum automatic operating level of the boiler is about 88,890 kg/hr (196,000 lb/hr) steam flow based on a turbine-generator output of about 23 MWe.

2.6.1.6 Startup and Standby

Warming the boiler and turbine from a cold (shutdown) condition to the minimum automatic operating level (88,890 kg/hr steam) requires burning approximately 2,830 m^3 at 16°C (100,000 scf) of natural gas, about 106 x 10^6 kJ (100 M Btu) over a 4 hour period. This warmup period is necessary to gradually increase boiler drum temperature and avoid damage due to thermal stresses.

The boiler can be "banked" at warm standby (316-371°C) following the 4 hour warmup period for an overnight period. Neglecting losses during standby, about 63.3 x 10^6 kJ (60 x 10^6 Btu) are required for initial warmup, and 42.2 x 10^6 kJ (40 x 10^6 Btu) to bring the unit to the minimum automatic controlled load of 23 MWe.

Following operation, the boiler can be banked at a hot standby (427-482°C) overnight. An estimated 15.8 x 10^6 kJ (15 x 10^6 Btu) are required to return the unit to the minimum automatic controlled load of 23 MWe.

2.6.1.7 Boiler Efficiency

The boiler efficiency varies slightly with different unit loads. Values of estimated boiler efficiency are shown at five loads on Table 2.6-1. These values were predicted based on boiler design information provided by the manufacturer. Actual boiler performance at full and part load has shown higher boiler efficiencies.

2.6.2 Turbine-generator

The major design features and operating limitations of the Newman Unit 1 turbine-generator are described in the following sections. A cross section of the turbine-generator is shown in Figure 2.6-3.

2.6.2.1 Design

The 75 MWe (nominal) Allis-Chalmers steam turbine-generator unit was designed to deliver 82 MWe continuously at 3,600 rpm. The tandem-compound, double-flow construction steam turbine is designed for throttle steam conditions of 10.1 MPa (1,450 psig), main steam temperature of 538°C (1,000°F), reheat temperature of 538°C (1,000°F), and 5.07 kPa (1.5 inches Hg) absolute backpressure.

The steam turbine is arranged for a single exhaust connection to the condenser and for extraction of steam at five points for feedwater heating and deaeration.

Two main steam stop valves are mounted on the front of the steam chest which is separate from the turbine proper. The steam chest contains six control valves with six inlet bend connecting pipes to the high pressure turbine. Two reheat intercept valves and two reheat stop valves are also included.

A turbine mechanical-hydraulic control system includes a hydraulic oil relay type constant speed governor. A steam chest control valve gear is automatically controlled from the load limit device and operating governor. The load limit is manually operated.

The alternating current generator is rated at 96,000 kVA, 0.85 power factor (lagging), 13,800 V, 3 phase, 60 Hz, 3,600 rpm, 4,017 amp per phase at 0.31 MPa (30 psig) hydrogen pressure.

2.6.2.2 Operation and Limitations

The performance of the turbine-generator and operating limitations associated with flow, temperature, and pressure are described in the following sections.

2.6.2.3 Performance

The turbine is designed to give the lowest heat rate when carrying a load of 81.5 MW at 85 power factor, 0.31 MPa (30 psig) hydrogen pressure, with an exhaust pressure of 5.07 kPa (1.5 inches Hg), and with steam extracted from the five extraction points to provide temperature of 235.7°C (456.3°F) for the feedwater leaving the first point heater.

The overall efficiencies of the generator and exciters are summarized in Table 2.6-2.

2.6.2.4 Temperature Limitations

The steam temperature at the turbine main stop valve shall average not more than 538°C (1,000°F) over any 12 month operating period. In maintaining this average, the temperature shall not exceed 546°C (1,015°F). For abnormal conditions, maximum temperature shall be limited to 552°C (1,025°F) for operating periods of not more than 400 hours for a 12 month period. In addition, steam temperature may rise to 566°C (1,050°F) for a 15 minute duration or less, aggregating not more than 80 hours per 12 month operating period.

The turbine may be operated with one reheat valve closed as long as the pipe metal temperature differential between the operating and isolated reheat steam headers is maintained at or below 10°C (50°F).

During startup, it is recommended that the exhaust temperatures be kept below 66°C (150°F) by increasing exhaust vacuum or by using water sprays in the exhaust ends.

2.6.2.5 Pressure Limitations

The steam pressure at the turbine main stop shall be controlled so that it does not exceed 10.1 MPa (1,450 psig) at rated output, but it may increase to 10.6 MPa (1,523 psig) as the turbine output approaches zero. During abnormal conditions, the pressure may rise to 13.1 MPa (1,885 psig) momentarily, but the aggregate duration of such swings shall not exceed 12 hours per 12 month operating period.

2.6.2.6 Load Limitations

The allowable rate of load change is based upon the measurement of metal temperatures at certain critical areas of the turbine. The turbine generator is equipped with metal temperature thermocouples located at the high pressure cylinder, reheat bowl of the combined high pressure - intermediate pressure cylinder, low pressure cylinder exhaust hood, steam inlet bends, and the steam chest.

Rate of loading the unit should be controlled in order that the following conditions are not exceeded:

Condition	Temperature Limit
Rate of metal temperature increase	149°C (300°F) per hour
Temperature differential between outer cylinder wall and cylinder flange, outer surface:	
(a) HP Turbine	93°C (200°F) differential
(b) IP Turbine	66°C (150°F) differential
Temperature differential	66°C (150°F) differential

between cylinder flange and corresponding bolt

Rapid metal temperature change allowed providing the new temperature is held constant for 1/2 hour before further changes — 38°C (100°F)

2.6.3 Boiler and Turbine Control Systems

The following sections describe the design philosophy and key design features of the control systems at Newman Unit 1.

2.6.3.1 Design Philosophy

The Newman 1 control system was designed for baseload operation, with automatic control available for loads as low as 23 MWe. Mechanical-hydraulic turbine controls interact with pneumatic boiler combustion controls in a boiler-following control mode. The boiler-following unit control concept is illustrated in Figure 2.6-4. A boiler following unit control scheme is one where the load is set at the turbine controls and the boiler controls react to maintain required steam pressure. This type control system is intended for units that are primarily baseloaded and change load gradually and infrequently.

2.6.3.2 Turbine Control System

Important elements of the turbine control system include the governing system, turbine steam valves, turbine trip system, and the load limit control and speed changer.

2.6.3.3 Governing System

The governing system consists of a main governor, an overspeed governor, and a load dump anticipator.

The turbine main governor is a centrifugal type, gear driven from the main turbine shaft. Decrease in generator load during normal operating conditions is maintained by increase in turbine shaft speed. Under these conditions, the governor causes the inlet valves to partially close and throttle steam flow. In the event of a generator load increase, which results in a turbine-generator shaft speed decrease, the governor and servomotor react in an opposite manner so as to open the steam inlet valves.

The overspeed governor is set to trip the machine at 110 percent of rated speed.

The load dump anticipator acts to close the reheat intercept valves and main inlet (control) valves to a position slightly in exceess of that required to carry the station auxiliary load.

The speed governor assumes control of the intercept valves to hold speed and closes the intercept valves if the speed is in excess of 101 percent. A roll-back relay operates the speed changer motor which closes the control valves to reduce turbine speed until the intercept valves open. This system is anticipatory by design to limit turbine overspeed when the main generator circuit breaker is tripped, in distinction from the two governors described above which operate when speed is already above normal.

2.6.3.4 Turbine Steam Valves

The main stop valves are opened by admitting stop valve control oil pressure which causes a piston to move the valve stem against a spring.

There are six plug type inlet (control) valves mounted in a steam chest separate from the turbine proper. A common cam shaft, also mounted on the steam chest, has a separate cam for each inlet valve. These individual cams open and position the spring-loaded inlet valves, as required by turbine load, as a function of main cam shaft position. A mechanical linkage connects the main cam shaft to the controls and governor. When the turbine is carrying load, the inlet valves are positioned by manual manipulation of the load limit control.

There are two reheat intercept valves: one located in each of the parallel high temperature reheat steam lines and immediately upstream of the reheat stop valves. Each intercept valve is a single seated globe type valve opened by the intercept valve operating oil pressure. If the reheat stop valves close because of a decrease in trip oil pressure, this closes the intercept valves automatically.

The intercept valves are wide open during normal turbine operation. Upon sudden load rejection, the turbine starts to increase shaft speed and the main governor reacts and causes the valves to begin to close. At 101 percent of normal speed, the intercept valves start to close and are fully closed at 103 percent speed. As the turbine shaft speed increases, the control system continues to close the intercept valves until the valves are tightly closed at approximately 103 percent of normal speed. If the shaft speed starts to decrease back toward normal operating speed before the intercept valves are completely closed, the control system reverses the action described above and opens the valves. There are two reheat stop valves: one in each of the two parallel high temperature reheat steam lines located just downstream of the reheat intercept valves. The stop valves are of an unbalanced, wing check type, opened by trip oil pressure. Loss of trip oil pressure closes the reheat stop valves.

2.6.3.5 Turbine Trip System

The turbine-generator unit is or can be tripped by the following:

- Manual trip button in control room
- Manual trip button on starting panel at front of machine
- Automatic trip on low condenser vacuum (18 inches hg abs)
- Automatic trip by solenoid valve
- Automatic trip by overspeed governor

The means for tripping the turbine is to drain oil back to the turbine oil tank which then permits the springs to close the main steam stop valves, reheat stop valves, and reheat intercept valves.

The vacuum trip mechanism is provided for the purpose of tripping the turbine upon loss of vacuum.

The solenoid trip can be actuated by the following:

- Boiler trip auxiliary relay
- Unit and generator differential relay
- Generator ground auxiliary relay
- Loss of field relay
- Negative phase overcurrent relay
- Control room benchboard mounted pushbutton
- Low relay oil pressure

The manual trip button on the turbine starting panel actuates the solenoid trip by a mechanical linkage.

The primary function of the boiler trip relay is to protect the reheater. The relay operates to trip the fuel to the boiler on load rejection if the turbine inlet (control) valves stay in the no-load position for more than 10 seconds. The relay operates instantaneously when the turbine main steam stop valves close. For operation of the unit at light loads and during startup, a setup circuit is provided that automatically puts the boiler trip relay in service after the unit reaches approximately 20-50 percent load. The boiler trip relay can be manually tripped by a control room benchboard pushbutton.

When the unit is tripped and after the intercept valves close, steam remains "bottled up" in the intermediate and low pressure sections of the turbine. To limit shaft acceleration due to this steam leaking through the shaft seals from the intermediate pressure to the low pressure turbines, a reheat diaphragm unloading valve and a balanced piston loading valve are provided. They discharge the steam to the main condenser.

2.6.3.6 Load Limit Control and Speed Changer

The load limit control is normally used to limit the maximum load to be carried on the unit and, as such, it is set at a load greater than the operating point or expected range. The load limit control may also be used to maintain a specific load on the unit and, at such times, the main governor does not act as a regulator and load increases cannot be made at the control board. The load limit device is a control oil flow regulator between the control oil supply from the main governor to the main servomotor which controls the inlet valves. The load limit device is operated from the starting panel at the front of the machine and the setting is indicated by a dial indicator above the control knob.

The load limit control is also used when starting the turbine and bringing it up to speed prior to loading the generator.

The speed changer can be controlled from either the knob on the starting panel at the front of the machine or by a control switch on the control room benchboard.

2.6.3.7 Boiler Control

The primary functions of the pneumatically operated combustion control system is to maintain required steam pressure at the turbine steam throttle valves by proportioning the fuel-air supply in accordance with steam demand for maximum combustion efficiency. Additional control functions include control of superheat and reheat temperture, and feedwater flow.

2.6.3.8 Steam Pressure Control

Changes in main steam flow to the turbine are accompanied by changes in the steam pressure. Following an initial steam pressure change, the master pressure regulator (sensitive to the pressure of steam to the turbine throttle) automatically restores the steam pressure to the set value of 10.1 MPa (1,450 psig) by appropriately adjusting the furnace firing rate with proper pneumatic signals to the forced draft fan inlet vane control drive and to the fuel gas control valve. The pneumatic signal to the former is biased as necessary by the fuel-air ratio controller to maintain the maximum combustion efficiency. However, the fuel-air ratio controller in turn may be biased slightly also by the excess air adjustment relay to alter fuel-air ratio for maintaining desired reheater outlet steam temperature.

2.6.3.9 Fuel-Air Ratio Control

The fuel-air ratio control receives pneumatic signals from the air flow transmitter and from the gas flow transmitter. The pneumatic signal from the air flow transmitter may be biased by another pneumatic signal from the reheat steam temperature control, prior to its being received by the fuel-air ratio control.

The fuel-air ratio control sends a pneumatic signal to bias the signal sent from the master pressure regulator to the forced draft fan inlet vane control drive, to provide for maximum combustion efficiency consistent with excess air alterations required for satisfactory reheat steam temperature control.

2.6.3.10 Fuel Control

Fuel flow to the burners is measured by a flowmeter which actuates a pneumatic transmitter. Signals from this transmitter are sent to the fuel-air ratio controller, the fuel gas flow recorder, and to a Standatrol relay installed in the pneumatic signal loading line from the master pressure regulator to the fuel gas control valve. The purpose of this relay, which also receives a pneumatic loading signal from the air flow transmitter, is to pevent the fuel-air ratio from rising to a dangerous value which could happen if the air flow was suddenly decreased to or near zero. This relay would cause the fuel flow to follow the air flow down, preventing the formation of a dnagerously rich fuel-air mixture and resulting in a hazardous conditions.

To prevent the occurrence of a dangerously lean mixture, a fuel minimum flow control valve is installed in parallel with the aforementioned fuel control valve. Should the fuel control valve be closed sufficiently so that the fuel pressure downstream becomes too low for stable combustion in the furnace, the fuel minimum flow control valve opens to maintain a minimum downstream fuel pressure sufficient to prevent the burners from losing ignition.

2.6.3.11 Air Flow Control

As mentioned under steam pressure control, air flow to the boiler is controlled by the forced draft fan inlet vane control drive which responds to a pneumatic signal received directly from the master steam pressure regulator. However, this pneumatic signal passes through a limiting relay which also receives a pneumatic signal indicating fuel flow. This limits the minimum signal to the forced draft fan to match minimum gas flow. Should, on an increase in boiler load, the fuel flow not respond (within limits) as quickly as required, the pneumatic signal to the forced draft fan vane positioner is delayed to maintain a safe fuel-air ratio for preventing blowing out the furnace burners.

2.6.3.12 Superheat Temperature Control

With steam flows greater than half-load, measures must be taken to limit the final steam temperature to the maximum design value of 541°C (1,005°F).

- Selection of fuel burners to be used.

- Attemperator sprays in the connecting pipes between the primary and secondary superheater sections.

Use of the lower two or three burner rows at any steam flow tends to increase furnace heat absorption in relation to other heating surfaces and have a resultant effect on lowering final superheat temperature. Conversely, at loads below half-load, firing the upper row or two rows of burners as required helps to increase final superheat temperature.

At high loads the total steam temperature leaving the superheater cannot be controlled by burner position alone and attemperator sprays must be used.

2.6.3.13 Reheat Temperature Control

The reheater is designed to produce a final steam temperature of 541°C (1,005°F). Attemperator sprays located in the low temperature reheat steam lines just ahead of the connections to the inlet header are provided. Water to the attemperators is taken from the fourth stage of the boiler feed pumps. At low steam flows, steam temperature can be maintained at or near 541°C (1,005°F) by increasing the percentage of excess combustion air.

2.6.3.14 Feedwater Control

The flow of feedwater, to maintain proper boiler drum level and provide for steam flow requirements, is regulated by a three-element type controller. This control directs the operation of the two feedwater regulating control valves, one in each of the boiler feed pump discharge lines.

2.6.4 Feedwater System

The feedwater system includes the condensate pumps, steam air jet ejector condenser, gland steam seal condenser, five stages of feedwater heaters, evaporator condenser, and boiler feed pumps.

At full turbine load, the feedwater temperature is raised to approximately 236°C (457°F) and pressure is raised to approximately 11.0 MPa (1,600 psia). The flow of feedwater, to maintain proper boiler drum level and provide for steam flow requirements, is regulated by a three-element type controller.

2.6.5 Condensing and Circulating Water Systems

The circulating water system includes two circulating water pumps which discharge cooling tower basin water through the condenser back to the cooling tower. The cooling tower is a cross-flow induced draft type with five cells. Circulating water makeup is supplied from the well water tank or the well water supply line to the tank. Cooling water for the generator hydrogen coolers and turbine oil coolers is supplied from the circulating water system.

2.6.6 Compressed Air Systems

All pneumatic instrument and control equipment is supplied by the instrument compressed air system which includes a single-stage, double-acting horizontal reciprocating compressor, aftercooler, moisture separator, air receiver, and air dryer. The air compressor is rated at 0.04 m^3/sec (80 scfm) and 791 kPa (100 psig). When instrument air pressure drops to 550 kPa (65 psig), service air is directed to the instrument compressed air system to ensure system requirements.

The service air system supplies compressed air for furnace door aspiration, blowing out fuel gas lines, and for general housekeeping purposes. The compressor is a two stage double-acting reciprocating unit capable of furnishing 0.2 m^3/sec (450 scfm) at 791 kPa (100 psig).

2.6.7 Chemical Feed System

During normal operation, phosphate and caustic are supplied to the boiler drum and sulfite is delivered to the economizer feed line. Sulfite is an oxygen savenger used to minimize corrosion of the economizer tubes. Phosphate is fed to prevent scaling of the heating surfaces in the steam generator by precipitating any residual hardness which may be present in the feedwater. A sludge is formed which is removed via the continuous boiler blowdown line. Caustic is injected to control the alkalinity and pH of the boiler water in order to minimize the metal embrittlement of boiler surfaces and tubes.

Magnesium oxide is injected into the boiler drum during startup to combine with silica and form a magnesium silicate which is discharged through the boiler blowdown line.

2.6.8 Electrical System

Newman Unit 1 generator is rated 96,000 kVA, 13.8 kV, 0.86 Pf, 3 phase, 60 Hz, and is directly connected to a bus in the 115 kV switchyard through a 95,000 kVA, FOA, 115 13.8 kV step-up main transformer. The generator is also directly connected to a 5,000 kVA, OA, 13.8 kV/2.4 kV station service transformer which is the normal source of 2,400 V station power for the unit.

Startup station power is supplied from the 115 kV switchyard through a 6,000/7,500 kVA, OA/FA, 115/2.4 kV, reserve station service transformer connected to the 2,400 V station service bus through an air circuit breaker. The reserve station service transformer 2,400 V secondary is also connected to the Unit 2 2,400 V station service bus through an air circuit breaker thereby providing an alternate startup power source for Newman Unit 1.

The 2,400 V station service system comprises a 2,400 V bus with feeder air circuit breakers rated 4.16 kV, 100,000 kVA interrupting capability at 2,400 V, and 40,000 amperes momentary. These supply power to large 2,400 V motors and to two 2,400/480 V station service transformers, one rated 300 kVA and the other 500 kVA. The transformers supply lighting, heating and ventilating, small motor, and all other low voltage loads associated with Newman Unit 1.

2.6.9 Fire Protection System

A fire protection system is provided for the general yard areas including the area adjacent to the cooling tower. The system consists of 20.3 cm (8 inches) underground main along the north side and east and west ends of the Newman Station. Water pressure to the system is boosted by a fire pump. Hydrants and hose stations are located at various points throughout the yard. The Newman Unit 1 main transformer, station service transformer, and the reserve station service transformer are provided with individual water spray systems.

TABLE 2.6-1

VARIATION OF UNIT HEAT RATE AND BOILER EFFICIENCY AS A FUNCTION OF LOAD

Gross Generation, MWe	Net Unit Output, MWe	Net Unit Heat Rate KJ/kWhr (Btu/kWhr)	Boiler Efficiency, %	Superheat Temp °C (°F)	Reheat Temp °C (°F)
83.1	79.6	10,799 (10,235)	84.4	538 (1,000)	538 (1,000)
79.2	75.7	10,778 (10,215)	84.4	538 (1,000)	538 (1,000)
55.2	52.1	11,110 (10,530)	84.1	538 (1,000)	538 (1,000)
41.1	38.2	11,706 (11,095)	84.1	538 (1,000)	491 (915)
22.7	20.4	13,737 (13,020)	84.2	477 (890)	413 (775)

Basis: Gas firing

6,800 Pa (2.0 inch Hg) condenser backpressure

NOTE:

Maximum net unit output is 82 MW.

TABLE 2.6-2

OVERALL EFFICIENCY OF GENERATOR AND EXCITERS AS A FUNCTION OF LOAD

Hydrogen MPa	Pressure Psig	kVA	kWe	Pf (Lagging)	Percent Efficiency
0.10	0.5	23,529	20,000	0.85	96.90
0.10	0.5	47,059	40,000	0.85	97.91
0.10	0.5	70,588	60,000	0.85	98.23
0.10	0.5	76,800	65,280	0.85	98.31
0.10	0.5	76,800	76,800	1.00	98.63
0.20	15	88,320	75,072	0.85	98.12
0.31	30	96,000	82,560	0.86	97.98

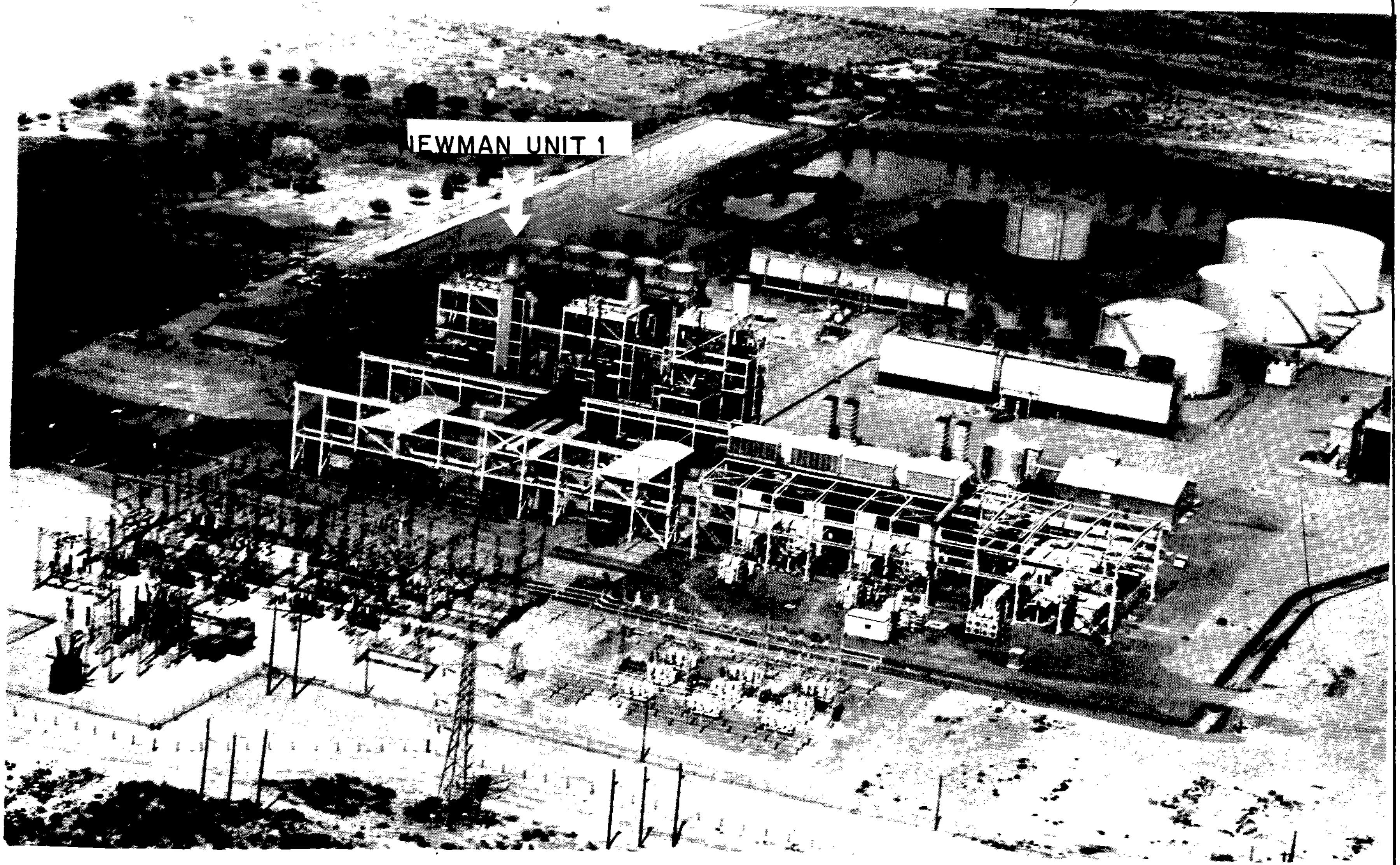


FIGURE 2.6-1
NEWMAN STATION UNITS 1-4

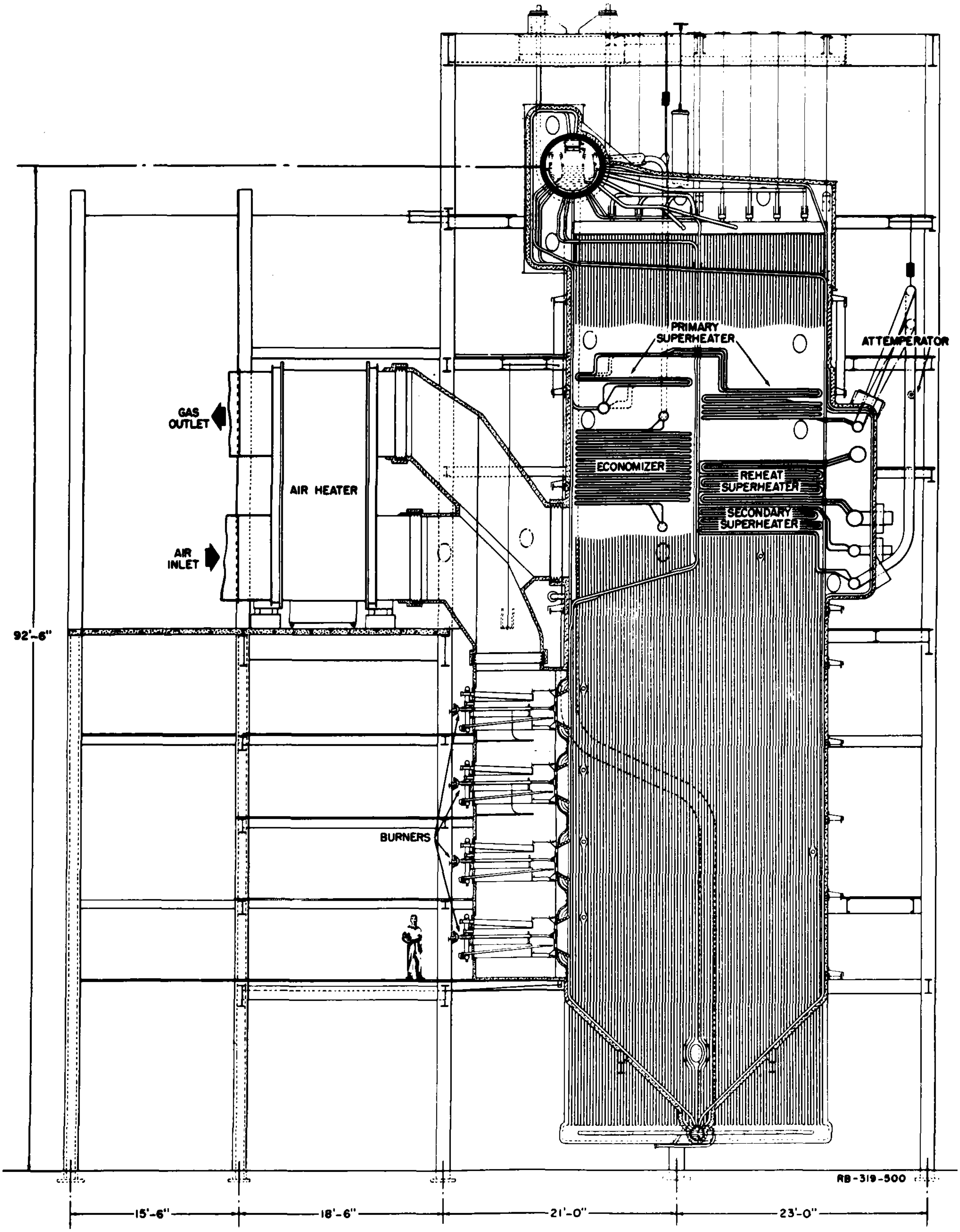


FIGURE 2.6-2
BOILER CROSS-SECTION

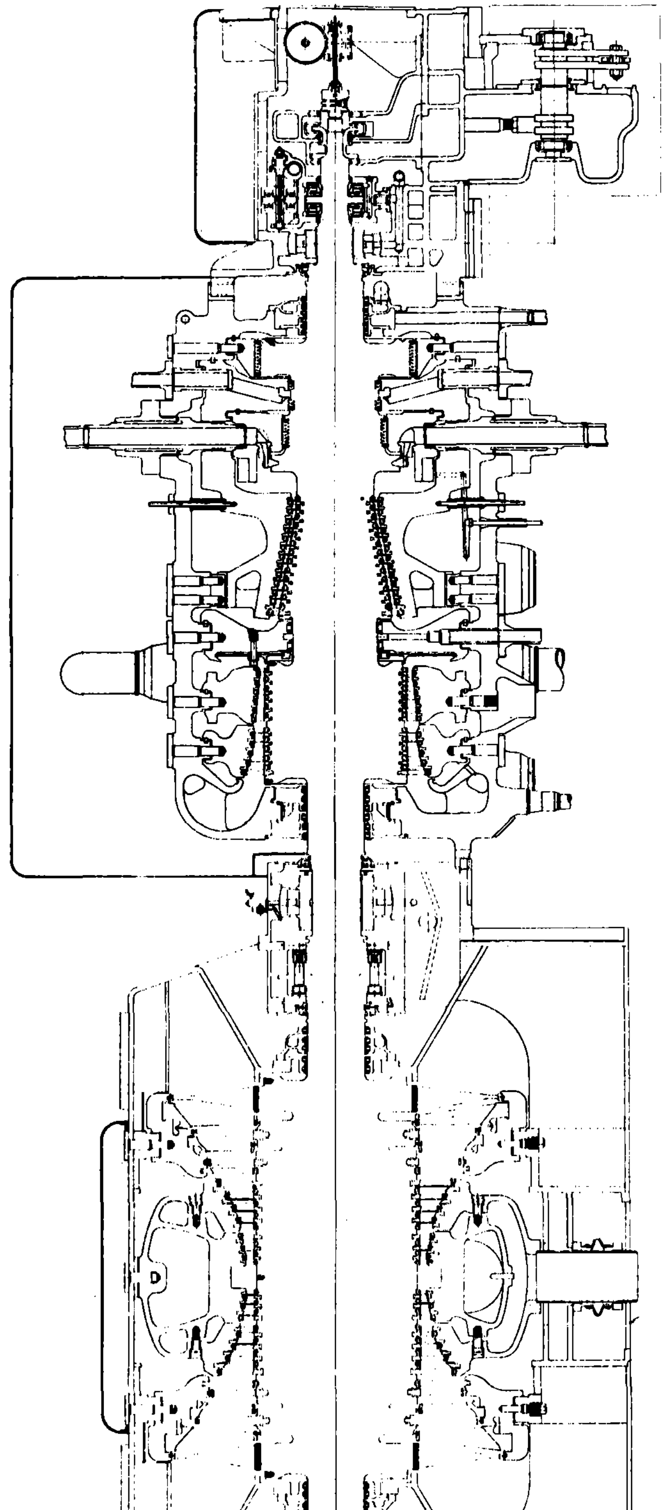


FIGURE 2.6-3
TURBINE CROSS-SECTION

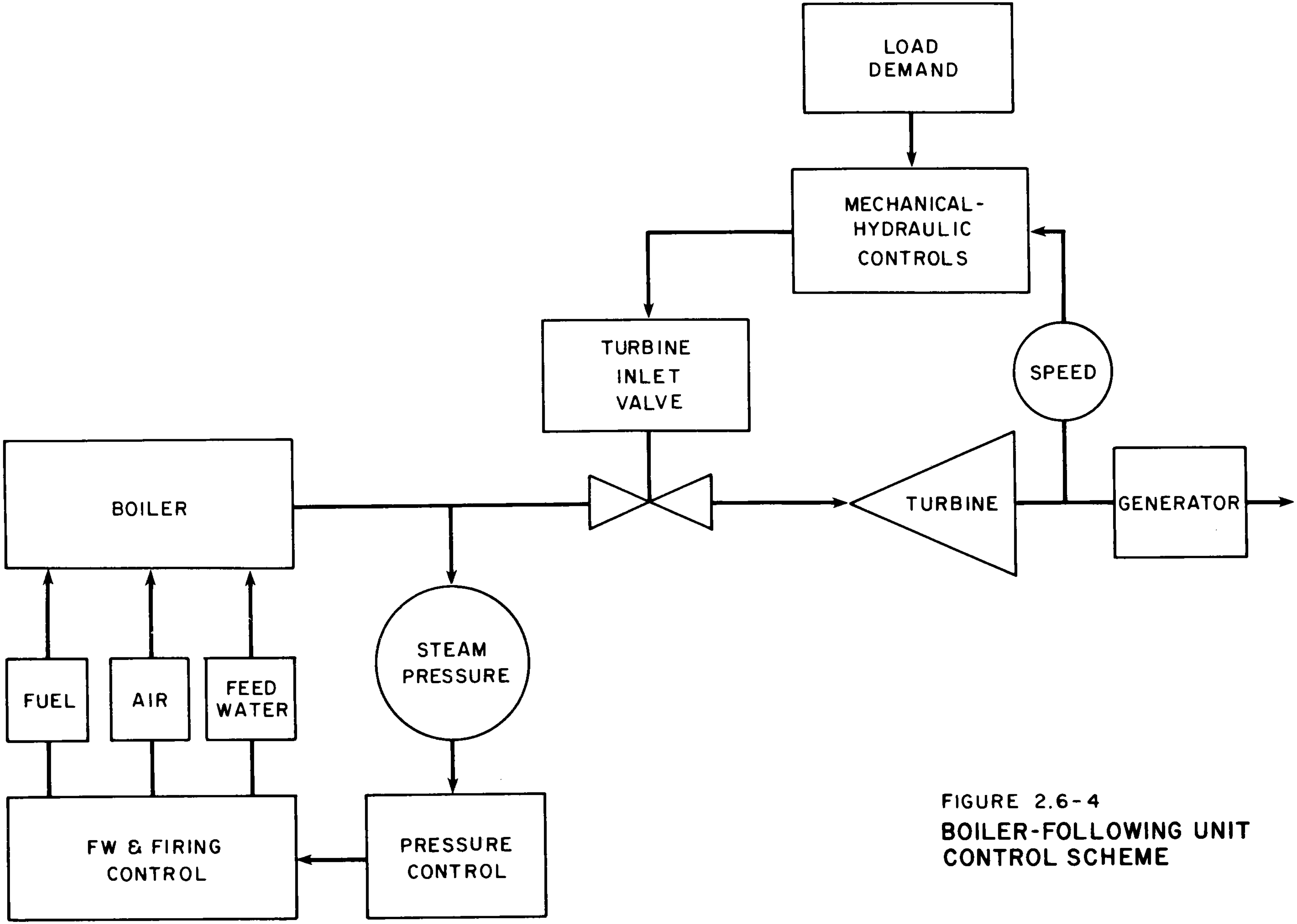


FIGURE 2.6-4
BOILER-FOLLOWING UNIT CONTROL SCHEME

2.7 EXISTING UNIT PERFORMANCE SUMMARY

This section summarizes the characteristics and performance of Newman Unit 1.

2.7.1 Unit Characteristics

Newman Unit 1, currently an intermediate load unit, operated approximately 70 percent of 1979 with a 46 percent capacity factor. Last year the unit had a scheduled outage rate of 4.4 percent, and a forced outage rate of 6.9 percent. The major forced outage in 1979 was due to a failure of a segment of the main steam line. Operating and maintenance costs (excluding fuel) for 1979 are estimated to be $383,000.

Newman Unit 1 consists of a 75,000 kW (nameplate) tandem-compound reheat turbine-generator and a 254,000 kg/hr (560,000 lb/hr) steam generator. This unit currently generates 82 MW (net) at full load. Steam conditions at the turbine throttle are 10.1 MPa (1,450 psig) and 538°C (1,000°F) with 538°C (1,000°F) reheat. The steam generator is designed to burn natural gas and occasional fuel oil.

The electrical output of the unit 96,000 kVA generator is delivered to the EPE system through a 95,000 kVA FOA 13.8/115 kV step-up transformer to the 115 kV substation transformer.

Table 2.7-1 summarizes the design conditions of the plant components at maximum unit capability.

2.7.2 Unit Performance

The original plant design heat balances at 83 MW gross and approximately half unit capability (41 MW gross) are presented in Figures 2.7-1 and 2.7-2, respectively. Actual performance indicates that the maximum unit gross output is 86 MWe versus 83 MWe . The design heat balance for 41 MWe shows the reheat temperature at 491°C (915°F) due to the lower burner firing rate. In actual operation at low loads, the reheat is maintained at 538°C (1000°F) by increasing the excess air to the boiler.

Table 2.6-1 summarizes the calculated unit heat rates, boiler efficiencies, and superheat and reheat temperatures at various loads. Overall efficiency of the generator and exciters as a function of load are tabulated in Table 2.6-2. Tests will be conducted during the solar repowering system design phase to update the performance of the unit and the values given in Tables 2.6-1 and 2.6-2.

TABLE 2.7-1

STATION DESIGN SUMMARY AT MAXIMUM UNIT CAPABILITY

Turbine-generator*		
Generation, kW (gross)	83,110	
Generation, kW (net)	79,585	
Steam at main stop valves		
Pressure, MPa (psig)	10.1	(1,450)
Temperature, °C (°F)	538	(1,000)
Steam at reheat intercept valves		
Pressure, MPa (psig)	2.9	(425)
Temperature, °C (°F)	538	(1,000)
Extraction pressures, MPa (psia)		
1st point (15th stage)	3.1	(452)
2nd point (21st stage)	1.2	(181.1)
3rd point (26th stage)	0.5	(79.3)
4th point (30th stage)	0.2	(24.7)
5th point (33rd stage)	0.05	(7.4)
Condenser vacuum, kPa (in Hg abs)	6.8	(2.0)
Flows, Kg/hr (lb/hr)		
To turbine main stop valves	256,800	(567,000)
To turbine intercept valves	230,500	(508,960)
1st point extraction	23,100	(51,110)
2nd point extraction	12,500	(27,570)
3rd point extraction[1]	12,600	(27,730)
4th point extraction	12,600	(27,750)
5th point extraction	11,200	(24,620)
To condenser	184,500	(407,370)
Circulating water to cooling tower, m^3/sec (gpm)	2.3	(36,800)
Steam Generator		
Steam flow at secondary superheater outlet, Kg/hr (lb/hr)	256,800	(567,000)
Drum pressure, MPa (psig)	11.1	(1,595)
Fuel gas consumed, m^3/hr (ft^3/hr)	21,200	(749,000)

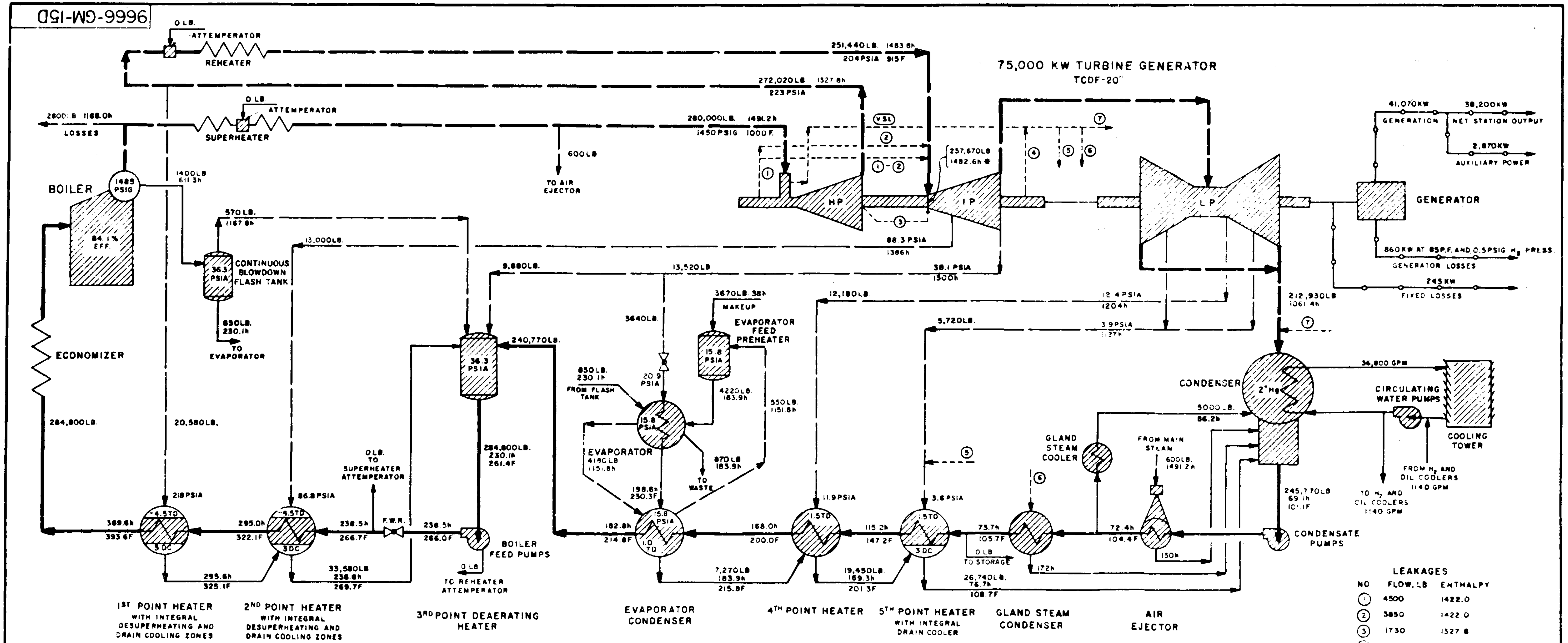
TABLE 2.7-1 (Cont)

Auxiliary Power		
Boiler feed pumps, condensate pumps, forced draft fan, circulating water pumps, cooling tower fans, air compressors, and miscellaneous, kWe	3,525	
Heat Rate (at 6.8 kPa, -Hg backpressure)		
Turbine heat rate, kj/kWhr (Btu/kWhr)	8,700	(8,290)
Station heat rate, kj/kWhr (Btu/kWhr)	10,800	(10,235)

NOTES:

* When operating at 0.87 power factor and 0.31 MPa (30 psig) H_2 pressure

1. Includes normal operation of evaporator to just makeup losses.



LEAKAGES

NO	FLOW, LB	ENTHALPY
1	4500	1422.0
2	3850	1422.0
3	1730	1327.8
4	320	1300.0
5	1570	1461.8
6	280	1324.0
7	220	1324.0
VSL	1750	1491.2

BASIS OF HEAT BALANCE CALCULATIONS

ELEVATION: PLANT IS APPROXIMATELY 4065 FEET ABOVE SEA LEVEL
AIR TEMPERATURE AVERAGE ANNUAL AMBIENT AIR TEMPERATURE IS 63.3F
FUEL NATURAL GAS
STEAM LOSSES 2800 LB, CONSTANT AT ALL LOADS
BOILER BLOWDOWN 0.5% STEAM GENERATION
BOILER EFFICIENCY ADJUSTED FOR ACTUAL INLET AIR TEMPERATURE AT 75.0
SUPERHEATER, REHEATER, MAIN AND REHEAT STEAM LINE PRESSURE DROPS CALCULATED AT ALL LOADS. REHEAT SYSTEM PRESSURE DROP EXPRESSED AS 8.5 PERCENT OF HIGH PRESSURE TURBINE EXHAUST PRESSURE AT THIS LOAD.
EXTRACTION LINE PRESSURE DROPS CALCULATED AT MAXIMUM LOAD AND EXPRESSED AS THE FOLLOWING PER CENT OF THE FLANGE ABSOLUTE PRESSURES FOR USE AT ALL LOADS

EXTRACTION LINE	1	2	3	4	5
PER CENT	2.2	1.7	4.8	4.0	6.4

EXTRACTION PRESSURES SHOWN AT OR NEAR THE TURBINE SYMBOL ARE TURBINE EXTRACTION FLANGE PRESSURES. PRESSURES SHOWN NEAR HEATER SYMBOLS ARE HEATER ENTRANCE PRESSURES
EVAPORATOR SYSTEM IS OPERATED TO REPLACE ESTIMATED STEAM AND WATER LOSSES FROM THE CYCLE BY THROTTLING COIL STEAM SUPPLY PRESSURE AS REQUIRED WITH SURFACE 50% CLEAN. EVAPORATOR BLOWDOWN QUANTITY BASED ON SOLIDS CONCENTRATIONS AS FOLLOWS EVAPORATOR SHELL, 3800 PPM; BOILER BLOWDOWN, 325 PPM; MAKEUP, 780 PPM.
WET BULB TEMPERATURES SHOWN ARE REQUIRED TO PRODUCE CORRESPONDING BACK PRESSURES WITH 36,800 GPM OF CIRCULATING WATER.
BASE HEAT BALANCE COMPUTED FOR 2"Hg BACK PRESSURE. ALL FLOWS, PRESSURES, TEMPERATURES AND ENTHALPIES REMAIN UNCHANGED FOR OTHER BACK PRESSURES, EXCEPT AS FOLLOWS: VALUES SHOWN IN TABLE, ENTHALPY AND TEMPERATURE OF CONDENSATE TO THE AIR EJECTOR, GLAND STEAM CONDENSER AND 5TH POINT HEATER, ENTHALPY AND TEMPERATURE OF DRAINS FROM 5TH POINT HEATER.

* INLET ENTHALPY OF IP TURBINE DETERMINED BY TURBINE MANUFACTURER'S PROCEDURE FOR HANDLING LEAKAGE 2

AUXILIARY POWER REQUIREMENTS ARE CALCULATED FOR ALL EQUIPMENT. THE MAJOR EQUIPMENT CONSIDERED IS AS FOLLOWS

REQUIREMENTS VARIABLE WITH CHANGE IN LOAD ON UNIT

EQUIPMENT	NUMBER OPERATING
2 BOILER FEED PUMPS	2
2 CONDENSATE PUMPS	1
1 FORCED DRAFT FAN	1
STATION SERVICE TRANSFORMER LOSS	

AVERAGE DAILY REQUIREMENTS, CONSIDERED CONSTANT AT ALL LOADS

EQUIPMENT	NUMBER OPERATING
1 INSTRUMENT AIR COMPRESSOR	1
1 SERVICE AIR COMPRESSOR	1
1 DEEP WELL PUMP	1
2 CIRCULATING WATER PUMPS	2
5 COOLING TOWER FANS	5

$$\text{TURBINE HEAT RATE} = \frac{3412.75(41{,}070+860+245)+212{,}930(1061.4-69.1)+26{,}740(76.7-69.1)+5000(86.2-69.1)+220(1324.0-69.1)}{41{,}070} = 8{,}665 \text{ BTU PER KWH}$$

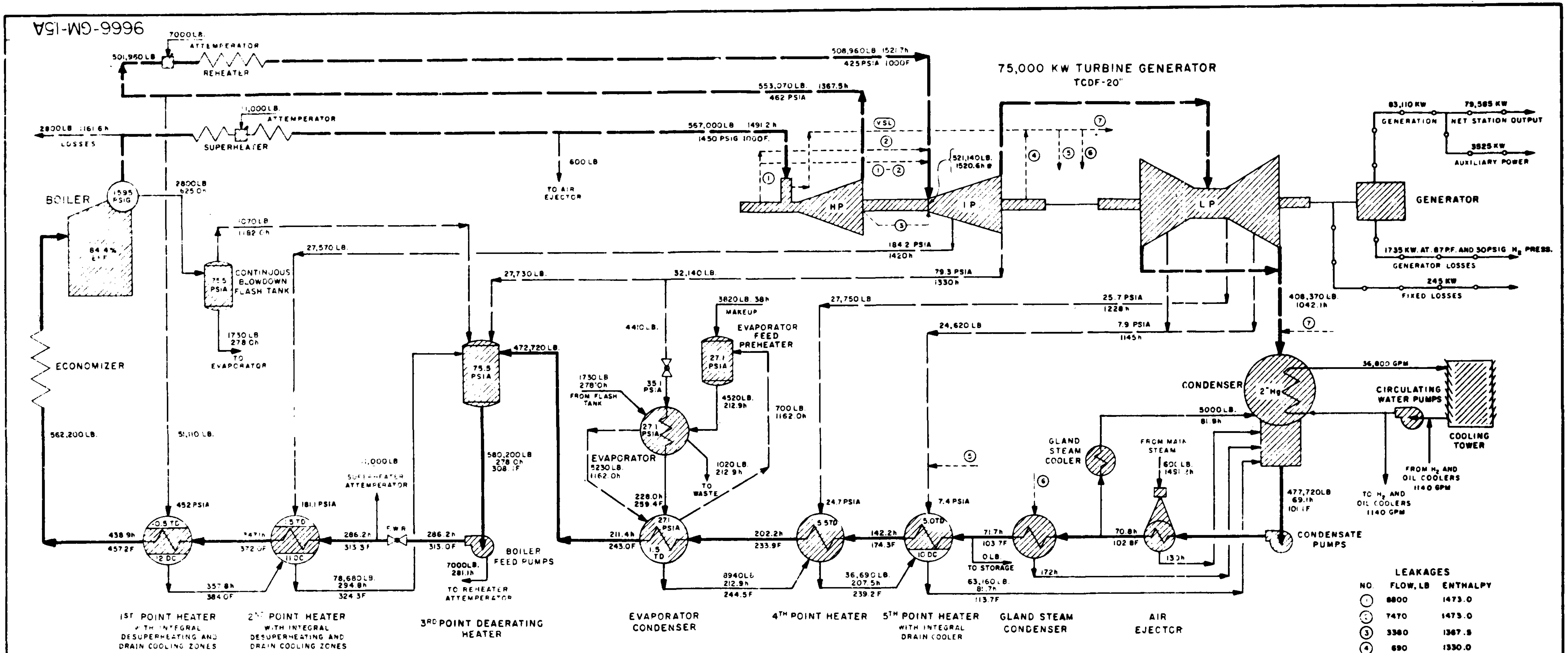
$$\text{STATION HEAT RATE} = \frac{280{,}600(1491.2-369.6)+2800(1168.0-369.6)+1400(611.3-369.6)+251{,}440(1483.8-1327.8)}{.841 \times 38{,}200} = 11{,}095 \text{ BTU PER KWH}$$

CONDENSER BACK PRESSURE "Hg	5TH POINT EXTRACTION FLOW LB	TURBINE EXHAUST FLOW LB	LPT END POINT ENTHALPY h	TURBINE EXHAUST ENTHALPY h	GENERATION KW	NET STATION OUTPUT KW	TURBINE HEAT RATE BTU/KWH	STATION HEAT RATE BTU/KWH	CIRC WATER TEMP F	WET BULB TEMP F
2.5	4,160	214,490	1064.5	1073.5	40,345	37,475	8820	11,310	94.0	—
2.0	5,720	212,930	1054.0	1061.4	41,070	38,200	8665	11,095	86.0	80.5
1.5	7,620	211,030	1040.0	1046.6	41,940	39,070	8485	10,850	77.0	69.0
1.0	10,110	208,540	1021.0	1030.9	42,830	39,960	8305	10,610	63.5	50.5

LEGEND

— —	STEAM
———	WATER
—o—	POWER, KW
LB	FLOW, POUNDS PER HOUR
h	ENTHALPY, BTU PER POUND
F	TEMPERATURE, DEGREES FAHR
TD	TERMINAL DIFFERENCE
DC	TERM DIFF DRAIN COOLER
KW	KILOWATTS
FWR	FEED WATER REGULATOR
Hg	PRESSURE, IN OF MERCURY, ABS
PSIA	PRESSURE, LB PER SQUARE IN., ABS
PSIG	PRESSURE, LB PER SQUARE IN., GAGE

FIGURE 2.7-2
HEAT BALANCE DIAGRAM - 41 MW LOAD



LEAKAGES

NO.	FLOW, LB	ENTHALPY
1	8800	1473.0
2	7470	1473.0
3	3380	1367.5
4	690	1330.0
5	1850	1445.6
6	360	1352.0
7	230	1352.0
VSL	1750	1491.2

BASIS OF HEAT BALANCE CALCULATIONS

ELEVATION: PLANT IS APPROXIMATELY 4065 FEET ABOVE SEA LEVEL

AIR TEMPERATURE: AVERAGE ANNUAL AMBIENT AIR TEMPERATURE IS 63.3F

FUEL: NATURAL GAS

STEAM LOSSES: 2800 LB, CONSTANT AT ALL LOADS

BOILER BLOWDOWN: 0.5% STEAM GENERATION

BOILER EFFICIENCY: ADJUSTED FOR ACTUAL INLET AIR TEMPERATURE AT 73.8

SUPERHEATER, REHEATER, MAIN AND REHEAT STEAM LINE PRESSURE DROPS CALCULATED AT ALL LOADS. REHEAT SYSTEM PRESSURE DROP EXPRESSED AS 8.0 PERCENT OF HIGH PRESSURE TURBINE EXHAUST PRESSURE AT THIS LOAD.

EXTRACTION LINE PRESSURE DROPS CALCULATED AT MAXIMUM LOAD AND EXPRESSED AS THE FOLLOWING PER CENT OF THE FLANGE ABSOLUTE PRESSURES FOR USE AT ALL LOADS

EXTRACTION LINE	1	2	3	4	5
PER CENT	2.2	1.7	4.8	4.0	6.4

EXTRACTION PRESSURES SHOWN AT OR NEAR THE TURBINE SYMBOL ARE TURBINE EXTRACTION FLANGE PRESSURES. PRESSURES SHOWN NEAR HEATER SYMBOLS ARE HEATER ENTRANCE PRESSURES.

EVAPORATOR SYSTEM IS OPERATED TO REPLACE ESTIMATED STEAM AND WATER LOSSES FROM THE CYCLE BY THROTTLING COIL STEAM SUPPLY PRESSURE AS REQUIRED, WITH SURFACE 50% CLEAN. EVAPORATOR BLOWDOWN QUANTITY BASED ON SOLIDS CONCENTRATIONS AS FOLLOWS: EVAPORATOR SHELL 3500 PPM, BOILER BLOWDOWN 4.5 PPM, MAKEUP 780 PPM.

WET BULB TEMPERATURES SHOWN ARE REQUIRED TO PRODUCE CORRESPONDING BACK PRESSURES WITH 36,800 GPM OF CIRCULATING WATER.

BASE HEAT BALANCE COMPUTED FOR 2" Hg BACK PRESSURE. ALL FLOWS, PRESSURES, TEMPERATURES AND ENTHALPIES REMAIN UNCHANGED FOR OTHER BACK PRESSURES EXCEPT AS FOLLOWS: VALUES SHOWN IN TABLE, ENTHALPY AND TEMPERATURE OF CONDENSATE TO THE AIR EJECTOR, GLAND STEAM CONDENSER AND 5TH POINT HEATER, ENTHALPY AND TEMPERATURE OF DRAINS FROM 5TH POINT HEATER.

*INLET ENTHALPY OF IP TURBINE DETERMINED BY TURBINE MANUFACTURER'S PROCEDURE FOR HANDLING LEAKAGE (2)

AUXILIARY POWER REQUIREMENTS ARE CALCULATED FOR ALL EQUIPMENT. THE MAJOR EQUIPMENT CONSIDERED IS AS FOLLOWS:

REQUIREMENTS VARIABLE WITH CHANGE IN LOAD ON UNIT

EQUIPMENT	NUMBER OPERATING
2 BOILER FEED PUMPS	2
2 CONDENSATE PUMPS	2
1 FORCED DRAFT FAN	1
STATION SERVICE TRANSFORMER LOSS	

AVERAGE DAILY REQUIREMENTS, CONSIDERED CONSTANT AT ALL LOADS

EQUIPMENT	NUMBER OPERATING
1 INSTRUMENT AIR COMPRESSOR	1
1 SERVICE AIR COMPRESSOR	1
1 DEEP WELL PUMP	1
2 CIRCULATING WATER PUMPS	2
5 COOLING TOWER FANS	5

$$\text{TURBINE HEAT RATE} = \frac{3412.75(83{,}110+1735+245)+408{,}370(1042.1-69.1)+63{,}160(81.7-69.1)+5000(81.9-69.1)+230(1352-69.1)}{83{,}110} = 8290 \text{ BTU PER KWH}$$

$$\text{STATION HEAT RATE} = \frac{556{,}600(1491.2-438.9)+11{,}000(1491.2-286.2)+2800(1161.6-438.9)+2800(625.0-438.9)+501{,}960(1521.7-1367.5)+7000(1521.7-281.1)}{.844 \times 79{,}585} = 10{,}235 \text{ BTU PER KWH}$$

CONDENSER BACK PRESSURE	5TH POINT EXTRACTION FLOW	TURBINE EXHAUST FLOW	LPT END POINT ENTHALPY	TURBINE EXHAUST ENTHALPY	GENERATION	NET STATION OUTPUT	TURBINE HEAT RATE	STATION HEAT RATE	CIRC. WATER TEMP.	WET BULB TEMP.
"Hg	LB	LB	h	h	KW	KW	BTU/KWH	BTU/KWH	F	F
2.5	21,680	411,310	1042.5	1049.6	82,295	78,770	8370	10,340	80.5	65.5
2.0	24,620	408,370	1032.0	1042.1	83,110	79,585	8290	10,235	72.5	51.5
1.5	28,210	404,780	1018.5	1035.3	83,805	80,280	8220	10,150	62.0	—
1.0	32,930	400,060	1000.0	1029.2	84,370	80,845	8165	10,075	47.5	—

LEGEND

- — — STEAM
- ——— WATER
- —o— POWER, KW
- LB: FLOW, POUNDS PER HOUR
- h: ENTHALPY, BTU PER POUND
- F: TEMPERATURE, DEGREES FAHR
- TD: TERMINAL DIFFERENCE
- DC: TERM. DIFF. DRAIN COOLER
- KW: KILOWATTS
- FWR: FEED WATER REGULATOR
- Hg: PRESSURE, IN. MERCURY ABS.
- PSIA: PRESSURE, LB PER SQUARE IN. ABS
- PSIG: PRESSURE, LB PER SQUARE IN. GAGE

FIGURE 2.7-1
HEAT BALANCE DIAGRAM- 83 MW LOAD

2.8 PROJECT ORGANIZATION

The project organization consists of an investor-owned utility, El Paso Electric Company (as the prime contractor), working in a conventional utility relationship with Stone & Webster and Westinghouse, and supported by a number of public sector agencies.

EPE Program Manager Mr. J. E. Brown was responsible for the technical and programmatic direction of the program in all aspects. In addition, EPE was responsible for all 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.

Stone & Webster Engineering Corporation of Boston, Massachusetts provided architect/engineer services which included the conceptual design of the solar repowered Newman Unit 1, cost estimating in support of the economic analysis and demonstration program, and construction planning for the demonstration program. Stone & Webster was the architect/engineer for Newman Unit 1 and is intimately familiar with the design of the unit and site-related working conditions. Mr. R. W. Kuhr was the Stone & Webster Project Manager.

Westinghouse Electric Corporation's Advanced Energy Systems Division was responsible for project integration and systems engineering, which included systems design and analysis, solar subsystem design and analysis, economic and network impacts and assessments, safety evaluations, and program planning for the demonstration phases of the project. Mr. W. G. Parker was the Westinghouse Project Manager for this effort.

The Texas Energy Advisory Council and the Regional Development Division of the Office of the Governor of Texas provided the assistance required to identify and resolve the institutional barriers and public issues associated with solar repowering.

After notification of contract award, EPE formed the Southwest Solar Repowering Utility Advisory Council consisting of 32 members (see Table 2.8-1) representing investor-owned, municipal, state, federal, district, and rural electric cooperatives. The purpose of this advisory council was to provide for an assessment of the program results from a broad utility perspective and to provide for early dissemination of the results to other utilities.

TABLE 2.8-1

SOUTHWEST SOLAR REPOWERING UTILITY ADVISORY COUNCIL

Investor Owned Systems

- Pacific Power & Light Co.
- New Mexico Electric Service Co.
- Public Service Company of New Mexico
- Sierra Pacific Power Co.
- Central Telephone & Utilities Corp.
- Utah Power & Light Co.
- Georgia Power Co.
- Dallas Power & Light Co.
- Houston Lighting & Power 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.
- Tuscon Electric Power Co.
- Gulf States Utilities Co.

Municipal Systems

- Farmington Electric Utility
- Colorado Springs Department of Public Utilities
- Austin Electric Dept.
- Garland Electric Dept.
- Lubbock Power & Light Dept.
- Los Angeles Department of Water & Power

Federal and District Systems

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

Rural Electric Cooperatives

- Arizona Electric Power Coop.
- Lea County Electric Coop. Inc.
- Plains Electric G & T Coop. Inc.
- Colorado Lite Electric Assn. Inc.
- Brazos Electric Power Coop. Inc.
- Western Farmers Electric Coop.

2.9 FINAL REPORT ORGANIZATION

The remainder of this report is written in a manner so that the reader may follow the flow of the results from the initial Baseline Configuration, to the Preferred Configuration, to the Conceptual Design, and through to the Development Plan for solar repowering Newman Unit 1.

As to the contents for the remainder of this volume, Section 3 of this report documents the methodology and trade iterations used by the EPE team to modify its origin Baseline Configuration for solar repowering Newman Unit 1. It also describes the selected Preferred Configuration in detail.

The conceptual design is detailed in Section 4 on a 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 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. In addition to a proposed schedule and milestone chart, the roles of the site owner, government, and industry in a subsequent solar repowering demonstration are discussed.

The completed Systems Requirements Specification (SRS) is contained in Volume II and the remainder of this report refers to the SRS on many occasions for those supporting details of data addressed and highlighted herein.

SECTION 3

SELECTION OF PREFERRED SYSTEM

This section of the report summarizes the selection process resulting in the most practical system configuration for solar repowering Newman Unit 1. Section 3.1 presents the characteristics of the alternative system configurations evaluated along with the rationale for selecting water/steam central receiver technology for this application. Section 3.2 summarizes the results of the subsystem trade studies leading to the selection of specific solar components and the heliostat field geometry/tower location. The system trade study results are presented in Section 3.3 including the rationale for selecting the preferred system configuration and the solar repowering percentage. Section 3.4 summarizes the characteristics of this preferred system.

3.1 DESCRIPTION OF SYSTEM ALTERNATIVES

The EPE system has a total generating capacity of 1,033 MWe. Sufficient land is available to apply solar repowering to all EPE gas and oil-fired units, which represent 922 MWe or 89 percent of the total system. EPE selected 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 14.2 km^2 (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 cyclic operating conditions that could result from solar application.

Newman Unit 1 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 a limited alternate fuel source). The Baseline Configuration for solar repowering Newman Unit 1 utilizes water/steam central receiver technology to provide main steam to the high pressure stage 10.1 MPa/538°C and reheat steam to the intermediate stage 2.9 MPa/538°C of the turbine generator. Fossil energy is used to supplement solar generated steam for intermittent cloudy day operation and for economic dispatch when solar energy is not available. This configuration was selected during the proposal preparation phase on the basis of providing an economically attractive system (estimated cost/value ratio of 0.75 - see Section 3.3) with minimum technology risk for operation in 1985 with hardware procurement beginning approximately 4 years earlier.

The rationale for EPE's choice of water/steam as the working fluid in its solar repowering conceptual design is that water/steam systems are the simplest, lowest technology solution to solar repowering existing generating units and will, therefore, minimize technical risk.

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

Water/steam is a technology familiar to the utility industry.

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.

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 and developed hardware and it will serve as a necessary stepping stone to later large-scale stand-alone solar facilities. EPE believes that the solar repowering design developed for Newman Unit 1 minimizes technical risk since it incorporates proven, standard water/steam technology. This minimization of technical risk is important to the conservative electric utility industry.

Expanding on the technical risk issue, an unfavorable solar repowering demonstration may imply that solar is not an acceptable generation alternative for the 1990's. In EPE's opinion, the system chosen for an initial demonstration must have a high probability to successfully prove that it may be suitably constructed and operated, widely integrated into electric utility systems, and that it satisfies the national interest aspect of the overall solar research program.

Table 3.1-1 has summarized the characteristics of the Baseline Configuration. The heliostat field was sized to provide a repowering fraction of 75 percent at an insolation level of 950 W/m^2 at 2 p.m. winter solstice. The heliostat field consisted of 4,735 heliostats (81.8 m^2 mirror area each) and provided 225 MWt to receivers mounted on a tower at an elevation of 170 m.

The principal solar/fossil interface between the existing Newman Unit 1 and the solar subsystem for the Baseline Configuration consists of (1) steam supply piping interface from the solar (both primary and reheat receivers) and the fossil steam generators, (2) feedwater piping interface supply 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.

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 generated steam is the primary means of ensuring that temperatures are maintained within turbine design limits. However, if required, heat flux control may be accommodated within the heliostat field controls. Solar generated steam is used whenever available, with fossil steam generation replacing any steam flow reduction due to intermittent cloud cover and for economic dispatch.

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 will be modified and interfaced with the solar system by means of a master control system.

The heliostats employed in the collector field for design analyses are the Westinghouse Second Generation Heliostats, which have a glass reflective surface area of $81.8m^2$ ($880 ft^2$), an aspect ratio of 1.5:1, a weight of 3,725 kg (8,200 pounds). This heliostat concept was selected as representative of the class of configurations that will be available in 1985 for solar repowering applications.

The external central receiver concepts (primary and reheat) employed for the Baseline Configuration are based on the advanced water/steam pumped recirculation central receiver technology being developed by DOE. This boiler technology is well known throughout the utility industry. Primary receiver length is 27.8m and the diameter is 18.4m. Length of the reheat receiver is 5.0m with a diameter of 18.4m. This technology was selected over the once-through boiler technology (see Section 3.2.2) on the basis of utilizing commercial/utility boiler design approaches, utilizing conventional boiler materials with known properties and demonstrated lifetimes, having the greatest potential to satisfy intermittent cloudy day operating requirements, minimizing maintenance, being available for a 1985 demonstration, and being more compatible with existing water treatment facilities and flow requirements of the existing recirculating boiler.

Table 3.1-2 summarizes the cost estimate for the Baseline Configuration for the demonstration unit and for the Nth commercial unit. These cost estimates evolved during the performance of the subsystem trade studies and were continuously updated during the performance of the system configuration evaluations.

The data presented in Table 3.1-2 were used for the EPE system network analysis (Section 3.3) to select the overall site-specific system configuration (but not necessarily the geometries for specific subsystems such as the heliostat field) and are based on utilizing a separate heliostat/receiver/tower subsystem located adjacent to the turbine building for supplying the reheat steam conditions as opposed to the field location established for the Baseline Configuration as indicated in Table 3.1-1. It should be further noted that the Preferred Configuration selected from the trade studies provides a heliostat north field geometry with a single tower, located adjacent to the turbine building, supporting both the primary and reheat receivers. The selected configuration does not influence the relative comparisons of the system alternatives since each alternative can utilize the north field geometry; rather, the primary effect is a reduction in the magnitude of the cost/value ratios which will be presented in Section 3.3.

Four alternate configurations (Table 3.1-1) were developed to assess the performance, economic attractiveness, ease of operation and maintenance, and environmental and safety impact of the Baseline Configuration. The alternate configurations were: (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 fossil fueled boiler used to supplement the solar generated reheat steam, and (3) a configuration using solar energy (with the option of buffer storage, the fourth configuration) to provide primary steam to the high pressure stage and using fossil energy, through incorporation of an auxiliary boiler, to provide reheat steam conditions. Alternate 2 was eliminated from further consideration during the initial performance of the trade studies on the basis of being less cost effective than the other system configurations while not offering any benefit in terms of improved operations, reduced maintenance, or enhanced reliability. The cost estimates for the alternate configurations are presented in Section 3.3.

TABLE 3.1-1

SOLAR REPOWERED NEWMAN UNIT 1 CHARACTERISTICS
OF ALTERNATE SYSTEM CONFIGURATIONS

	Baseline Configuration	Alternate 1	Alternate 2	Alternate 3	Alternate 4
1. CONFIGURATION DESCRIPTION					
(a) Primary Steam	Solar	Solar	Solar	Solar	Solar
(b) Reheat Steam	Solar	Solar	Solar	Auxiliary Heater	Auxiliary Heater
(c) Buffer Storage	----	Primary/ Reheat	Primary	----	Primary
(d) Intermittent Cloudy Day	Fossil Boiler	Buffer Storage	Buffer Storage/ Auxiliary Heater	Fossil Boiler	Buffer Storage/ Auxiliary Heater
(e) Economic Dispatch	Fossil Boiler	Fossil Boiler	Fossil Boiler	Fossil Boiler	Fossil Boiler
2. REPOWERED UNIT CHARACTERISTICS					
(a) Unit Type	Reheat Steam Turbine	Reheat Steam Turbine	Reheat Steam Turbine	Reheat Steam Turbine	Reheat Steam Turbine
(b) Unit Rating	79.6 MWe	79.6 MWe	79.6 MWe	79.6 MWe	79.6 MWe
(c) Repowering Percentage	75%	75%	75%	64%	64%
(d) Collector Subsystem					
- Field Configuration	360	360	360	360	360
- Field Area	1.7km	1.7km	1.7km	1.7km	1.7km
- Heliostat Area	387,100m	387,100m	387,100m	329,000m	329,000m
- Number of Heliostats	4,735	4,735	4,735	4,025	4,025
(e) Primary Receiver					
- Type	External	External	External	External	External
- Size	18.4 m dia by 27.8 m long	18.4 m dia by 27.8 m long	18.4 m dia by 27.8 m long	18.4 m dia by 27.8 m long	18.4 m dia by 27.8 m long
- Heat Loss	25 MWht	25 MWht	25 MWht	25 MWht	25 MWht

TABLE 3.1-1 (Cont)

	Baseline Configuration	Alternate 1	Alternate 2	Alternate 3	Alternate 4
(f) Reheat Receiver					
- Type	External	External	External	----	----
- Size	18.4 m dia by 5.0 m long	18.4 m dia by 5.0 m long	18.4 m dia by 5.0 m long	----	----
- Heat Loss	5 MWht	5 MWht	5 MWht	----	----
(g) Tower					
- Number	1	1	1	1	1
- Height	170 m	170 m	170 m	155 m	155 m
(h) EPGS					
- Gross Unit Efficiency	41.3	41.3	41.3	41.3	41.3
- Net Unit Efficiency (Solar/Fossil)	37.5/39.5	37.5/39.5	37.5/39.5	37.5/39.5	37.5/39.5
- Turbine	10.1 MPa/538°C/ 538°C	10.1 MPa/538°C/ 538°C	10.1 MPa/538°C/ 538°C	10.1 MPa/538°C/ 538°C	10.1 MPa/538°C/ 538°C
- Port Load	EPE Correction Curve	EPE Correction Curve	EPE Correction Curve	EPE Correction Curve	EPE Correction Curve
- Minimum Output	8MWe	8MWe	8MWe	8MWe	8MWe
- Heat Rejection	Wet Cooling Tower	Wet Cooling Tower	Wet Cooling Tower	Wet Cooling Tower	Wet Cooling Tower
(i) Fossil Boiler					
- Type	Gas/Oil	Gas/Oil	Gas/Oil	Gas/Oil	Gas/Oil
- Rated Load Efficiency	84.4%	84.4%	84.4%	84.4%	84.4%
- Part Load	84.4%	84.4%	84.4%	84.4%	84.4%
- Startup Energy	106x10 kJ (100 MBtu)	106x10 kJ (100 MBtu)	106x10 kJ 100 MBtu)	106x10 kJ (100 MBtu)	106x10 kJ (100 MBtu)
- Bank Energy	15.8x10 kJ/startup (15 MBtu/startup)	----	----	15.8x10 kJ/Startup (15MBtu/startup)	----

TABLE 3.1-1 (Cont)

	Baseline Configuration	Alternate 1	Alternate 2	Alternate 3	Alternate 4
- Minimum Standby	36%	----	----	36%	----
(j) Auxiliary Heater					
- Startup Energy/ Bank Energy	----	----	37.1x10 kJ (35 MBtu)/ 8x10 kJ (7.5 MBtu)	37.1x10 kJ (35 MBtu)/ 8x10 kJ (7.5 MBtu)	37.1x10 kJ (35 MBtu)/ 8x10 kJ (7.5 MBtu)
- Efficiency	----	----	85%	85%	85%
(k) Buffer Storage					
- Size	----	15 Min	15 Min	----	15 Min
- Efficiency	----	100%	100%	----	100%
- Turbine	----	482°C/482°C	----	----	482°C

TABLE 3.1-2

SOLAR REPOWERED NEWMAN UNIT 1 BASELINE CONFIGURATION - 75% REPOWERING FRACTION (SOLAR REHEAT-SEPARATE TOWER) REVISED COST ESTIMATES (1980 MILLIONS OF DOLLARS)

	Category	Demonstration Unit	Nth Unit
5100	Site Improvements	5.6	5.6
5200	Administrative Areas	1.0	1.0
5300	Collector Subsystem	86.0	22.2
5400	Receiver Subsystem	22.2	19.5
	Primary Receiver	(10.5)	(8.4)
	Reheat Receiver	(2.8)	(2.2)
	Primary Tower	(2.4)	(2.4)
	Reheat Tower	(1.0)	(1.0)
	Primary Piping	(4.5)	(4.5)
	Reheat Piping	(1.0)	(1.0)
5500	Master Control Subsystem	4.6	1.1
5600	Nonsolar Energy Subsystem	0.5	0.5
5700	Energy Storage Subsystem	0	0
5800	Electric Power Generating Subsystem	3.4	2.2
	Total Direct Cost	123.3	52.1
	Contingency and Spares (15 Percent)	18.5	7.8
	Indirect Costs (15 Percent)	18.5	7.8
	Total Capital Investment	160.3	67.7
	AFUDC (20 Percent)	32.0	13.5
	Total Capitalization	192.3	81.2
	Annual O&M (3 Percent)	5.8	2.4

3.2 SUBSYSTEM ANALYSIS RESULTS

This section presents the trade-off study results for the collector, receiver, and thermal energy buffer storage subsystems.

3.2.1 Collector Field Studies

The Baseline Configuration utilizes a 360° field of heliostats located north of Newman Unit 1. The primary and reheat receivers are located at the top of a single tower that is approximately 0.762 km (2,500 feet) from the turbine building. Trade studies were performed for the collector subsystem to assess the merits of (1) alternate field locations, (2) north field with the tower adjacent to the turbine building (requiring the relocation of Farm Road 2529) versus the 360° field of heliostats for both the primary and reheat receivers, (3) a separate heliostat field and tower for both the primary and reheat receivers, and (4) locating the reheat receiver at a station below the top of the primary tower. The results of these trade studies are summarized in Table 3.2-1. The most cost effective configuration utilizes a north field of heliostats with a single tower housing both the primary and reheat receivers located near the turbine building. The centerline of the reheat receiver for this configuration is located at a station approximately 60 m below the centerline of the primary receiver.

This configuration results in an effective cost savings of approximately 12 million dollars when compared to the Baseline Configuration (including provision for relocating Farm to Market Road 2529 to the north). This cost saving is primarily realized from a reduction in the number of heliostats resulting from the north field and from savings in primary and reheat piping resulting from locating the tower near the turbine building.

3.2.2 Water/Steam Receiver Concepts

The Baseline Configuration defined in the proposal for solar repowering Newman Unit 1 uses first generation water/steam central receiver technology (once-through boiler) to provide main steam to the high pressure stage (10.1 MPa/538°C) and reheat steam to the intermediate stage (2.9 MPa/538°C) of the turbine generator. A trade study was performed to assess the merits of the application of improved water/steam receiver concepts (recirculation boilers) to repowering Newman Unit 1.

Four water/steam receiver concepts were reviewed for this application as follows:

Receiver Configuration	Primary Vendor Contacted
External/Once-Through Boiler	Rockwell International
External/Forced Recirculation Boiler/Screened Tube Concept	Babcock and Wilcox
External/Forced Recirculation Boiler	Combustion Engineering
Cavity/Natural Recirculation Boiler	Martin-Marietta/ Foster Wheeler

The first concept is currently being developed by DOE for the 10 MWe Central Receiver Pilot Plant under construction at Barstow, California. Full scale, single panel tests of this concept have been completed at the Central Receiver Test Facility in Albuquerque, New Mexico. DOE as part of the Advanced Water/Steam Receiver Program is studying the latter three concepts. The Phase 1 conceptual design studies were completed for each concept in early 1980. A series of meetings was held with each of the vendors and data packages were provided for use in the performance of the EPE Program. Note that the vendors indicated a willingness to respond to a future receiver procurement specification to be issued as part of the design phase of the demonstration program even though the configuration may differ from their recommended designs. This trade study is therefore concerned only with selecting a receiver concept. A vendor will be competitively selected in a subsequent program phase.

Table 3.2-2 presents a summary of key design, performance, and cost characteristics for each of these concepts. These data were developed on the basis of providing a primary receiver thermal power output of 141 MW which is equivalent to a 75 percent repowering fraction.

The alternate concepts were compared on the basis of the following criteria: performance, costs, development risk, operating and maintenance, reliability, safety, and new technology demonstration. The characteristics of each of the receiver concepts relative to these criteria are also summarized in Table 3.2-2. The water/steam recirculation boiler technology was selected for this repowering application over the once-through boiler technology on the basis of utilizing proven commercial/utility boiler design approaches, utilizing conventional boiler materials with known properties and demonstrated lifetimes, having the greatest potential to satisfy intermittent cloudy day operating requirements, minimizing maintenance, more closely matching existing water treatment facilities capabilities, and being available for a 1985 demonstration. The external, pumped recirculation receiver was preferred to the cavity, natural recirculation receiver on the basis of lowest capital cost, comparable performance and reliability, a delivery schedule more compatible with a 1985 demonstration, less susceptibility to flow stagnation and burnout in low heat flux regions, and ease of replacement, if necessary, of the superheater tubes. The comparison was close enough, however, that EPE would not object to substitution of an internal cavity receiver if it was desirable to demonstrate this concept.

3.2.3 Thermal Energy Buffer Storage (TES) Concepts

Four thermal energy buffer storage (TES) concepts were evaluated to determine if the inclusion of buffer storage as part of the solar repowering subsystem is cost effective for this appplication. A buffer storage system is not technically required to permit unit operation during intermittent cloudy days since the existing fossil boiler can be fired at a rate (10-20 percent steam flow/minute) sufficient to offset most of the anticipated insolation transients. Three of the TES concepts utilize low vapor pressure storage media (HITEC).

In the first concept, the charging steam from the receiver is first desuperheated, condensed, and subcooled, which in turn heats the storage media liquid. In this single-set sensible heat storage system, the maximum achievable storage temperature is less than 371°C (700°F), therefore, the maximum steam temperature that can be generated by this TES system is less than 343°C (650°F).

The second TES concept uses a two-set sensible heat storage system. In this concept, the superheated charging steam supplies energy to a high temperature sensible heat storage set, while the latent heat and subcooling of the charging steam are utilized in heating a low temperature sensible heat storage set. The high temperature storage set has a top storage temperature of 510°C (950°F), sufficient to produce superheat steam 482°C at a pressure level compatible with the intermediate pressure (IP) turbine.

The third TES concept stores only the energy from the superheat of the charging steam, while the saturated steam is then directed to the feedwater heaters. This concept can provide primary and reheat steam at a temperature of 482°C (900°F).

The first concept was discarded on the basis of not having the temperature capability to buffer the high pressure stage transients. Due to the increased number of heat exchangers and storage vessels, the second concept was judged to be more costly than the third approach. The third concept was developed in further detail to establish a capital cost estimate.

Figure 3.2-1 shows a flow schematic for this low vapor pressure storage media (HITEC) concept. The achievable heat rate is about 9,411 kJ/kWh (8,920 Btu/kWh) with a net electrical output of 73

MWe; the reduced output resulting from the reduction in steam temperature to 482°C. This concept also has a very limited (slow) charging rate. For example, if only the first point feedwater heater is supplied by the saturated steam from the charging circuit, it would require 4 hours to fully charge the TES (15 minutes to discharge). The capital cost estimate for this concept is approximately 6 million dollars (as indicated on Figure 3.2-1).

In the low vapor pressure storage media concept, the cost of the heat exchangers comprises the greater part of the total TES cost. Therefore, the fourth concept studied minimizes heat exchanger components in an effort to reduce cost. A variable pressure accumulator (VPA) is utilized to minimize the heat transfer surface area. The flow schematic of the TES system is shown in Figure 3.2-2. In charging this system, the superheat of the charging steam is transferred to the high temperature sensible heat set, and the latent heat is transferred to hot water. Assuming the VPA fully-charged pressure is 10.3 MPa (1,500 psia) and the fully-discharged pressure is 3.4 MPa (500 psia), then when fully discharged, 90 percent of the accumulator volume is filled with saturated high temperature water at 313°C (596°F), with a cushion of saturated steam (at the same temperature and pressure) above it. In the discharge mode, steam is drawn from the top as the pressure in the steam cushion decreases; some of the water in the vessel flashes to steam. The steam from the accumulator is superheated to 482°C (900°F) in the single heat exchanger and directed to the IP turbine. As flashing to steam is continued, the water decreases in temperature, the saturation pressure decreases, and the water level lowered by the amount of water converted to steam. In the discharged state, the accumulator water volume is 60 percent. In this concept, all evaporation and steam generation are internal to the VPA. The heat rate is about 11,078 kJ/kWh (10,500 Btu/kWh) and produced a net electrical power of 54 MWe. The capital cost estimate for this concept is approximately 5 million dollars as shown in Figure 3-2; the major cost item is the accumulator.

The value of thermal energy buffer storage for this solar repowering application was established by dispatching the Baseline Configuration and Alternate 1 (Table 3.1-1) on the EPE system (see Section 3.3). This analysis indicated that the capital cost of the thermal energy buffer storge subsystem for providing primary and reheat steam must be less than $1.5 to 2.5 million to be cost effective for solar repowering Newman Unit 1; otherwise, it is more cost effective to utilize the existing fossil boiler to supplement the solar generated steam for operation of the unit during cloudy days provided the boiler can accommodate such supplemental operation. Since none of the concepts evaluated have projected capital costs close to this range and since the boiler itself does not present any unreasonable operational constraints, the inclusion of a thermal

TABLE 3.2-1

COLLECTOR SUBSYSTEM - TRADE STUDY RESULTS

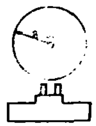
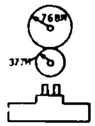
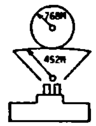
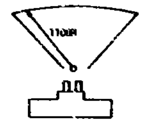
	Baseline Configuration	Separate 360° Reheat Field	Separate N-Reheat Field	North Field
				
1. Configuration Description				
Solar Repowering Fraction (%)	75	75	75	75
Primary/Reheat Field	360°/360°	360°/360°	360°/North	160° N/160° N
No. of Towers	1	2	2	1
Primary/Reheat C/L Height (m)	170/155	159/66	159/132	190/132
Outermost Heliostat Radius (m)	820	770	770	1100
2. Primary Receiver				
Type	External	External	External	External
Size (m)	16.5 dia x 24.5 long	15.0 dia x 27.0 long	15.0 dia x 27.0 long	15.0 dia x 20.0 long
3. Reheat Receiver				
Type	External	External	External	External
Size (m)	16.5 dia x 5.0 long	9.9 dia x 11.5 long	16.5 dia x 16.5 long	15.0 dia x 20.0 long
4. No. of Heliostats				
Primary	4023	4048	4048	3790
Reheat	712	702	605	615
5. Thermal Power (2 PM Winter Solstice)				
Primary (MWt)	191	193	193	192
Reheat (MWt)	34	34	33	33
6. Demonstration Unit Cost (1980 M$)				
Collector Subsystem	86.0	86.3	84.5	80.0
Receiver Subsystem				
Primary Receiver	10.5	10.5	10.5	10.5
Primary Tower	2.9	2.6	2.6	3.1
Primary Piping	3.7	3.7	3.7	1.3
Reheat Receiver	2.8	2.8	2.8	2.8
Reheat Tower	---	1.0	2.2	---
Reheat Piping	4.0	2.5	1.0	1.8
TOTAL	109.9	109.4	107.3	97.7

TABLE 3.2-2

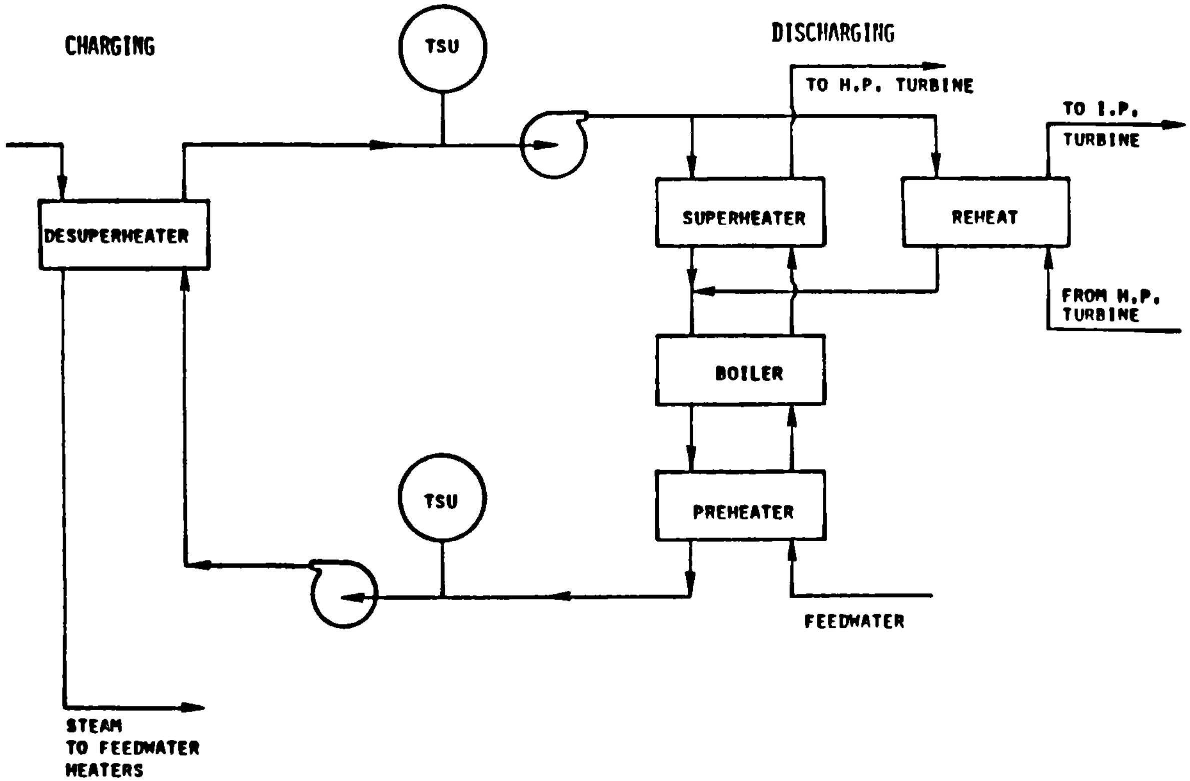
CHARACTERISTICS OF ALTERNATE RECEIVER CONCEPTS

Criteria	Receiver Alternatives: Cavity Configuration Natural Recirculation Boiler	External Configuration Forced Recirculation Boiler Screened Tube Concept	External Configuration One Pass Once-Through Steam Generator	External Configuration Forced Recirculation Boiler High Temperature Concept
Performance				
Outlet Temperature	516°C (Scalable to 555°C)	516°C (Scalable to 555°C)	516°C (Scalable to 555°C)	555°C (Scalable to 594°C)
Outlet Power	141 MW	141 MW	141 MW	141 MW
Efficiency	96 - 89%	85 - 87%	84 - 86%	85 - 87%
Capital Costs	11.5M $	10.5M $	13.4M $	7.9M $
Development Risk				
Time Frame (from Contract Date through Checkout)	5 Years	3.5 Years	3.5 Years	4 Years
Risk	Low risk design with well established boiler technology, conservative design approach, and less risk associated with coating degradation.	Low risk design with well established boiler technology, conservative design approach, and small risk associated with coating degradation due to screened tubes.	High risk design with boiler technology that requires verificaion to handle dynamic variations. Design less conservative in terms of tube size and control systems.	Intermediate risk with well established boiler technology; however, less conservative design approach and greater risk associated with coating degradation.
Operating Maintenance	Conventional boiler and simple control systems with no pumping. Relatively slow transient response. Cavity may reduce impact of cloud cover transients. Replacement of panels is more difficult for cavity than external configuration.	Conventional boiler with forced pumping and control system. Ribbed tube design enhances stability. Continuous pumping power is required. Panel concept enhances replacement time.	Most complex system with complex control and pumping system to react to transients. Small orificed tubes may be susceptible to plugging.	Conventional boiler with forced pumping and control system. Continuous pumping power is required. Superheater exposed to larger heat flux gradients with orificing required to match flow with gradient.

TABLE 3.2-2 (Cont)

Criteria	Receiver Alternatives: Cavity Configuration Natural Recirculation Boiler	External Configuration Forced Recirculation Boiler Screened Tube Concept	External Configuration One Pass Once-Through Steam Generator	External Configuration Forced Recirculation Boiler High Temperature Concept
Reliability	Highest reliability due to simplest design with passive pumping and control. Natural circulation may be susceptible to reverse or stagnant flow leading to a burnout in low heat flux area.	Intermediate reliability with forced pumping and control system for recirculating boiler. Screen tube design reduces and flattens superheater heat flux and enhances lifetime.	Lowest reliability due to complex orificing. Pumping and flow control system for once-through boiler. Most susceptible to DNB.	Intermediate reliability with forced pumping and control system for recirculating boiler. Higher quality of 0.5 makes tube design more susceptible to DNB, although ribbed tube concept may offset problem.
Safety Factors	Exposure due to potential stagnation in low heat flux zones.	Steam exposure due to failure in recirculating pump and control system are failures peculiar to forced circulation system.	Greatest potential for failure - most complex pump and control system add failure modes leading to steam exposure.	Steam exposure due to failure in recirculating pump and control system are failures peculiar to forced circulation system.
New Technology Demonstration	First system demonstration of cavity concept. Natural recirculation boiler in solar application.	Forced recirculation boiler in solar application.	Repeat of Barstow demonstration.	Forced recirculation boiler in solar application.

FLOW SCHEMATIC

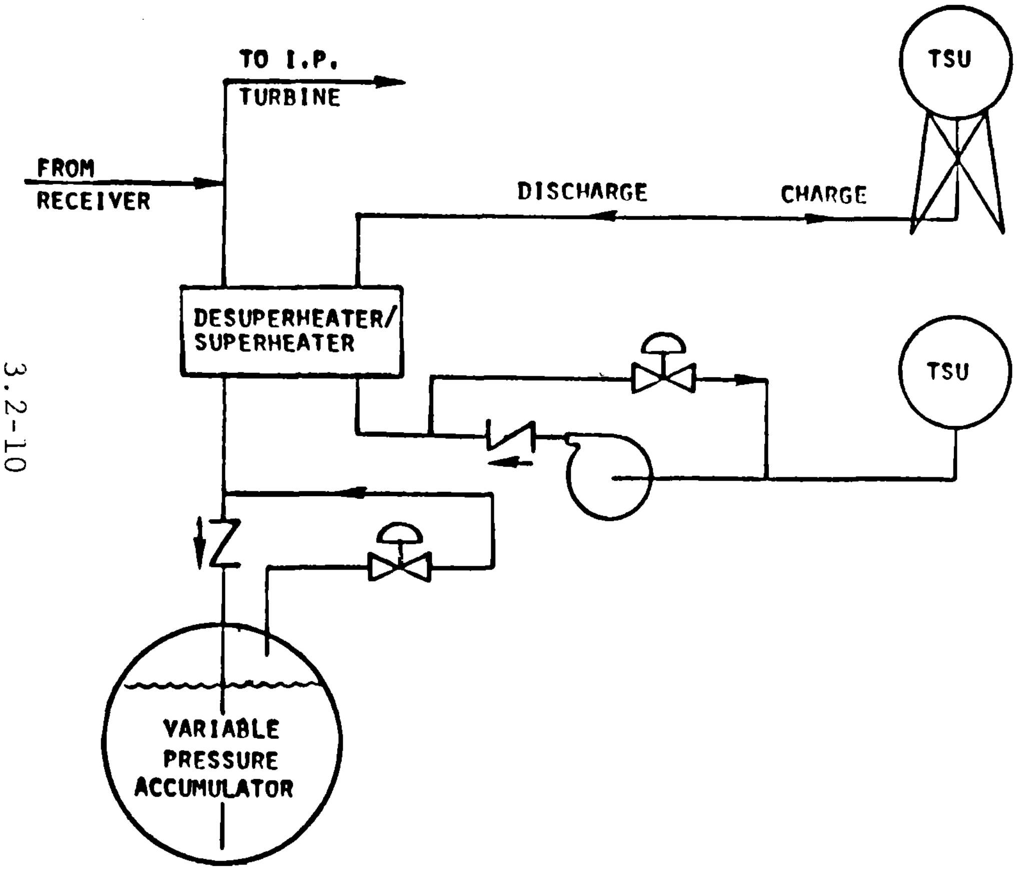


COST ESTIMATE (1980 M $)

Desuperheater	1.19
Boiler	1.88
Superheater	1.02
Reheater	0.79
High Temperature Storage Tank	0.22
Low Temperature Storage Tank	0.16
Hitec	0.61
Hitec Pumps	0.12
Piping	0.03
Total	6.02

FIGURE 3.2-1
LOW VAPOR PRESSURE STORAGE MEDIA CONCEPT USING DESUPERHEAT TO CHARGE SYSTEM

FLOW SCHEMATIC



COST ESTIMATE (1980 M $)

Variable Pressure Accumulator	3.94
High temperature storage tank	0.13
Low temperature storage tank	0.09
Hitec	0.06
Hitec Pump	0.02
Condenser/superheater	0.76
Piping	0.02
Total	5.01

FIGURE 3.2-2
VARIABLE PRESSURE ACCUMULATOR
HEAT STORAGE CONCEPT

3.3 SYSTEM ANALYSIS RESULTS

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 a major concern to EPE. This involves 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 using the methodology and computer programs developed by Westinghouse as part of EPRI Contract RP-648. The following general assumptions were made for analyses:

- 1985 initial year of operation
- EPE planned system 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
- Newman Unit 1 operated from either solar, fossil, or a combination of solar and fossil modes
- Day's insolation profile and load demand known in advance
- Thirty year operating life

The characteristics of the planned (1985) EPE system were modeled in detail. Hourly load demand, generation unit descriptions, and conventional fuel constraints were considered. Eighty-nine percent of the present EPE system generation capacity is composed of gas- and oil-fired units; however, by 1985 this percentage is expected to be reduced to approximately 50 percent by the planned addition of nuclear baseload units. The gas- and oil-fired units will be operated primarily on gas between 1985 and 1990. Because of the existing Federal regulations restricting the use of natural gas as a utility fuel after 1990, operation will be mostly on oil beyond this date. For the analysis it has been assumed that all gas- and oil-fired units operate on gas from 1985 to 1990 and on oil beyond 1990.

Two economic scenarios were defined by EPE for use in the analysis (Table 3.3-1). Except for the escalation rate for gas and oil, the scenarios are identical. The A scenario assumes an 8 percent escalation rate and the B scenario a 12 percent rate.

The solar repowered Newman Unit 1 is dispatched on the EPE system to maximize the benefit derived from solar repowering. The ability to operate on fossil fuel has been maintained in the repowered unit. The unit can operate and produce rated power using steam generated from the solar receiver (primary and reheat), the fossil boiler, or a combination of solar produced steam and fossil during cloudy days. A cloudy day for the purpose of the cost/value analysis is defined as a day during which sky cover exceeds 0.5 for 2 or more consecutive hours.

In general, any day in which sky cover exceeds 0.3 can be classified as cloudy. As part of EPRI Contract RP-648-1, a comparison between insolation transients (for various degradation levels and time periods) and sky cover for a range of 0.3 to 0.7 for Albuquerque, New Mexico indicated that a correlation between these variables was not possible from the existing data base. For example, a sky cover of 0.3 on the data records may correspond with more insolation transients of greater magnitude and longer duration than a sky cover of 0.7 and vice versa. A sky cover value of 0.5 was selected until improved weather records and data on sky cover versus insolation transients are available for the El Paso region, or until planned pilot plant experiments for solar thermal electric plants produce data indicating a correlation between sky cover and plant operating capabilities on "solar only."

The operation scenario assumed for the fossil boiler is important in determining the economic benefit of solar repowering. In order for the existing Newman Unit 1 boiler to be capable of responding to insolation variations during periods of intermittent cloud cover and to produce 538°C (1,000°F) steam from both the primary and reheat sections, the boiler must be operating at a minimum of 36 percent of rated thermal output. The boiler response time to achieve 100 percent rated output (steam flow) from this operating level is less than 10 minutes.

Two boiler operating scenarios were evaluated for the repowered unit:

<u>Fossil Boiler Is Operated Only on Cloudy Days</u>

The fossil boiler is assumed to be started from a cold condition for each cloudy day and also on those days it is economical to dispatch the unit on fossil fuel relative to the balance of the EPE system. A 6 hour startup period is typical for the boiler in order to reach 36 percent of rated load. The fossil boiler is maintained in this minimum load condition (36 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 when it is required to overcome cloud-produced insolation transients in order to maintain rated steam conditions at the turbine inlet. With this scenario, the fossil boiler is shut down at the end of each cloudy day unless economic dispatch considerations would continue its use.

Fossil Boiler Is Operated Daily

This second scenario assumes that the fossil boiler is only shut down to a cold condition for routine or forced maintenance; three cold starts are assumed throughout the year. During cloudy days when the plant is operating from solar generated steam, the fossil boiler is maintained in a hot condition similar to the above scenario. At the end of the day, however, the boiler may be banked (pending economic dispatch of the unit on fossil fuel) and maintained in a warm standby condition overnight. The boiler is also banked during clear days or when it is not economical to operate the plant in either solar or fossil modes. No fossil energy is required to maintain the Newman Unit 1 boiler in a warm standby condition for periods as long as several days; for longer periods the boiler must be intermittently fired. The boiler can then be fired to achieve the 36 percent of rated output point from the warm standby condition in approximately 2 hours.

The latter boiler operating scenario was selected for Newman Unit 1 on the basis of requiring less fossil fuel to operate the unit and thus resulting in a more favorable cost/value ratio. This operating scenario was used for most of the cost/value analysis.

Table 3.3-2 summarizes the results of the cost/value analysis for the Baseline Configuration (defined in Table 3.1-1). These data indicate that the Baseline Configuration results in substantial fossil fuel savings that are equivalent to approximately 110,000 barrels of oil per year and has the potential (Nth unit) to be economically competitive (depending on the fossil fuel escalation rate) on the EPE system. In addition, the data show that the repowered Newman Unit 1 is economically dispatched using fossil fuel due to its high efficiency of operation.

The Baseline Configuration (Table 3.1-1) was a solar repowering fraction of 75 percent. This repowering fraction was found to be close to optimum at 75 percent. Solar repowering fractions of 25, 50, and 100 percent were also considered; these fractions correspond to 1,578 heliostats having a glass area of 82 m^2/heliostat comprising the collector field, 3,155 heliostats, and 6,315 heliostats, respectively. Figure 3.3-1 presents the results of this analysis. The results indicate that the lowest cost/value ratio is fairly insensitive to repowering fractions between 50 and 100 percent. The insensitivity of the cost/value ratio to repowering fraction (which was not observed in previous analyses performed for other southwestern utiliites) primarily results from a favorable economic dispatch of the repowered Newman Unit 1 on the EPE system on fossil fuel.

EPE operating personnel have established that, for a demonstration unit, the minimum repowering fraction considered acceptable to adequately demonstrate the engineering, operating, and maintenance aspects of solar repowering is 50 percent. As illustrated in Figure 3.3-1, little economic incentive exists for considering repowering fractions greater than 50 percent. Therefore, the conceptual design of the preferred concept for the demonstration unit will be based on a 50 percent repowering fraction.

The operating scenario for the Baseline Configuration (Table 3.1-1) assumes that the fossil boiler, as noted above, is maintained at a firing rate equal to 36 percent of rated electrical output in the hot condition. The sensitivity of the cost/value ratio to variation of firing rate percentage was evaluated by considering steam flows representing 28 and 50 percent of rated electric output; the former value corresponds to EPE's spinning reserve (23 MWe output) operating history for this unit.

The results of this analysis indicate that reducing the hot condition percentage to 28 percent reduces the cost/value ratio by approximately 2 percent and that an increase to 50 percent increases the cost/value ratio by less than 2 percent. Once again, the insensitivity of the cost/value ratio is attributed to the favorable economic dispatch of this unit on fossil fuel.

The value of thermal energy buffer storage was established by comparing the cost/value ratios for the Baseline Configuration and Alternative 1 (Table 3.1-1). The capital cost of the thermal energy buffer storage subsystem for providing primary and reheat steam must be in the range of 1.5 to 2.5 million dollars to be cost effective for solar repowering Newman Unit 1; otherwise, it is more cost effective to utilize the existing fossil boiler to supplement the solar generated steam for operation of the unit during cloudy days.

The above analysis has primarily focused on the Baseline Configuration. To provide a comprehensive evaluation of the Baseline Configuration relative to the alternative configurations identified in Table 3.1-1, a set of evaluation criteria were developed as follows:

Cost
Annual electrical energy output
Cost/benefit ratio
Annual fossil fuel savings
Operating and maintenance
Reliability
Environmental, institutional, and safety factors

Technical risk for 1985
New technology demonstration

Characteristics of the Baseline Configuration and Alternatives 1, 3, and 4 relative to these criteria are summarized in Table 3.3-3. Alternatives 1 and 4 which include buffer storage are considered less attractive than the configurations without buffer storage. The primary reason is that a buffer storage subsystem is not cost effective for solar repowering Newman Unit 1. A buffer storage subsystem is likewise not technically required to permit unit operation during intermittent cloudy days since firing of the existing fossil boiler can be increased at a rate sufficient (10-20 percent steam flow/minute) to offset most of the anticipated insolation transients. The inclusion of a buffer storage subsystem in the demonstration unit could be accommodated if desired by DOE to demonstrate this technology and would result in a modest savings in fossil fuel as indicated in Table 3.3-3; however, the fuel savings are not expected to offset the anticipated capital cost (Section 3.2). In addition, maintenance requirements will be increased, reliability will be reduced, and technical risks and costs associated with a system configuration utilizing a fast response buffer storage system will be increased in comparison to the Baseline Configuration.

In general, the Baseline Configuration is more attractive than Alternative 3 for this repowering application. Table 3.3-4 summarizes the strengths and weaknesses of these two configurations relative to the evaluation criteria. The primary factors in the selection of the Baseline Configuration over Alternative 3 is that it has the more favorable cost/value ratio, it offers the greatest potential to conserve fossil fuel resources, and it provides the capability to demonstrate solar-only operation with relatively small penalties in terms of operating and maintenance constraints, and it is most reliable.

TABLE 3.3-1

EPE ECONOMIC SCENARIOS (1985)

	A	B
Present Worth Discount Rate	12%	12%
Carrying Charge Rate	16%	16%
Capital Cost, $/kWe (c-t/c-c/coal/nuc)	300/600/1400/1700	300/600/1400/1700
Fuel Cost ($/MBtu)		
Gas/ Oil/ Oil/ Oil/ Coal/Nuc	3.66/6.5/7.5/7.53/1/5/1.0	3.66/6.5/7.5/7.53/1.5/1.0
Fuel Escalation Rate (%) (gas/oil/coal/nuc)	8/8/7/7	12/12/7/7
Capital Escalation Rate	8%	8%
O&M Escalation Rate	7%	7%

TABLE 3.3-2

COST/BENEFIT ANALYSIS RESULTS FOR BASELINE CONFIGURATION FOR SOLAR REPOWERING NEWMAN UNIT 1 EPE SYSTEM/ECONOMIC SOLAR REPOWERING FRACTION (75 PERCENT)

(10^6 1980 Dollars)

	Demonstration Unit		Nth Unit	
Direct Plant Cost	123.3		52.1	
Plant Cost (PWRR, M$)				
Capital	206.6		87.3	
Operating	71.8		30.2	
Total	278.4		117.5	
Value (PWRR*, M$)				
Fuel Escalation Rate	8 Percent	12 Percent	8 Percent	12 Percent
Fuel Savings	110.6	186.0	110.6	186.0
Fuel Cost	-28.5	-48.3	-28.5	-48.3
Variable O&M	3.5	3.5	3.5	3.5
Capacity Credit	10.2	10.2	10.2	10.2
Total	95.8	151.4	95.8	151.4
Cost (mills/kWh)	190.0	212.0	94.6	107.5
Cost/Benefit Ratio	2.91	1.84	1.23	0.78
Energy (10^6kWh)	191.3		191.3	
Capacity Factor	0.265		0.265	

* Present worth of revenue requirements method

TABLE 3.3-3

CHARACTERISTICS OF ALTERNATE SOLAR REPOWERING SYSTEMS

Criteria	System Alternatives: Baseline Configuration Primary Steam - Solar Reheat Steam - Solar Buffer Storage - None	Alternate 1 Primary Steam - Solar Reheat Steam - Solar Buffer Storage - Primary/Reheat	Alternate 3 Primary Steam - Solar Reheat Steam - Aux Heater Buffer Storage - None	Alternate 4 Primary Steam - Solar Reheat Steam - Aux Heater Buffer Storage - Primary
Cost (Total Capitalization)	Demo Plant 192M \$ Nth Plant 81M \$	Demo Plant 201M \$ Nth Plant 91M \$	Demo Plant 166M \$ Nth Plant 71M \$	Demo Plant 176M \$ Nth Plant 80M \$
Annual Electrical Energy Output	191 x 106kWh	173 x 106kWh	191 x 106kWh	173 x 106kWh
Cost/Benefit Ratio (8% Fuel Escalation)	Demo Plant 2.91 Nth Plant 1.23	Demo Plant 2.92 Nth Plant 1.31	Demo Plant 3.04 Nth Plant 1.29	Demo Plant 3.25 Nth Plant 1.48
Annual Fossil Fuel Savings				
Equivalent Barrels of Oil/Year	109,400	115,700	80,000	99,600
Operating and Maintenance Factors	Next to fewest added components More complex heliostat control system Turbine inlet temperature control is complicated by solar reheat due to fractional variations in energy input Next to most impact on operator training	Most added components More complex heliostat control system Turbine inlet temperature control is complicated by solar reheat due to fractional variations in energy input. Usage of buffer storage increases complexity. Requires most training of operators	Fewest added components Less complex heliostat control system Turbine inlet temperature control is less complex with auxiliary boiler for reheat Least impact on training of operators	Next to most added components Less complex heliostat control system Turbine inlet temperature control is less complex with auxiliary boiler for reheat. Use of buffer storage increases complexity. Next to least impact on training of operators
Reliability Factors	Intermediate impact on reliability Most heliostats Control system for focusing on 2	Greatest impact on reliability Most heliostats Control system for focusing on 2 receivers	Least impact on reliability Fewest heliostats Control system for focusing on 1 receiver	Intermediate impact on reliability Fewest heliostats Control system for focusing on 1 receiver

1 of 3

TABLE 3.3-3 (Cont)

Criteria	System Alternatives: Baseline Configuration Primary Steam - Solar Reheat Steam - Solar Buffer Storage - None	Alternate 1 Primary Steam - Solar Reheat Steam - Solar Buffer Storage - Primary/Reheat	Alternate 3 Primary Steam - Solar Reheat Steam - Aux Heater Buffer Storage - None	Alternate 4 Primary Steam - .Solar Reheat Steam - Aux Heater Buffer Storage - Primary
	receivers			
	2 receivers	2 receivers	1 receiver	1 receiver
		Buffer storage and connections to 2 receivers	Oil fired auxiliary heater may be less reliable for fast transient application	Buffer storage and connection to 1 receiver
				Oil fired heater may be less reliable for fast transient application
Environmental, Institutional and Safety Factors	Less failure modes	Most failure modes	Least failure modes	Less failure modes
	Larger terrestrial field for heliostats	Largest terrestrial field for heliostats and buffer storage	Smallest terrestrial field for heliostats	Smaller terrestrial field for heliostats and buffer storage
	Greatest reduction in air pollution	Greatest reduction in air pollution	Reduction in air pollution	Reduction in air pollution
			Requires Texas air Control Board Licensing and National Energy Act variance for new heater.	Requires Texas air Control Board Licensing and National Energy Act variance for new heater.
Technical Risk for 1985	Development of low cost heliostat in progress	Development of low cost heliostat in progress	Development of low cost heliostat in progress	Development of low cost heliostat in progress
	Primary solar receiver requires design and test to spec.	Primary solar receiver requires design and test to spec.	Primary solar receiver requires design and test to spec.	Primary solar receiver requires design and test to spec.
	Reheat receiver requires design and test to spec.	Reheat receiver requires design and test to spec.	Fast response auxiliary heater requires design and test to spec.	Fast response auxiliary heater requires design and test to spec.
		Needs development of low cost, high temperature, fast response buffer storage.		Needs development of low cost, high temperature, fast response buffer storage

TABLE 3.3-3 (Cont)

Criteria	System Alternatives: Baseline Configuration Primary Steam - Solar Reheat Steam - Solar Buffer Storage - None	Alternate 1 Primary Steam - Solar Reheat Steam - Solar Buffer Storage - Primary/Reheat	Alternate 3 Primary Steam - Solar Reheat Steam - Aux Heater Buffer Storage - None	Alternate 4 Primary Steam - Solar Reheat Steam - Aux Heater Buffer Storage - Primary
New Technology Demonstration	Low cost heliostat	Low cost heliostat	Low cost heliostat	Low cost heliostat
	Total solar input capability	Total solar input capability	Partial solar input capability	Partial solar input capability
	Primary receiver	Primer receiver	Primary receiver	Primary receiver
	Reheat receiver	Reheat receiver	Auxiliary heater	Auxiliary heater
		Buffer storage		Buffer storage

TABLE 3.3-4

COMPARATIVE EVALUATION OF SYSTEM ALTERNATIVES

	Baseline Configuration	Alternative 3
STRENGTHS:	Most favorable cost/ benefit ratio	Lowest total capital costs
	Additional annual fossil fuel savings (over 30 percent)	
		Least requirements for operating and maintenance
	Little impact on reliability	Least impact on reliability
	Very little impact on safety and evironment	Very little impact on safety and evironment
	Very little technical risk	Very little technical risk
	Demonstrates total solar input capability	
WEAKNESSES:	Control of turbine inlet temperature with solar reheat may require further consideration.	Does not demonstrate total solar input capability
		Increases fossil fuel consumption

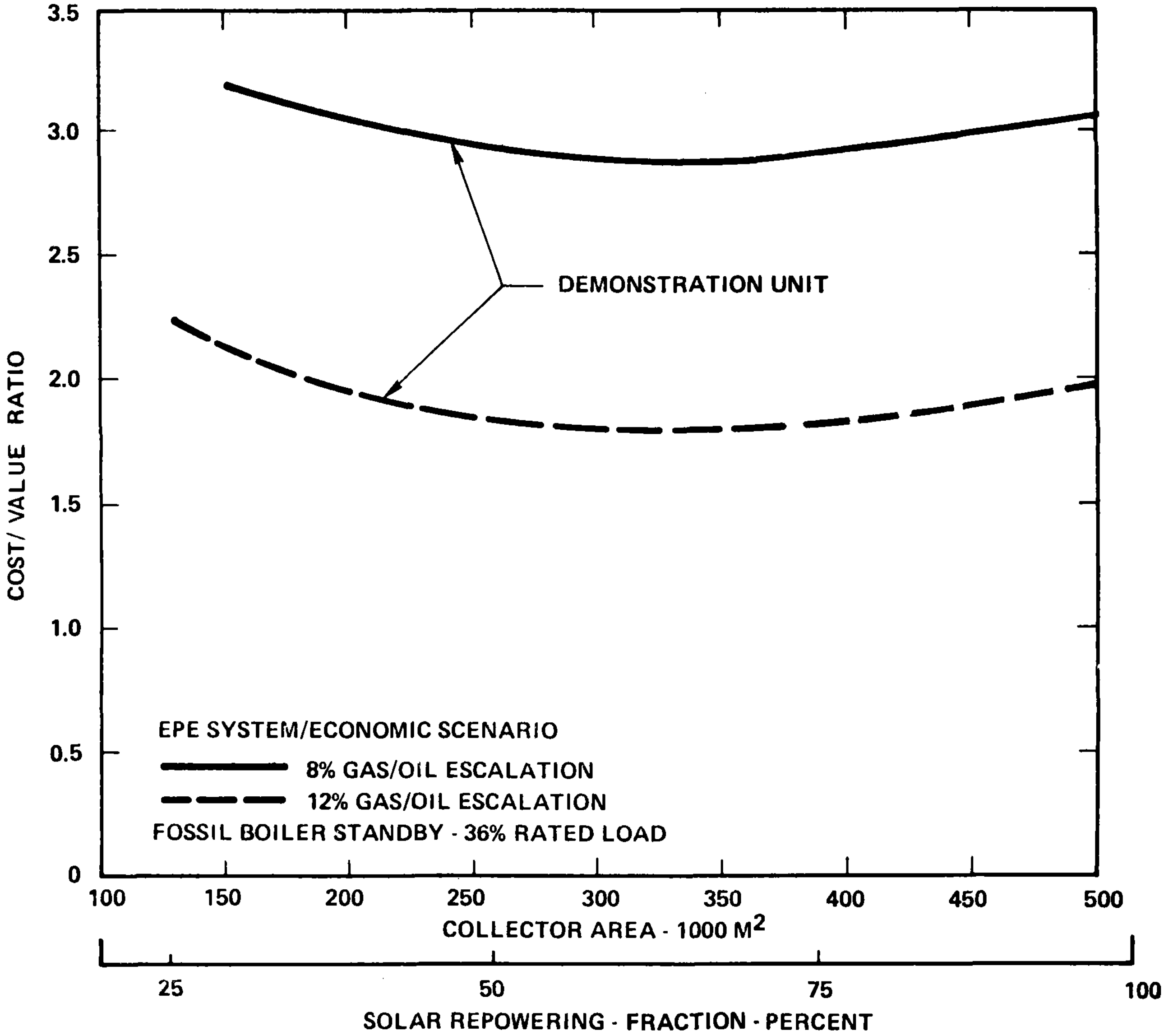


FIGURE 3.3-1
REPOWERING FRACTION ANALYSIS
FOR THE BASELINE CONFIGURATION

3.4 CHARACTERISTICS OF PREFERRED SYSTEM

The Preferred Configuration for solar repowering Newman Unit 1 is identical to the Baseline Configuration in that solar energy is used to provide steam to the high pressure and intermediate stages of the turbine generator. The system and subsystem analyses summarized in Sections 3.2 and 3.3, however, have resulted in numerous modifications to the Baseline Configuration to be incorporated into the Preferred Configuration.

Table 3.4-1 summarizes the characteristics of the Preferred Configuration for the solar repowering demonstration at Newman Station. The Preferred Configuration, based on a solar repowering fraction of 50 percent, utilizes a north field (160° arc) of heliostats. A single tower housing the primary and reheat receivers is located adjacent to the turbine building. The primary receiver design is a drum type boiler with pumped recirculation, using an external screened tube concept, which is being developed by DOE as part of the Advanced Water/Steam Receiver Program.

TABLE 3.4-1

SOLAR REPOWERED NEWMAN UNIT 1
CHARACTERISTICS OF PREFERRED CONFIGURATION

Unit Type	Reheat steam turbine
Unit Rating	82 MWe
Solar Repowering Percentage*	50 Percent
Plant Operating Scenario	Maximize solar benefit Fossil operation only on cloudy days Economic dispatch on fossil energy
Collector Subsystem	
Field configuration	North field (160° arc)
Field area	1.5 km2 (includes exclusion area)
Heliostat area	246,000m2
Number of heliostats	2,776
Receiver/Tower Subsystem	
Primary receiver type	External (pumped, recirculation boiler/screened tube concept)
Primary receiver size	12m dia x 16.5m long (210° arc)
Reheat Receiver	
Type	External
Size	12m dia x 16.5m long (210° arc)
Tower Height	
Number of towers	1
Primary receiver C/L	155m
Reheat received C/L	138m
Electrical Power Generation Subsystem	
Cycle	Steam Rankine (reheat)
Net unit efficiency (solar/fossil)	37.5/39.5
Turbine inlet	10.1 MPa/538°C/538°C
Heat rejection	Wet cooling tower
Fossil Boiler	
Type	Gas/oil
Rate load efficiency	84.4%
Automatic operation	Minimum 28% of rated unit electrical output
Startup energy/cold condition	106 x 106kJ/startup
Warm standby	15.8 x 106kJ/startup

NOTE:

* Based on an insolation level of 950 watts/m2

SECTION 4

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 498 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 Preferred Configuration for solar repowering Newman Unit 1 is illustrated in Figure 4.1-1. Conceptual design drawings of the Preferred Configuration are presented in Volume III (Appendix B). The Preferred Configuration utilizes water/steam central receiver technology to provide main steam to the high pressure stage, 10.1 MPa/538°C (1,450 psig/1,000°F), and reheat steam to the intermediate stage, 2.9 MPa/538°C (425 psig/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 when solar energy is not available.

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.

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 generated steam ensures that the temperatures are maintained within turbine design limits. Solar generated steam is used for most of the flow, with fossil steam generation to replace any steam flow reduction due to intermittent cloud cover and for economic dispatch when solar energy is nonavailable.

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 of the Preferred Configuration. 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.

The heliostats employed in the collector field are the Westinghouse Second Generation Heliostats, which have a glass reflective surface area of 81.8 m^2(880 ft^2), an aspect ratio of 1.5:1, and a weight of 3730 kg(8210 lb). This heliostat concept was selected as representative of the class of heliostats that will be available in 1985 for solar repowering applications.

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) employed for the Preferred Configuration are based on the improved water/steam pumped recirculation central receiver boiler technology being developed by DOE that 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 the 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 the 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 receiver and the chemical energy in fossil fuels from 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 piping equipment required to interface the solar steam supply system.

FIGURE 4.1-1
SOLAR REPOWERED NEWMAN UNIT 1

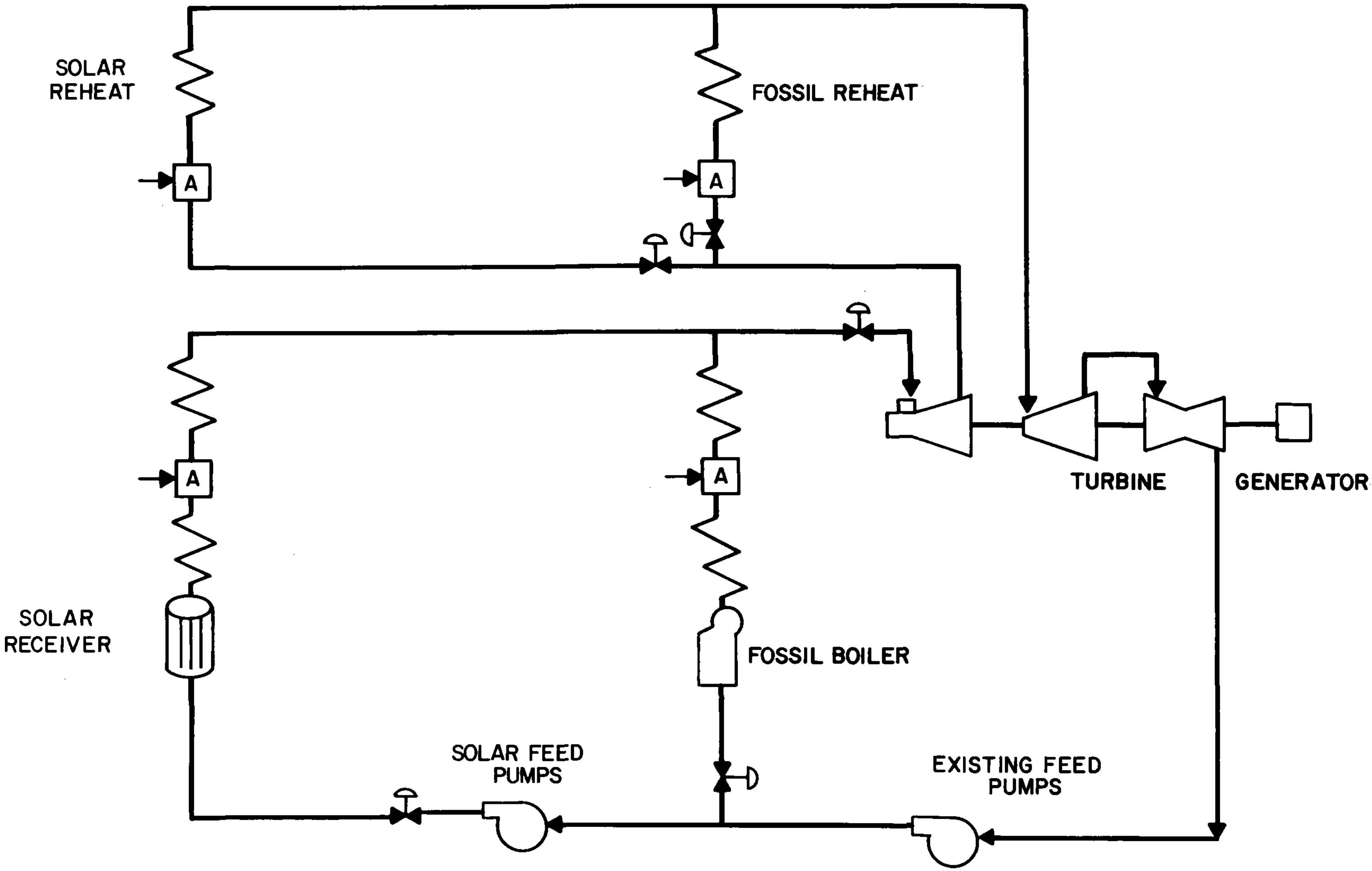


FIGURE 4.1-2
SIMPLIFIED FLOW SCHEMATIC

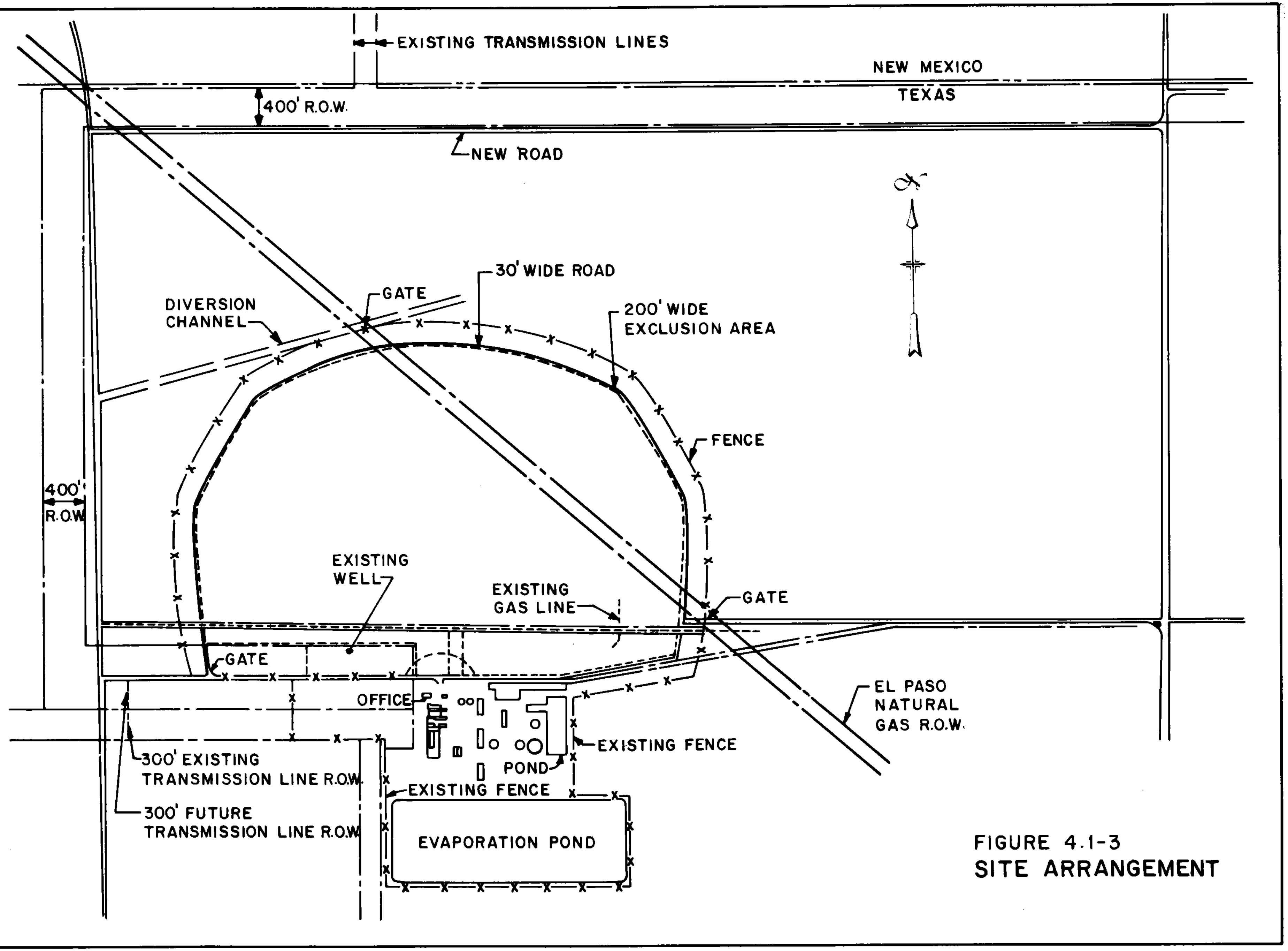


FIGURE 4.1-3
SITE ARRANGEMENT

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 of the rated net electrical output, 82 MWe, at the design point solar conditions corresponding to noon summer 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 Westinghouse 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,

TABLE 4.2-1

SYSTEM PERFORMANCE REQUIREMENTS

Unit Rating	82 MWe
Solar Repowering Percentage*	50 percent
Design Point	Noon summer solstice
Electric Power Generation	
Cycle	Steam
Net unit efficiency (solar/fossil)	37.5/39.5
High pressure turbine inlet	10.1 MPa/538°C
Intermediate turbine inlet	2.93 MPa/538°C
Main steam flow	257,143 kg/hr
Collector Subsystem (Design Point Conditions)	
Power incident on primary receiver	
Noon Summer	105 MWt
Noon Winter	118 MWt
Power incident on reheat receiver	
Noon Summer	25 MWt
Noon Winter	27 MWt
Receiver Subsystem**	
Power absorbed in primary receiver (Noon Summer)	92 MWt
Primary steam outlet flow	129,000 kg/hr
Primary receiver outlet pressure/ temperature	10.8 MPa/549°C
Allowable primary receiver pressure drop	1.72 MPa
Design heat flux (water/steam tubes) in primary receiver (noon winter)	0.60/0.3 MW/m^2
Power absorbed in reheat receiver	13 MWt

1 of 2

TABLE 4.2-1 (Cont)

Reheat steam outlet flow	115,400 kg/hr
Reheat receiver outlet pressure/ temperature	2.97 MPa/549°C
Allowable reheat pressure drop	172 kPa
Fossil Energy Subsystem	
Efficiency	84.4%
Automatic operation	28% minimum load
Cold condition startup energy	10.6×10^7kg (100 MBtus)
Warm standby startup energy	1.6×10^7kg (15 MBtus)

NOTES:

* Based on an insolation level of 950 watts/m^2

** 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.

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 210 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 3.4-1. 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 plant 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 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 converted to oil in 1990, as may be required by the National Energy Act, 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 isolation 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 is 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 1.50 km^2 (370 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 are 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.

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

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 includes paved roads and fences to provide access to the solar collectors and receivers and 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 requires 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 for the heliostat field and 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.

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 high pressure feedwater heater is split, with part of the flow going to the fossil boiler and the remainder going to the solar feed pumps. These pumps boost the feedwater pressure to overcome pressure losses in the solar receiver and piping. 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.

- The 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 summer solstice).
- The solar insolation is 950 W/m^2.
- The heliostats are placed in a radial stagger arrangement so as to minimize the effects of blocking shading.
- Solar energy is used both to generate and superheat primary steam and is used for reheat.
- The heliostat design is based on the Westinghouse Second Generation Heliostat.
- The repowered unit is operated with steam produced from either the solar or fossil boiler or from a combination of both.
- The 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 summer solstice design point and for annual average conditions. The effect of varying operating modes (level and ratio of fossil and solar produced electrical power output) has been evaluated to determine its impact on the thermal power absorbed in the solar receivers. The station heat rates are listed in Table 4.5-1 for eight operational modes.

At the design point, 105 MW of thermal power is absorbed by the steam in the two solar receivers. The thermal power incident on the receiver surfaces is 130 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 summer solstice. 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 (2,776 heliostats) is shown in Table 4.5-2 with the direct solar insolation at 950 W/m^2.

With a north collector field, the cosine loss is greatest at summer solstice. Therefore, the selection of the design point at summer solstice assures that, at noon on any good clear day (insolation greater than 950 W/m^2), the repowered Newman Unit 1 would have the capability to produce more than 41 MW net of electrical power from solar energy while operating in the hybrid mode. This also means that the solar steam generating and transfer components (receivers, piping, and pumps) are designed with the noon winter solstice considered (peak thermal power).

Based on the Solmet weather tapes for El Paso in the years 1964 to 1970, there are typically 100 to 200 hours/year where the direct solar insolation is greater than 1,000 W/m^2. With a solar insolation of 1,000 W/m^2, the repowered Newman Unit 1 could produce approximately 50 MW net electrical power from solar while operating in the hybrid mode or the solar-only mode. If the solar receivers were designed to absorb the peak solar insolation, which occur only a relatively small fraction of the year, the cost of the receivers would be increased. Furthermore, the radiation and convection losses would also be increased for every hour of operation, resulting in a reduction of the net electrical power produced by solar energy. Therefore, in the preliminary design phase the most cost-effective size for the solar receivers will be determined.

As indicated in Table 4.5-2, the annual average power incident on the solar receivers is 129 MW with a direct normal isolation value of 950 W/m^2 which corresponds closely to the design point (noon summer solstice). The efficiency chart for annual average conditions is shown on Figure 4.5-2 which is also similar to the design point efficiencies. The corresponding annual average heat rate is therefore approximately 9,854 kJ/kWh (9,340 Btu/kWh).

4.5.2 Solar Receiver/Fossil Boiler Transient Interaction

This section describes the solar transient analysis that has been performed to evaluate the consequences of cloud shadow passage over the collector field. The underlying assumptions used in the development of the model are described, a simplified block diagram of the computer simulation is presented, and the conclusions of the analysis are discussed.

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 (TAF). 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

Design Cloud Shadow Velocity

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, in Reference FSCM 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 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 Main and Reheat Steam Flow and Steam Temperature

The fossil boiler main 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 main 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 is performed using TAF, a FORTRAN language program that 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 temperature is controlled to maintain a present 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/sec) and 78 percent flow (55.7 kg/sec). Table 4.5-3 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 nearly constant to avoid a turbine pressure trip.

Several key observations can be made from the transient analyses. The results show in Figures 4.5-5 to 4.5-9 that, for the average 8.0 m/sec (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 transient.

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. 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/sec 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 main turbine is stable with fluctuations less than ±5 percent for the 10 percent cloud cover case. Likewise, power output remains very stable. With 50 percent cloud cover, 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, 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 and 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 show that the turbine pressure transient is significantly reduced. Also, no significant steam flow overshoot is observable. The power output transient is related to the inital 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 depreciation 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.

TABLE 4.5-1

STATION HEAT RATES

Operational Mode	Net Generation, MWe Fossil/Solar	Percent of Rated Main Steam Flow	Auxiliary Power, MWe	Net Station Heat Rate 103 kj/kWh (Btu/kWh) Fossil	Solar
Fossil/Solar	41.0/41.0 (Design Pt)	103	3,99	10.7 (10,124)	9.0 (8,545)
Fossil/Solar	20.5/41.0	77	3.84	11.1 (10,541)	9.3 (8,853)
Fossil/Solar	20.5/20.5	37	3.27	11.8 (11,176)	9.9 (9,380)
Fossil only	82.0/-	100	3.56	10.8 (10,250)	-
Fossil only	41.0/-	53	2.90	11.6 (11,000)	-
Fossil only	20.5/-	31	2.30	13.7 (13,000)	-
Solar only	-/41.0	53	3.27	-	9.9 (9,380)
Solar only	-/20.5	31	2.46	-	11.7 (11,060)

Rated main steam flow is 258,100 Kg/hr (567,000 lb/hr).

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 higher if steam temperatures are maintained at 538°C at partial loads.

TABLE 4.5-2

CONCEPTUAL SOLAR FIELD PERFORMANCE

	Power Incident on Receivers (MWt)
Noon summer solstice	130
Noon equinox	137
Noon winter solstice	145
2 p.m. winter solstice	140
Annual average	129

TABLE 4.5-3

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

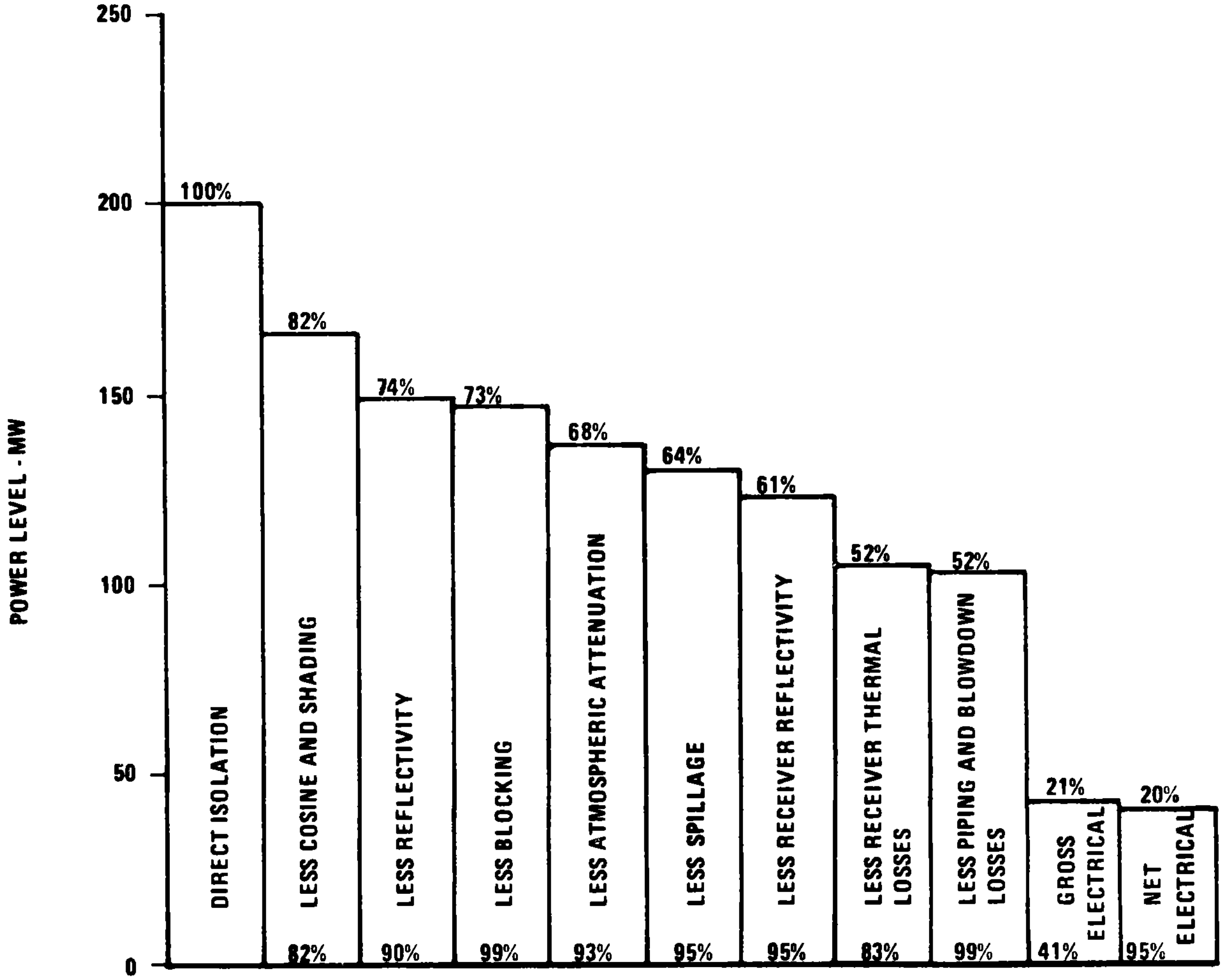


FIGURE 4.5-1
SOLAR REPOWERING NEWMAN UNIT 1 EFFICIENCY CHART (DESIGN POINT - NOON SUMMER SOLSTICE - 950 W/M^2 INSOLATION)

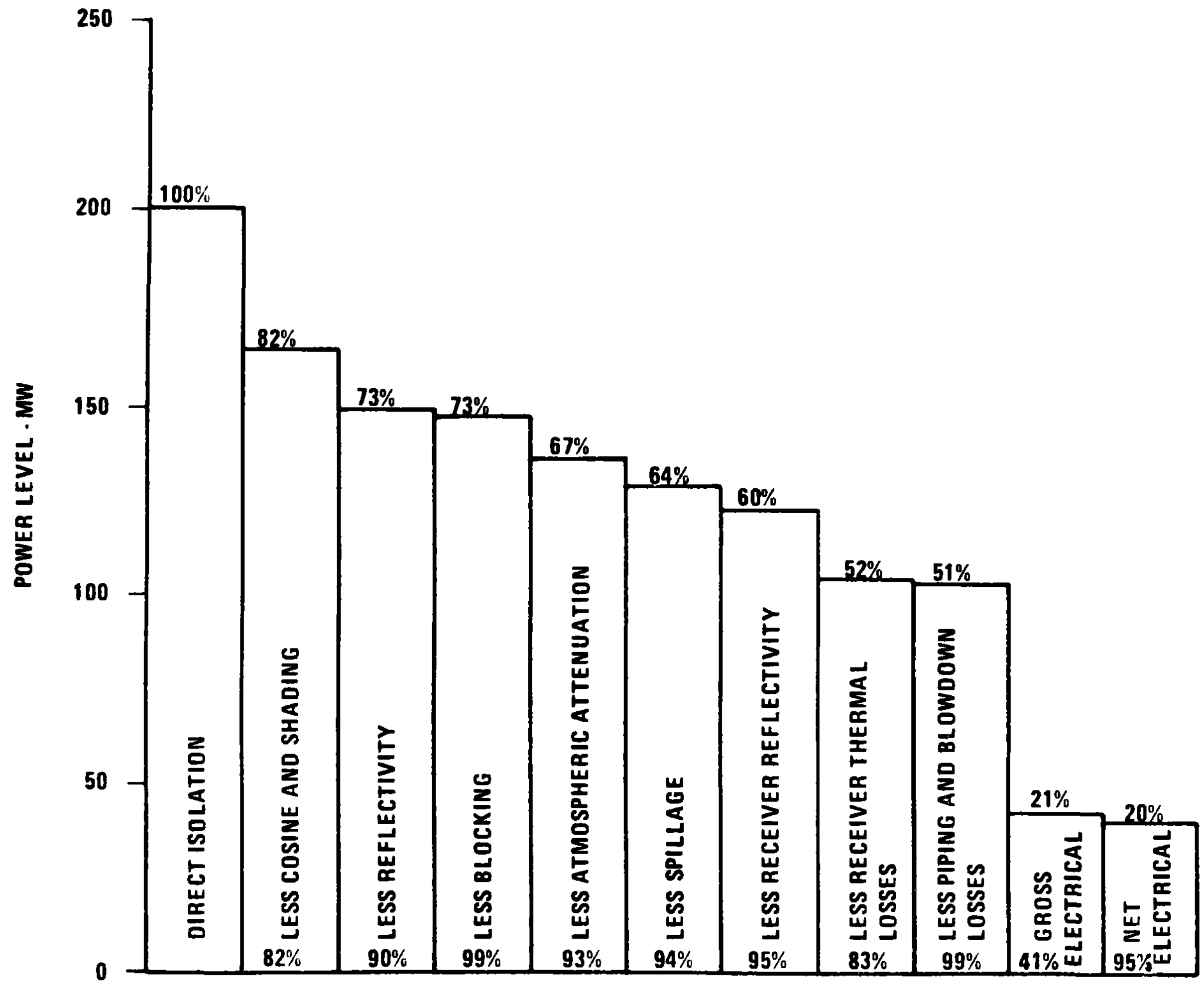


FIGURE 4.5-2
SOLAR REPOWERING NEWMAN
UNIT 1 EFFICIENCY CHART
ANNUAL AVERAGE

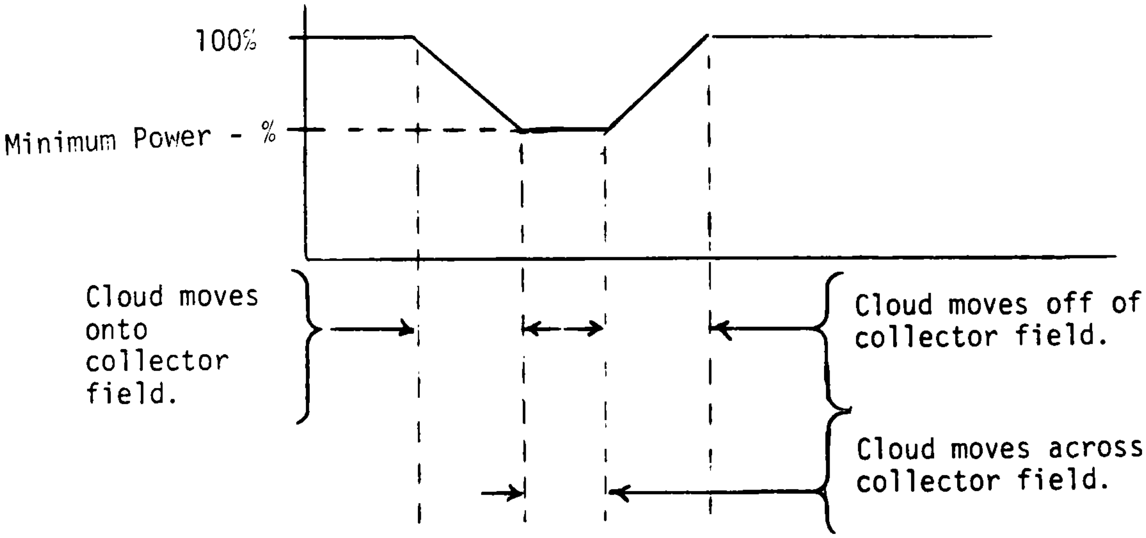


FIGURE 4.5-3
NSRM FORCING FUNCTION

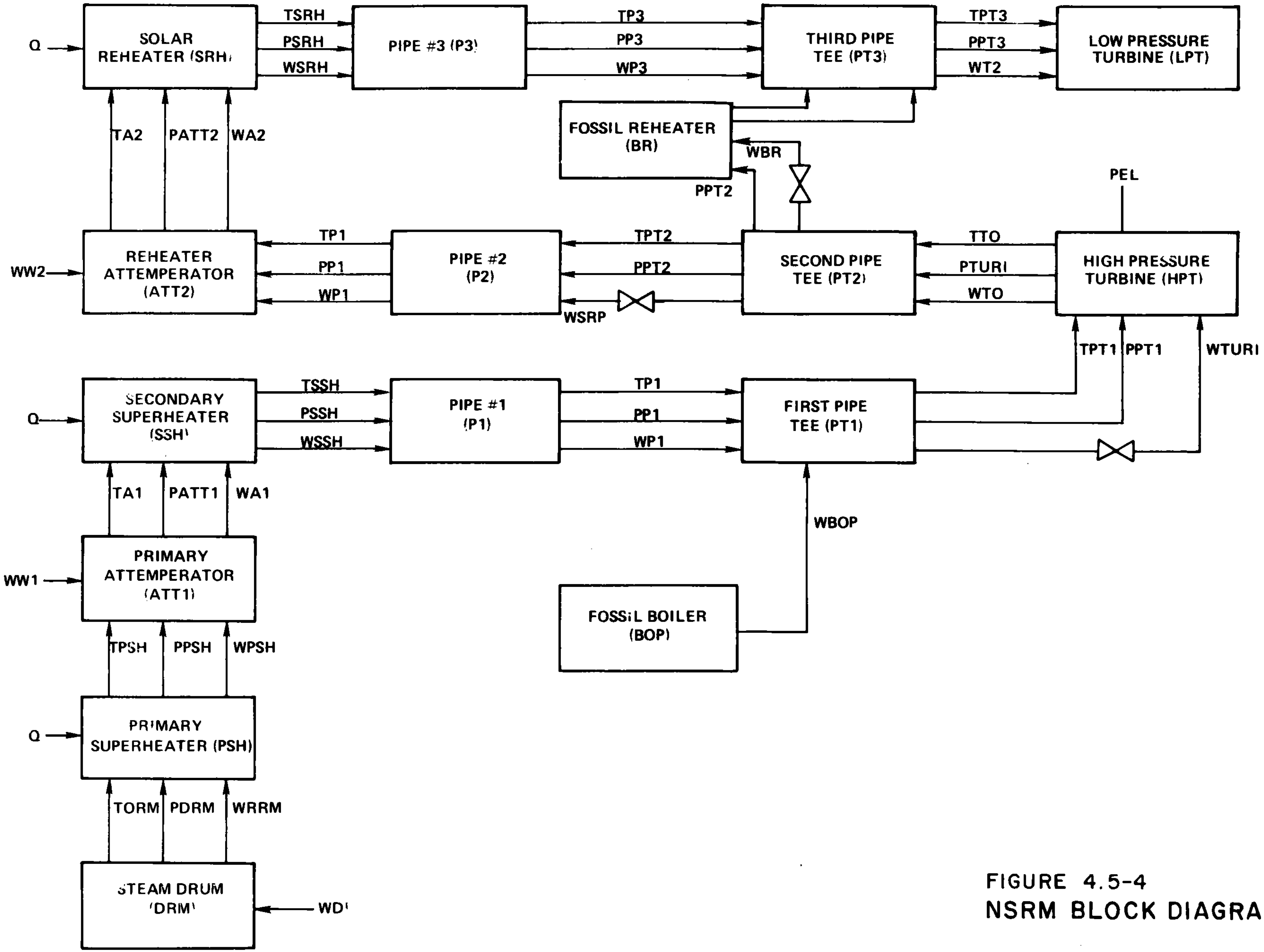
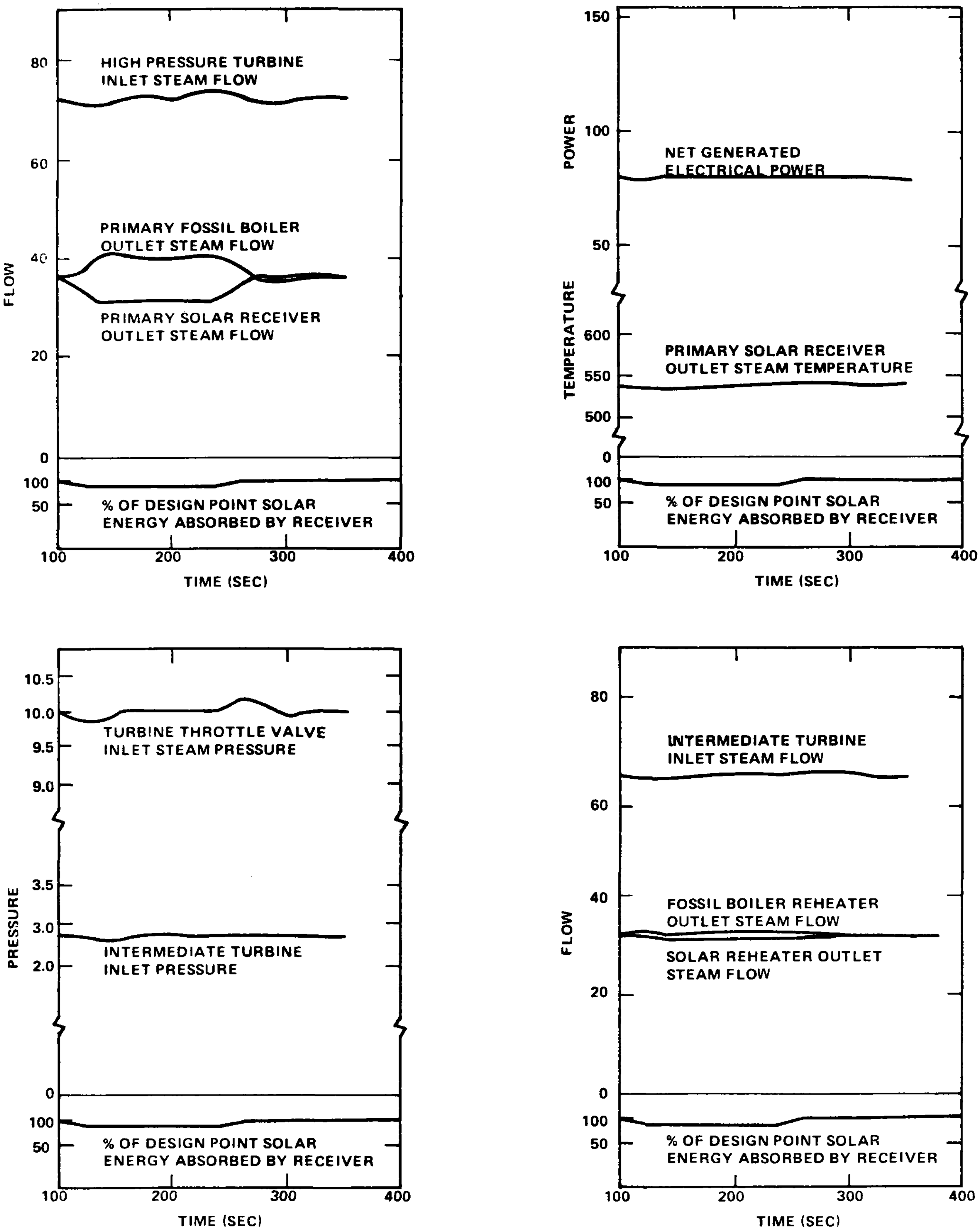
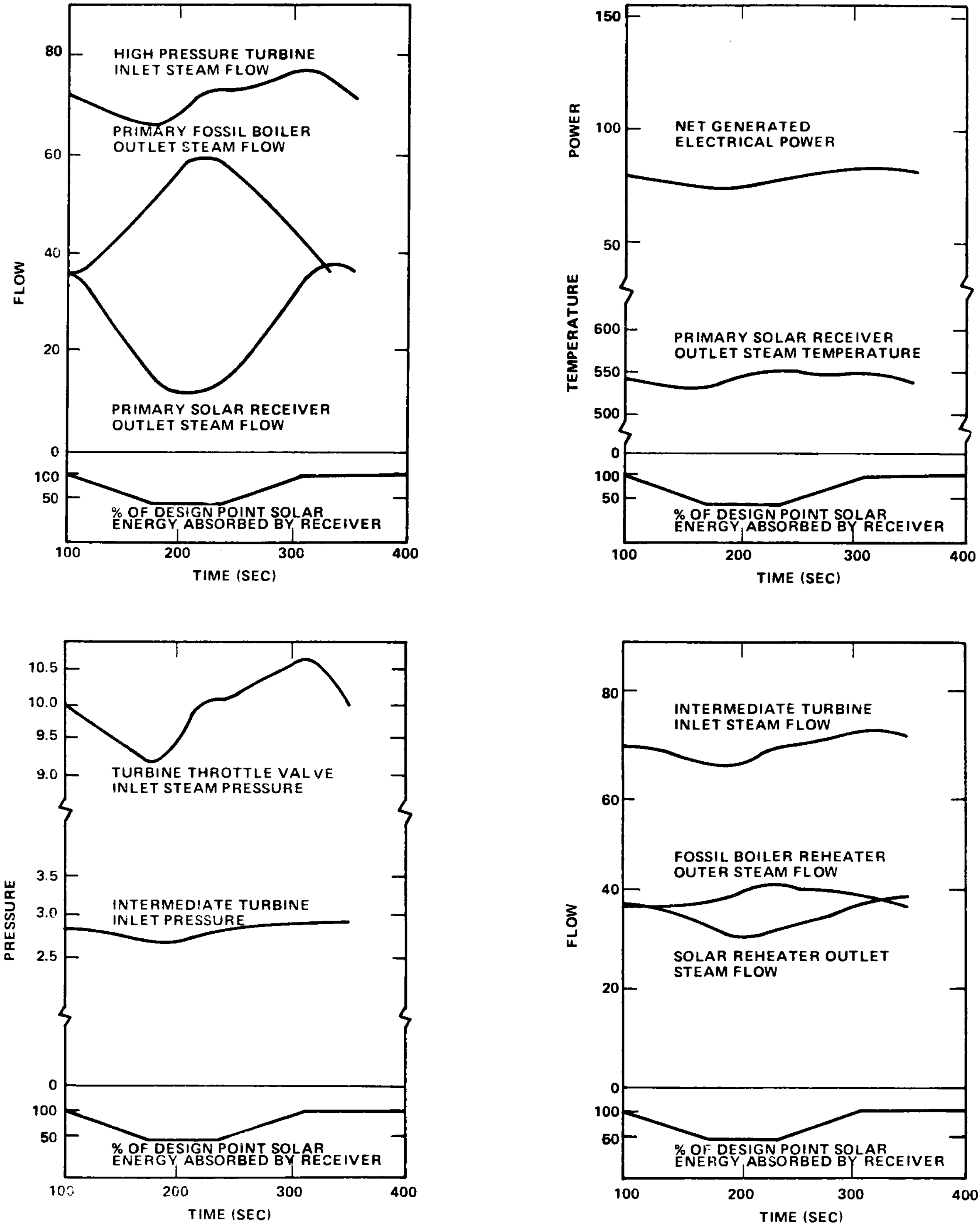


FIGURE 4.5-4
NSRM BLOCK DIAGRAM



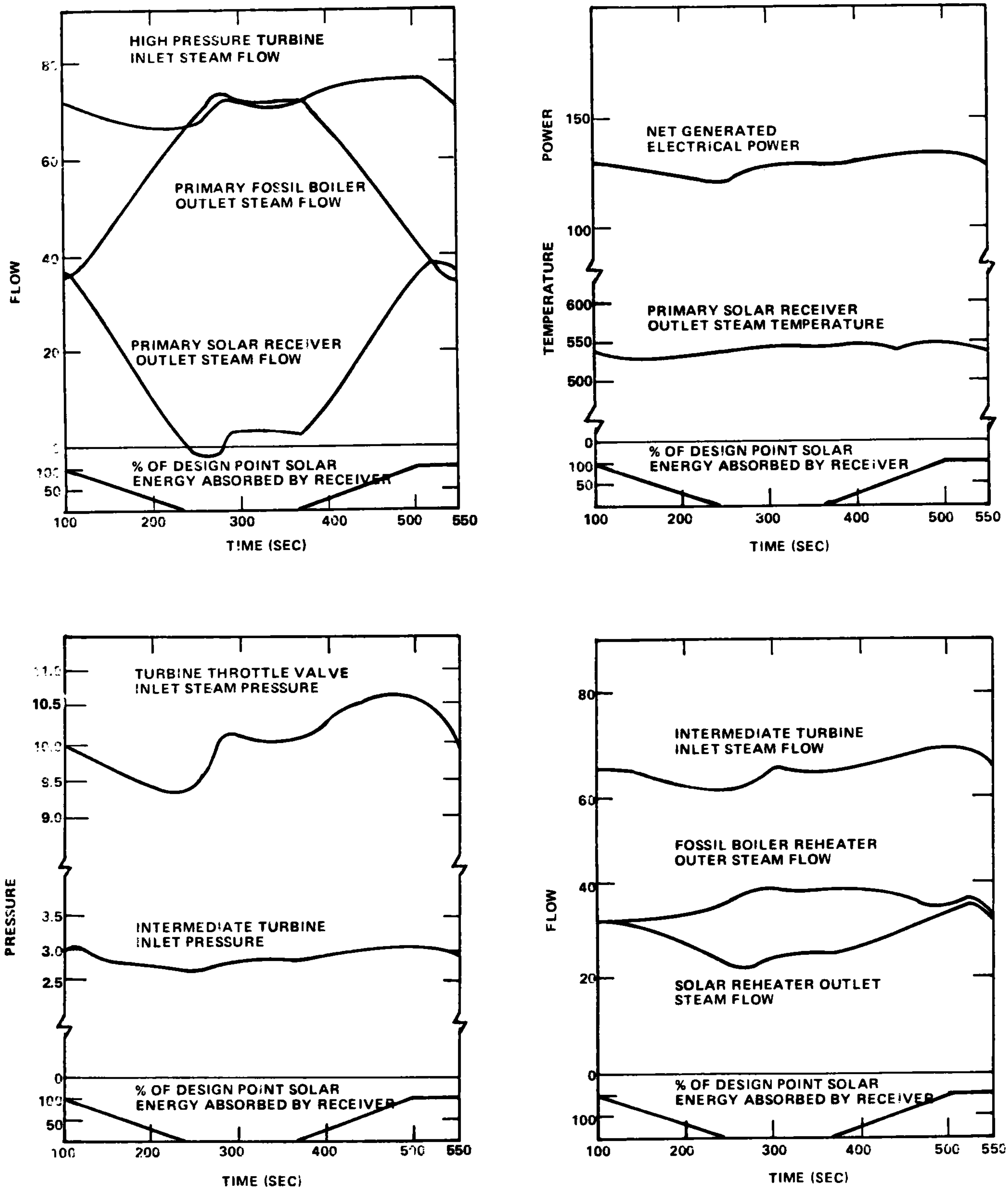
NOTE: 20%/MIN BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

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



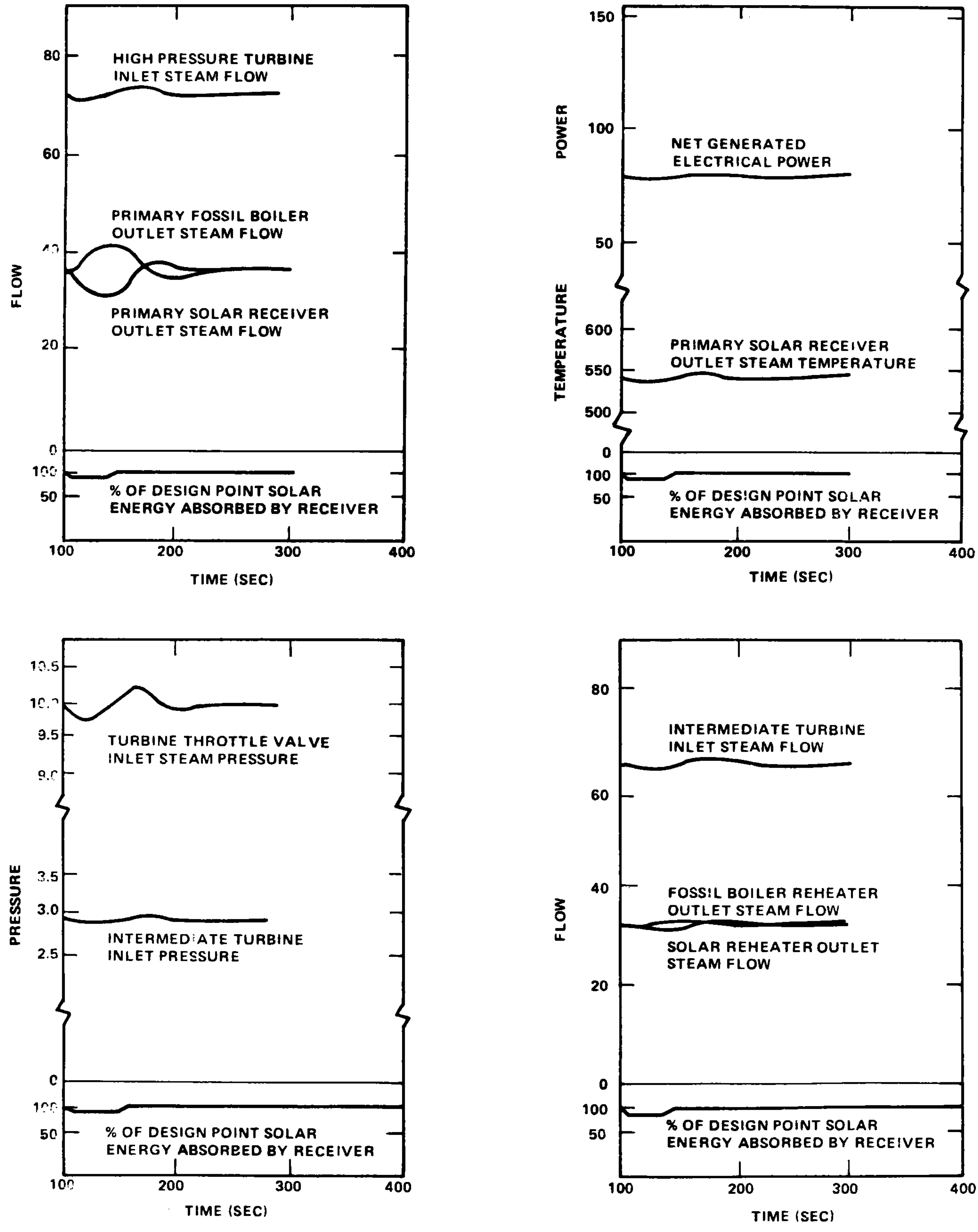
NOTE: 20%/MIN BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

FIGURE 4.5-6
NSRM TRANSIENT RESPONSE TO 50% CLOUD COVERAGE WITH 8m/sec VELOCITY



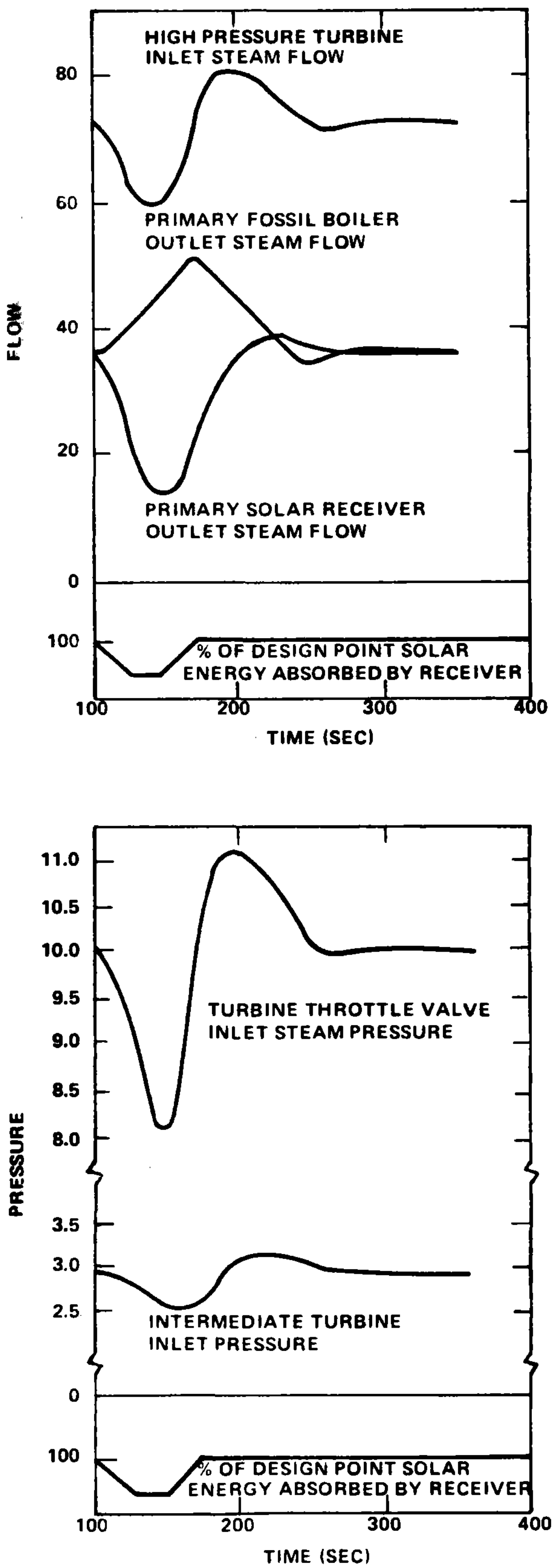
NOTE: 20%/MIN BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

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



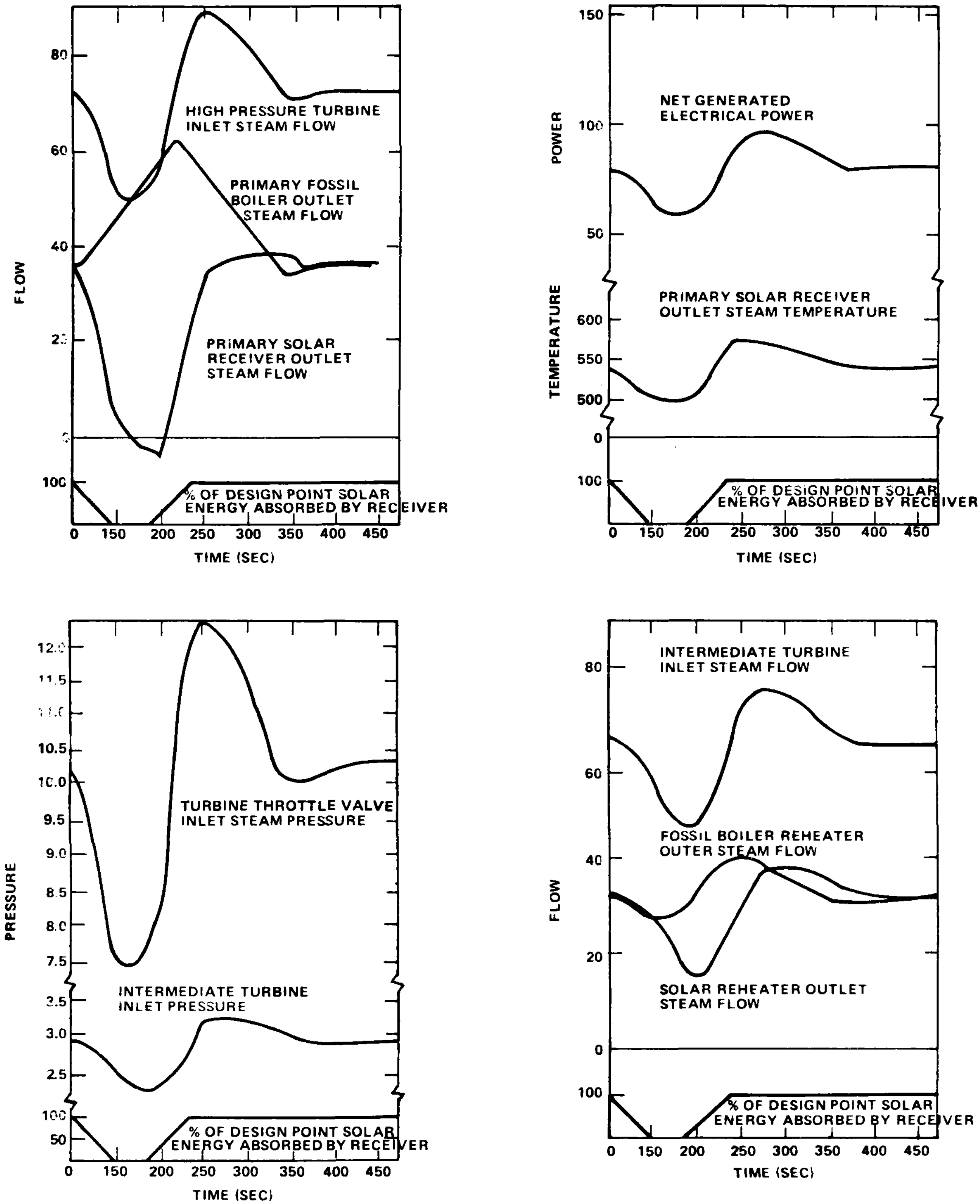
NOTE: 20%/MIN BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

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



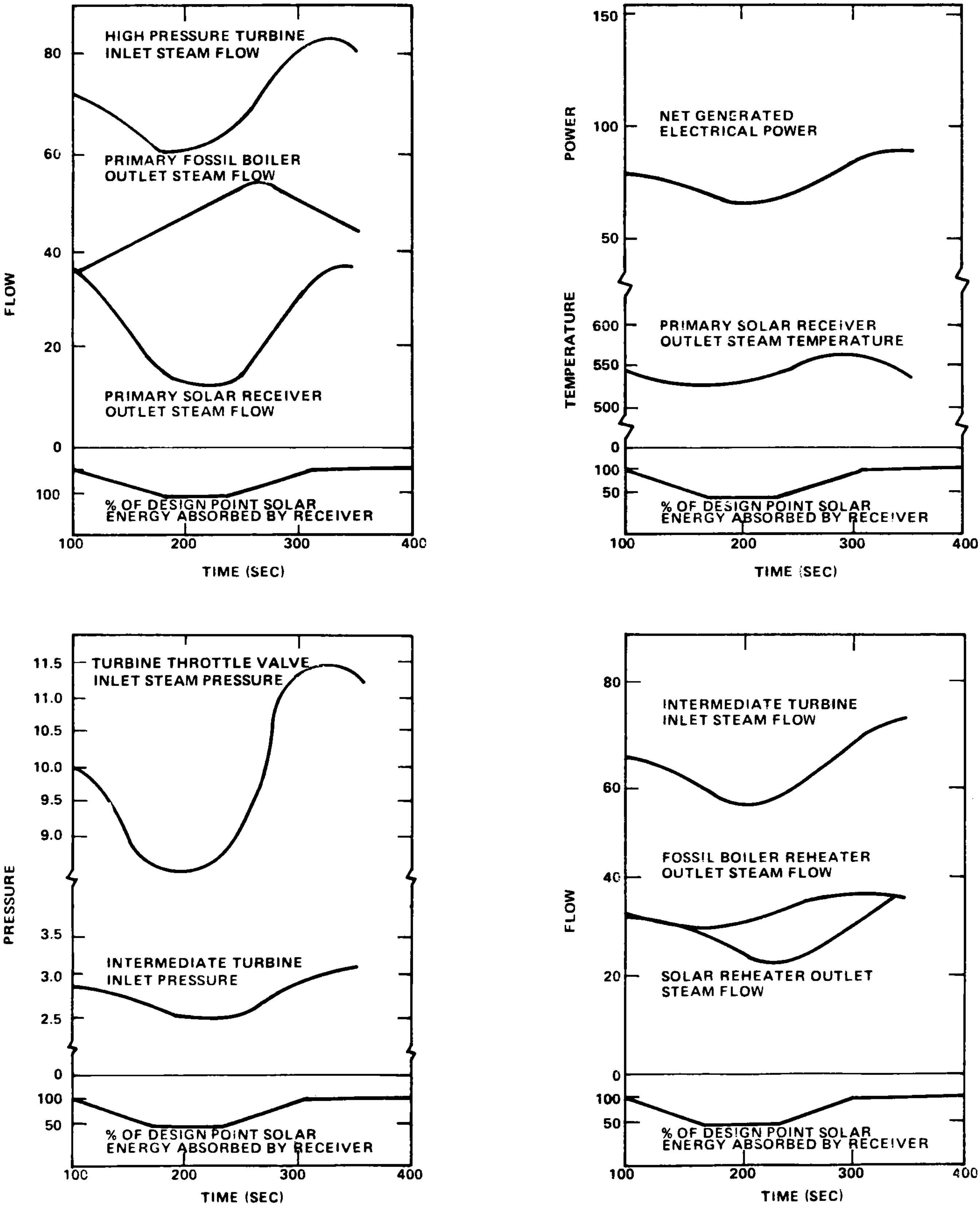
NOTE: 20%/MIN BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

FIGURE 4.5-9
NSRM TRANSIENT RESPONSE TO 50% CLOUD COVERAGE WITH 22 m/sec VELOCITY



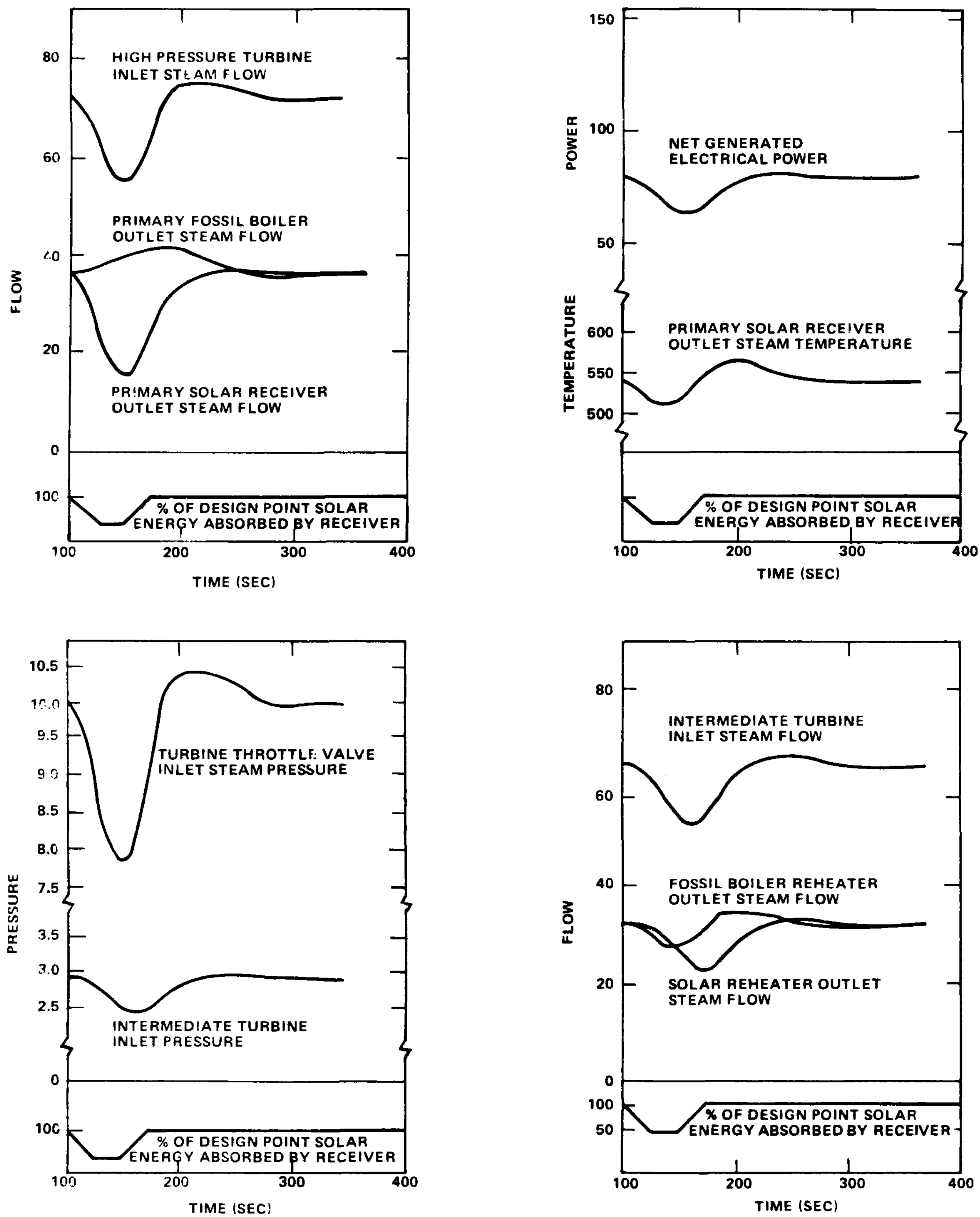
NOTE: 20%/MIN. BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

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



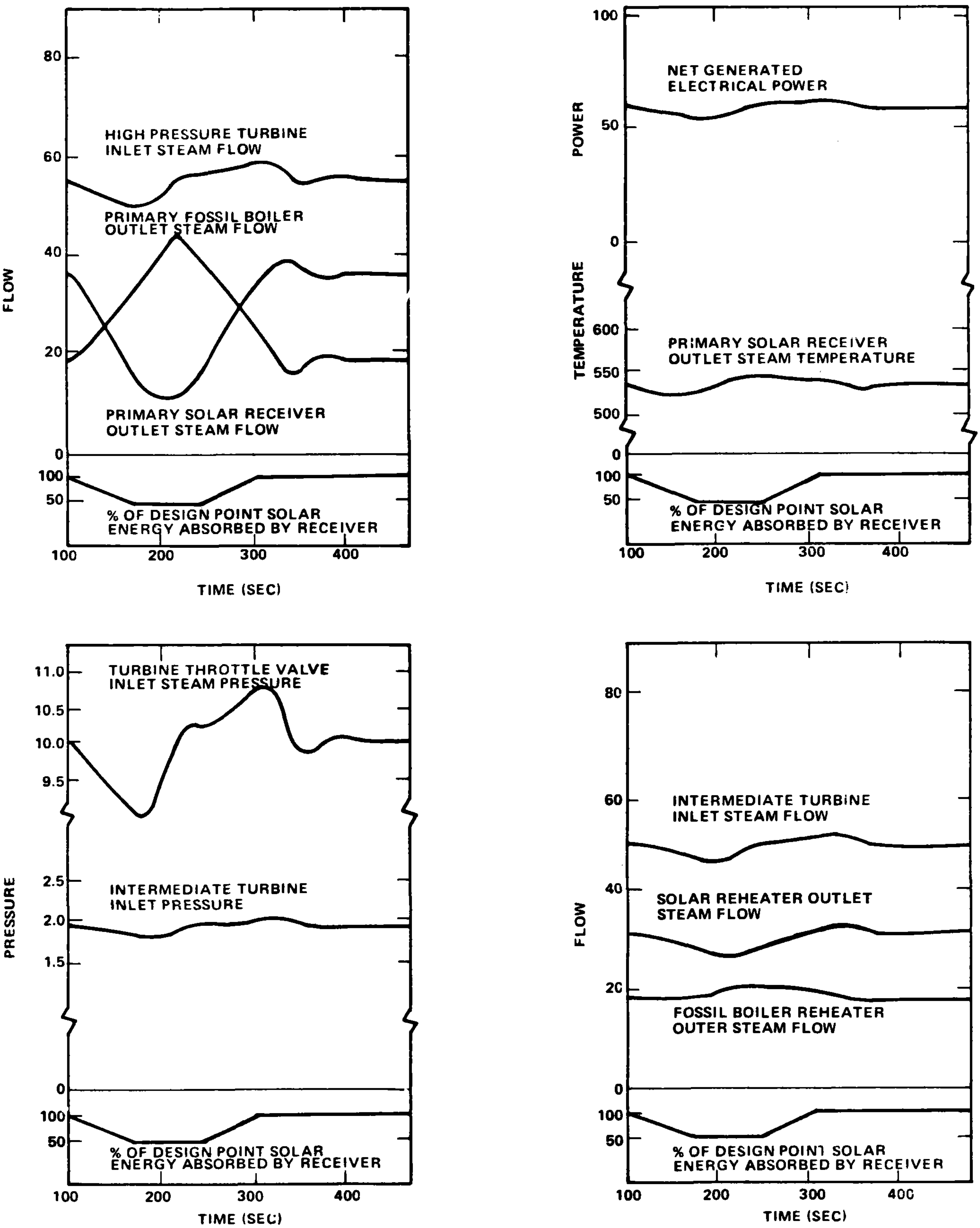
NOTE: 10%/MIN. BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

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



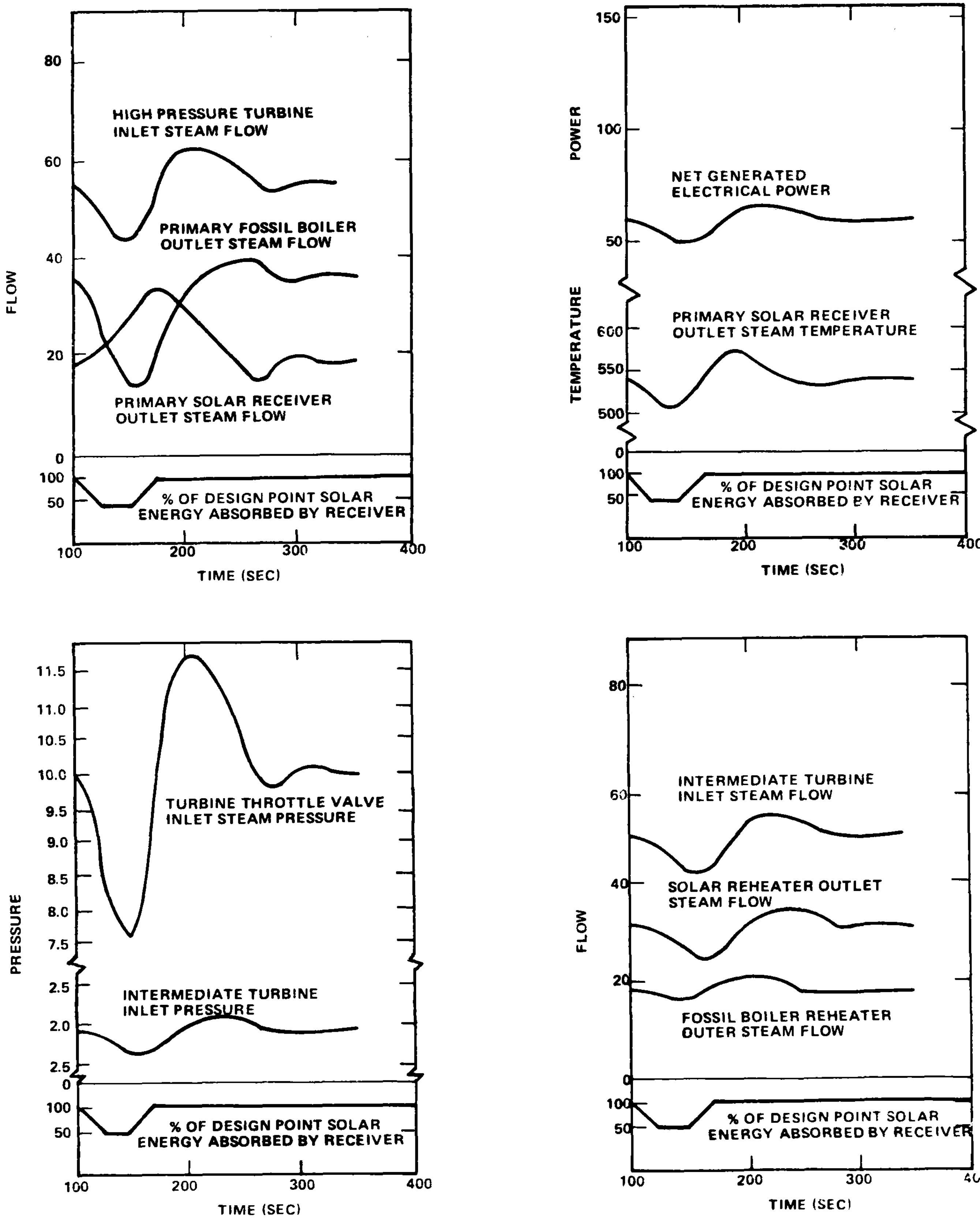
NOTE: 6.3%/MIN. BOILER RESPONSE LIMIT
50/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

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



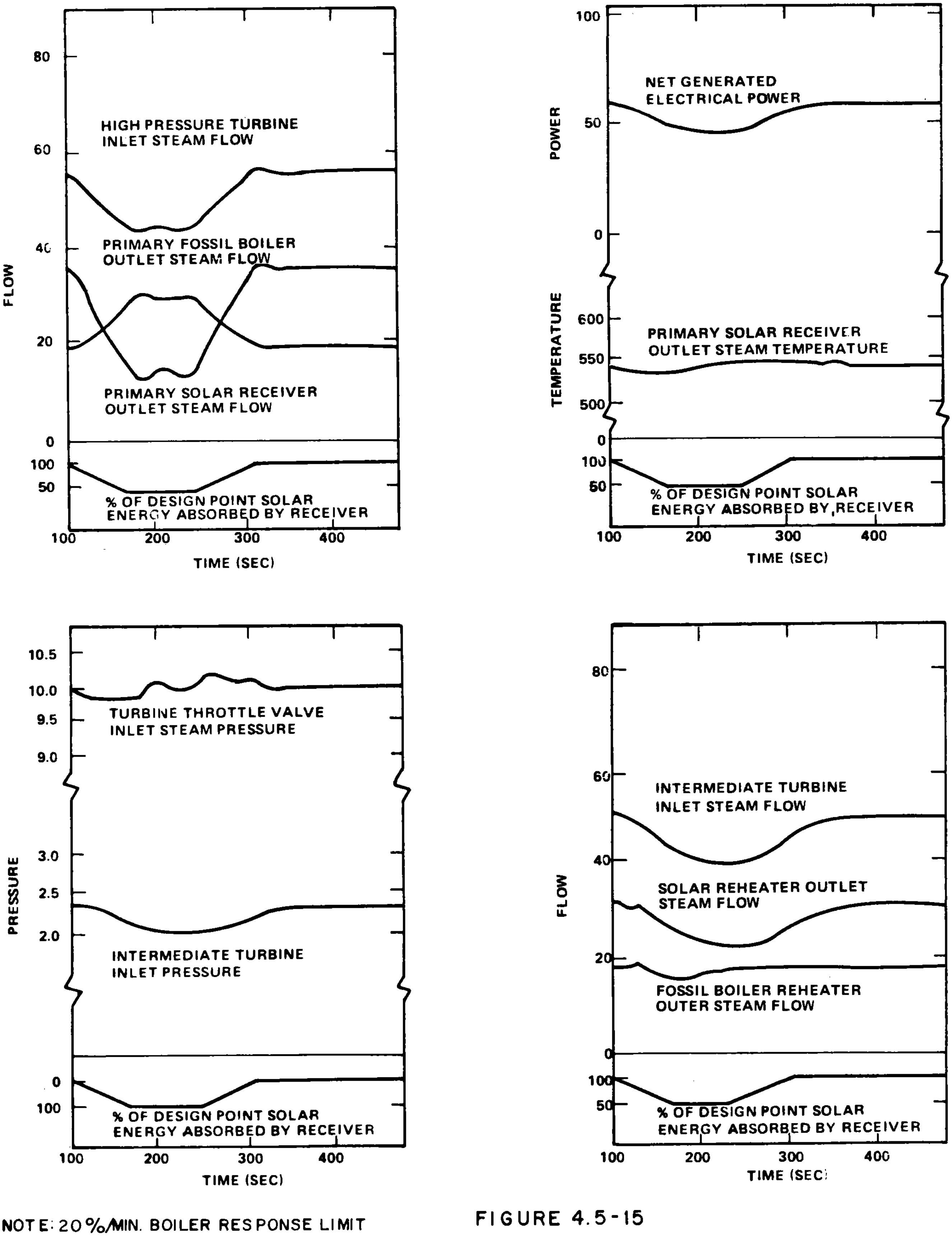
NOTE: 20%/MIN. BOILER RESPONSE LIMIT
28/50 FOSSIL/SOLAR FLOW DISTRIBUTION
FIXED THROTTLE VALVE

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

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 and Appendix A (System Requirements Specification). 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 and described in Appendix A is presented in Table 4.6-2.

The total estimated construction and related costs for solar repowered Newman Unit 1 is $164,000,000. This estimate is based on an assumed installed collector field cost of $\$230/m^2$, 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 cost of collector hardware delivered to the site were to double from $\$150/m^2$ to $\$300/m^2$, the total estimated construction cost would increase from $164 to $203 million. The total cost is based on the engineering and construction schedule discussed in Section 7, requiring approximately 31 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 $75.9 million. Direct costs are defined as the present day (1980) material and labor costs associated with the delivery and installation of each subsystem identified in the 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.

Documentation has been prepared for each element of the direct costs. Labor rates are based on a rate survey by Stone & Webster's Construction Department. Contract labor rates used vary from $16.00 to $30.00, depending on the craft.

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 42 percent of the total direct cost at $150/m^2$.

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 $3.3 million in 1980 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 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 $11.4 million in 1980 dollars.

4.6.4 Allowance for Indeterminants

An allowance for indeterminants of 15 percent is 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 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 more meaningful collector system cost data from manufacturers. Efforts to solicit this information are currently underway. 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 indeterminants included in the estimate is approximately $13.6 million in 1980 dollars.

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 1980 and the actual dates equipment is procured. Escalation was applied to the total present-day cost (excluding owner's costs) for the expenditures schedule described in Section 7.7. The resulting escalation is 33 percent of the present-day cost or approximately $34.5 million.

4.6.6 Owner's Costs

Owner's costs estimated for this project are approximately $3.5 million. A breakdown of the owner's costs is presented in Table 4.6-3. Each component of the owner's costs 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 $0.31 million, and $0.27 million for changing future transmission facilities for a total of $0.58 million. In addition, an estimated 0.49 km^2 (121 acres) of right-of-way are required, resulting in a land cost of approximately $0.48 million at an assumed $1.00 per m^2 ($4,000 per acre).

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 $0.89 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, but 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 1.5 km^2 (370 acres) of land will be required for the new facilities associated with repowering Newman Unit 1. The cost of this land is approximately \$1.3 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 \$0.1 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.

4.6.7 Allowance for Funds Used During Construction (AFUDC)

An allowance for 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 9 1/4 percent applied to the total estimate (excluding owner's costs) using the expenditures schedule described in Section 7.7. AFUDC is estimated at approximately \$21.5 million.

TABLE 4.6-1

CONSTRUCTION COST ESTIMATE SUMMARY

Account/Description		(In Thousands Of Dollars)
5000 Facility Cost		
5100 Site Improvements	$ 3,100	
5200 Administrative Areas	500	
5300 Collector System	50,900	
5400 Receiver System	13,700	
5500 Control System	3,700	
5600 Fossil Energy System	-	
5700 Energy Storage System	-	
5800 Electric Power Generation	5,100	
Total Direct Cost		77,000
Productivity Adjustment of 0.95		(1,100)
Total Direct Cost Including Productivity Adjustment		75,900
Distributable Costs		3,300
Total Construction Cost		79,200
Indirect Costs		11,400
Total Construction and Indirects		90,600
Allowance for Indeterminates		13,600
Total Present-day Estimate (1980 dollars)		104,200
Escalation		34,500
Escalated Cost		138,700
Owner's Costs		3,500
AFUDC		21,500
Total (1985 dollars)		$163,700

TABLE 4.6-2

COST ACCOUNT SCOPE DEFINITION

Account	Definition/Scope
5000	Total Direct Cost - Solar Repowering Newman Unit 1
5100	Site Improvements
5110	Clearing and Grubbing - heliostat field and roads
5120	Diversion Channel and Drainage - heliostat field
5130	Crushed Rock Surface - heliostat field
5140	Roads and Fencing - entire site
5200	Site Facilities (Structural and Electrical Work Only)
5210	Control Room Extension
5220	Solar Feed Pump Building
5230	Maintenance Building Extension
5300	Collector Subsystem
5310	Heliostats - delivered and assembled
5320	Heliostat Installation
5330	Heliostat Foundations
5340	Field Wiring, Electrical, and Controls
5350	Perimeter Lighting - along fence surrounding collector field
5360	Beam Characterization System (BCS)
5400	Receiver Subsystem
5410	Receivers - Primary and Reheat
5420	Tower - includes foundation, platforms, etc
5430	Electricals - power supply to tower and receiver

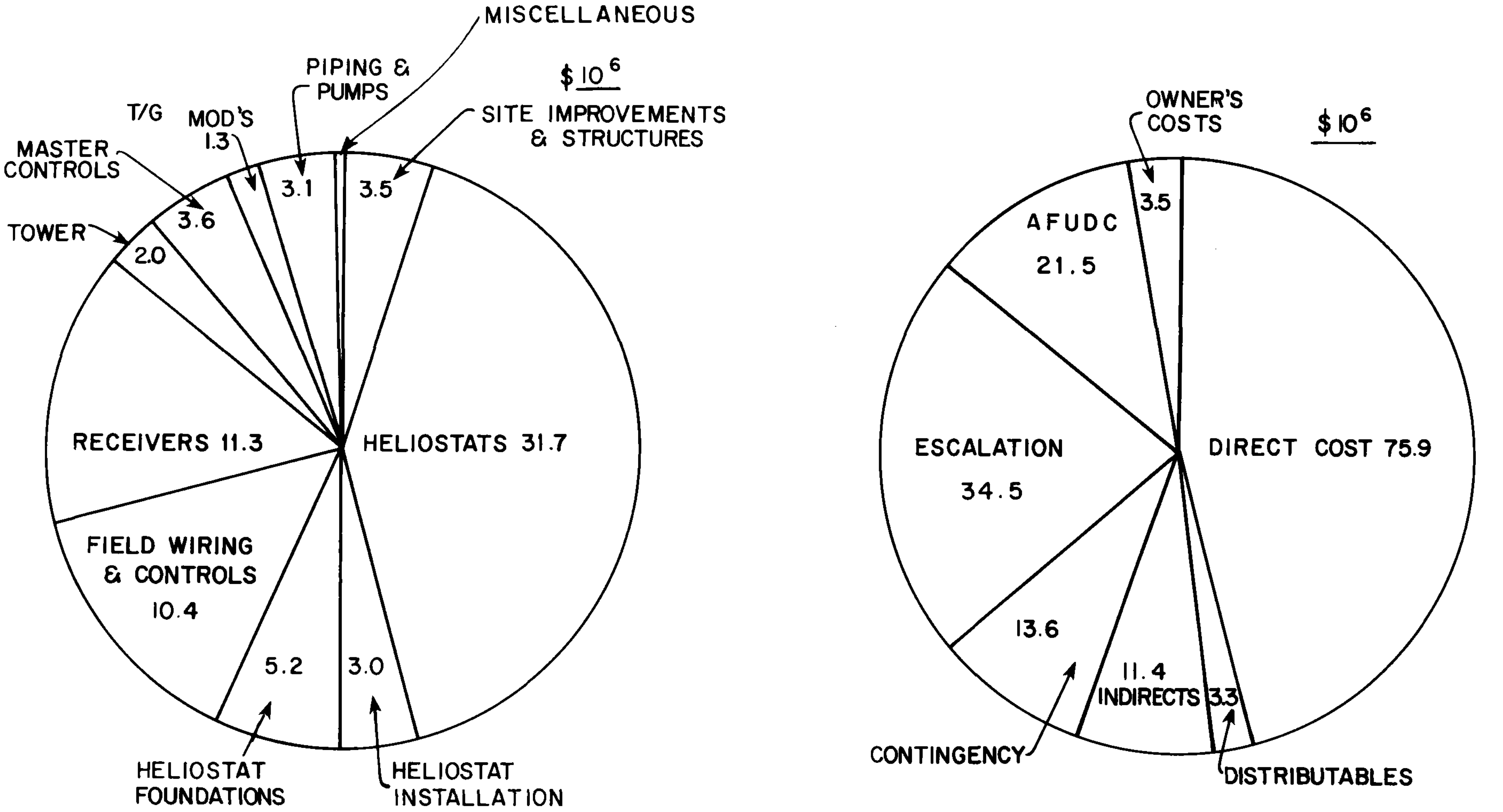
TABLE 4.6-2 (Cont)

Account	Definition/Scope
5500 Control Subsystem	
5510	Master Control System - includes all new control and control modifications except BCS (5360), DEH (5810), and miscellaneous instrumentation (5520).
5520	Miscellaneous Instruments - Fossil boiler combustion controls, feedwater controls, and steam temperature and flow controls
5800 Electrical Power Generating Subsystem	
5810	Turbine generator: Digital Electronic Hydraulic Control System (replaces existing mechanical hydraulic controls)
5820	Piping and Pumps - solar feedwater pumps; main and reheat steam piping and feedwater piping from receiver to interface with existing piping at at the turbine building. Includes pipe supports, insulation, and all valves except control valves (in 5520)
5830	Electrical - all electrical equipment and power supplies except heliostat field wiring, receiver, and tower electricals

TABLE 4.6-3

OWNER'S COSTS

Description	(In Thousands of 1980 Dollars)
Relocation of Transmission Lines	
Right-of-Way Land	$ 484.0
Engineering and Construction	580.5
Relocating State Highway	889.3
Environmental Studies	100.0
Public Relations Activities	50.0
Site Land Requirement	1,295.0
Relocating Employee Park	100.0
Total	$3,498.8
Use	$3,500.0



TOTAL – $ 75,900,000
(1980 DOLLARS)

DIRECT COST BREAKDOWN

TOTAL - $ 164,000,000
(1985 OPERATION)

CONSTRUCTION COST BREAKDOWN

FIGURE 4.6-1
CONSTRUCTION COST BREAKDOWN

4.7 OPERATIONS AND MAINTENANCE COSTS AND CONSIDERATIONS

Operations and maintenance (O&M) costs have been estimated for solar repowered Newman Unit 1. Annual O&M costs are estimated at approximately $3.3 million/year in 1980 dollars. 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 plant operating personnel, the cost of operating consumables, and other fixed costs incurred whether or not the plant operates.

Plant operating personnel for the existing and repowered Newman Unit 1 are listed in Table 4.7-2. An estimated 15 full-time (equivalent) employees are currently assigned to Newman Unit 1. This number would be expanded to approximately 26 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. Total salaries and overhead are estimated to be about $890,000/year in 1980 dollars. Total operations costs for OM110 escalated to 1985 dollars are $1,250,000/year.

An allowance of $120,000/year in 1985 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 are approximately $82,000/year in 1980 dollars.

Other fixed operating expenses, OM130, include items such as insurance, taxes, wastewater disposal, etc. An allowance of $100,000/year in 1985 dollars is included to cover these costs.

Total costs for OM100, Operations, is approximately $1,470,000 in 1985 dollars.

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 is assumed to be 2 percent of the escalated, installed direct cost of heliostat equipment, or $890,000/year in 1985 dollars.

Receiver maintenance and repair cost is assumed to be 3 percent of the escalated, installed, direct cost of the receivers, or $320,000/year in 1985 dollars.

Balance-of-plant maintenance and repair costs are estimated based on recently reported maintenance-related costs for the Newman Station escalated to 1985, or approximately $400,000/year. An additional allowance of $200,000/year in 1985 dollars is estimated for boiler maintenance and repairs associated with extending its lifetime by 20 years.

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

60/40 material/labor split for all maintenance

50/50 split between OM210 (Spare Parts) and OM220 (Material for Repairs); except boiler maintenance and repair materials are allocated entirely to OM220.

No items applying to OM230 (Other)

50/50 split between scheduled and corrective labor in OM300.

Total annual Maintenance Materials, OM200 cost is approximately $1,090,000 in 1985 dollars. Total annual Maintenance Labor, OM300, is estimated at $720,000 in 1985 dollars.

TABLE 4.7-1

ANNUAL PLANT OPERATIONS AND MAINTENANCE COSTS

		(In Thousands of 1985 Dollars)	
OM100	Operations		1,470
OM110	Operating Personnel	1,250	
OM120	Operating Consumables	120	
OM130	Other Fixed Expenses	100	
OM200	Maintenance Materials		1,090
OM210	Spare Parts	483	
OM211	Turbine and Electrical Plant	(60)	
OM212	Collector Equipment	(267)	
OM213	Receiver Equipment	(96)	
OM214	Thermal Storage Equipment	0	
OM215	Fossil Boiler Equipment	(60)	
OM220	Materials for Repairs	603	
OM230	Other	0	
OM300	Maintenance labor		720
OM310	Scheduled Maintenance	362	
OM320	Corrective Maintenance	362	
			\$3,280

TABLE 4.7-2

PLANT OPERATING PERSONNEL

	Number of Full-Time Employees Assigned to Solar Repowered Newman Unit 1	Existing Employees at Newman Unit 1
Station Superintendent	0.25	0.25
Supervisor of Operation	0.25	0.25
Supervisor of Maintenance	0.25	0.25
Plant Engineer	0.25	0.25
Maintenance Foreman	0.75	0.75
Operating Shift Supervisor	1.00	1.00
Control Operator	3.00	1.00
Assistant Control Operator	1.00	1.00
Plant Equipment Operator	1.00	1.00
Electrician	3.50	1.50
Boiler and Condenser Mechanic	5.00	3.00
Maintenance Helper	3.00	1.00
Utility Man	1.00	1.00
Instrument Technician	3.00	1.00
Chemical Technician	0.5	0.50
Station Clerk	1.25	0.25
Janitors and Landscaping	1.0	1.00
	26	15

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 2,776 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 consists of 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, 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) and oil fuel; 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 Review

A number of reports have been issued that address the safety aspects that are unique to the application of a solar central receiver system. Among these are three reports that deal with the 5 MWt Solar Thermal Test Facility (STTF) which has been constructed at the Sandia Laboratories in Albuquerque, New Mexico (Haus et. al., 1975; Brumleve, 1977; Young, 1977; Telecon, Brumleve, 1980). The MITRE Report (Haus et. al.) discusses a) the requirements for fire protection, and b) the potential glare from the heliostat mirrors and its effect on the pilots that take off and land aircraft at the two airports that border the Sandia facility: Kirtland Air Force Base and the Albuquerque Municipal Airport. The Martin-Marietta heliostat design for the STTF consists of 25 individual facets or mirrors to produce the 37 m^2 of reflective surface, and each of these facets is slightly dished and can be individually focused onto the receiver at the top of the tower, each one at a different angle. Therefore, their effect on a pilot's vision is expected to be slight, similar to flying across the choppy water of a lake.

An additional consideration with regard to air traffic in the Sandia area is the 61 m (200 foot) tall tower. Since this tower was designed to conform to FAA regulations for aircraft safety, any danger is expected to be minimal. Moreover, the tower location is indicated on the pilot's instrument approach plates (Jepson Charts) for Albuquerque so that all aircraft can avoid it. Some thermal turbulence is also created by the heat plume rising from the tower. The combination of these three potential safety impacts (glare, obstruction, and turbulence) on air traffic may potentially neccessitate slight modifications in the flight paths over the Sandia Laboratories area.

Significant efforts have been performed in assessing the eye hazards and evaluating the glint aspects in the development of the STTF (Brumleve, 1977; Young, 1977). Potential eye hazards associated with concentrated reflected light (solar reflectance hazards) were evaluated. Specific light intensities and hazardous ranges of single and multiple coincident heliostat beams have been assessed for conditions at both ground level and in the air space above the facility. The possible long- and short-range distractive effects of reflected beams were also discussed. Certain beam control modifications which needed to be incorporated so as to minimize the altitude at which overflying aircraft could encounter unsafe levels were described. Recommendations were made by Brumleve with respect to the STTF for further evaluation of the intensity excursions during fail-safe shutdown situations and for specific experiments that could be used to verify analytical models and to assess the distractive glint effects.

Excerpts from some of the conclusions drawn by Brumleve, along with additional specific notations which apply, in general, to a solar repowered unit are as follows:

> With regard to the application of the 25 faceted heliostat design by Martin-Marietta at the STTF, the reflected beam from any single heliostat with a focal length shorter than about 260 m constitutes a potential eye hazard that extends for a comparatively short distance on either side of its focal point. This hazard zone is generally confined to 20-30 m on either side of the focal point with the shorter focal length beams being the most hazardous.
>
> Specific beam control measures need to be incorporated as a result of possible multiple beam intensities so as to minimize the altitude at which overflying aircraft might encounter eye hazards. These effort were designed to effectively preclude intensities greater than one sun and thereby prevent unsafe retinal irradiances at altitudes greater than about 200 m during normal operations.
>
> Although, during certain types of fail-safe shutdown, the potential for momentary excursions of greater than one-sun intensity may extend to several hundred meters, these types of failures were considered to be very rare.
>
> Based on the Martin-Marietta cavity receiver for the STTF, the reflected light from diffuse surfaces located in the focal zone does not appear to present a hazard except in controlled areas near the top of the tower.

The potential fire hazard which might exist for the shorter focal length heliostats needs to be evaluated for the conditions in which the beams might impinge on a combustible material.

Recent experimental results (Telecon, Brumleve, 1980) have, for the most part, verified the analytical models discussed by Brumleve (1977). These experiments have confirmed that reflected light from solar receivers made of diffuse materials does not constitute a severe hazard at ground level. However, the reflected light is bright and uncomfortable and results in a visual afterglow effect. As a result, personnel who must work in an area where they are exposed to reflected receiver light must wear protective eyeglasses or goggles. American Optical Type 486B or 488, shade 5 or darker, have been recommended for the protective goggles of personnel who must move about in an active heliostat field.

Experiments with helicopters have somewhat alleviated the concern that pilots overflying a heliostat field might encounter eye hazards. It was found that the scattered light was sufficient to provide a warning of the beam intensity and allow sufficient time for the eyes to react normally in order to prevent retinal damage. Note, however, that these experiments were conducted with slow flying helicopters. The effects on pilots flying faster fixed-wing aircraft remains a concern that requires further investigation and/or specific safety precautions.

4.8.3 Design Guidelines

Numerous codes and regulations are applicable to the health and safety considerations of the solar repowered Newman Unit 1. Special attention should be 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 as well as 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 nearby residents, aircraft pilots and passengers, and highway travelers.

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 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 reduce these potential hazards or annoyances. 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 receiver 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.

4.8.5 References

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.

Telecon, Brumleve, T.D., Sandia Laboratories, Livermore and Lance, J.R., Westinghouse Advanced Energy Systems Division, May 6, 1980.

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 450 - 550 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 1.5 km^2 (370 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 may occur during construction and should be the subject of further study.

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 from several miles in this undeveloped industrial area but should not represent a major visual impact. Concerns related to possible ground glare have been reviewed and are considered minimal. The receiver centerline height is 155 m (509 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 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 the heliostat field. 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 km^2 (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 S&W 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 1.5 km^2 (370 acres), represents about 0.001 percent of the 1,100 km^2 (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 dunes and desert shrubs 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 km^2 (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 1970 population of 359,291 for El Paso County and 322,261 for the City of El Paso. The El Paso Department of Planning, Research, and Development estimated the January 1, 1979 population of the county to be 457,000 (27 percent change) and 410,000 (27 percent change) for the city (El Paso PRD, 1979).

The NPA has a 1970 population of 55,337 and, as of January 1, 1978, was estimated to have a population of 73,212 (El Paso PRD, 1978), an increase of 32 percent.

The county's population is projected to reach about 493,000 in 1980 and 544,000 in 1985; the city's projected population for the same years is 448,000 and 496,000; and the NPA's projected population for 1980 is 86,000 and 95,000 for 1985 (El Paso PRD, 1978 and 1979). Preliminary data available from the 1980 census for the county indicate that the population may have reached 500,000.

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 1979 ranked the El Paso metropolitan area as 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 1979 numbered 168,561, with 155,252 employed and 13,309 unemployed, giving an average unemployment rate of 7.9 percent (the State average was 4.2 percent) (El Paso IDC, 1978-1980; Morrow, EPE). Contract construction accounted for more than 8,000 jobs in 1979. 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 NPA. Vacant land comprises 70 percent of the acreage in the NPA, including the Franklin Mountains State Park. The NPA Land Use Plan, however, proposes that the majority of this land be developed as low density residential areas by the year 2000 (Land Use Plan, 1978).

A working sand quarry is located approximately 1.6 km (1 mile) north-northeast of the proposed site, a sanitary land fill 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 km^2 (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 km^2 (per $mile^2$). The sites contain artifacts such as pottery, tools, chipped stone and grinding materials, dwelling foundations, and hearth areas (Land Use Plan, 1978; Tel Con 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; Tel Con J. Hendrick, 1980). No excavation work is being undertaken for this survey (El Paso Park Plan, 1978). At the present time, over 40 archaeological 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 will be 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 1978-1979 enrollment of 114,582 (DPRD, 1979). Three school districts are located in the NPA and as of October 1979, this enrollment was 18,620. It is anticipated that by the year 2000, the NPA will require approximately double the existing school facilities (DPRD, 1978). El Paso County has 23 private schools with a 1978-1979 enrollment of 5,264 (DPRD, 1979). Three institutions of higher education are located in El Paso.

The El Paso park system has a total of 13 km^2 (3,190 acres) of developed and undeveloped recreation facilities (El Paso Park Plan, 1978-2000). The NPA has three district parks and nine 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 three new neighborhood parks and hiking trails (DPRD, 1978).

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, 1978-1980).

4.9.2.4.6 Transportation

The prepared 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 1977 Average Daily Traffic Count (ADT) for War Road was 2,720; the ADT for McCombs Street was 2,090 (DPRD, 1978).

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, 1978-1980). 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 4.9 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

At the start of construction, the work force will increase by about 67 workers per month until approximately 400 workers are onsite. This peak work force will be maintained for 20 months at which time it will decrease by about 67 workers per month until construction is complete.

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 168,500 with a 7.9 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 (7.9 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 1.5 km^2 (370 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 4.9-1. 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 30.5 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 15 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. Because the field will be covered with a layer of gravel, the runoff and siltation are expected to be reduced. However, 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

<u>Land Use</u>

The use of approximately 1.5 km^2 (370 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/under-developed and will serve as a buffer zone between the two uses.

<u>Work Force</u>

The operating work force for this facility will be approximately 26 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).

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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

TABLE 4.9-1(Cont)

Scientific Name	Common Name	Origin	Source
GERANIACEAE (Geranium Family)			
Erodium cicutarium (L.) L'Her	Alfilerillo	I	1
GRAMINEAE (Crass 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 breiifolius	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
SOLANACEAE (Nightshade Family)			
Lycium sp.	Wolf-berry		2
Solanum elaegnifolium Cav.	Silverleaf Nightshade	N	1

TABLE 4.9-1(Cont)

Scientific Name	Common Name	Origin	Source
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/cf^{3})

5. Oil heat content - 41.8 x 10^{9} J/m^{2} (150,000 Btu/gal)

6. EAP's AP-42 Emission Factors (Texas SO_2 Emission Standard)

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 allows 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, prepaying 20 to 30 years of conventional fuel expenditures in initial capital investments will strain a utility's financial structure. 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. El Paso Electric 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, El Paso Electric Company 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, solar manufacturers will be equally unsure and will "gingerly" approach any opportunities they may have to make significant 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 7.8 entitled "Roles of Site Owner, Government, and Industry." El Paso Electric realizes that there are risks inherent in early solar demonstrations, 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 could certainly become an institutional barrier to early solar demonstrations.

SECTION 5

SUBSYSTEM CONCEPTUAL DESIGN, COST, AND PERFORMANCE

The purpose of this section is to provide conceptual design information on the subsystem level for solar repowered Newman Unit 1. Functional requirements, design characteristics, performance, and cost are addressed for each subsystem.

5.1 SUBSYSTEM DEFINITION

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

Collector Subsystem
Receiver Subsystem
Fossil Boiler 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 the Westinghouse Second Generation Heliostat concept.

The receiver subsystem 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 pump, internal receiver piping valves, and control equipment to regulate flow temperature and pressure and to ensure safe operation. Also included are elevators, hoist, platform, etc to provide for inspection and maintenance.

The fossil boiler 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 boiler 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. 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 feedwater pumphouse, 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 Westinghouse Second Generation Heliostat. The design description, performance characteristics, and cost data for this heliostat are utilized in this concept as representative of the class of heliostat configurations that will be available for solar repowering Newman Unit 1.

5.2.1 Functional Requirements

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.

The collector field is designed so that 105 MWt of the redirected solar energy impinges on the primary receiver and 25 MWt impinges on the reheat receiver at noon summer solstice with a direct normal insolation value of 950 W/m^2.

The collector field design considers the following:

Heliostat capital cost
Operations and maintenance cost
Field wiring 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.

Heat fluxes on the tower and normally unirradiated portions of the receiver subsystem are limited to 25 kW/m^2 (7,880 Btu/ft^2 hr).

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 5.2-1 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. 13505-FM-31B-SR, found in Appendix B. The heliostat array consists of 2,776 Westinghouse Second Generation Heliostats.

The design characteristics of the Westinghouse Second Generation Heliostat are given in Figure 5.2-2. The heliostat meets the requirements of the Sandia Specification A10772 for performance, operational requirements, survival loads, and environmental conditions and lifetime. The 81.8m^2 (880 $feet^2$) of front surface mirrors is expected to have a reflectance of 0.935. The overall dimensions are 7.6 by 110.0m (25 by 36 feet) for the reflective surface and the maximum height above ground is 8.8m (28.8 feet). The weight of the heliostat, excluding foundations, is 3,725Kg (8,200 lb).

<u>Lattice Structure/Elevation Ring Assembly</u>

A three-bay rectangular lattice structural frame assembly provides support for the thirteen 1.5 by 3.7m (5 x 12 foot) and the two 1.52 by 3.05m (5 by 10 foot) mirrors of the heliostat. This structural frame is supported by two 4.9m (16 foot) diameter elevation rings that are secured to a frame between the end and center bays through a diametral spoke in each wheel. A diagonal strut is provided in each of the end bays of the frame for in-plane stiffness. Tie rods are provided in front of and behind the mirror panels between the ends of the structural frame and the elevation rings for out-of-plane and torsional stiffness. The tie rods permit a lightweight mirror support structure that is rigid and adjustable. Two struts are connected to the rim of one of the elevation rings and the diametral spoke of the other elevation ring to stiffen the structural frame under in-plane end loads that tend to rock the elevation rings on the frame.

Mirror Module

The mirror module has a cylindrically curved 0.64 cm (0.25 inch) thick front-surface silvered glass mirror with a vertical cylindrical axis and radius of curvature of 636m (2,086 feet). The silvered reflective surface is coated with a thin transparent titanium dioxide film to prevent corrosion or damage of the silvered surface. Three longitudinal stainless steel stringers are bonded to the backside of the mirror panel to stiffen the mirror panel and provide a structure to which brackets could be mounted to secure the mirror module to the lattice structural frame. These stringers are made from 436 stainless steel, which has a coefficient of thermal expansion approaching that of glass to minimize thermal bowing of the mirror panel over the operating temperature range.

A laminated glass mirror panel with three back-silvered thin front glass sheets and a thick backing glass sheet is used in the prototype heliostats because the process for applying the protective film on the front-surface silvered glass mirror is still under development.

Azimuth Assembly

The azimuth assembly is a welded structure consisting of a 4.6m (15 foot) diameter ring to which four posts 2.2m (7.2 feet) high and a diametral spoke are attached. The posts carry rollers on which the elevation rings rotate. The spoke supports the elevation drive assembly and the pulley for the idler elevation ring tie-down cable.

Pillars/Foundation

A 0.61m (2 foot) high pillar is interposed between each of the three foundations and azimuth assembly. The pillars are equally spaced around the azimuth ring. Three rollers at the top of each pillar permit azimuth rotation of the heliostat with lateral and vertical restraint. The bottom of the pillar has a flange which is welded at the corners to the foundation.

The foundation is a 0.33m (13 inch) diameter wood pile with a steel reinforcing cap at the top. Three steel pins are used to secure the cap to the pile. The pile is 6.2m (20.3 feet) long and is imbedded 5.8m (19 feet) in the ground. The heliostat loads are distributed between the three foundations by tieing them together with steel rods. One of the foundations supports the azimuth drive assembly.

Drive System

Rotation of the heliostat about the elevation and azimuth axes is accomplished by driving one of the elevation rings and the azimuth ring with a ball-cable mounted on the rim of the rings. The ball-cable is driven by a sprocket mounted on the output shaft of a two-stage worm gearbox powered by an ac induction motor. The ends of the ball-cable are secured to the elevation and azimuth rings and the cable balls engage spherical pockets in the sprocket. The ball-cables are pretensioned to avoid backlash and slack under operating conditions. In addition to permitting elevation rotation, the elevation ball-cable serves as a holddown device to prevent the wind force from lifting the elevation drive ring off its rollers. An idler cable is provided around the other elevation ring to also hold it down on its rollers. The ball-cables are secured to the elevation and azimuth wheels in such a manner that 270 degrees of rotation can be obtained. This rotation is more than necessary for both axes and permits over-the-shoulder motion of the heliostat so that "gimbal lock" is avoided.

The drive assembly motors, gear boxes, and rollers are sealed and environmentally protected. The sprocket pockets incorporate drilled passages that permit entrapped dirt and sand to be expelled and allow proper meshing of the ball-cables, in the sprocket pockets.

5.2.2.2 Collector Control

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 694 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 27 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 HFC 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 2,776 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 command 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 any 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 target.

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 on the receiver.

There can be two types of shutdown operation: one is the Normal Shutdown, such as the one executed at the 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 facing down mirrors. The stow azimuth for each heliostat is approximately equal to the azimuth for the Standby operation relative to 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 or receiver failure. In order to insure that an Emergency Shutdown command can be always issued to the heliostats, even in case of HAC or HFC failure, a wire with low voltage is connected to all HCs and a switch is available to the plant operator. Placing of an electrical ground on this wire produces an Emergency Shutdown command to all heliostats in the array regardless of the conditions of the HAC and the HFCs.

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, an 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 calibration receivers below the reheat receiver. The PCS and the beam characterization system (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 ay 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 is stored in the HFC for future use 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 is 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 customary 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. 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 is also 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 of any fixed angular position.

Communication

During Communication operation, the HAC, HFCs, and HCs are in contact among 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 is 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 110 kW. Therefore, during normal operation, the array power requirement is 270 kW.

5.2.3 Collector Performance

The collector field is sized and configured to redirect solar energy so that, on summer solstice with a solar insolation of 950 W/m^2, 105 MWt of solar power impinges on the primary receiver and 25 MW of solar power impinges on the reheat receiver. The cosine loss is greatest at summer solstice with a north field. Therefore, with equal solar insolation at noon on other days of the year, the power incident on the receiver is greater than at noon summer solstice (design point). This effect is shown in Table 5.2-1.

Table 5.2-2 is a detailed field power distribution table that shows the distribution of thermal power of the incoming rays from the point of hitting the mirrors surface to the point of entering the receiver.

5.2.4 Collector Field Costs

The collector field costs are estimated based on a heliostat price of $\$230/m^2$ which includes all components including the field control unit, foundations, installation, and field wiring costs. Total collector field costs are summarized below for the initial demonstration.

	In Millions of 1980 Dollars		
	Material	Labor	Total
Heliostats	31.7	-	31.7
Installation	-	3.2	3.2
Foundation	3.2	2.1	5.3
Field Wiring	2.7	7.1	9.8
Totals	37.6	12.4	50.0

TABLE 5.2-1

CONCEPTUAL COLLECTOR PERFORMANCE

	Thermal Power Incident on Receivers (MWt)	
	Primary	Reheat
Noon summer solstice	105	25
Noon equinox	110	27
Noon winter solstice	118	27
2 PM winter solstice	114	25
Annual average	105	24

Based on clear days, the annual average power is almost equal to the design point.

Solar Insolation 950 W/m^2

TABLE 5.2-2

DETAILED FIELD POWER DISTRIBUTION

Description of Ray	Power (MWt) 2pm WS	Noon WS	Noon SS	Noon EQ	Annual Avg
Incoming Ray Hits Mirror	182.2	188.2	167.9	179.9	166.9
Reflected Ray Absorbed	18.2	18.8	16.5	18.5	16.4
Reflected Ray Hits Back of Mirror	1.9	2.0	2.0	2.3	1.8
Ray Clears Mirrors	162.1	167.4	149.5	159.0	148.7
Ray Absorbed between Mirror Receiver	11.6	11.7	10.5	11.2	10.4
Ray Hits Receiver Place but Misses Receiver	11.4	11.3	9.9	11.2	10.0
Ray Enters Receiver	139.2	144.4	129.1	136.6	128.3

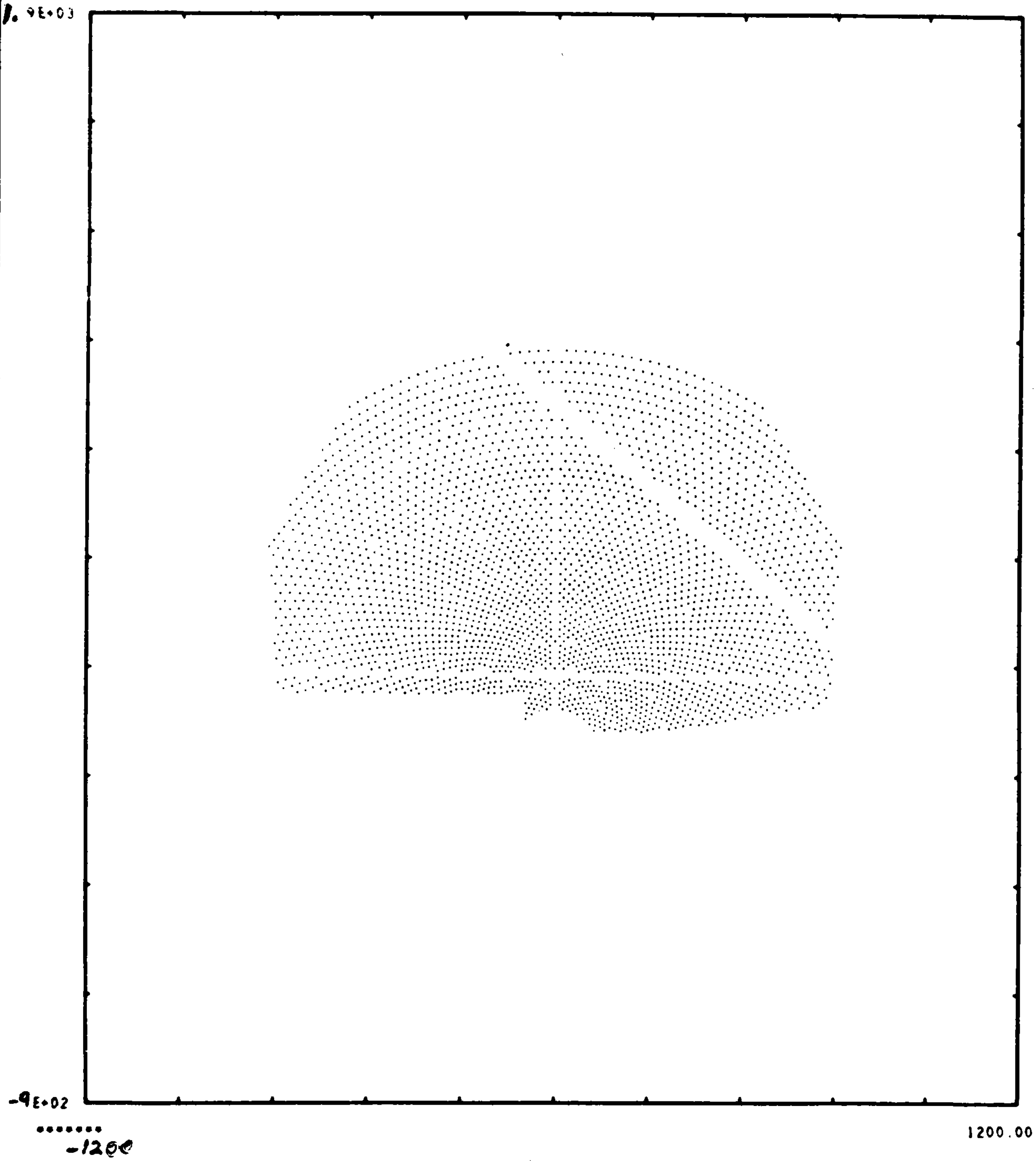
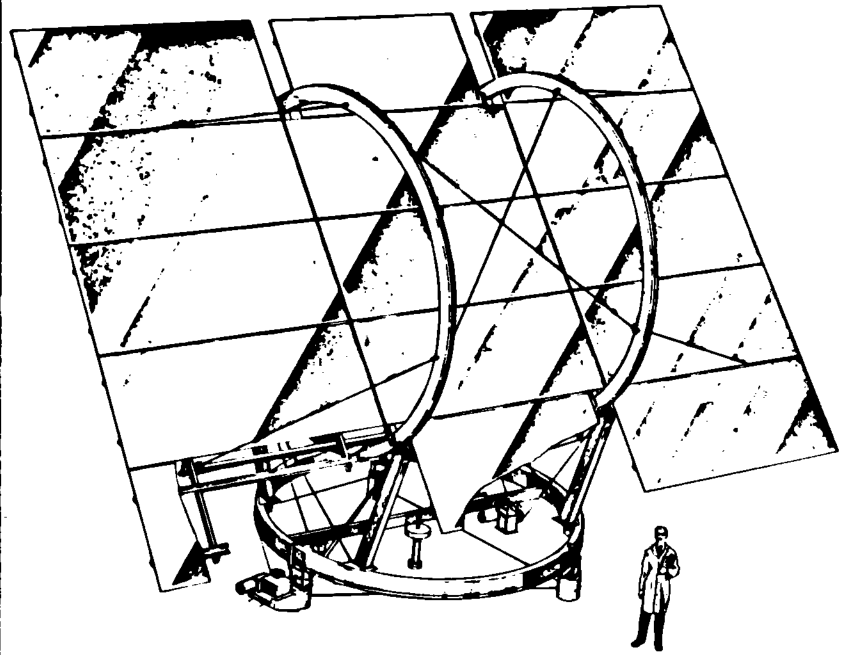


FIGURE 5.2-1
COLLECTOR FIELD LAYOUT



HELIOSTAT CHARACTERISTICS	
ASPECT RATIO	1.5:1 (7.6M x 11.0M)
MIRROR AREA	$81.8M^2$
MIRROR PANEL	LAMINATED GLASS PANELS
ELEVATION WHEELS	4.9M DIA.
AZIMUTH RING	4.57M DIA.
WEIGHT	3725KG

FIGURE 5.2-2
HELIOSTAT DESIGN

5.3 RECEIVER SUBSYSTEM

The receiver subsystem provides the means for transferring the incident radiant power from the collector subsystem into superheated steam. The receiver subsystem consists of primary and reheat receivers, a single tower structure, receiver support structure, riser and downcomer piping, a hoist, elevator, and stairways. A Preferred Configuration is recommended for this solar repowering application based on the results of a trade-off study described in Section 3. The Preferred Configuration is an 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 Babcock and Wilcox 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° north field.

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

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, startup, 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 is a description of the receiver performance for normal steady state conditions and budgetary cost estimates.

5.3.1 Functional Requirements

The receiver subsystem shall include a primary receiver and a reheat receiver and shall provide a means of transferring the incident radiant power from the collector into superheated steam and transport of the steam to the high pressure 10.1 MPa/538°C (1,450 psig/1,000°F) turbine and the intermediate 2.93 MPa/538°C (410 psig/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 primary receiver shall be capable of operating safely and reliably for 30 years with heat flux levels not exceeding 0.60 MW/m^2 for water-cooled tubes and 0.3 MW/m^2 for the superheater tubes at the noon winter solstice with an incident power level of 117 MWt. At the noon summer solstice, the primary receiver shall be capable of absorbing 92 MWt with a receiver incident power level of 105 MWt. Steam shall be generated at the rate of 129,000 kg/hr (284,000 lb/hr) with outlet conditions of 10.8 MPa/549°C (1,550 psig/1,020°F). The corresponding inlet temperature is 238°C (460°F) and the maximum allowable pressure drop shall be 1.72 MPa (250 psig).

The reheat receiver shall be an external panel configuration capable of operating safely and reliably with an absorption heat flux level not exceeding 0.14 MW/m² shall be at the noon winter solstice within the incident power level of 28 MWt. At the noon summer solstice, the reheat receiver shall be capable of absorbing 13 MWt with a receiver incident power level of 25 MWt. Steam is generated at the rate of 115,400 kg/hr (254,500 lb/hr) (including attemperation) with outlet conditions of 2.97 MPa and 549°C (416 psig and 1,020°F). The corresponding inlet temperature is 382°C (720°F), and the maximum allowable pressure drop shall be 172 kPa (25 psig).

The receivers shall be designed to be subjected to cyclic service with approximately 10,000 startup/shutdown cycles and a number of cloud transient cycles to be determined during the design phase. 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/hourly 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 131 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 and 18.3 m respectively.

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

5.3.2 Design

The primary and reheat receiver geometry and performance characteristics are summarized in Figure 5.3-1 based on this selection. The combined primary and reheat receiver sections are 12.6 m in diameter, 31.4 m vertically, and are mounted on top of a concrete tower 130.5 m high as shown schematically in Figure 5.3-2. The tower is located adjacent to the existing unit to minimize the length of the steam piping, and the heliostat field is entirely north of the tower, occupying approximately 160°. For this reason, all the heat collector panels occupy the northern 240° of the cylinder, with the southern 120° closed in by an inactive fairing to prevent unsymmetrical wind loading of the receiver and tower. Within the northern 240°, the upper half of the receiver ($414.3m^2$) is covered by the primary steam generator panels, and the lower half ($362.5m^2$ over 210°) is covered by the reheater panels, with no gap between these zones as shown in Figure 5.3-2. The top of the receiver is closed by a shallow conical (160° apex angle) roof, and the lower edge of the receiver is extended as a reflective skirt to protect the tower concrete.

The primary receiver shown in Figure 5.3-3 includes a forced recirculation boiler with a recirculation ratio of 3.5. Vertical economizer tubes and boiler tubes are located radially outboard of the vertical superheater tubes; the circumferential spacing of these vertical tubes is selected so that they partially shadow or "screen" the superheater tubes. Because of this nonuniform screening effect, all superheater tubes operate at approximately the same heat flux, which (at maximum insolation) is about the same as is used in a conventional fossil fueled superheater.

The flow path through the boiler is conventional. To maintain the liquid level in the steam drum as steam is delivered (through the superheater panels) to the turbine, feedwater is admitted at a controlled rate into the "economizer" tubes where it is preheated. From these tubes the feedwater flows into the steam drum. Liquid 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 30 percent quality steam, collected by the upper header and returned to the drum. Steam is released from the upper part of the drum according to the turbine throttle setting, passes through centrifugal separators, and then flows into the first stage of the superheater, which is one-third of the superheater panels. The output of the primary superheater stage is collected and mixed in a header, attemperated, and distributed to the intermediate superheater panels. The output of the intermediate superheater stage is conditioned in the same way and routed to the secondary superheater stage. The output of this stage is delivered to the main steam line (through the tower) connected to the turbine.

The superheater tubes are finned tubes with parallel flow, with the fins welded together to form a light-tight membrane panel. Each panel has its own inlet and outlet header and insulation blanket, with inlet and outlet headers projecting radially inward into the receiver space. The attemperation is also located inside the light-tight membrane, so that all assembly and maintenance operations can be peformed by personnel inside the receiver.

The screen tubes are installed outboard of the light-tight wall by radial inward motion of a jib crane trolley. They each have horizontal extensions that penetrate the membrane wall radially and are connected to headers inside the receiver. The steam generator tubes are rifled so that they operate safely below the DNB limit.

The reheat receiver consists of 16 panels with the flow direction horizontally as in Figure 5.3-1. The panels are arranged in a 4 by 4 matrix encompassing a 210° angle shown schematically in Figure 5.3-4. The four columns of reheater panels each consists of four panels. The tubes in each panel are connected by headers for parallel flow, and the four panels are stacked vertically to form a column, which has its own insulation blanket on the inner face. The headers for each tube panel project radially inward into the receiver. The flow from the four panels of rehater tubes in each panel is not mixed together. Instead, each panel is connected to a specific panel on the adjacent column to form four intermeshed paths across the circumference of the reheater. These paths are routed to equalize the thermal power absorbed in the four paths. The estimate of total weight for the steam generating components plus concrete tower is shown in Table 5.3-1.

Although the primary and reheat receivers are thermally independent and are each served by a dedicated set of heliostats, they are supported by the same structure. This structure, shown schematically in Figure 5.3-5, consists of eight columns bolted to foundation plates on the top of the tower. The columns are interconnected by trusses at the tower surface and 14 other elevations to form a rigid octagonal space frame; diagonal bracing between these elevations increases the 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 spaceframe at whatever elevations the sizes of the boiler components dictate.

The major load on the space frame is the weight of the panels and boiler components, 659,000 kg (1,451,400 lb). Of this, 621,000 kg (1,369,000 lb) is fairly uniformly distributed around 240° of the receiver, and the remaining 37,400 kgs (82,400 lb), the steam drum, is supported at two diametrically opposite locations. If the distributed loads are carried by seven of the eight columns and the steam drum is supported by four of these, the column loads are 88,700 kg (195,500 lb) on each of three columns and 98,000 kg (216,200 lb) on each of the other four. If a compressive stress of 69 kPa (10,000 psi) is allowed in each column, the required cross sectioned area of each column is only 139 cm^2 (21.6 in^2); this area is provided by a 30.5 cm x 30.5 cm x 117 kg/m (12 in. x 12 in. x 79 lb/ft) wide flange column.

The major lateral load on the receiver is caused by the wind; if the design wind load is 161 km/hr (100 mph) at 9.1 m (30 feet) elevation, a reasonable value is 248 km/hr (154 mph) at 163 m (535 feet), the top of the receiver. The resulting wind load is 747 kg/m^2 (153 lb/ft^2), which produces a moment of 1.16 x 10^6 Kg-m (100.587 x 10^6 in.-lb) at the receiver-tower interface. If this moment is resisted by two 30.5 cm x 30.5 cm x 117 kg/m (12 in. x 12 in. x 79 lb/ft) wide flange columns (each having a section modulus of 1,753 cm^3 (107 $in.^3$)), the resulting bending stress is only 44.1 kPa (6,400 psi). The design basis for this structure may be seismic loading; it is apparent, however, that the requirements are not severe.

In the foregoing discussion it was assumed that loads were shared by seven columns instead of eight. This was assumed so that the capability of one column, the one toward the south, could be dedicated to the support of a whirly crane. Such a crane can be stowed, with its mast and boom parallel and vertical, by lowering the base of the mast down into the unused 120° segment of the receiver. It can be deployed by raising the tip of the mast above the receiver roof (through a hatch in the roof), and then rotating the boom in the vertical plane into a horizontal position. If the boom reaches beyond the north wall of the receiver, this crane can service all the receiver panels directly and all components inside the receiver through access hatches. It is unlikely that such a crane could lift the dry steam drum, but this component could be installed by special hoists. The whirly crane is sized to lift all other components from ground level; the size of the receiver panels may be based upon the lifting capacity of this crane. The concrete tower and its foundation are designed to resist stresses resulting from the weight of the receivers, the weight of the tower, and the effect of wind or earthquake, whichever is critical. Deflection of the tower is limited to a specified value to minimize the loss of radiant flux energy on the receivers.

The concrete tower and its foundation are designed to resist stresses resulting from the weight of the receivers, the weight of the tower, and the effect of wind or earthquake, whichever is critical. Deflection of the tower will be limited to a specified value to minimize the loss of radiant flux energy on the receivers.

5.3.3 Receiver Control Methods

Two primary areas of concern must be considered in devising a receiver control system to respond to startup/shutdown transients and cloud cover transients. One area of concern is the protection of receivers to ensure meeeting the 30 year lifetime. Principal constraints are to minimize superheater tube temperatures and circumferential tube temperature gradients. The second area is the protection of the turbine generator subsystem. Factors such as steam temperature response rates and pressure level imbalances between the solar and fossil boilers must be considered.

Four basic methods of control are employed in the receiver subsystem. The first method is passive and implicit in the usage of several design features which include:

Use of ribbed boiler tubes

High recirculation ratio

Use of three superheater passes in primary reciver

Use of screened tube concept to flatten superheater heat fluxes

Flow arrangement for reheat receiver to balance heat loads

The second method of control which provides the primary active response to cloud cover transients is the use of attemperation. In the primary receiver two stages of attemperation between the three superheater passes is envisioned. One stage of attemperation will be used to control the reheat receiver outlet temperatures. With an attemperation flow capacity of approximately 10 percent of design receiver flow in the primary receiver and a capacity of 8 percent for the reheat receiver, it is anticipated that safe control of receiver tube temperatures and steam outlet temperatures can be maintained with cloud coverage up to approximately 40 percent.

Another active control design feature is the inclusion of butterfly valves at each superheater panel inlet and the reheat panel inlets to restrict flow to cold panels and increase flow to hot panels. With approximately a 70 percent open setpoint, it is anticipated that adequate temperature control can be maintained through the combined use of attemperation and valve movement with approximately 60 percent cloud coverage.

Further active control of the receivers and balancing of heat loads between the primary and reheat receivers is provided by refocusing of heliostats from one receiver to the other. This method of control is enhanced by the close proximity of the primary and reheat receivers.

5.3.4 Performance

Receiver performance is defined for the design point condition of noon summer solstice. Typical heat flux maps have also been defined and considered for other times including noon winter solstice, noon vernal equinox, 2 p.m. winter solstice, and annual average. The receiver performance for the design point analysis is summarized in this section. Transient receiver response characteristics have also been estimated as part of the overall system performance and are discussed in Section 4.5.

The primary receiver is sized to intercept approximately 105 MWt at noon summer solstice with the absorption heat flux level on the boiler tubes maintained below 0.60 MW/m² for the noon winter solstice. As a result of preliminary analyses, a 15.7 m height by 12.6 m diameter by 240° angle primary receiver surface area was selected. For a north field of 2,776 heliostats, of which approximately 2,280 heliostats are focused on the primary receiver, the corresponding heat flux distributions are shown in Tables 5.3-2 and 5.3-3 for the noon summer solstice and noon winter solstice. The noon summer solstice heat flux distribution represents not only system design point conditions but is also representative of the annual average flux distribution. The total energy incident on the receiver is 105 MWt and 118 MWt respectively for the summer and winter solstices. An initial evaluation of performance indicates that a 549°C (1,020°F) and 10.8 MPa (1,550 psig) outlet conditions are obtainable at the summer solstice design point consistent with a 30 year life capability. At this condition the estimated efficiency of the receiver including radiation, convection, and conduction losses is 89.9 percent. Thus the design goal of absorbing 92 MWt should be achievable. With the proper sizing and spacing of the superheater and boiler tubes, it is also anticipated that the peak superheater flux can be maintained at 0.3 MW/m² and that the pressure drop can be maintained below the maximum allowable drop of 1.72 MPa (250 psi) for the design flow of 129,000 kg/h (284,000 lb/hr).

Similarly, the reheat receiver is sized to intercept approximately 25 MWt at the noon summer solstice with the absorption heat flux level on the boiler tubes maintained below 0.14 MW/m² at noon winter solstice. The surface dimensions selected for this receiver are 15.7 m high by 12.6 m diameter by 210° angle. With approximately 500 heliostats focused on the reheat receiver, the corresponding heat flux distributions are shown in Tables 5.3-4 and 5.3-5 for noon summer and winter solstices. The total energy incident on the receiver are 25 and 27 MWt respectively. The peak heat flux on the reheat receiver is 0.135 MW/m² which meets the design goal of 0.14 MW/m². For the design flow of 115,400 kg/hr (254,000 lb/hr), outlet conditions of 2.97 MPa (416 psig) and 549°C (1,020°F) are achievable at noon summer solstice for 30 year life with a receiver efficiency of approximately 60 to 70 percent. This will meet the net absorbed power requirement of 13 MWt. By proper sizing of the tubes and panels, the pressure drop allowance of 172 kPa (25 psi) should also be achievable.

The heat flux distributions developed for these initial evaluations were based on a three point aiming strategy with the heliostats that are targeted on the reheat receiver arranged in an annular ring nearest to the tower. One of the objectives of future studies will be to consider alternative aiming strategies and dispersion of heliostats targeted on the two receivers to determine their effect on flattening heat flux profiles and reducing spillage losses.

5.3.5 Receiver Cost Estimate

A budgetary estimate of the costs for the primary and reheat receivers subsection consistent with the configuration and sizes discussed above is shown in Table 5.3-6. This estimate, obtained from Babcock & Wilcox, includes the primary and reheat receivers, internal support structure, cranes, elevator, and hydraulic equipment. Included in this estimate are detailed design engineering and field erection costs.

A cost comparison study was made to determine whether a reinforced concrete tower or a structural steel tower would provide greater economy. The tower cost model developed by Sandia Laboratories was used to make this evaluation. Parameters used in the cost model are tower height, receiver weight, height and diameter, wind velocity, and peak ground acceleration. Based on values specific to the El Paso site, the concrete tower proved to be more economical than the steel tower. In addition, the concrete tower provides sheltered interior space for mechanical and electrical components such as piping, valves, control systems, and elevator.

The estimated installed cost of the receiver tower and foundation is approximately $2.1 million in 1980 dollars.

TABLE 5.3-1

RECEIVER COMPONENT WEIGHTS

Component	Weight (Kg)	Percent of Total
Main Steel Structure	442	40.1
Connections	34	3.1
Platforms	51	4.6
Stairs	21	1.9
Steel Buckstays for Panel Supports	82	7.4
Drum (Empty)	32	2.9
Water in Drum	6	0.5
Pump	29	2.7
Headers	18	1.6
Circulating Piping Plus Valves	47	4.3
Panels with Water Plus Attachments	295	26.8
Crane	45	4.1
	1,102	100.0

TABLE 5.3-2

PRIMARY RECEIVER FLUX MAP, NOON SUMMER SOLSTICE
MW/m2

	Angle from North								
	-180	-135	-90	-45	0	45	90	135	180
15.7									
	0.0000	.0346	.1182	.1780	.1620	.1182	.0279	.0014	
13.7									
	.0040	.0600	.2139	.3508	.3826	.2352	.0638	.0026	
11.8									
	.0026	.0757	.3441	.5009	.4624	.3402	.0877	.0014	
9.8									
	.0040	.0638	.3282	.4916	.4730	.3641	.0811	.0026	
7.9									
	.0014	.0625	.3760	.4996	.4836	.3601	.0851	.0053	
5.9									
	.0040	.0757	.3336	.4464	.4624	.3269	.0625	.0040	
3.9									
	0.0000	.0439	.2564	.2843	.2950	.2113	.0452	.0014	
2									
	0.0000	.0119	.0903	.1595	.1462	.0891	.0266	.0014	
0									
Height (m)									

TABLE 5.3-3

PRIMARY RECEIVER FLUX MAP, NOON WINTER SOLSTICE
MW/m2

	Angle from North								
	-180	-135	-90	-45	0	45	90	135	180
15.7	.0008	.0375	.1526	.1860	.2159	.1463	.0282	0.0000	
13.7	.0015	.0651	.2843	.4283	.3844	.2592	.0589	.0032	
11.8	.0015	.0715	.3519	.5125	.5399	.3995	.0650	.0015	
9.8	.0039	.0879	.3755	.5407	.5934	.3885	.0769	.0015	
7.9	.0015	.0824	.4062	.5706	.5714	.3764	.0730	.0039	
5.9	.0024	.0793	.3420	.4909	.5291	.3662	.0754	.0032	
3.9	0.0000	.0408	.2379	.3954	.3728	.2692	.0588	0.0000	
2	.0008	.0236	.1014	.1611	.1721	.1117	.0173	0.0000	
0									

Height (m)

TABLE 5.3-4

REHEAT RECEIVER FLUX MAP, NOON SUMMER SOLSTICE

	Angle from North																
	-180		-135		-90		-45		0		45		90		135		180
15.7																	
		.0002		.0055		.0163		.0230		.0242		.0158		.0044		0.0000	
13.7																	
		0.0000		.0153		.0805		.1134		.1162		.0795		.0128		0.0000	
11.8																	
		0.0000		.0108		.0823		.1178		.1131		.0847		.0141		0.0000	
9.8																	
		0.0000		.0166		.0877		.1366		.1314		.0840		.0148		0.0000	
7.9																	
		.0002		.0136		.0808		.1252		.1223		.0800		.0150		0.0000	
5.9																	
		0.0000		.0188		.0847		.1147		.1198		.0867		.0133		0.0000	
3.9																	
		0.0000		.0081		.0711		.0887		.0988		.0727		.0074		0.0000	
2																	
		0.0000		.0002		.0082		.0129		.0092		.0081		.0003		0.0000	
0																	
Height(m)																	

TABLE 5.3-5

REHEAT RECEIVER FLUX MAP, NOON WINTER SOLSTICE
MW/m2

Height (m)	Angle from North: -180	-135	-90	-45	0	45	90	135	180
15.7	0.0000	.0047	.0233	.0259	.0255	.0235	.0060	0.0000	
13.7	0.0000	.0109	.0823	.1112	.1117	.0822	.0090	0.0000	
11.8	0.0000	.0085	.0868	.1251	.1257	.0899	.0087	0.0000	
9.8	0.0000	.0123	.0993	.1352	.1284	.0996	.0115	0.0000	
7.9	0.0000	.0085	.0875	.1285	.1253	.0886	.0085	0.0000	
5.9	0.0000	.0105	.0947	.1263	.1322	.0907	.0115	0.0000	
3.9	0.0000	.0045	.0668	.1041	.1075	.0666	.0050	0.0000	
2	0.0000	.0008	.0130	.0176	.0183	.0150	.0001	0.0000	
0									

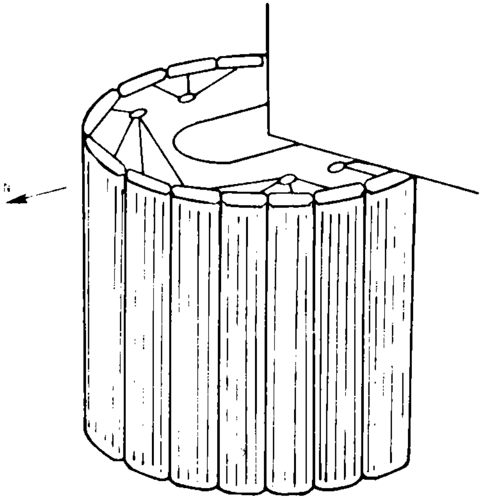
TABLE 5.3-6

BUDGETARY COST ESTIMATE
FOR RECEIVER SUBSYSTEM
(1980 DOLLARS)

Main Receiver Boiler Superheater and Economizer	$ 3,230,000
Reheater	1,300,000
Structural Steel and Platforms	1,000,000
Auxiliaries (Circulating Pump Elevator and Crane	470,000
Contract Engineering	1,000,000
Boiler Controls (Drum Level, SH and RH Steam Temperature, Valves, Etc)	650,000
Erection (Labor, Tools, Supervison)	3,850,000
	$11,500,000

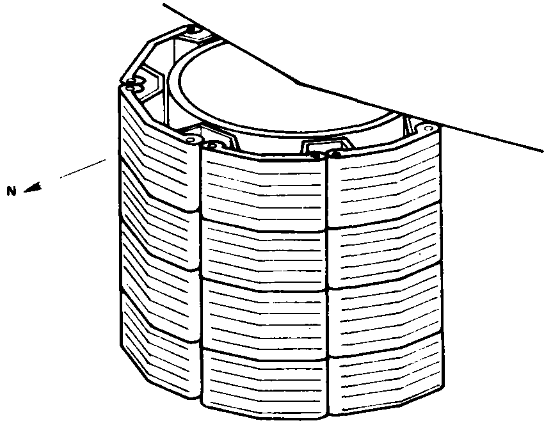
CONFIGURATION: EXTERNAL CONFIGURATION
FORCED RECIRCULATION
SCREENED TUBE CONCEPT
1 TOWER WITH PRIMARY AND REHEAT RECEIVER
160° NORTH FIELD

PRIMARY RECEIVER



ABSORBED POWER = 92 MW (50% REPOWER)
MAXIMUM HEAT FLUX = 0.60 MW/m^2
OUTLET TEMPERATURE = 549°C
OUTLET PRESSURE = 10.8 MPa
PRESSURE DROP = 1.72 MPa
LENGTH = 15.7 m
DIAMETER = 12.6 m
ENCLOSED ANGLE = 240°
PANELS = 16
CENTERLINE ELEVATION = 155 m

REHEAT RECEIVER



ABSORBED POWER = 13 MW (50% REPOWER)
MAXIMUM HEAT FLUX = 0.14 MW/m^2
OUTLET TEMPERATURE = 549°C
OUTLET PRESSURE = 2.97 MPa
PRESSURE DROP = 0.172 MPa
LENGTH = 15.7 m
DIAMETER = 12.6 m
ENCLOSED ANGLE = 210°
PANELS = 16
CENTERLINE ELEVATION = 138 m

FIGURE 5.3-1
RECEIVER CONCEPTUAL DESIGN

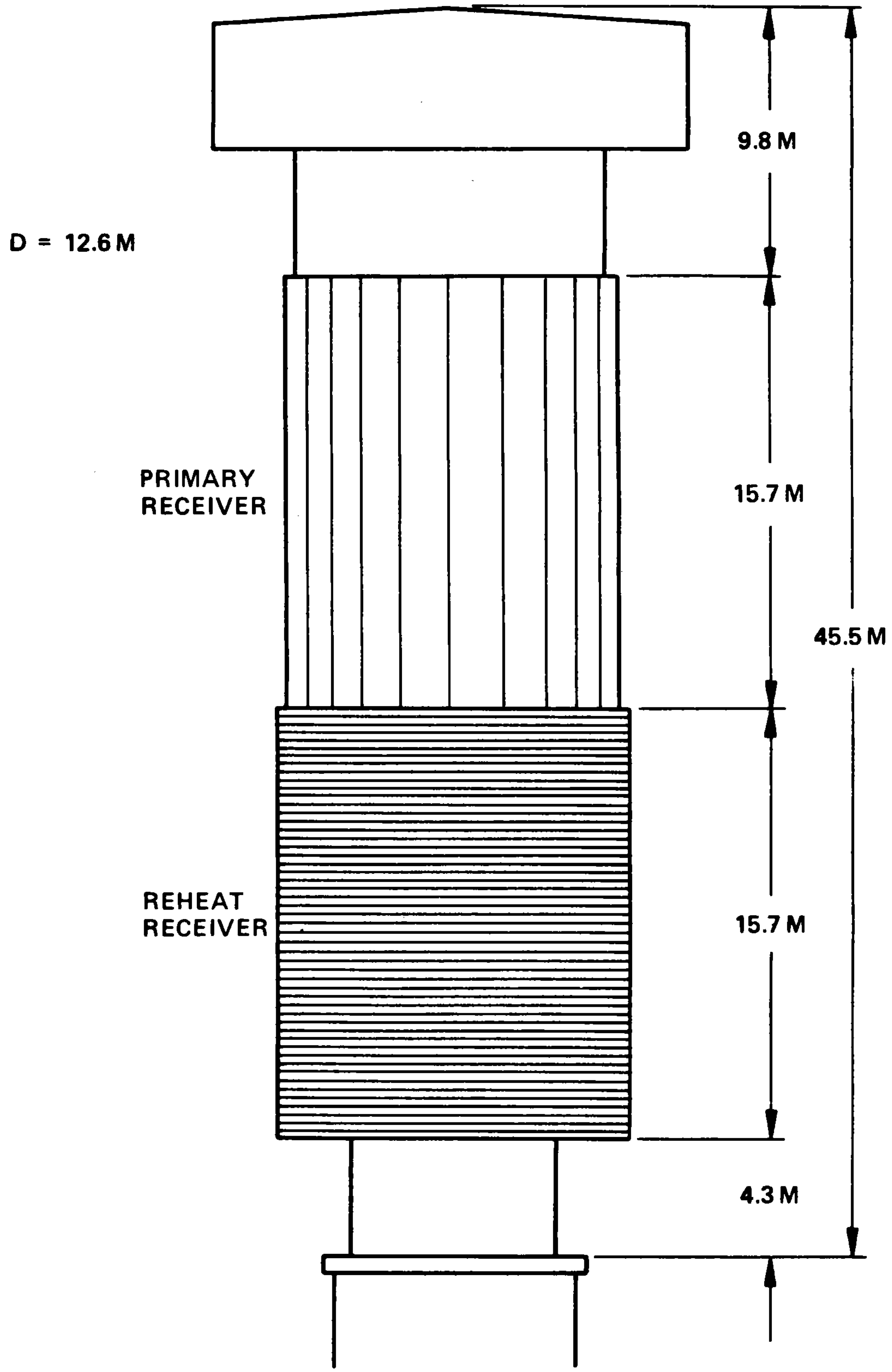
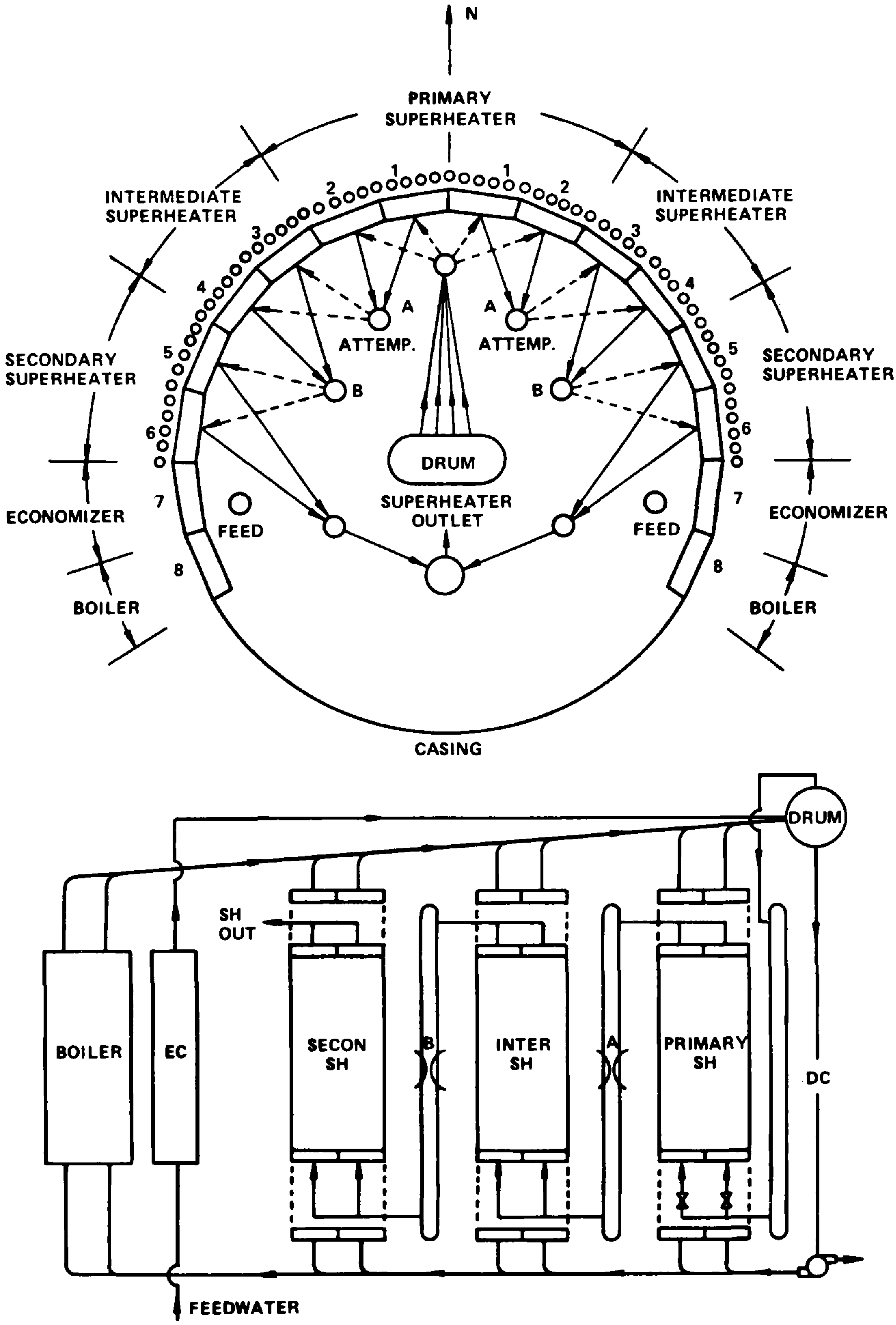
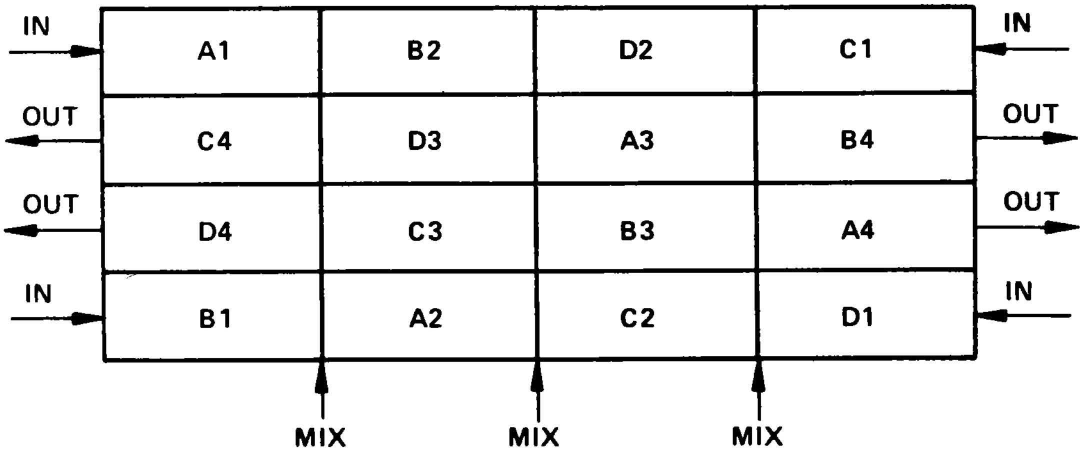


FIGURE 5.3-2
PROPOSED RECEIVER CONFIGURATION



EXTERNAL RECEIVER

FIGURE 5.3-3
PRIMARY RECEIVER CONCEPT



FLOW PATHS

PATH A: A1 → A2 → A3 → A4

PATHS B, C, & D ARE SIMILAR

FIGURE 5.3-4

SCHEMATIC ARRANGEMENT OF SOLAR REHEATER PANELS

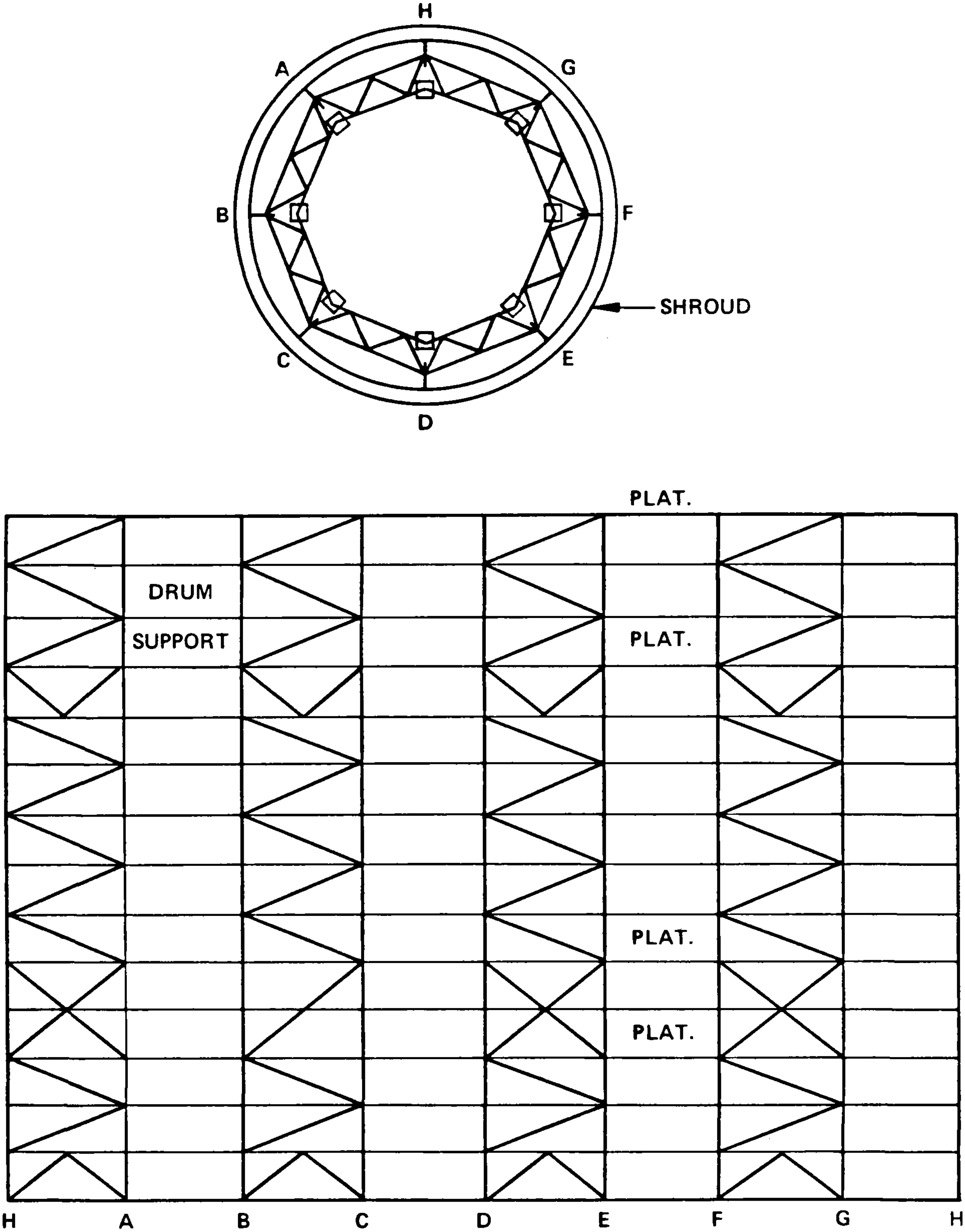


FIGURE 5.3-5
RECEIVER SUPPORT STRUCTURES

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 Section 2.7.

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, 13505-FM-26A-SR, 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 points for feedwater and main steam piping are shown in Figure 5.5-1. Interface points for low and high temperature reheat piping are shown in Figure 5.5-2.

Flow diagrams 13505-FM-2A-SR, 13505-FM-3A-SR, and 13505-FM-9-SR detail 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 downstream of the first point extraction heater is split by the solar and boiler feedwater control valves. A 20.3 cm (8 inch) nominal size line from the existing feedwater line conveys part of the feedwater flow 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 preheat 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 B. 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 m^3/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 12.2 MPa (1,765 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, 13505-EW-S1A-SR in Appendix B, 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 repowering 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 100 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, each feeding four 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 13505-EW-S1A-SR-1. Each transformer, centrally located to approximately 174 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, is 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 60 aluminum 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 61 m (200 foot) intervals. The horizontal illumination level at ground level is an average of 5.4 lx (0.5 foot-candles).

Lighting power is supplied by a 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 the table.

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 $5.12 million in 1980 dollars. These costs include modifications to the existing turbine generator for cycling operation; 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.

Turbine generator modifications, including the DEH, are estimated at $1,350,000 in 1980 dollars.

Piping, valves, pumps, and related equipment are estimated at $3,220,000 in 1980 dollars.

Electrical equipment provided to support electrical power requirements is estimated to cost approximately $560,000 in 1980 dollars.

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 (1,450 psig)
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 537°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 (1,450 psig) at rated output
   b. 10.6 MPa (1,523 psig) as turbine approaches zero output
   c. 13.0 MPa (1,885 psig) 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)	.20(.50)	c.s.	37(120)
at Pump Outlet	10.2(4)	.17(.44)	c.s.	15(50)
	15.2(6)	.22(.56)	c.s.	213(700)
Main Steam	30.5(12)	.52(1.31)	CR/MO	238(780)
Low Temperature				
Reheat	35.6(4)	.23(.59)	c.s.	21(70)
	61.0(24)	.23(.59)	c.s.	210(690)
High Temperature				
Reheat	35.6(14)	.23(.59)	CR/MO	21(70)
	61.0(24)	.23(.59)	CR/MO	229(750)

NOTES:

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

TABLE 5.5-3

STATION HEAT RATES

Operational Mode	Net Generation, MWe Fossil/Solar	Percent of Rated Main Steam Flow	Auxiliary Power, MWe	Net Station Heat Rate 103 kj/kWh (Btu/kWh) Fossil	Solar
Fossil/Solar	41.0/41.0 (Design Pt)	103	3,99	10.7 (10,124)	9.0 (8,545)
Fossil/Solar	20.5/41.0	77	3.84	11.1 (10,541)	9.3 (8,853)
Fossil/Solar	20.5/20.5	37	3.27	11.8 (11,176)	9.9 (9,380)
Fossil only	82.0/-	100	3.56	10.8 (10,250)	-
Fossil only	41.0/-	53	2.90	11.6 (11,000)	-
Fossil only	20.5/-	31	2.30	13.7 (13,000)	-
Solar only	-/41.0	53	3.27	-	9.9 (9,380)
Solar only	-/20.5	31	2.46	-	11.7 (11,060)

Rated main steam flow is 258,100 Kg/hr (567,000 lb/hr).

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 higher 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

Main Steam Temperature °C (°F)	Reheat Steam Temperature °C (°F)	Reheat Pressure Drop kPa (Psi)	Decrease In Net Unit Output (MWe)	Increase in Net Unit Heat Rate kJ/kWhr (Btu/kWhr) 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 (60)	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)

NOTE:

All other operating conditions consistent with full load operation shown on heat balance for 83 MW in Section 5.1.

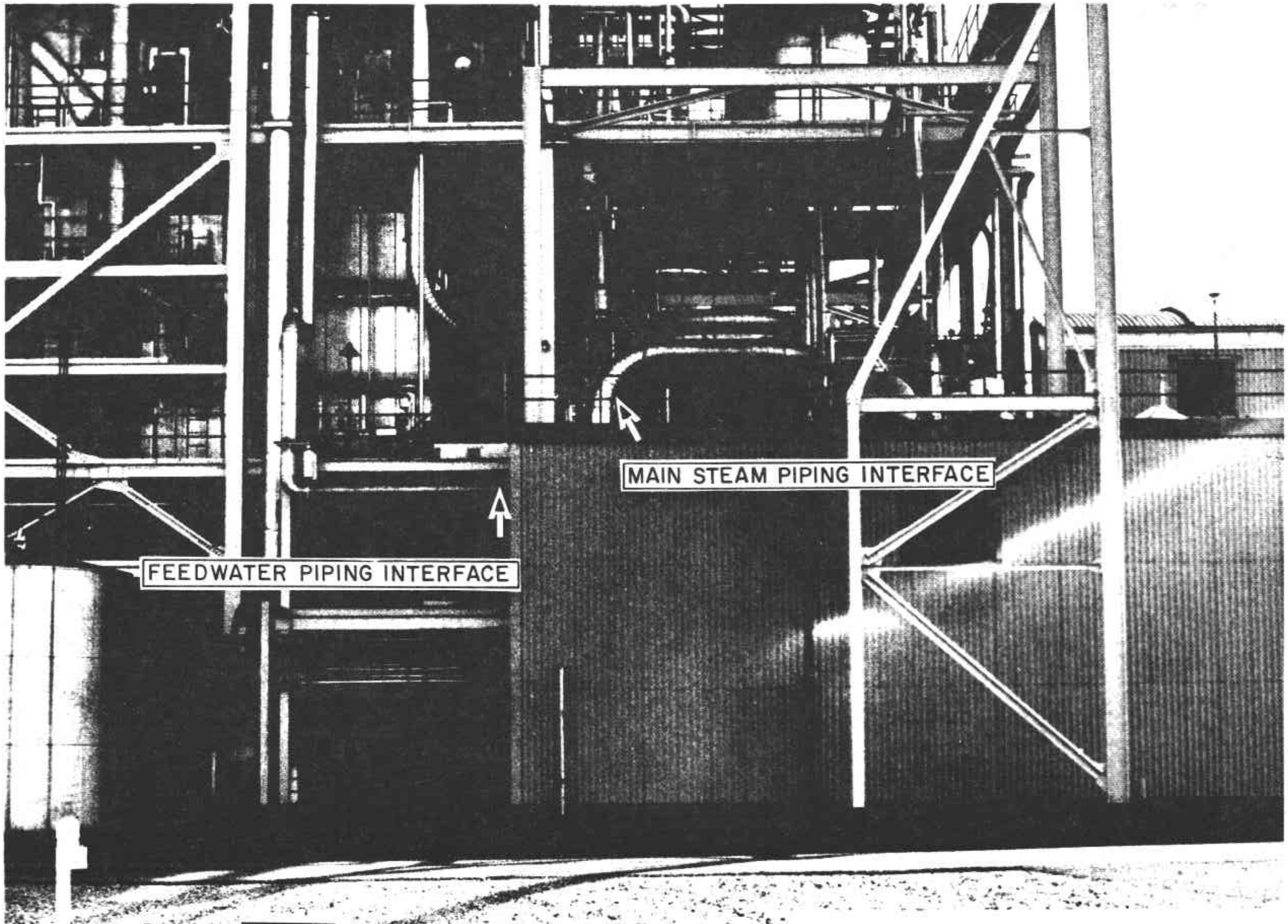


FIGURE 5.5-1
MAIN STEAM AND
FEEDWATER PIPING INTERFACE

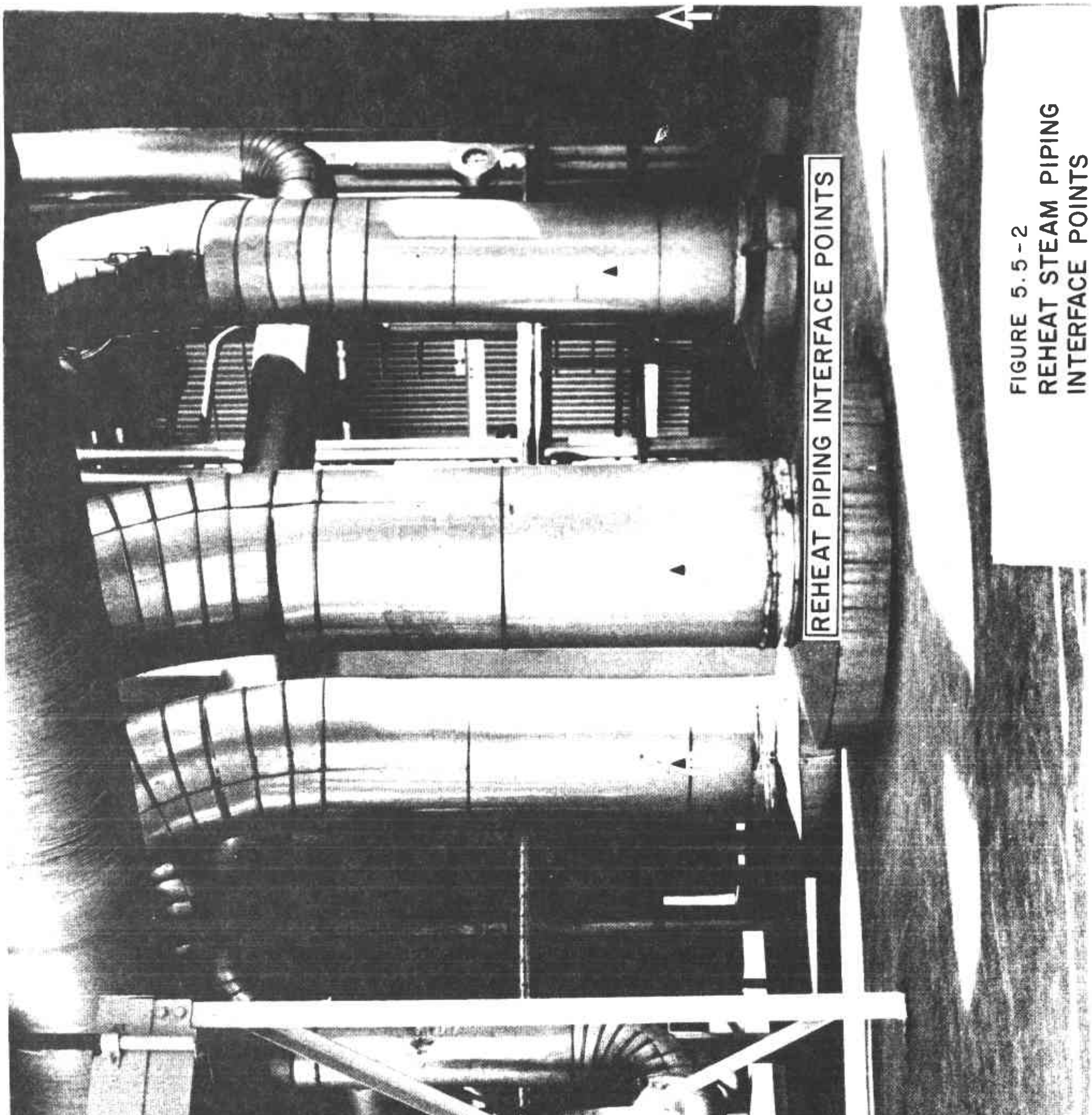


FIGURE 5.5-2
REHEAT STEAM PIPING
INTERFACE POINTS

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 daily cycling of the unit and utilize fossil and solar energy for generation of electrical power. The MCS shall control the solar steam supply system and the existing plant equipment in a safe and reliable condition under all modes of operation.

The MCS shall permit the operator to select one of three plant operating modes: a fossil mode, a solar mode, or a combined solar/fossil mode.

The MCS shall operate the plant 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 PCS will include full system redundancy where feasible. A failure of one central processing unit will not cause a reduction in control, monitoring, display, or other required plant control function.

Comprehensive Operator/Plant Interface

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 providing 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 only where necessary. The following criteria will be used:

Direct interface with MCS.

Significant enhancement of the repowered units ability to meet the design requirements.

Ability of the equipment to function properly for the required 30 year lifetime.

In general, all the instrumentation that will be replaced meets two or more of the above criteria.

5.6.1.2 Design Philosophy

Solar repowered 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 plant systems and overall plant control are incorporated in a centralized, mini-computer-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 plant 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 processor 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 plant 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 plant 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 plant 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 colorgraphic CRT and control functions keyboard.

One engineer's/programmer's console, with colorgraphic 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 CRT 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, pressures level 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

Plant operations displays/records

In addition to the above, the PCS includes a comprehensive direct digital control (DDC) software system. The DDC systems perform 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 could have an important impact on the schedule for engineering and construction for the repowering project.

5.6.3 Operator/Plant Interface

5.6.3.1 Control Levels

The plant can be operated at no less than three levels of control with the operator's responsibilities varying with each level.

Automatic

At this level the PCS is providing overall plant control and subsystem integration and coordination. The PCS optimizes the operation of the plant by evaluating many environmental, plant, system, and component variables, characteristics, and responses. The operator simply monitors the performance and status of the plant, 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 plant 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 plant shutdown.

The portion of the emergency trip and interlock system necessary for operating/equipment safety 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

The operator and engineer communicate with the system through two I/O CRT communication consoles, illustrated in Figure 5.6-1. The operator's console is mounted in the main control board and the engineers' console is in the results room. One operator and one engineer 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 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 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

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 (HFC)

The HFC handles a field of 26 or 27 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 2,776 heliostats.

Each sector contains up to 702 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 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. The 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. The purpose of the system is to permit the automatic real time evaluation of the 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, deflect their beams from the receiver to the respective calibration target. Beam size, shape, centroid, flux distribution, and power are measured for each heliostat. This is a passive process made possible by the 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, 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, the canting of the 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.

The 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. The output of the cameras is also transmitted to the BCS computer where a video switch selects each camera. Central processing units, CRT displays, keyboards, printers, video digitizers, and data recorders are utilized to extract the needed data. Meteorological data and solar irradiance data are also delivered to the BCS computer to close the loop on the evaluation of heliostat beam characteristics.

The BCS computer and the HAC work in direct communication, under the PCS supervision, in the 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 or directly on the calibration target as necessary to perform the measurements. The plant 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 plant operator is simply notified so that he can take the necessary action to restore normal conditions.

5.6.4.5 Collector Control Operation

All the detailed control algorithms for operation of the heliostats during the various modes are stored in the bubble memory of the HFC. The 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 down-loading new routines through the same communication network utilized for control of the array. The 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.

The heliostat control arrangement is designed to achieve the intended performance at all levels with very little human intervention. All the 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 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 by the operator.

One of the principal concerns associated with the design of the operations control strategy is to minimize the impact of malfunctions, occurring at any level, on the performance of the components not directly affected by the malfunction. Abnormal conditions are relayed through the communication network to the MCS.

Alignment can take place on a continuous basis, if necessary, 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 the 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. The 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 the necessary commands to verify correct aiming at the calibration target and to make the 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 the alignment of its field 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 system.

The receiver controls are composed of four main independent controls:

- Superheat steam temperature control
- Panel bias valve control
- Reheat steam temperature control
- Feedwater 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. Two stages of water attemperation are used to control superheat steam temperature. 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. A single stage of water attemperation is used to control reheater outlet temperature. 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 is 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 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 and the primary superheater outlet temperature to prevent the first stage of attemperation from over-spraying 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. These valves under normal, steady-state conditions are throttled to approximately 70 percent open. If, during a transient, the outlet temperature exceeds 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 is controlled by a single stage attemperator at the reheater inlet in combination with heliostat control when the attemperator is out of the control range(see Figure 5.6-3). Reheater outlet temperature is compared with its setpoint and the resulting error is used to develop a demand for reheater attemperator flow.

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 is possible.

When the reheat attemperator reaches its upper flow limit, sufficient 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 5.6-6).

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 drum level is used.

5.6.6 Fossil Boiler Control

The fossil boiler subsystem includes the existing fossil-fueled boiler and associated boiler controls as described in Section 5.2.

The fossil boiler subsystem is modified to provide state-of-art control components to improve the reliability and availability of the subsystem. The 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 are 20 years old and are not expected to function properly for many of the 30 years for which the repowered unit is designed. Bailey Meter Company is no longer manufacturing this line of instrumentation or the spare parts to keep it operating.
>
> The combustion controls have a major control and monitoring interface with the PCS.
>
> In order to limit the effects of solar transients on the turbine generator, the fossil unit dynamic response must be as fast as possible within the design limitations of the existing unit.

The new combustion controls employ new electronic components and state-of-the-art control concepts.

The 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 5.6-7). 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. The 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 5.6-8.)

Like the combustion control system, the feedwater controls instrumentation will be replaced by electronic equipment, but will retain the three-element control concept. The 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, the control logic is implemented in the PCS. (See Figure 5.6-9.)

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 part 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 5.6-10. The results 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 5.6-10, adjacent to the results room is the computer room which houses the CPU for the PCS, the DEH, the HAC, and BCS computers together with all peripheral and support cabinets. This room is segregated from the relay room (also in this figure) so as to avoid noise pickup originating from relay or electromagnetic equipment.

Provisions are made to add suitable HVAC equipment located on the result center level to supply the proper environment for operator comfort and operation of the computer and other electronic equipment.

The evaluation led to the modification, addition, and/or changes in the following major areas:

Control Room
Results Center
Control Board
Boiler Controls
Turbine Controls
Burner Controls
Instrumentation

5.6.7.2 Control Room

The existing control room is presently shared by Newman Units 1, 2, and 3. Due to the additional controls associated with the solar unit, the 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 the expansion of 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 is located above the existing control room and will be 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 corrosives 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 5.6-11.

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 system 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 5.6-7
- Burner controls
- Steam temperature controls (Figures 5.6-4 and 5.6-9)
- Feedwater controls (Figures 5.6-6 and 5.6-8)

The combustion control philosophy follows the present state-of-the-art approach, e.g., cross limiting with a feed-forward load indicator and 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. The steam temperature controls (superheat and reheat) and the 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 the 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 the expected cyclic operation of the fossil/solar hybrid plant, 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.

- Measure shaft eccentricity, vibration, metal temperatures.

- Calculate rotor stresses and adjust turbine speed accordingly.

- Self-diagnostic features to evaluate the validity of control information

Execute 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 colorgraphic 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 it is 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 board 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.

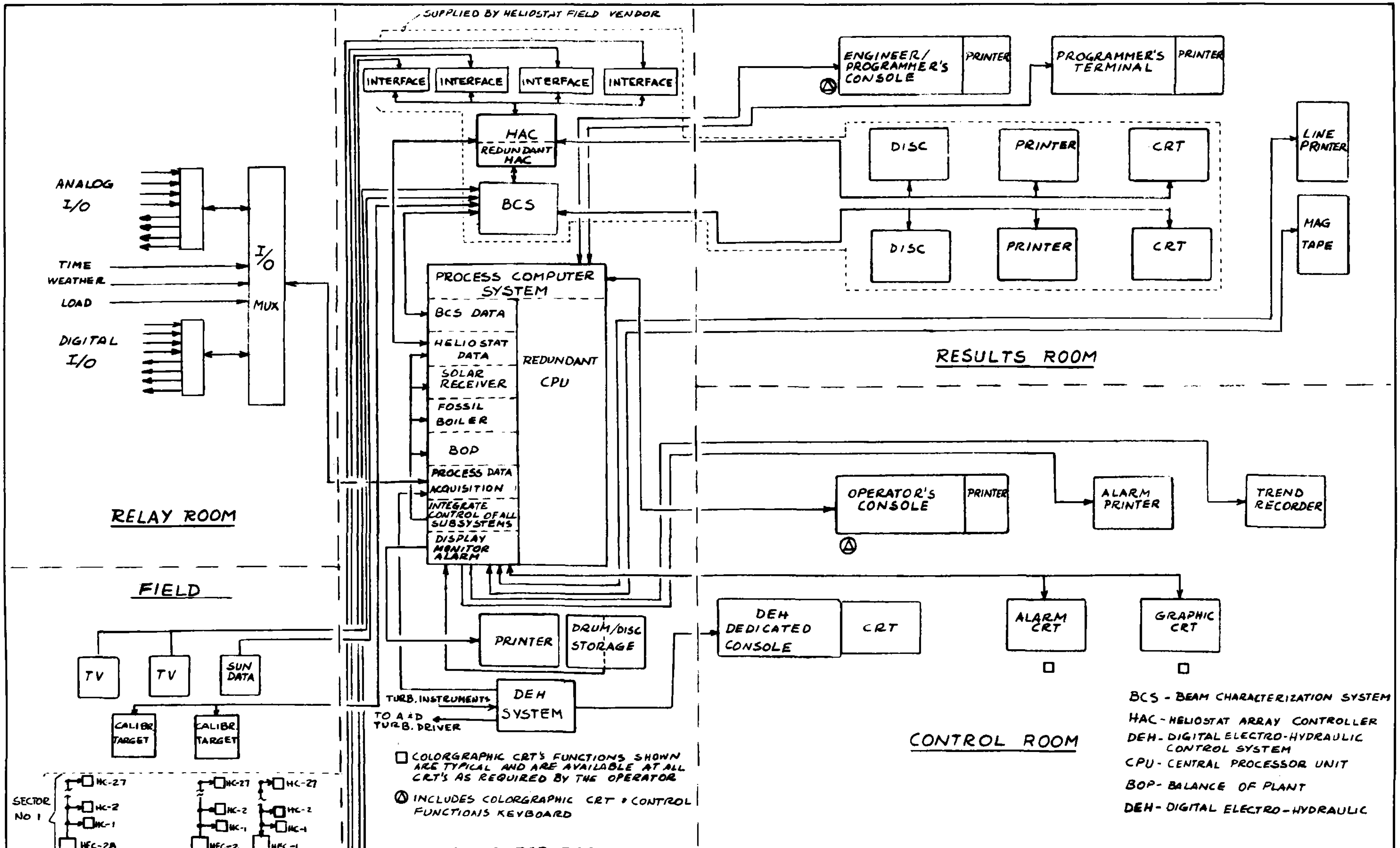


FIGURE 5.6-1
MASTER CONTROL SYSTEM

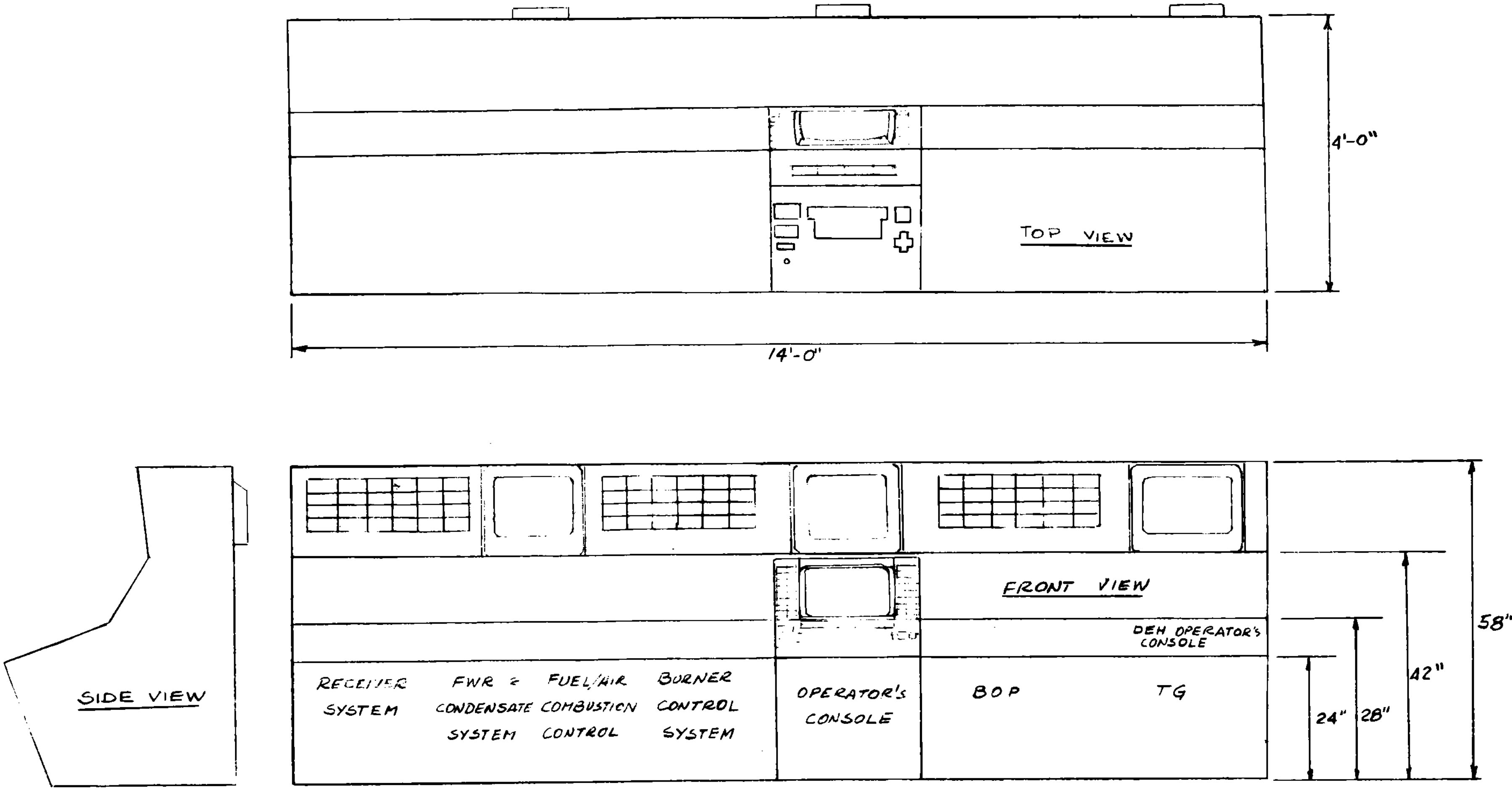


FIGURE 5.6-2
MAIN CONTROL BOARD

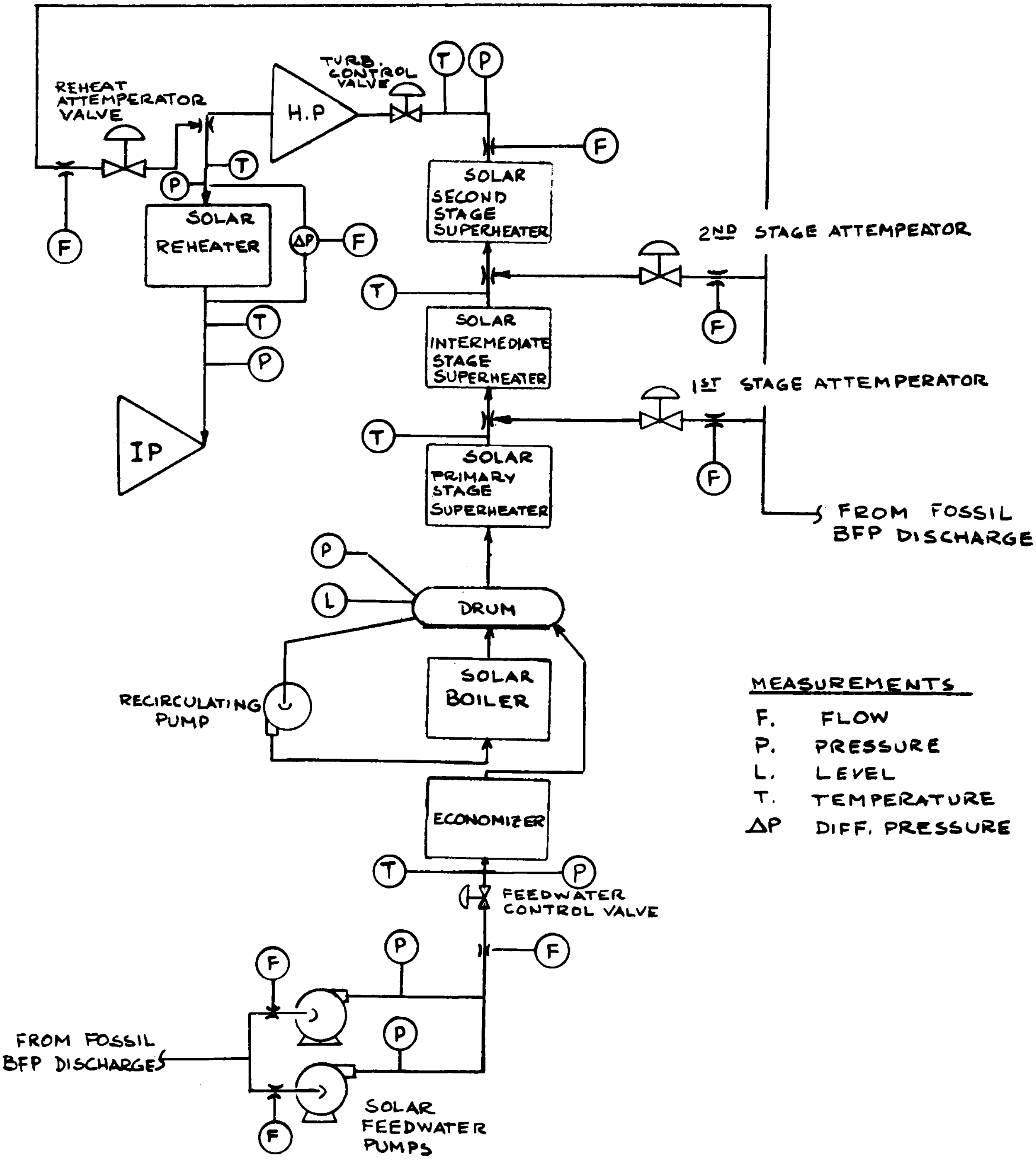


FIGURE 5.6-3
RECEIVER SIMPLIFIED FLOW DIAGRAM

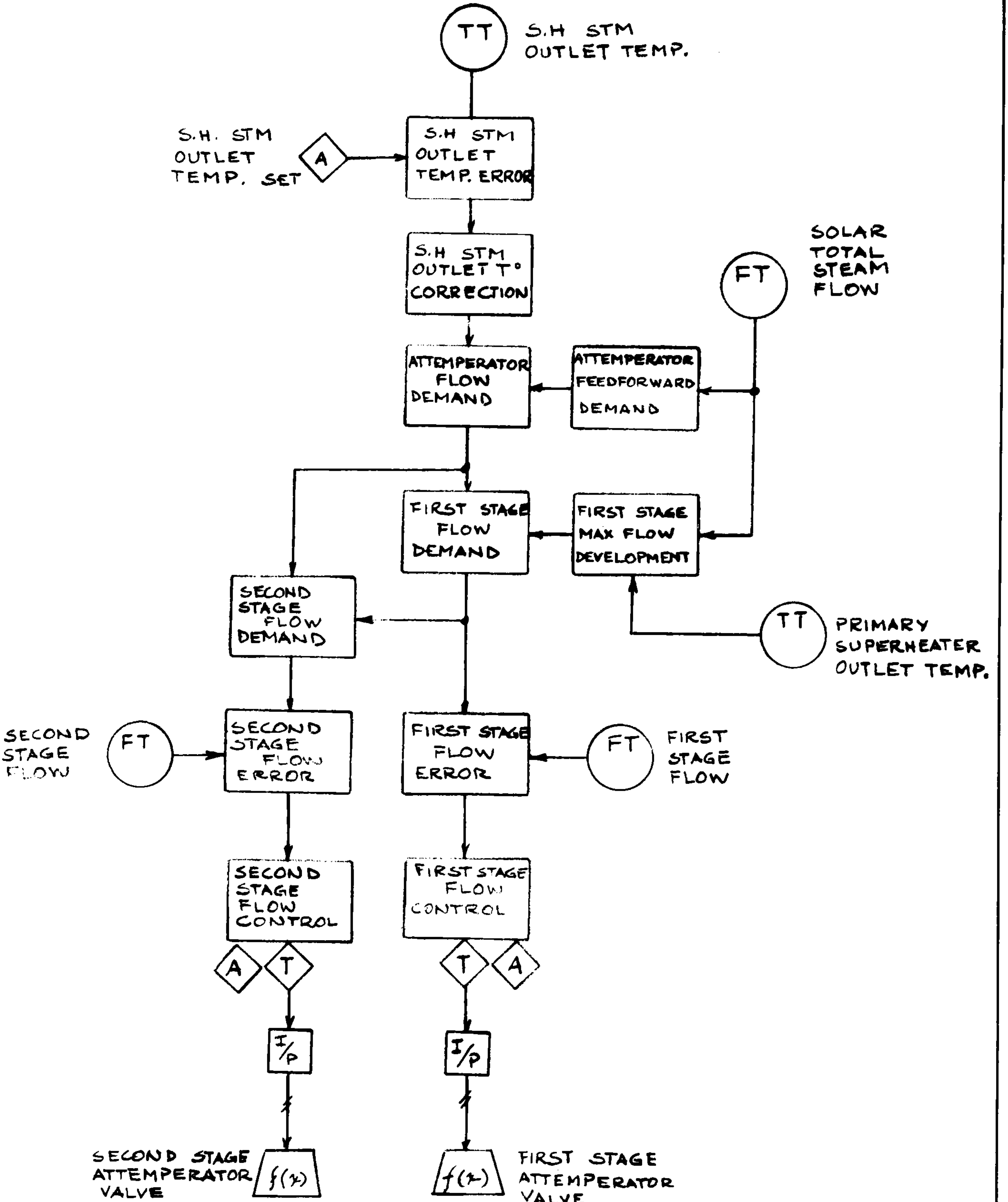


FIGURE 5.6-4
SOLAR RECEIVER SUPERHEAT STEAM TEMPERATURE CONTROL

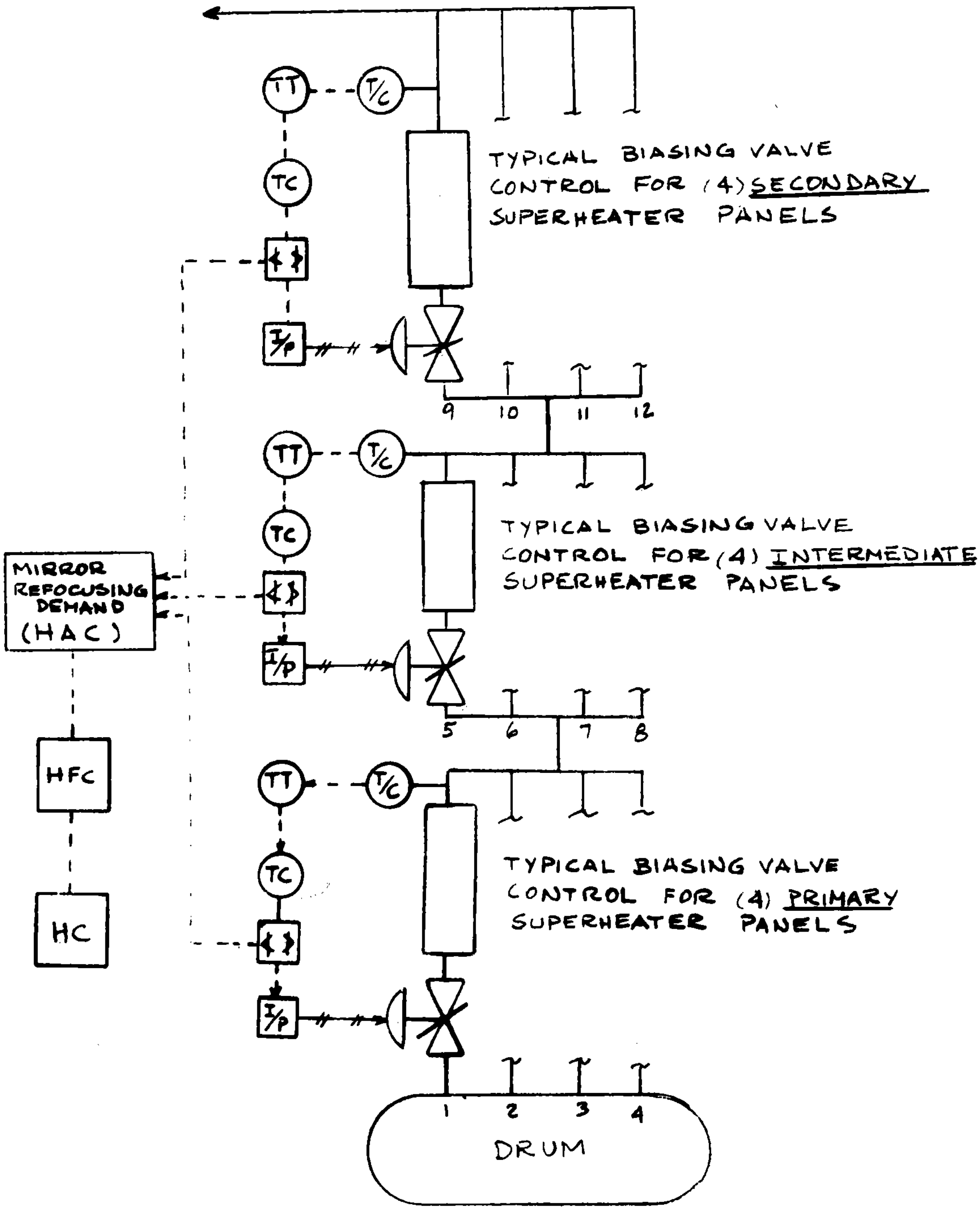


FIGURE 5.6-5
BIASING VALVE CONTROL

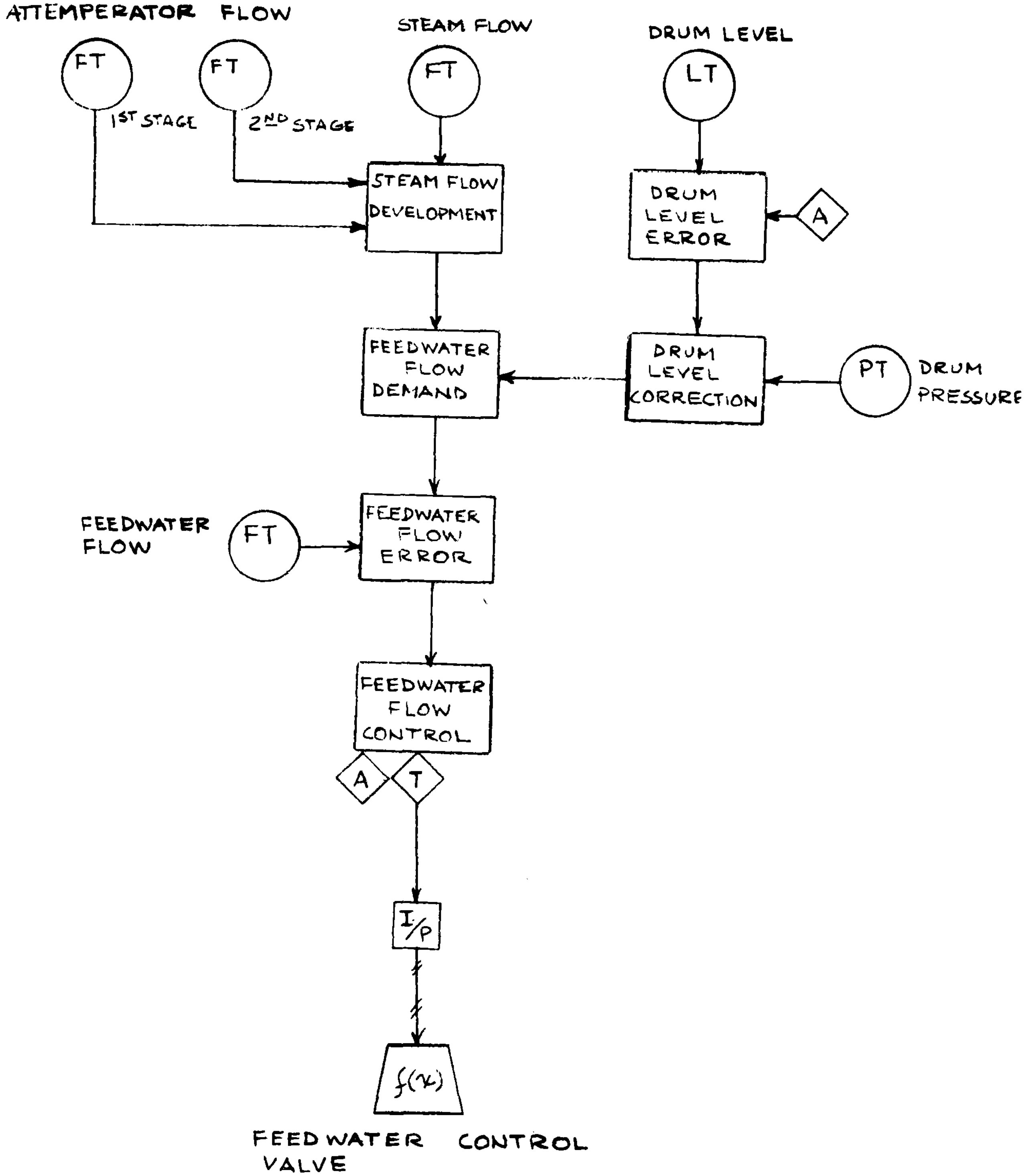


FIGURE 5.6-6
SOLAR FEEDWATER
CONTROL SYSTEM

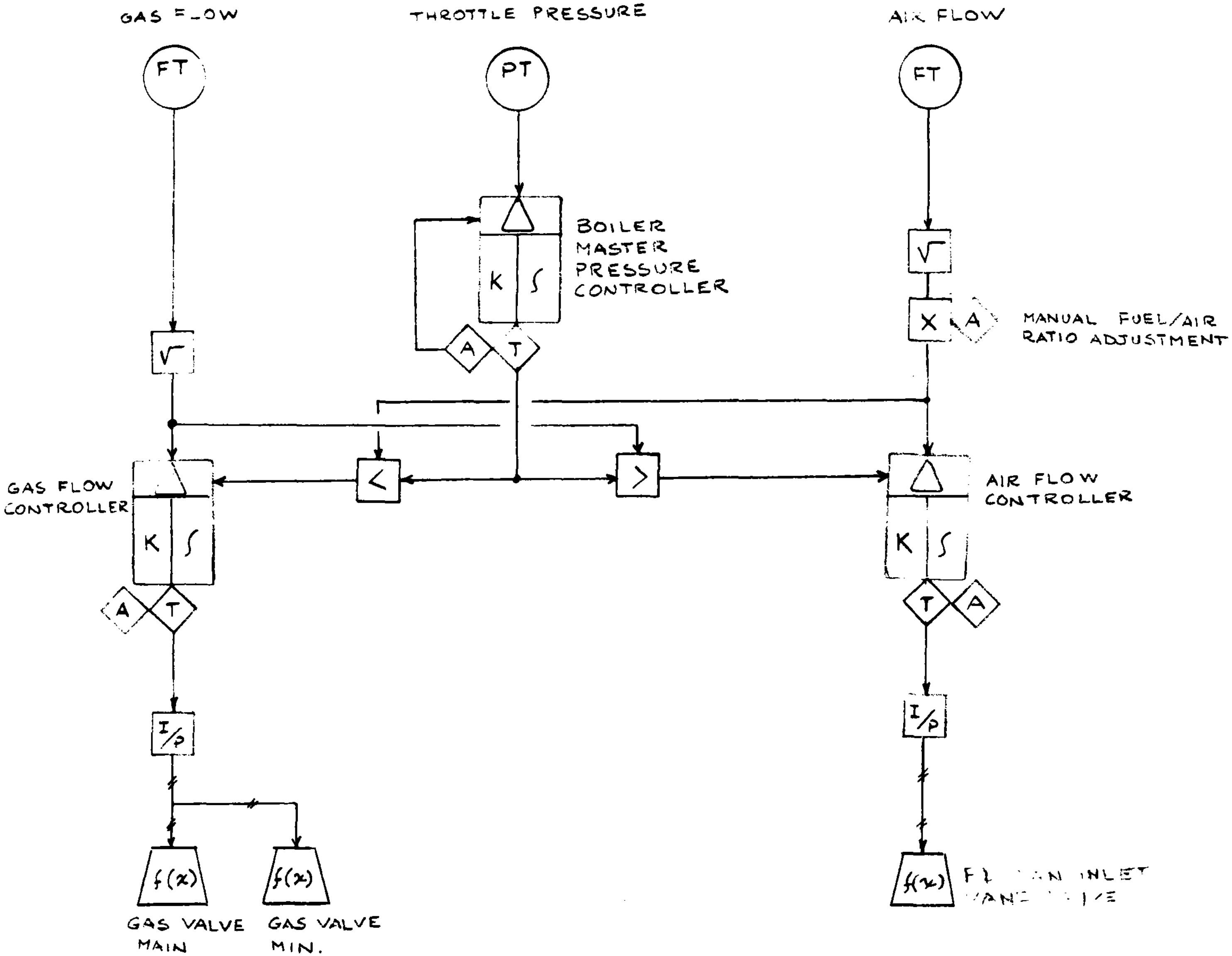


FIGURE 5.6-7
COMBUSTION CONTROLS WITH MANUAL FUEL / AIR ADJUSTMENT

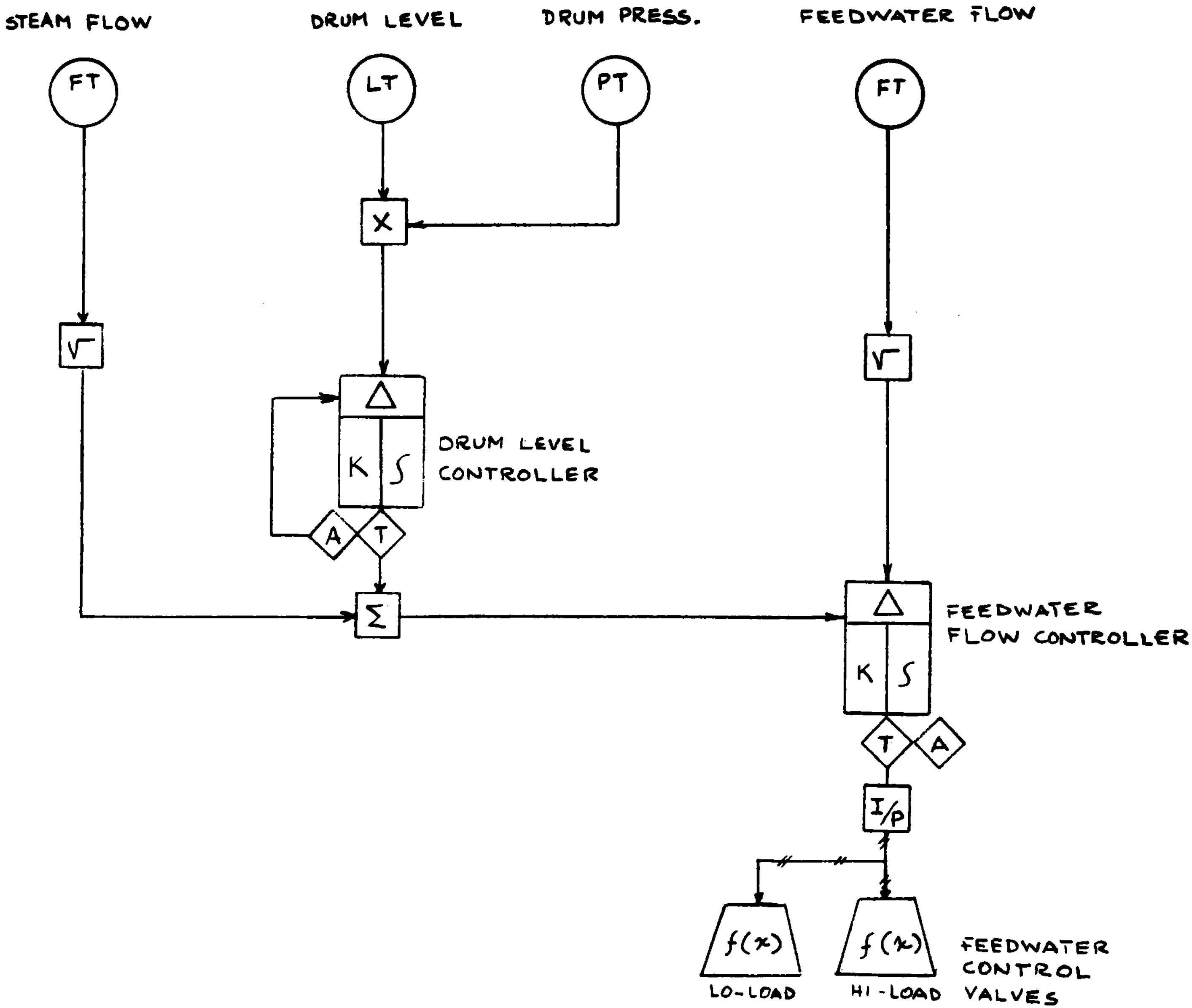
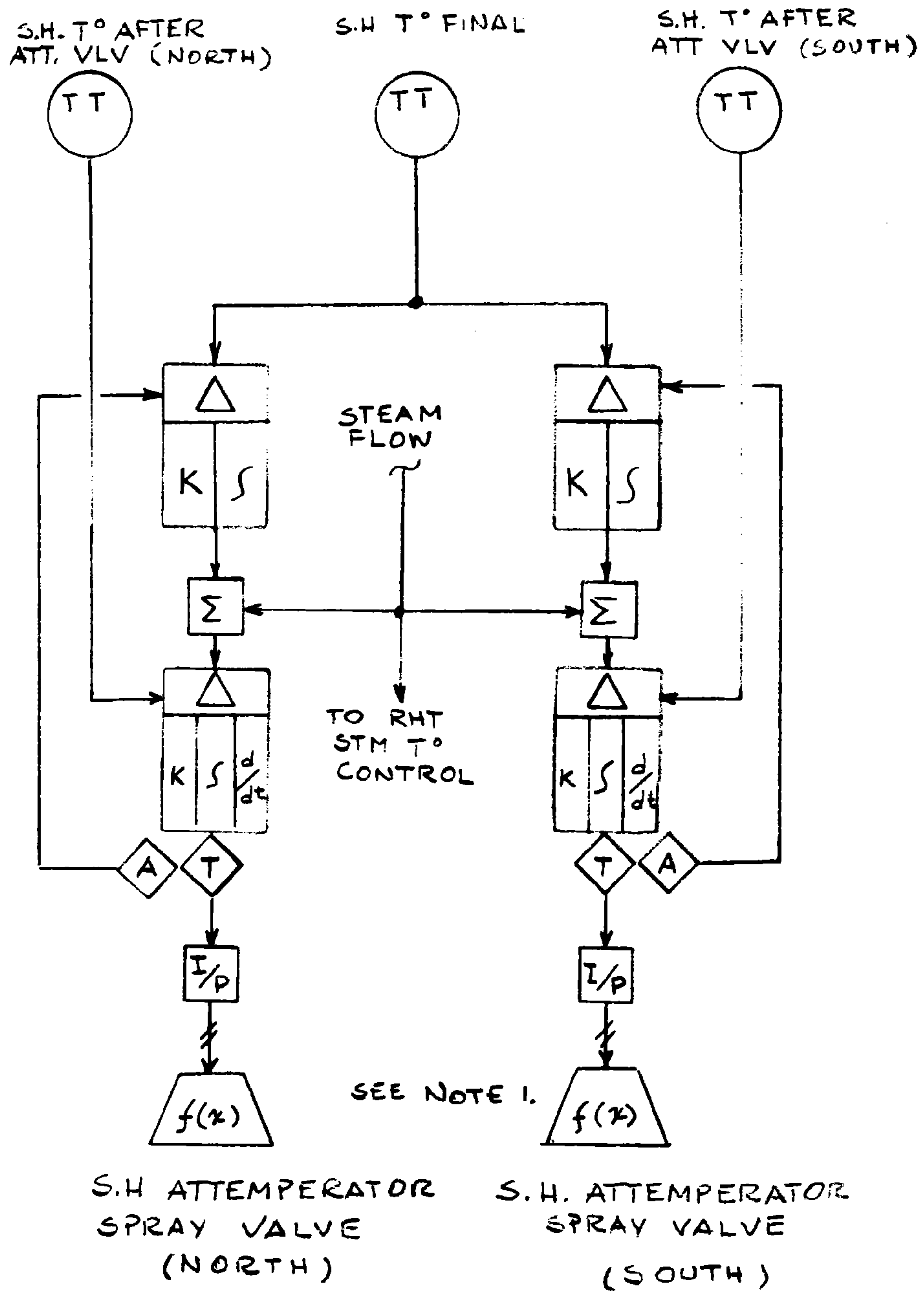


FIGURE 5.6-8
FEEDWATER CONTROL SYSTEM



NOTE 1. SUPERHEAT STEAM TEMP. CONTROL SHOWN. REHEAT STEAM TEMP SIMILAR

FIGURE 5.6-9
STEAM TEMPERATURE CONTROL SYSTEM

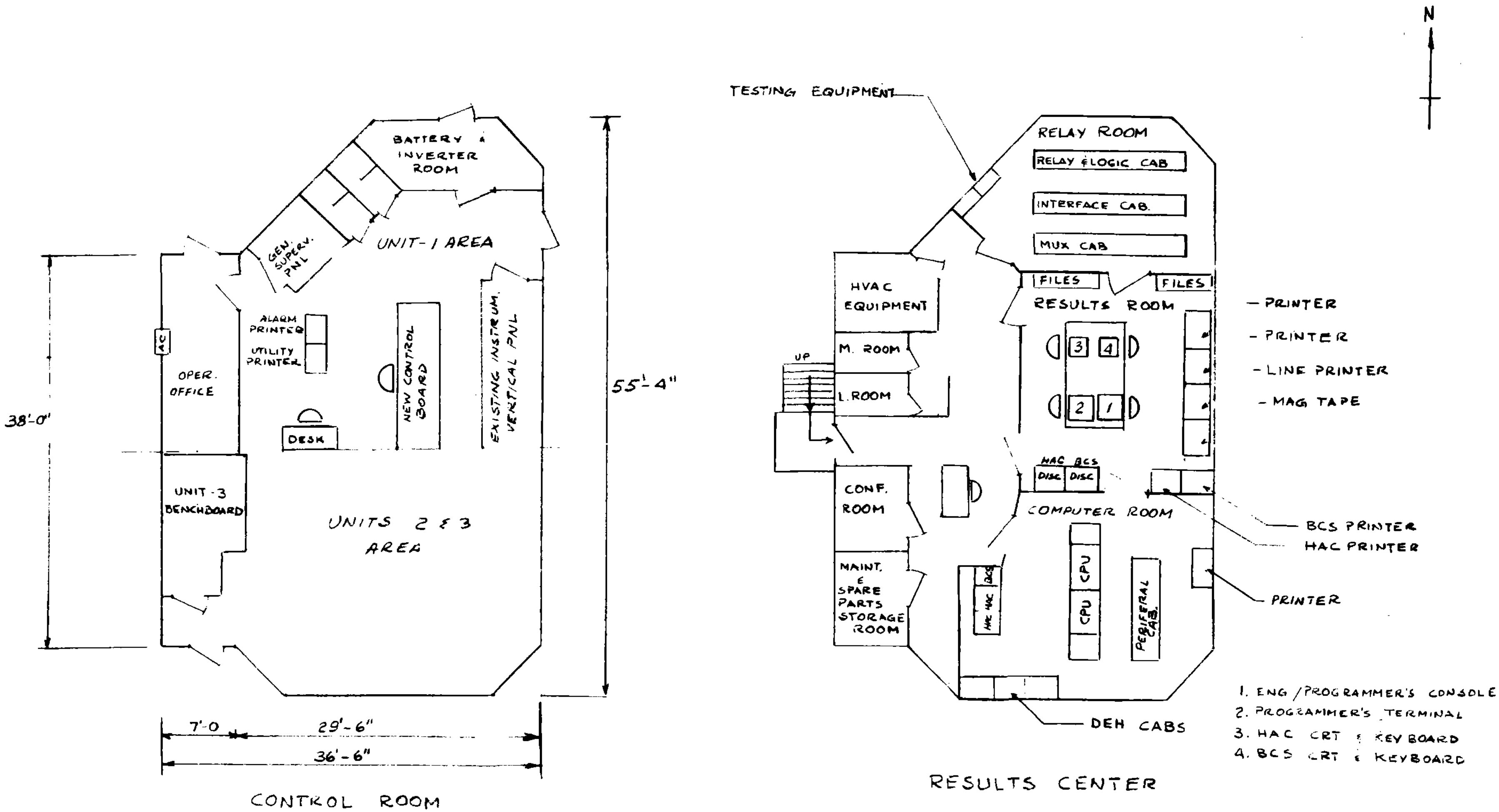


FIGURE 5.6-10
CONTROL & RESULTS ROOM

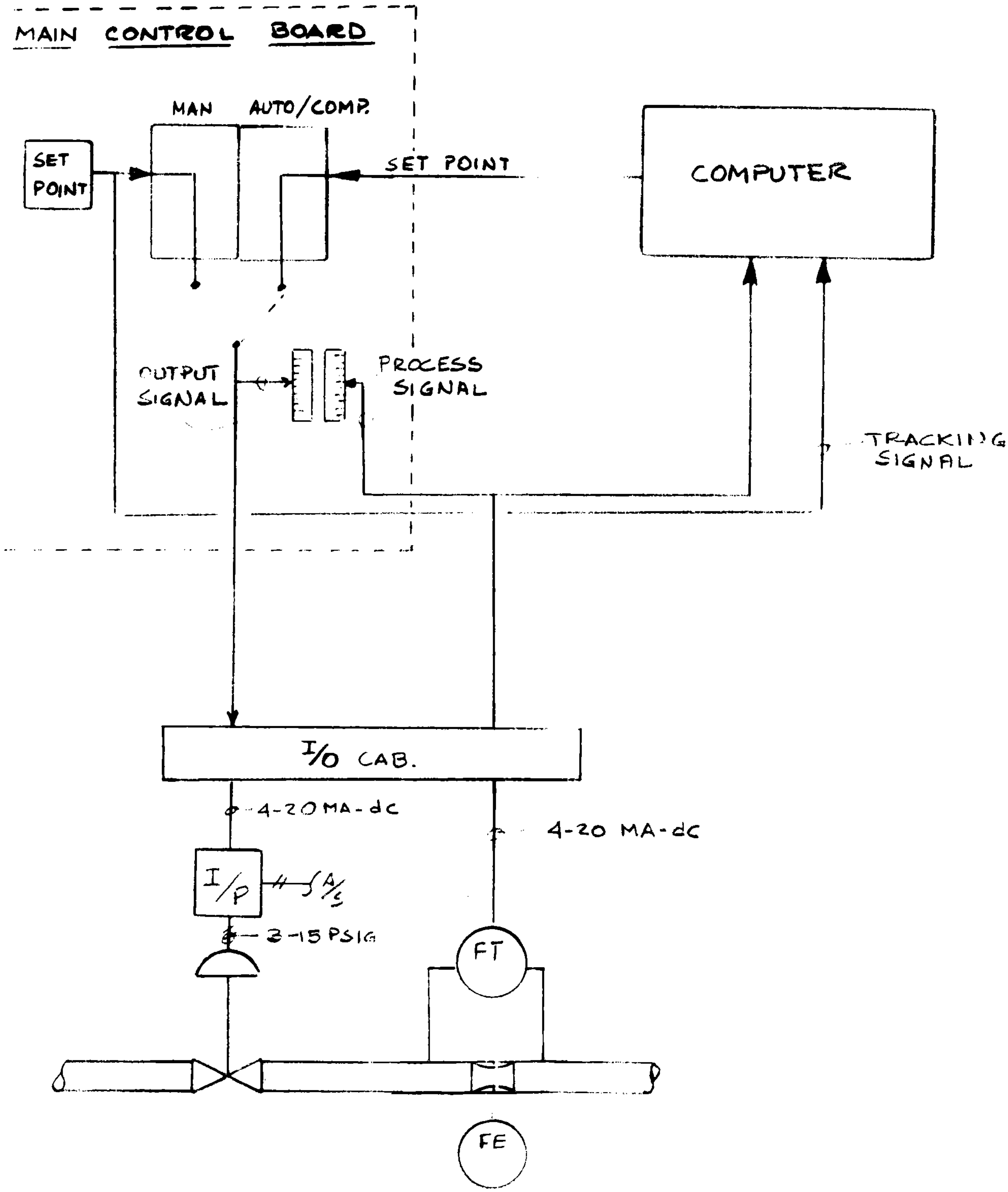


FIGURE 5.6-11
COMPUTER/CONTROL BOARD INTERFACE

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 and covered with 5.1 cm (2 inches) of crushed stone. Access to the heliostats for inspection and maintenance is 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. 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 $\$3.1 \times 10^6$. The site preparation costs are itemized in Table 5.7-1 and include the

TABLE 5.7-1

SITE IMPROVEMENT COSTS

Clearing and Grubbing	$ 530,000
Diversion Channel and Drainage Ditches	280,000 1,450,000
Crushed Rock Surface	-
Roads and Fencing	870,000
Total (1980 dollars)	$3,130,000

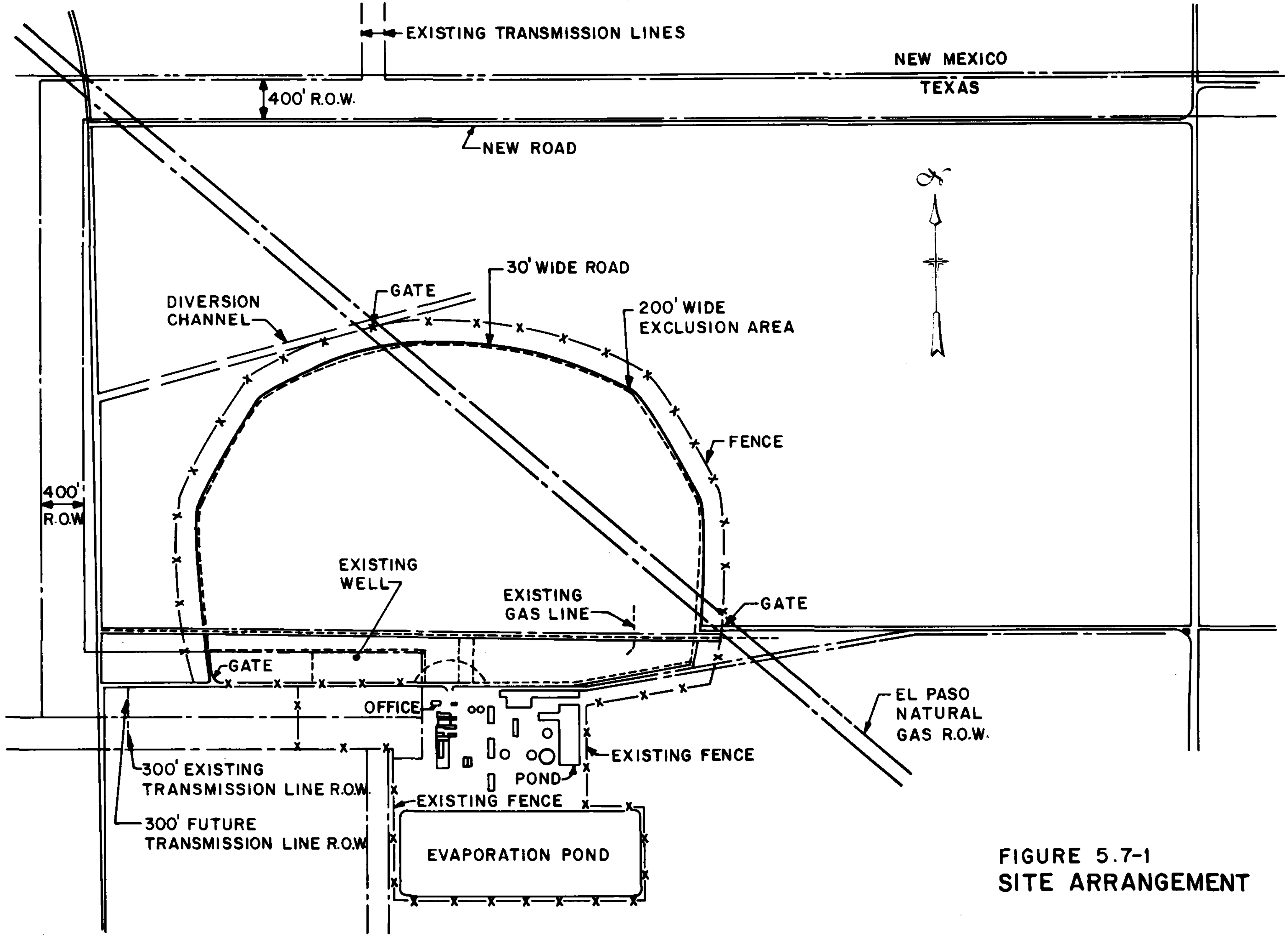


FIGURE 5.7-1
SITE ARRANGEMENT

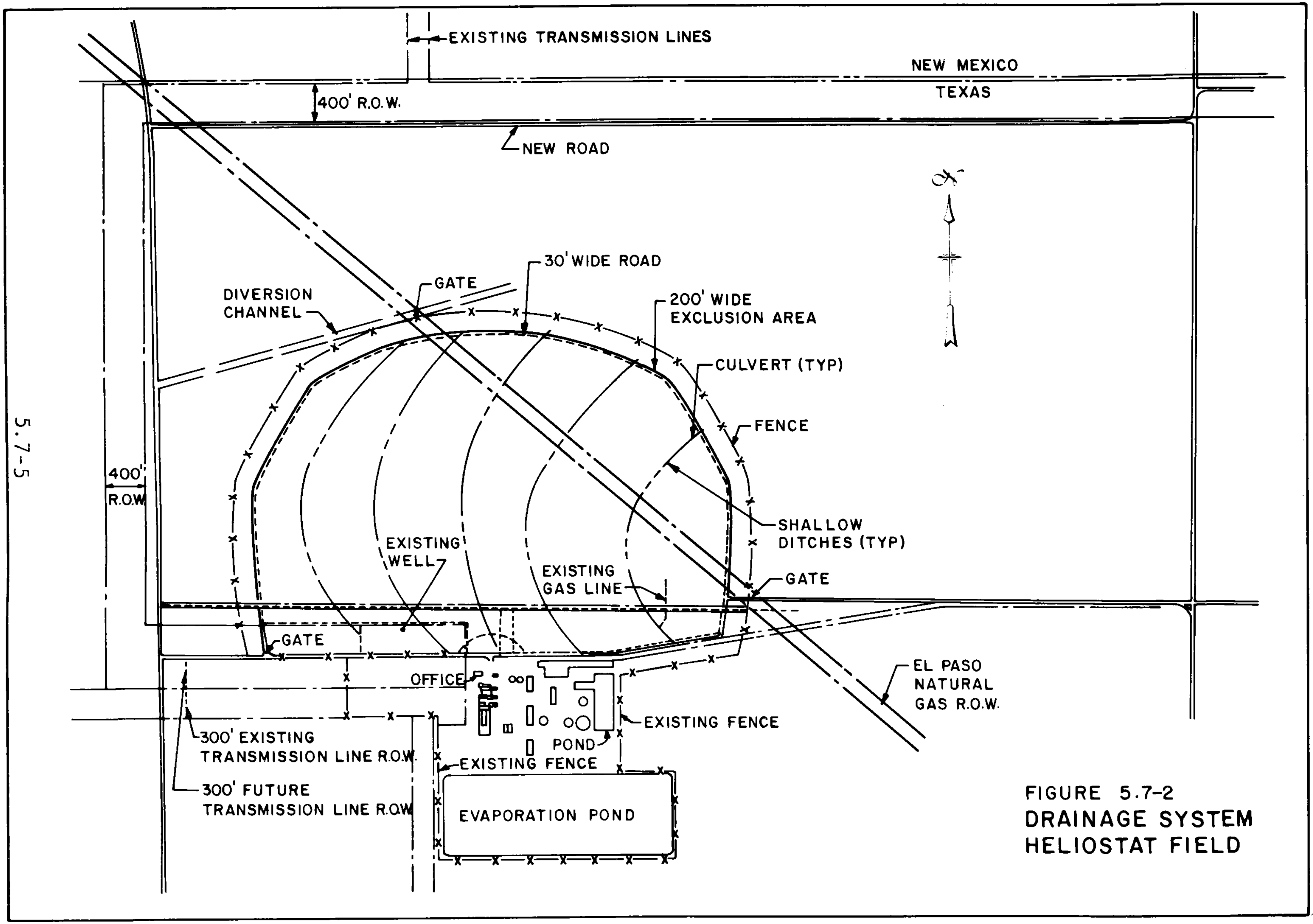


FIGURE 5.7-2
DRAINAGE SYSTEM
HELIOSTAT FIELD

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 B 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 5.6-4. 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.

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 $495,000.

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 conceptual design of the repowered unit described in Section 4. The analysis described herein is similar to the analysis performed as part of system trade-off studies in Section 3.3 (System Analysis Results) except that the following changes have been incorporated:

Reference unit description has been revised consistent with the conceptual design presented in Section 4.

The EPE system description has been revised to reflect the April 1980 expansion plan for future power generation capability.

The economic scenario has been modified to approximate EPE system changes.

The cost of the repowered unit has been revised consistent with the data presented in Sections 4.6 and 4.7.

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 Section 3.3.

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 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 impact is a major concern to El Paso Electric Company. This involves 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:

1985 Initial year of 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 a 27 month test and engineering evaluation period

Newman Unit 1 operated from 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 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 and outputs for further analysis 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 condition (standby) 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

Oil Startup Logic

Oil Buffer for Insolation Transients

Closeup Potential Shutdown Windows

High Wind Speed Solar Shutdown

Boiler Efficiency Corrections

Oil Recovery of Low Insolation

Economic Oil Dispatch

Hot Standby Oil (Option)

Economic Shutdown at End of Day

Cost/Value of Daily Oil 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

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

TABLE 6.1-3

OPERATING VALUE FACTORS

Isolation 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

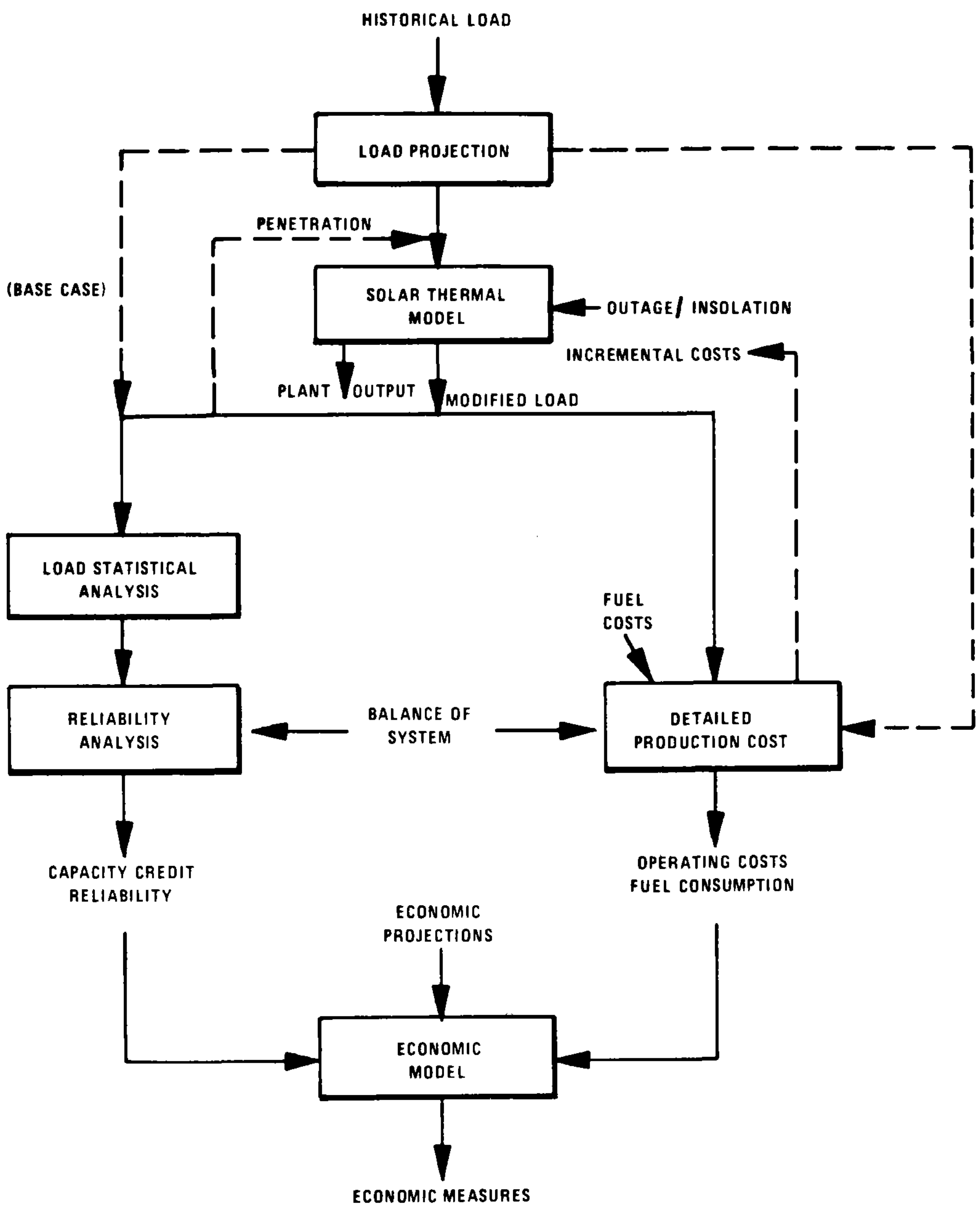


FIGURE 6.1-1
ECONOMIC MODEL FLOW DIAGRAM

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 summer solstice based on an insolation level of 950 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 Section 3.3).

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 August 1985

8/85 to 12/86, the fossil boiler produces 41 MWe minimum when the unit is operating on solar; the unit is also economically dispatched on fossil.

1/87 - 12/87, the fossil boiler produces 23 MWe minimum when the unit is operating on solar; the unit is also economically dispatched on fossil.

Beyond 1987, 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 29 months of engineering test and evaluation, the solar repowered unit is dispatched, as noted above, in a manner similar to conventional fueled units making maximum use of the available solar energy. The fossil boiler is cycled daily; i.e., the fossil boiler is only shut down to a cold condition for routine or forced maintenance; three cold starts are assumed throughout the year for the economic evaluation. 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 is also banked during clear days or when it is not economical to operate the plant in either solar or fossil modes. No fossil energy is 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 will be 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 1989 it is assumed the unit will burn oil. It is also assumed that all other gas fired units on the EPE system are also operated on oil after 1989 for the purpose of this economic evaluation.

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	211,000 m^2 (effective)
Number of Heliostats	2,776
Primary Receiver	
Type	External (pumped, recirculation boiler/screened tube concept
Size	12.6m dia x 15.7m long (240° arc)
Outlet Temperature	549°C (1,020°F)
Reheat Receiver	
Type	External
Size	12.6m dia x 15.7m 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	139 m
Electric Power Generation Subsystem	
Cycle	Steam Rankine (reheat)
Net Unit Efficiency	40 percent
Turbine Inlet	10.1 MPa/538°C/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 950 watts/m^2

6.3 EPE SYSTEM DESCRIPTION

The detailed economic evaluaton 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 1,033 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 10 percent is supplied by 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 in August 1985; the operating scenarios for the unit are described in Section 6.2. The EPE system expansion plan (April 1980) is given in Table 6.3-1 for the years 1980 through 2000. During this time frame, most of the planned capacity additions are in the form of nuclear (Palo Verde) and coal (New Mexico) plants. In 1985, approximately 40 percent of the generating capacity is coal and nuclear and by the year 2000 this will increase to 75 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

Table 6.3-1 identifies the peak load forecast for the EPE system. The peak load forecasted for 1980 is 712 MWe and by the year 2000 the system load is expected to increase to 1,834 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 1985 to 2014.

TABLE 6.3-1

GENERATION EXPANSION PLAN

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Existing Resources										
Rio Grande	346[1]	346	346	346	325[7]	325	325	306[8]	306	306
Newman	474[2]	474	474	474	474	474	474	474	474	474
Four Corners	102[3]	102	102	99[6]	99	99	99	99	99	99
New Resource Additions										
Copper	73	73	73	73	73	73	73	73	73	73
Palo Verde				200	400	400	600	600	600	600
New Mexico Coal										
Capacity Sales										
SCE	100	75	50							
PNM	-0-	-0-	-0-	66	66	66	66	66	66	44
Net Available Resources	895	920	945	1,126	1,305	1,305	1,505	1,486	1,486	1,508
Peak Load[4]	712	742	776	809	847	892	936	983	1,030	1,085
Reserve Margin	183	178	169	317	458	413	569	503	456	423
Reserve Requirement[5]	183	184	186	253	255	258	260	262	265	267
Surplus (Deficiency)	0	(6)	(17)	64	203	155	309	241	191	156

TABLE 6.3-1 (Cont)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Existing Resources											
Rio Grande	241[9]	241	241	241	241	241	241	241	194[11]	147[12]	147
Newman	456[10]	456	456	456	456	456	456	456	456	456	456
Four Corners	99	99	99	99	99	99	99	99	99	99	99
New Resource Additions											
Copper	73	73	73	73	73	73	73	73	73	73	73
Palo Verde	600	600	600	600	600	600	600	600	600	600	600
New Mexico	75	75	150	150	225	225	300	300	300	300	300
Coal						175	175	350	350	525	525
Capacity Sales											
SCE											
PNM	44	44	44	44	44	44	44	44	44	44	44
Net Available Resources	1,500	1,500	1,575	1,575	1,650	1,825	1,900	2,075	2,028	2,156	2,156
Peak Load[4]	1,141	1,189	1,245	1,310	1,375	1,444	1,511	1,591	1,670	1,752	1,834
Reserve Margin	359	311	330	265	275	381	389	484	358	404	322
Reserve Requirement[5]	270	272	275	279	282	285	289	293	297	301	305
Surplus (Deficiency)	89	39	55	(14)	(7)	96	100	191	61	103	17

NOTES:

1. Derate R.G. 1-5 for cooling tower capacity.
2. Derate Newman 4 for high ambient temperature.
3. Derate Four Corners for 755 MW, losses and startup.
4. Peak forecast dated November 7, 1979. Extended forecast, December 4, 1979.
5. Reserve requirement 5 percent Peak (RG 8 = 147MW; PV = 200 + 13S.U. = 213MW)
6. Derate for pollution control equipment.
7. Retire R.G. 1 & 2
8. Retire R.G. 3
9. Retire R.G. 4 & 5
10. Derate Newman for fuel oil
11. Retire R.G. 6
12. Retire R.G. 7

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.

The sensitivity of the economic results to solar repowered unit cost assumptions is established in Section 6.5 by considering a range of ±25 percent for the capital and operation and maintenance costs. 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 of 10 and 8 percent, respectively. 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 12 percent escalation rate. The discount rate used in the analysis for both scenarios is 12 percent with a fixed charge rate of 16 percent. The economic scenarios are consistent with a long term general inflation rate of 7 percent. In addition to the EPE economic scenarios, DOE defined a set of capital and fuel cost data and fuel escalation rate data. The DOE data are also given in Table 6.4-1. EPE data for the present worth discount rate, carrying charge rate, and capital and operation and maintenance escalation rates are assumed for the DOE scenario.

TABLE 6.4-1

ECONOMIC SCENARIOS (1985)

	EPE Scenarios		
	A	B	DOE Specified Data
Present Worth Discount Rate	12%	12%	12%*
Fixed Charge Rate	16%	16%	16%*
Capital Cost, \$/kWe (c-t/c-c/coal/nuc)	300/600/1400/1600	300/600/1400/1600	190/360/860/1000
Fuel Cost (\$/MBtu) Gas/Oil/Coal/Nuc	4.5/12/1.5/1.9	4.5/12/1.5/1.0	2.50/4.00/1.25/0.85
Fuel Escalation Rate (%) (Gas/Oil/Coal/Nuc)	10/8/7/7	10/12/7/7	11/12/10/9
Capital Escalation Rate	7%	7%	7%*
O&M Escalation Rate	7%	7%	7%*

NOTE

* EPE data used.

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 eight 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.

Due to the complexities of the multi-year analysis, questions dealing with changes in solar repowered unit parameters, such as solar system startup energy, are not easily answered. Problems of this sort lend themselves more to a 1 year simulation in which the solar repowered unit's lifetime impact is derived from the 1 year static analysis. In performing this static analysis, the mature operation of the solar repowered unit was modeled for a typical year. Sensitivity to solar system startup energy, unit cost, and economic scenario resulted from this analysis. In addition, information concerning typical unit operation was obtained and is shown in this section.

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. Years 1985 through 1989 assumed gas burned in the repowered unit and on the rest of the utility system. After 1989, oil replaced gas throughout the system. The numbers presented in the table are in millions of 1980 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.

Section 6.2 contains a complete description of the operating scenario. A brief summary is incorporated in the following paragraph.

The negative net savings (shown in Table 6.5-1) for years 1985 through 1987 imply that the cost of operating the solar repowered unit during these years exceeds the savings attributable to it. The operating strategy for these years requires the fossil boiler to operate at a certain output level (50 percent for years 1985 and 1986, 28 percent for 1987) whenever solar insolation is available. During this evaluation period this operating strategy forced a significant amount of fossil fuel to be burned in the boiler. There were also cloudy days with small amounts of solar insolation when it was not economical to start the solar repowered unit at all, due to this forced boiler operation scenario if the additional fossil energy output was not needed. This restriction resulted in a significantly higher fuel cost and a slightly lower fuel savings during these years, than would have occurred without the restriction. Subsequently, the O&M costs incurred by the repowered unit were added to its fuel cost, and the overall net savings became negative.

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, it was necessary to assume the operation of the solar repowered unit constant in years 1990 through 1994, 1995 through 1999, and 2000 through 2014. The lifetime net operating savings of the solar repowered unit is $27.7 million dollars. This is for the production of 3,461,700 MWhe.

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) and for the economic scenario supplied by DOE. For details on these three economic scenarios, see Section 6.3. The numbers shown in this table are present worth of revenue requirements expressed in 1980 millions of dollars. The base economic scenario (A) resulted in a cost/value ratio of 2.27.

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 from economic dispatch, and fossil from forced operation. This figure does indeed show a significant energy contribution from the forced supplemental fossil operation during the years 1985 through 1987, as was stated earlier. The percentage of fossil energy produced during supplemental fossil operation after 1987 decreased because the fossil boiler operating restriction was lifted. After 1985, the amount of solar energy produced was relatively constant. Slight variations were due to a difference in the number of days the unit was not brought on line, even though some solar insolation existed, because the savings did not exceed the costs incurred by firing the fossil boiler.

Figure 6.5-2 shows the conventional energy, in millions of MBtus, displaced by the solar repowered unit. The solar repowered unit saves the equivalent of 4 million barrels of oil over the 30 year lifetime. For every one barrel of oil burned in the solar repowered unit by the existing boiler, approximately five barrels of oil are saved due to operation of the unit on solar energy. As was expected, the bulk of the energy displaced by the repowered unit was gas/oil (gas until 1990, oil thereafter). The total lifetime energy displaced was about 28 million MBtus of gas/oil and about 8 million MBtus of coal. The solar repowered unit consumed about 12 million MBtus of gas/oil over its life including economic dispatch. Thus, the net energy displaced was about 16 million MBtus of gas/oil and about 8 million MBtus of coal.

6.5.2 Tax Incentive Impact

One potential means to enhance the economic attractiveness of the solar repowering demonstration is to permit EPE to use a higher investment tax credit than would normally be permitted for conventional units.

The base economic scenario includes in its calculation of a 16 percent fixed charge rate a 10 percent investment tax credit (ITC). The effect of an additional 10 percent ITC reduced the fixed charge rate to 14.1 percent. This in turn reduced the revenue required to support the capital investment. A comparison of a 10 and 20 percent ITC is shown in Table 6.5-4. The lower fixed charge rate reduced the capital revenue requirements by $14.2 M (1980 $). This resulted in a cost/value ratio of 2.06.

6.5.3 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 of 15 MWht 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. The one year simulation was used 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 are summarized in Table 6.5-5. The total values shown in the table are only slightly different ($88.3 M vs $90.3 M) for 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 (178.0 vs 179.5 GWhe). Note that the total value shown in the OMWht case does not include the additional fossil fuel consumed for solar startup requirements. It is felt that when this cost is included, it will offset the small fuel value advantage shown for the OMWht case.

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.

6.5.4 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 costs. The results presented in this section reflect variations in these two parameters.

Because of the methodology employed, variations in solar repowered unit costs can be analyzed easily. Table 6.5-6 shows the impact on the cost/value ratio of a ±25 percent change in solar plant cost. The numbers were developed employing the EPE A economic scenario and are expressed in 1980 millions of dollars. A direct relationship can be seen to exist, e.g., a ±25 percent change in cost with a constant value results in a ±25 percent change in cost/value.

A change in oil escalation rate from 8 to 12 percent resulted in a larger lifetime fuel value and cost, as expected (see Table 6.5-7). The majority of the fuel displaced by the solar repowered unit was oil; therefore, it follows that, if the price of the oil is higher, the value of the displaced fuel is greater. However, this larger oil escalation rate also results in a higher lifetime fossil fuel cost.

A larger overall lifetime value resulted in the 12 percent oil escalation rate scenario. The cost/value ratio dropped from 1.69 to 1.04 as is shown in Table 6.5-7.

6.5.5 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 one year solar simulation performed in 1985 and one intended to graphically demonstrate the operation of the unit.

A typical daily operation of the solar repowered unit is displayed in Figure 6.5-3. The total output of the solar repowered unit over the entire day is shown in this graph. The unit net output is represented by the solid line. The dashed line enclosed by a 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.

Solar output first appears in hour 8 and lasts until hour 16. The maximum solar contribution during the day is about 47 MWe (hour 12). The graph shows a large amount of energy produced from the fossil boiler due to economic dispatch. In hours 9 through 17, fuel is burned to bring the output of the unit up to its maximum level, 82 MWe. For overall system requirements, it is not economic to operate the fossil boiler in hour 18, therefore the output of the boiler is reduced to its minimum operating level. Additional fossil fuel is then consumed to operate the unit at its maximum output in hours 19 through 21 due to economic dispatch. The unit shuts down after hour 21.

How the daily operation of the solar repowered unit adjusts the original system loads is shown in Figure 6.5-4. The original load is represented by the solid line. The dashed line represents the original load adjusted by the total solar unit contribution. Conventional units are operated on power purchased to meet this adjusted load.

Figure 6.5-5 graphically displays a typical week of the repowered unit operation. Again, the solid line represents the unit output, and the dashed line is the solar contribution. The first and last days of this week contain only solar output. The fossil boiler was not fired as it was not deemed economical due to the somewhat smaller system loads on these weekend days. This can be seen in Figure 6.5-6 which displays the original and adjusted EPE system loads for the same week. The fourth day of the week demonstrates a zero unit output due to a forced outage.

Figure 6.5-7 is a yearly total solar repowered unit output duration curve. Displayed in this graph is the total output (solar and fossil) of the repowered unit versus hours of operation. The unit operates at its maximum output of 82 MWe for about 1,350 hours during the year. This output characteristic represents a 24.8 percent capacity factor, including economic dispatch.

The original and adjusted EPE system annual load duration curves are shown in Figure 6.5-8. 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.

6.5.6 Alternate Repowering Option

An alternative to solar repowering of the Newman Unit 1 was briefly assessed. The option considered was the use of coal gasification rather than solar thermal. No detailed design work was performed for this assessment, however, general cost and performance data previously derived by Stone & Webster for other projects were used.

It should be noted that a gasification system solely to repower the Newman Unit 1 would probably be impractical. This impracticality arises due to the need for a much larger gasification unit than would be required for the Newman Unit to realize a reasonable economy of scale. Cost numbers for a larger gasification unit, which might be shared by other generating plants, was used in this assessment. The Newman Unit 1 was assigned its repowered cost on a pro rata basis.

Also, the economic dispatch assumptions included considerable plant maneuvering, with annual capacity factors at times approaching 30 percent. This is also undesirable for a gasification unit, which calls for a constant gas production level.

A brief economic assessment of repowering with a coal gasifier was performed using cost numbers derived from a larger plant economy of scale and ignoring possible maneuvering constraints. Using this repowering option with the current El Paso Electric generation expansion plan, the impact estimates are shown in Table 6.5-4. This table reflects the present worth of revenue requirements for the 8 percent oil escalation case, Scenario A.

The cost/value ratio compares somewhat favorably with the 2.27 obtained for the similar solar thermal repowering case.

Using the economics postulated, an even more conventional option would be to build an additional new coal plant (which cannot be accomplished by the 1985 time frame). Using the wide spread assumed for oil and coal costs, an additional coal plant should have a cost/value ratio of close to 0.5.

TABLE 6.5-1

ANNUAL OPERATING COSTS AND SAVINGS
(1980 M$, Gas to Oil Beyond 1989)

Year	Savings Fuel	Savings O&M	Costs Fuel	Costs O&M	Net Savings
1985	2.30	0.05	1.66	0.85	-0.16
1986	3.23	0.61	2.70	1.68	-0.54
1987	2.78	0.27	1.75	1.62	-0.31
1988	2.55	0.1	1.06	1.54	0.05
1989	3.34	0.11	1.90	1.47	0.08
1990	8.16	0.12	3.40	1.41	3.47
1995	6.14	0.12	1.78	1.12	3.36
2000	4.61	0.12	1.04	0.89	2.80
30 Year Total PW	98.3	3.6	45.6	28.6	27.7

TABLE 6.5-2

MULTI-YEAR COST/VALUE SUMMARY

1980 M$ PWRR

	Economic Scenario		
	A	B	DOE
Solar Plant Cost			
Capital	119.6	119.6	119.6
O&M	28.6	28.6	28.6
TOTAL COST	148.2	148.2	148.2
Solar Plant Value			
Fuel Value	98.3	154.4	57.0
Variable O&M	3.6	3.6	3.6
Fuel Cost	-45.6	-69.3	-25.0
Capacity Credit	8.9	8.9	5.7
TOTAL VALUE	65.2	97.6	41.3
Net Value	-83.0	-50.6	-106.9
Cost/Value Ratio	2.27	1.52	3.59

TABLE 6.5-3

ENERGY OUTPUT SUMMARY

Year	Total Unit Output (MWe Hr/year)	Solar Output (MWe Hr/year)	Fossil Output-Economic Dispatch (MWe Hr/year)
1985	98.3×10^3	30.7×10^3	31.9×10^3
1986	184.4	70.8	4.3
1987	145.7	75.7	9.1
1988	120.3	76.6	24.8
1989	159.5	78.1	62.3
1990 - 1994	136.5	77.2	40.6
1995 - 1999	113.0	76.2	20.7
2000 - 2014	100.4	74.7	13.6

TABLE 6.5-4

TAX INCENTIVE IMPACT
1980 M$ PWRR, EPE/"A" ECONOMIC SCENARIO

	10% ITC	20% ITC
Solar Plant Cost		
Capital	119.6	105.4
O&M	28.6	28.6
TOTAL COST	148.2	134.0
Solar Plant Value	65.2	65.2
Net Value	-83.0	-68.8
Cost/Value Ratio	2.27	2.06

TABLE 6.5-5

SOLAR STARTUP IMPACT
(0 vs 15 MWHt)

1980 M$ PWRR, EPE/"A" ECONOMIC SCENARIO

	Startup Heat	
	OMWHt	15MWHt
Solar Plant Cost		
Capital	119.6	119.6
O&M	29.6	29.6
TOTAL COST	149.2	149.2
Solar Plant Value		
Fuel Value	186.6	184.8
Variable O&M	0.6	0.6
Fuel Cost	-106.0	-106.0
Capacity Credit	8.9	8.9
TOTAL VALUE	90.3	88.3
Net Value	58.9	60.9
Cost/Value Ratio	1.65	1.69

TABLE 6.5-6

SOLAR PLANT COST SENSITIVITY
1980 M$ PWRR, EPE/"A" ECONOMIC SCENARIO

	-25%	Base	+25%
Solar Plant Cost			
Capital	89.7	119.6	149.5
O&M	22.2	29.6	37.0
TOTAL COST	111.9	149.2	186.5
Solar Plant Value			
Fuel Value	184.8	184.8	184.8
Variable O&M	0.6	0.6	0.6
Fuel Cost	-106.0	-106.0	-106.0
Capacity Credit	8.9	8.9	8.9
TOTAL VALUE	88.3	88.3	88.3
Net Value	-23.6	-60.9	-98.2
Cost/Value Ratio	1.27	1.69	2.11

TABLE 6.5-7

ECONOMIC SCENARIO SENSITIVITY
(8% vs 12% Oil Escalation)

1980 M$ PWRR

	EPE Scenarios	
	A	B
Solar Plant Cost		
Capital	119.6	119.6
O&M	29.6	29.6
TOTAL COST	149.2	149.2
Solar Plant Value		
Fuel Value	184.8	314.8
Variable O&M	0.6	0.6
Fuel Cost	-106.0	-180.4
Capacity Credit	8.9	8.9
TOTAL VALUE	88.3	143.9
Net Value	-60.9	-5.3
Cost/Value Ratio	1.69	1.04

TABLE 6.5-8

ECONOMIC ESTIMATES FOR REPOWERING WITH COAL GASIFIER
(EPE/"A" Economics, 1980 M$ PW)

Repowering Cost	
Capital (PW)	171
Fixed O&M	104
Total Cost	275
Value	
Fuel Saved	291
Fuel Used	-63
Variable O&M	11
Capital Saved	9
Total Value	248
Net Value	-27
Cost/Value Ratio	1.1

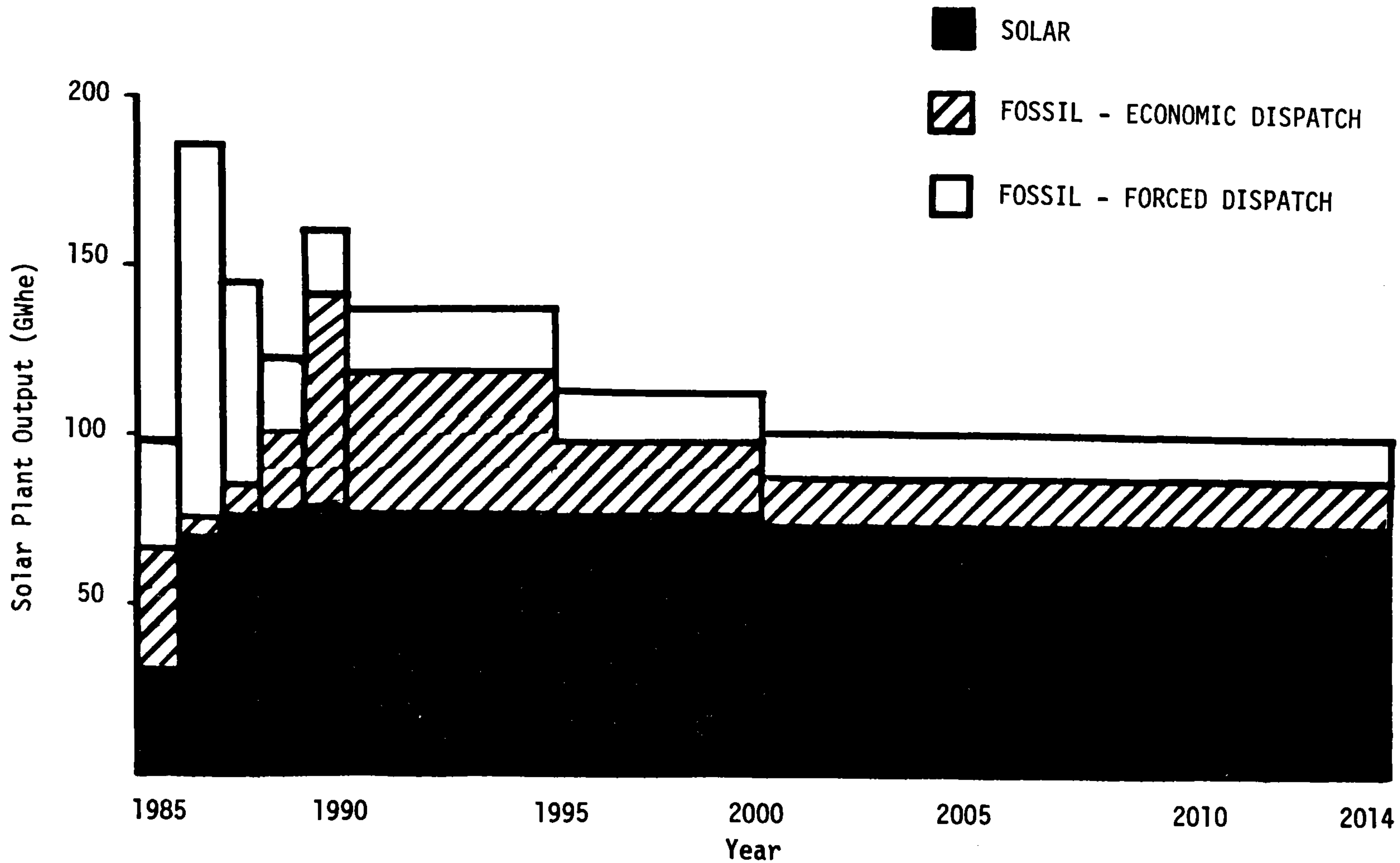


FIGURE 6.5-1
SOLAR REPOWERED UNIT ENERGY OUTPUT

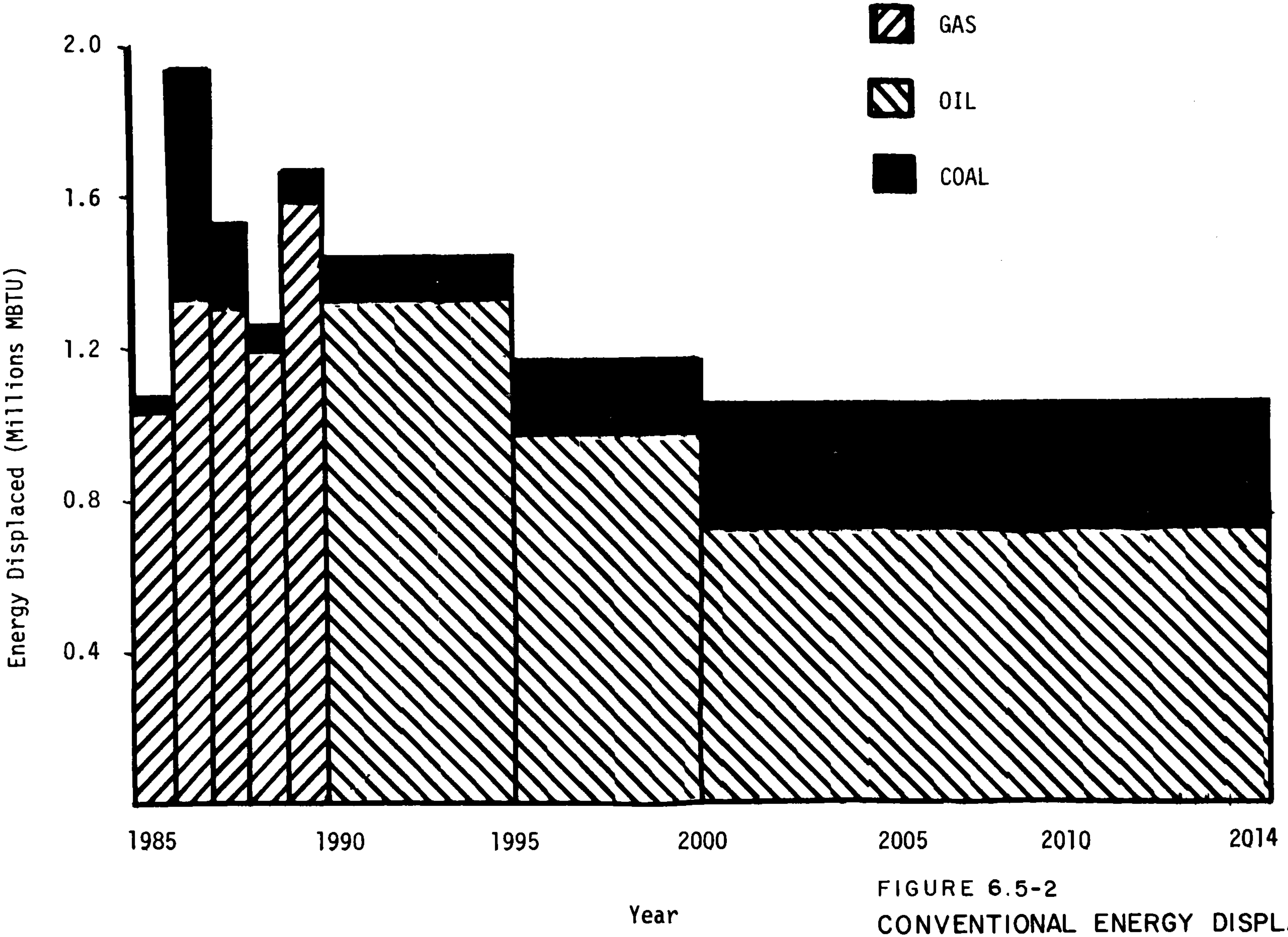


FIGURE 6.5-2
CONVENTIONAL ENERGY DISPLACED BY THE SOLAR REPOWERED UNIT

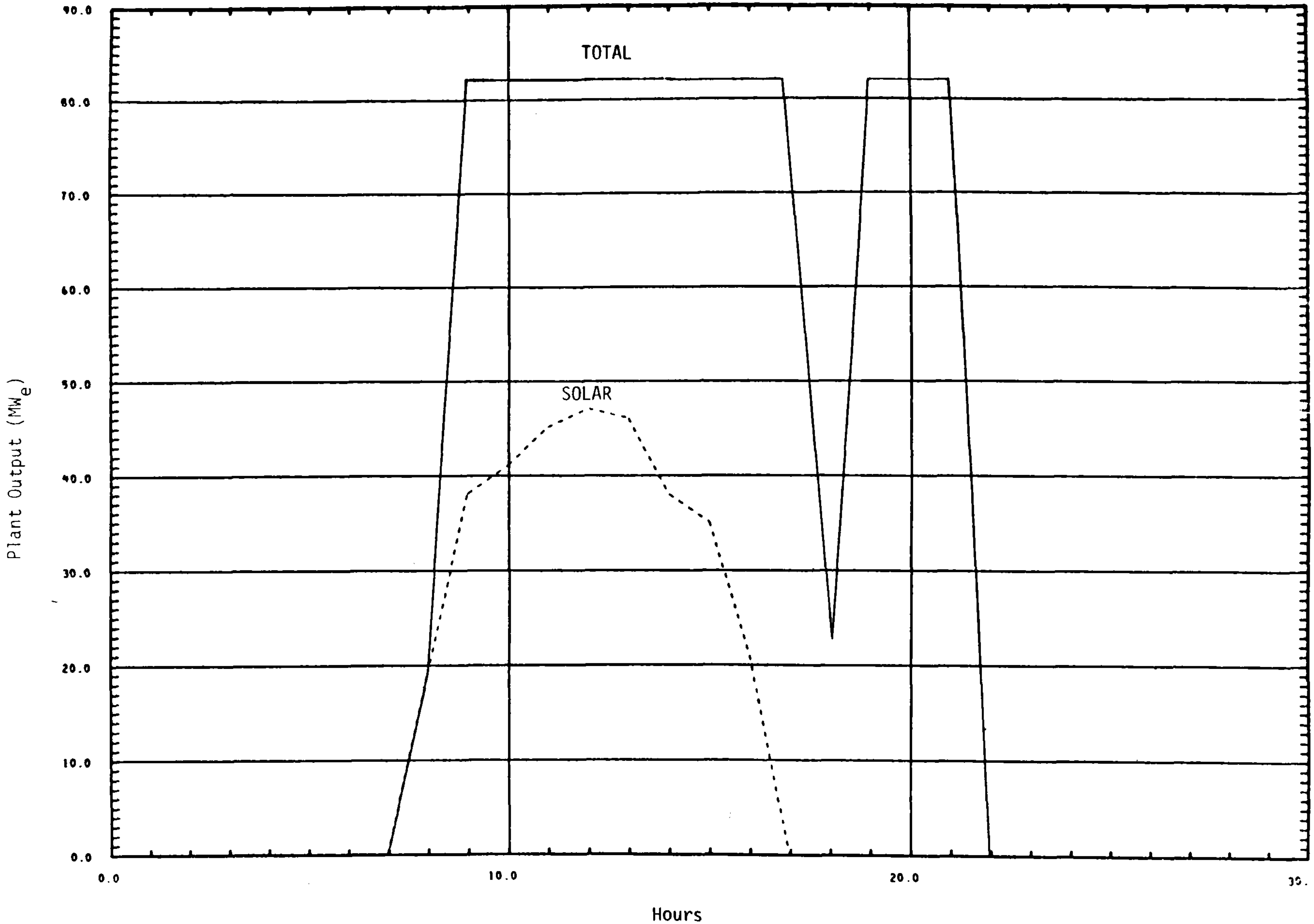


FIGURE 6.5-3
TOTAL PLANT OUTPUT AND SOLAR OUTPUT

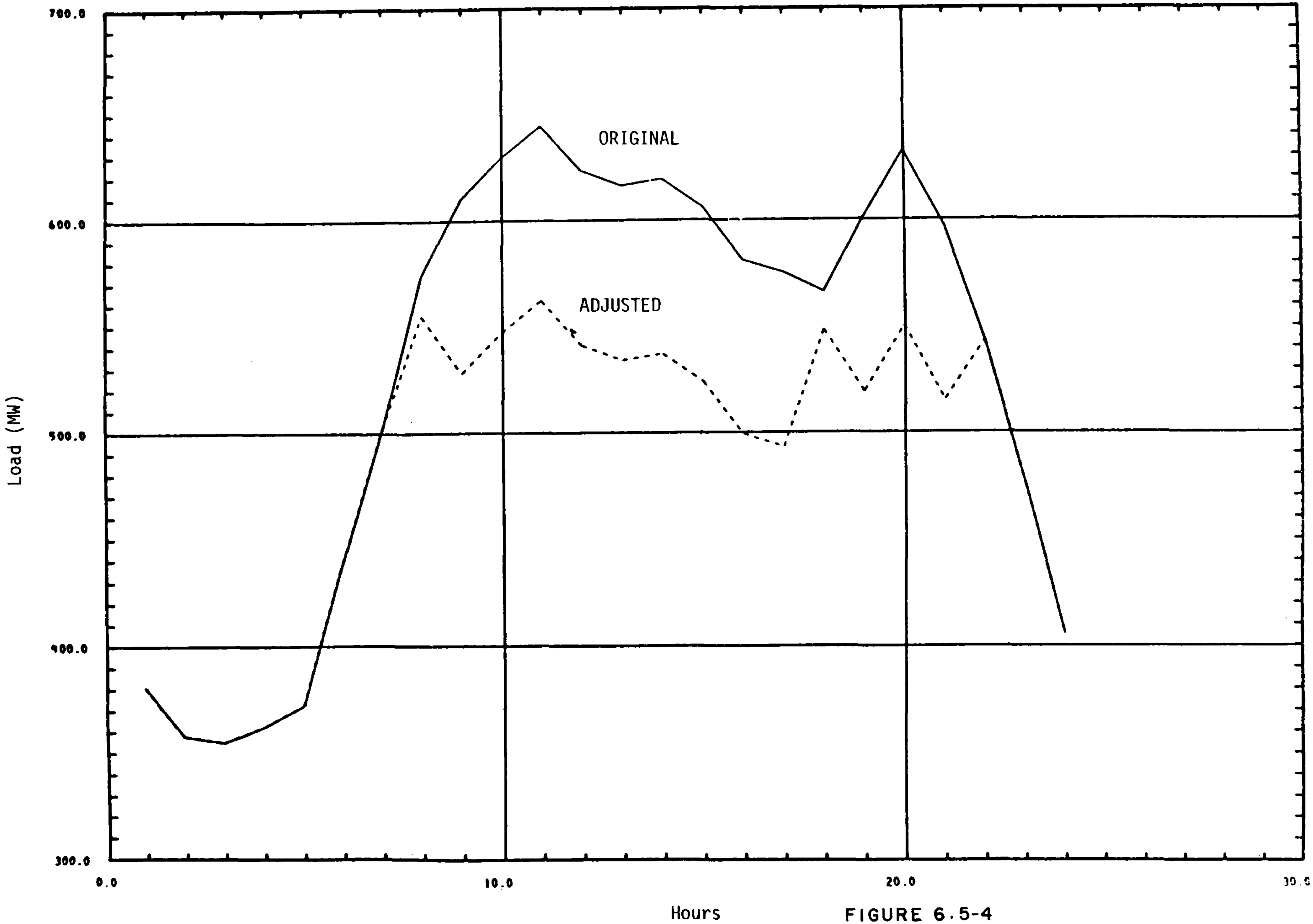


FIGURE 6.5-4
ORIGINAL SYSTEM LOAD AND ADJUSTED LOAD

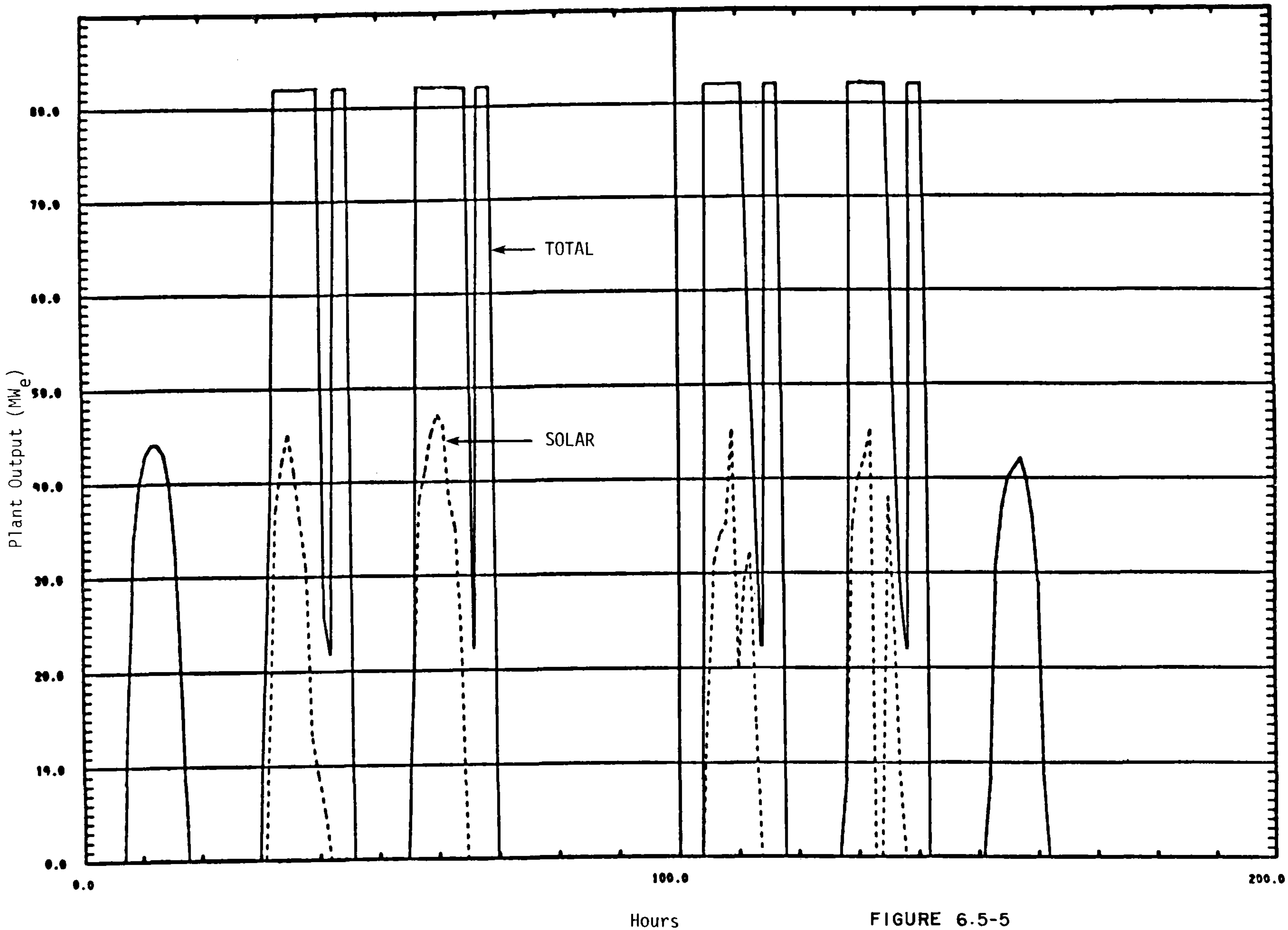


FIGURE 6.5-5
TOTAL PLANT OUTPUT AND SOLAR OUTPUT

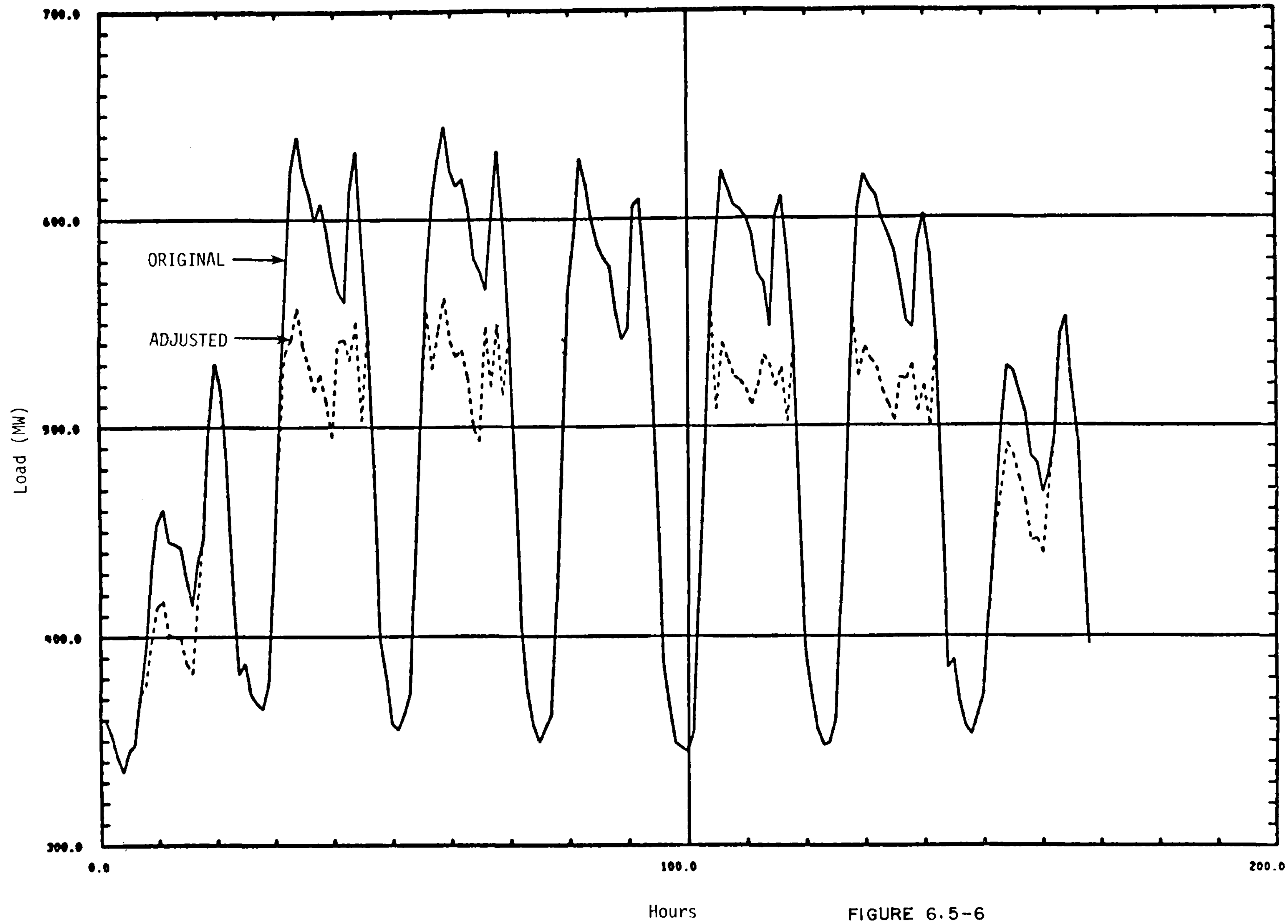


FIGURE 6.5-6
ORIGINAL SYSTEM LOAD AND ADJUSTED LOAD

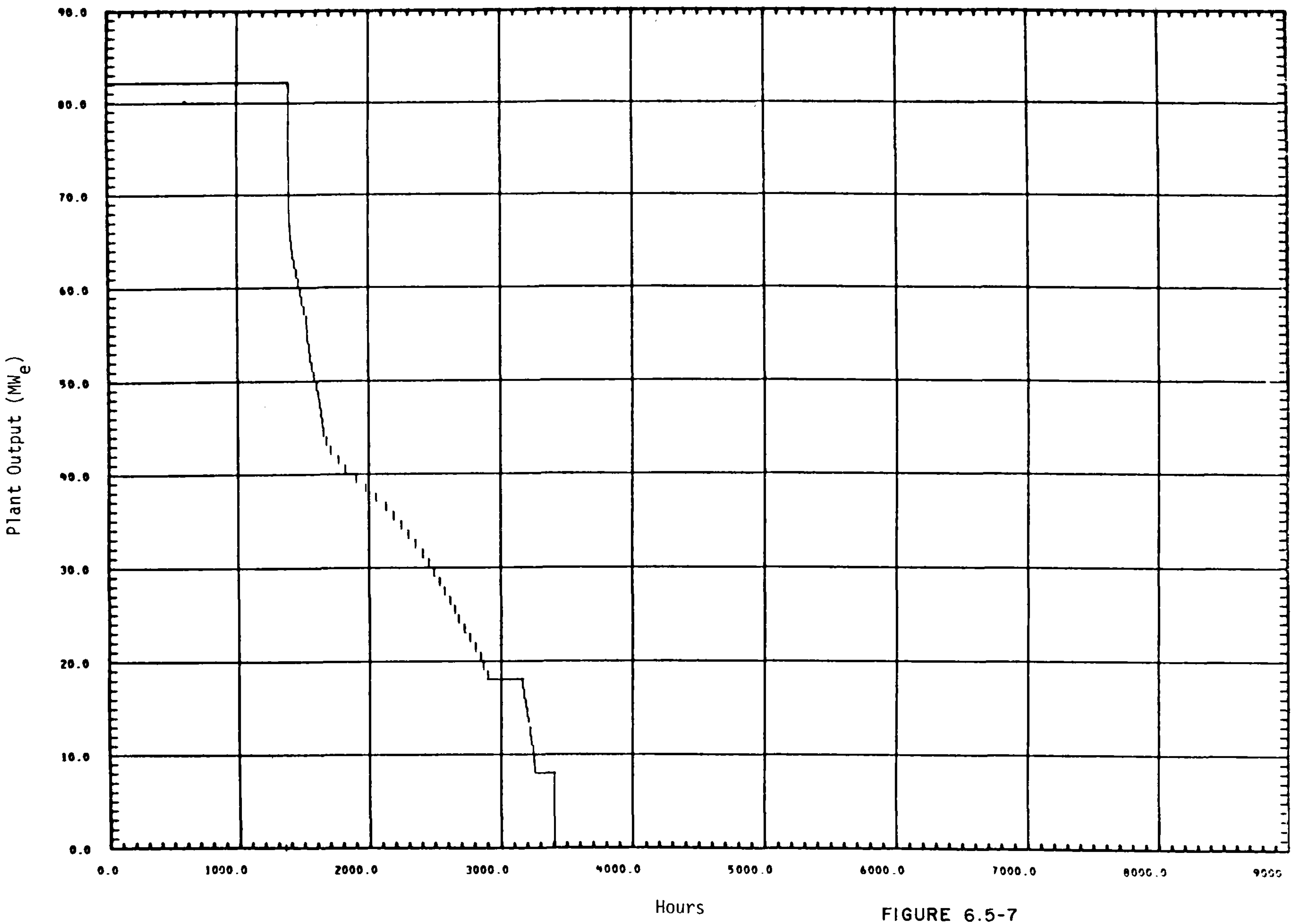


FIGURE 6.5-7
TOTAL PLANT OUTPUT DURATION CURVE

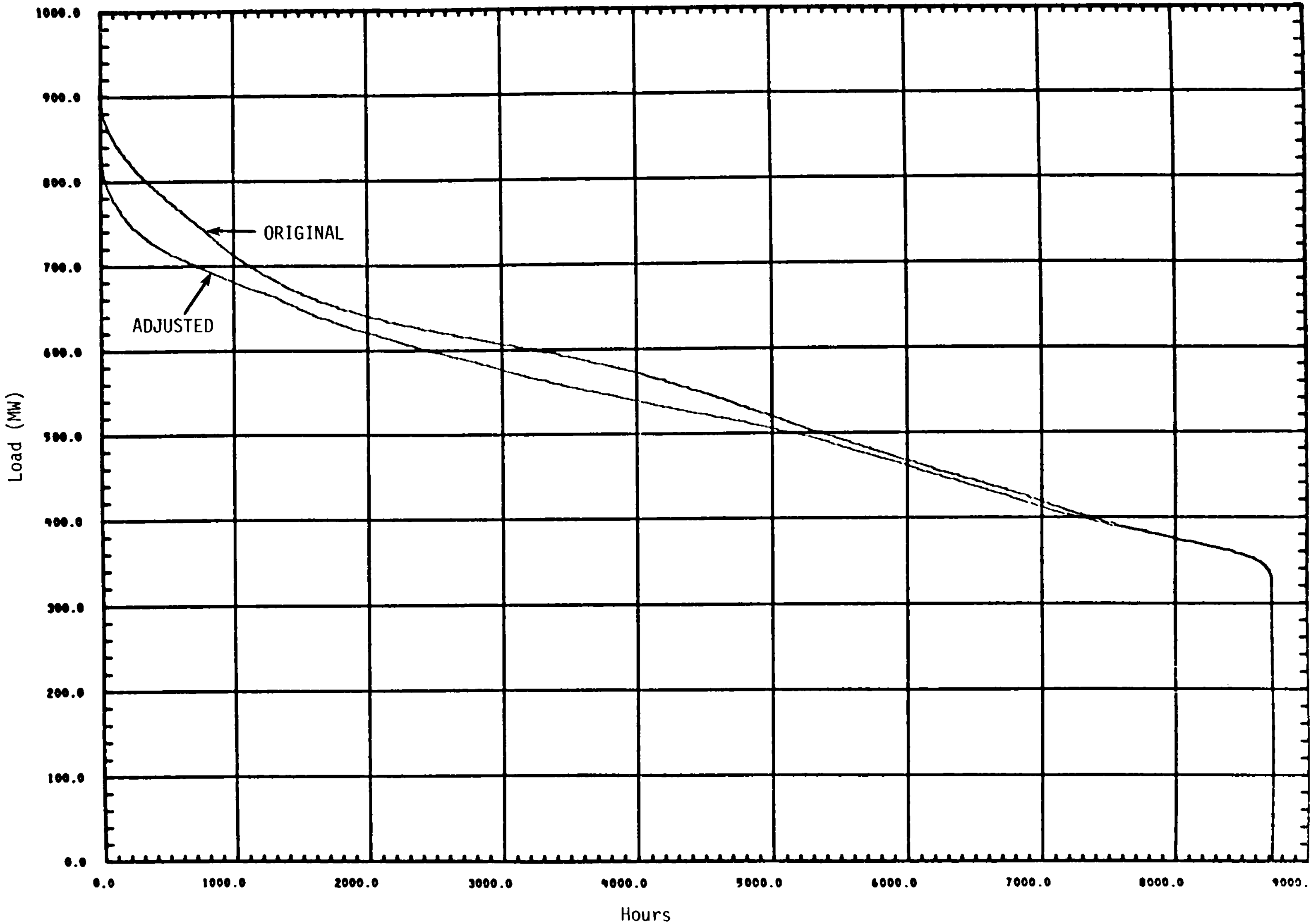


FIGURE 6.5-8
ORIGINAL LDC AND ADJUSTED LDC

SECTION 7

DEVELOPMENT PLAN

The steps required to proceed from the 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 1985.

A Work Breakdown Structure provided in Table 7.1-1, summarizes the major areas of activity occurring over a 7 year period beginning in 1981.

7.1 DESIGN PHASE

The design phase encompasses several activities that focus on the development of more detailed engineering information, procurement of long lead hardware, and revisions of design information based on vendor's 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 plant design descriptions and requirements to the level of detail necessary for preparation of bid packages for major hardware procurements, and for construction subcontracting.

Preliminary design phase activities will include detailed planning and scheduling through construction, procurement of 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 the overall project schedule. Also, selection of equipment manufacturers for the collector and receiver subsystems will have a major impact on the 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.

7.1.2 Procurement

Procurement of major equipment and construction subcontracts represents an important activity that will have considerable impact on system 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.

7.1.3 Detailed Design

Detailed design information will be developed based on vendor information. Drawings for equipment and facilities construction will be prepared.

TABLE 7.1-1

WORK BREAKDOWN STRUCTURE

1100	Site Preparation and Procurement	1110	Site Procurement
		1120	Site and Facilities Plan
		1130	Site Preparation
		1140	Facility Modifications
		1150	Insolation Data Collection
		1160	Environmental Impact Statement
1200	System Engineering	1210	System Requirements
		1220	System Design
		1230	System Analysis
		1240	Safety Analysis
		1250	Plans
1300	Electric Power Generation Subsystem	1310	Preliminary System Design
		1320	System Design and Modification
		1330	Component Design
1400	Unit Control and Data Acquisition	1410	Preliminary System Design
		1420	Component Design
		1430	Computers
		1440	Interface and Check Logic
		1450	Peripheral Equipment
		1460	Consoles
		1470	Sensors and Field Cables
		1480	Interface Equipment
		1490	Recorders
1500	Collector Subsystem	1510	Preliminary System Design
		1520	Heliostats and Auxiliary Equipment
		1530	Control
		1540	Foundation/Pedestal
		1550	Beam Characterization System
1600	Receiver Subsystem	1610	Preliminary System Design
		1620	Receiver
		1630	Tower
		1640	Riser/Downcorner
		1650	Auxiliary Equipment
1700	Plant Operation and Maintenance	1710	Operating Crew
		1720	Manuals
		1730	Operation
1800	Commercialization Planning	1810	Utilities
		1820	Others
1900	Program Management	1910	Administration

TABLE 7.1-1 (Cont)

1920	Planning
1930	Reporting
1940	Quality Control
1950	Reviews

7.2 CONSTRUCTION PHASE

Construction work at the site is scheduled to begin approximately 31 months after completion of 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 contruction 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 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 plant 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 the hoist at the top of the receiver structure.

Newman Unit 1 will be shut down approximately six months in early 1985, 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 49 months following initiation of the 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 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 plant 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 weather and other environmental impacts, off-design operating conditions, trends (from checkout performance) such as degradation, and maintenance requirements.

7.5 JOINT USER/DOE OPERATION PHASE

The operation phase will be defined in detail during the next 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 utility operations will be evaluated jointly by EPE and DOE for approximately 29 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 during 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. 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 plant 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.

The 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 plant 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 phases. Upon completion of a predefined period of joint DOE/utility 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 55 months are required between initiation of the design phase and full operation of solar repowered Newman Unit 1.

Figure 7.6-1 summarizes the major milestones that would occur following initiation of preliminary design work in June 1981.

Figure 7.6-2 provides a more detailed schedule showing activities during the Design, Construction, Checkout, and Startup phases.

Construction work is started approximately 31 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 1985. 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 plant operation can begin with a partial heliostat field in place, the collector subsystem installation schedule is less critical than receiver installation.

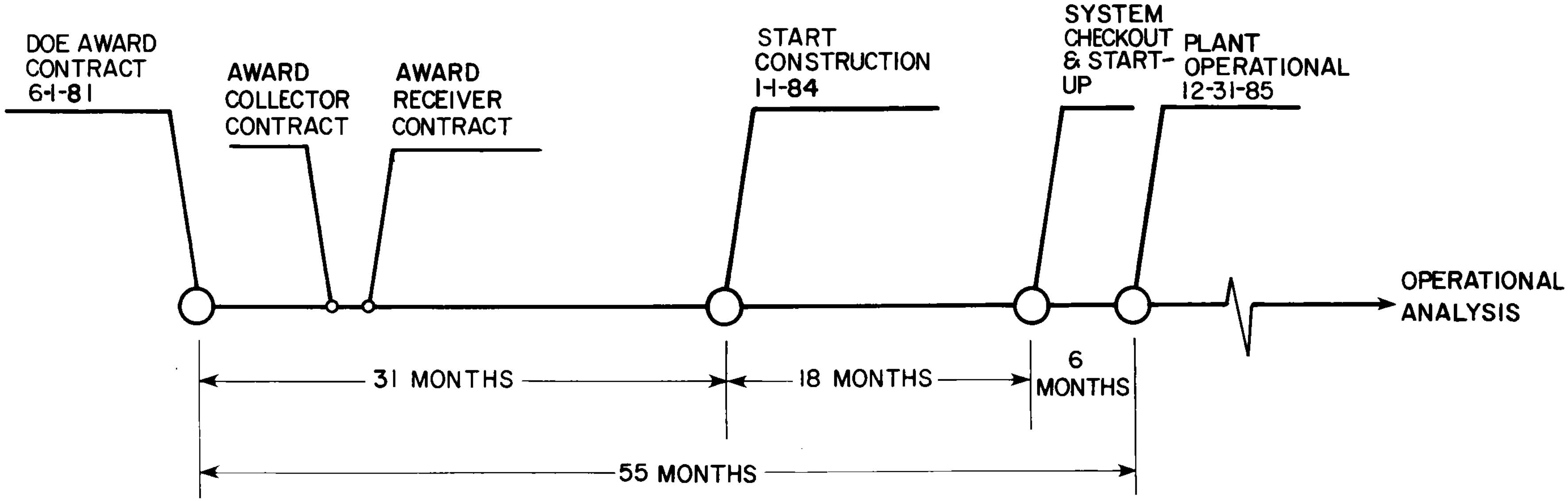


FIGURE 7.6-1
PROJECT SUMMARY MILESTONE SCHEDULE

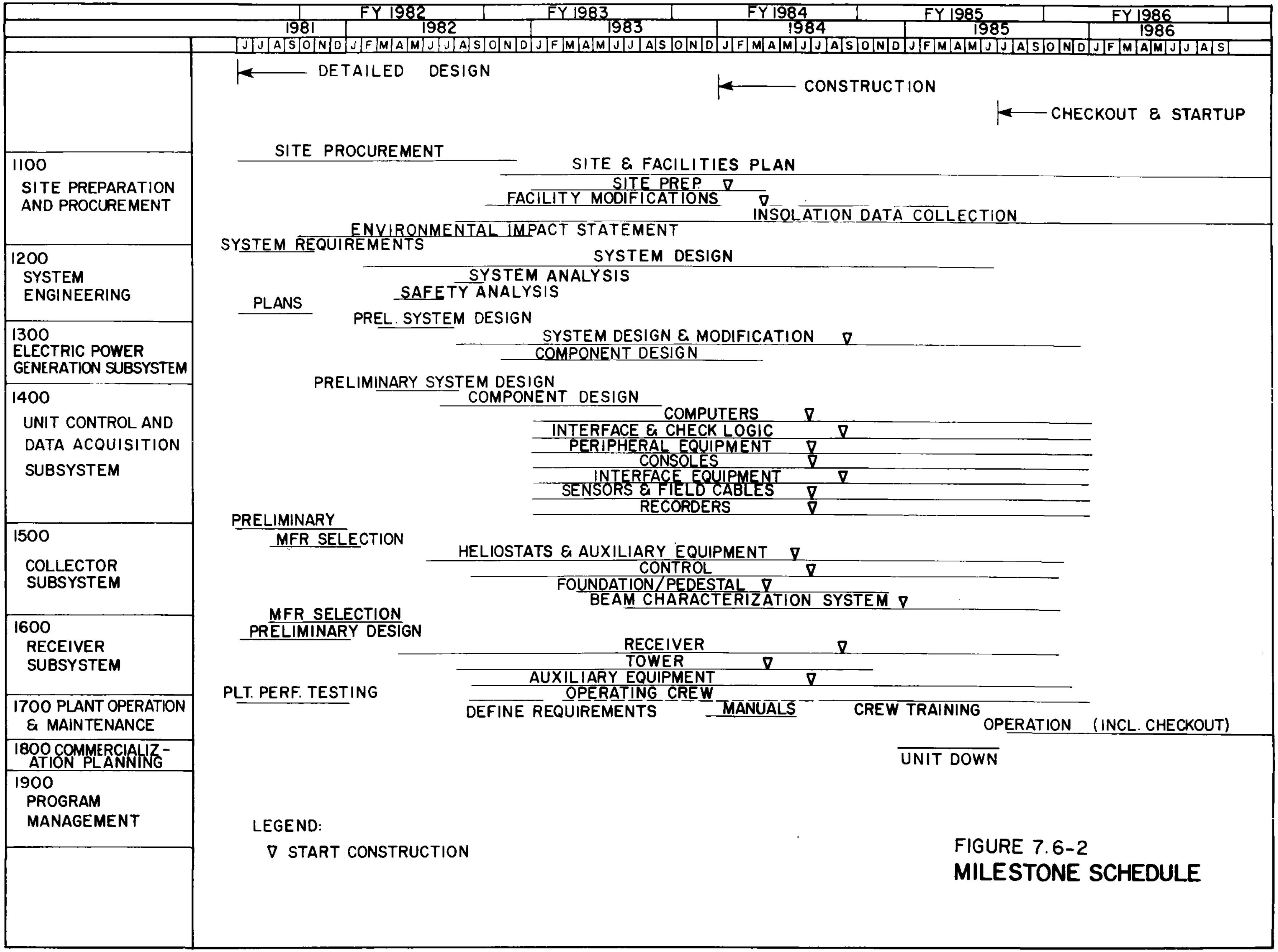


FIGURE 7.6-2
MILESTONE SCHEDULE

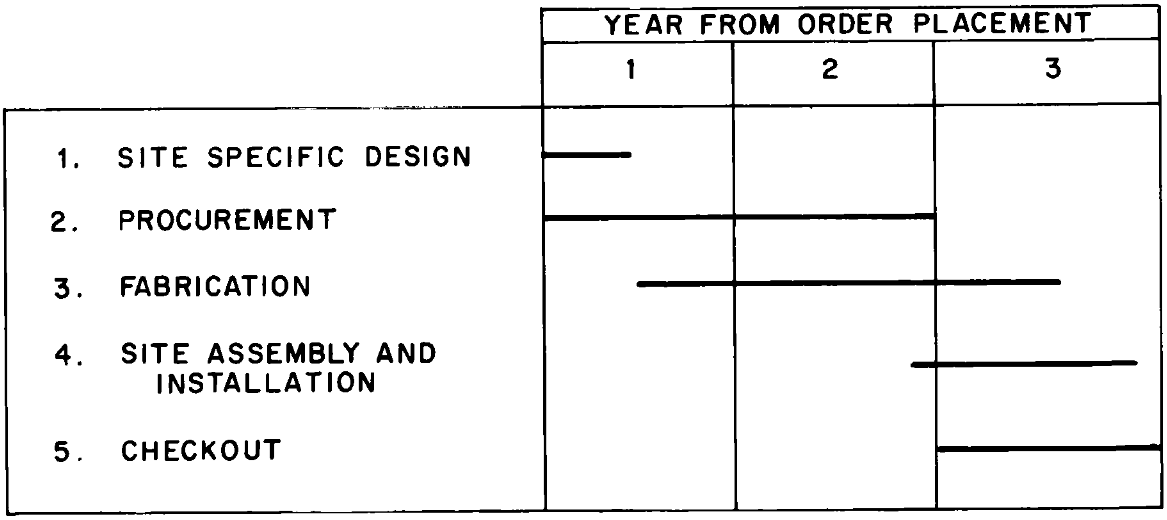


FIGURE 7.6-3
HELIOSTAT SCHEDULE

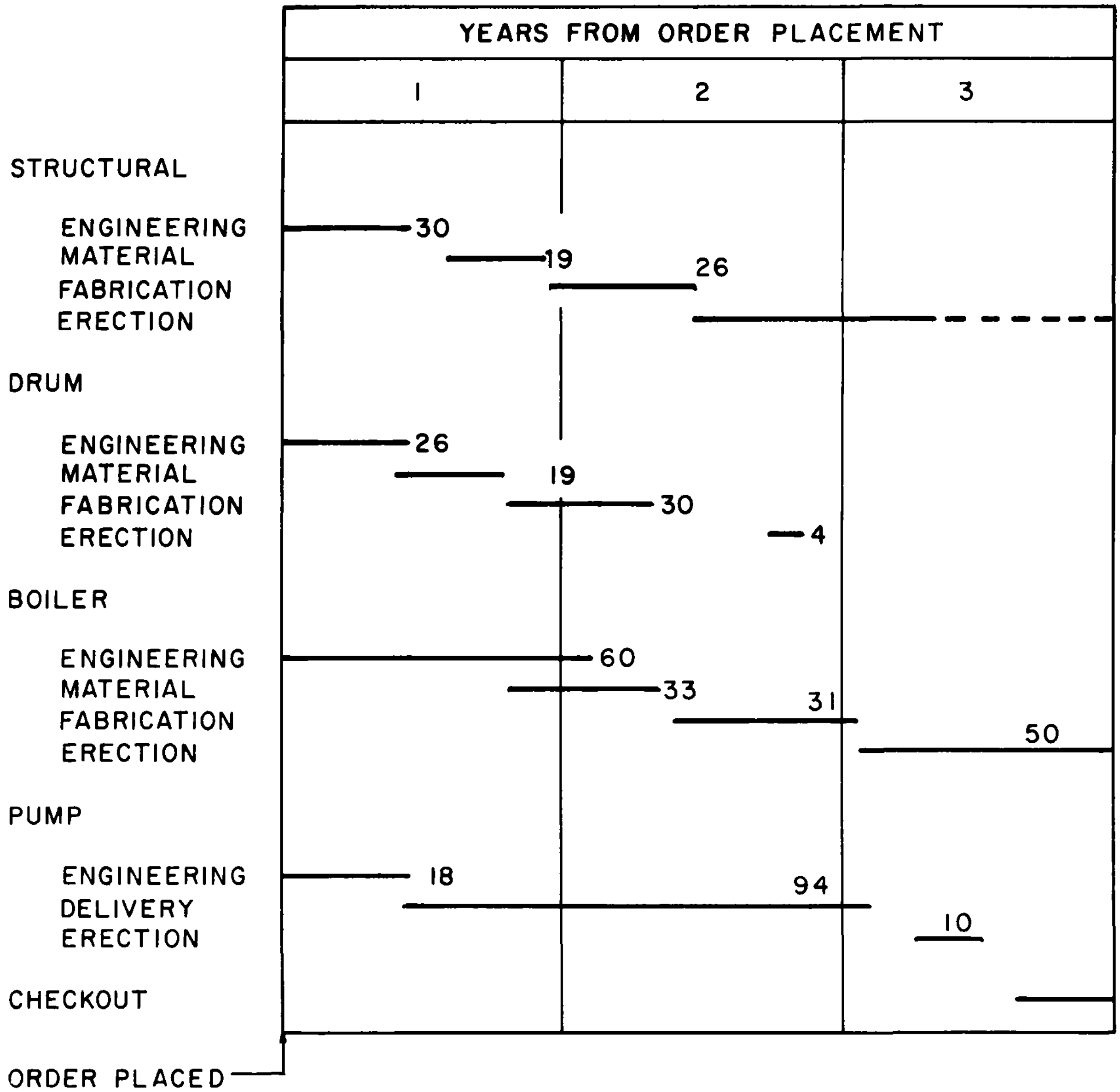


FIGURE 7.6-4
RECEIVER SCHEDULE

7.7 EXPENDITURES SCHEDULE

An estimated $164 million will be required during the design and construction period for this project between 1981 and 1985, including escalation, contingency, and AFUDC. A preliminary estimate of annual capital requirements was developed utilizing cost information described in Section 4.6, and the Project Milestone Schedule in Section 7.6. The results of this cash flow analysis are shown in Table 7.7-1.

Assumptions used in calculating the annual cash flow are as follows:

1. Receiver and collector costs are distributed linearly over the 3 year fabrication and installation period.

2. Remaining activities are allocated based on the Milestone Schedule assuming payments are made concurrently with each activity.

3. Escalation and AFUDC are estimated based on the estimated cash flow.

4. Contingency is distributed based on total direct costs.

5. Owner's Costs are primarily attributable to purchasing land and rerouting transmission lines, so most of the Owner's Costs are included during the first 3 years.

The results indicate that the peak annual capital requirement is in 1984, for approximately $66 million, and that only about $22 million of the $164 million are required during the first 2 years of this 5-year period. The cash flows estimated at this time are very sensitive to the commercial agreements that will be negotiated with the heliostat and receiver manufacturers. The cash flows could be expected to vary significantly following preliminary detailed discussions with these vendors about commercial terms.

TABLE 7.7-1

EXPENDITURES SCHEDULE
(Millions of Dollars)

	Total	1981	1982	1983	1984	1985
Present Day	104.2	3.0	13.3	21.5	43.2	23.2
Escalation	34.5	0.3	2.2	5.6	15.6	10.8
AFUDC	21.5	0.1	1.0	3.0	6.9	10.5
Owners Costs	3.5	1.3	1.0	1.0	0.1	0.1
Total	163.7	4.7	17.5	31.1	65.8	44.6

7.8 ROLES OF SITE OWNER, GOVERNMENT, AND INDUSTRY

In the interest of hastening the commercial viability of solar repowering concepts, it is imperative that a demonstration program be undertaken that will meet all desired programmatic objectives in a successful manner. To enhance the probability of success, EPE feels that appropriate levels of technical and financial risk must be accepted by the site owner/utility, government, and industry and that the roles and responsibilities of each entity must be clearly defined.

El Paso Electric Company believes that the site owner, in this case an electric utility, must take the role of overall project leadership/management. The site owner in this role must have sufficient contractual authority and responsibilities to allow it to exercise strong project leadership without unnecessary "disruption" of cost/schedular considerations by governmental (DOE) partners.

El Paso Electric Company would provide a construction project with experienced utility management, design, construction, and operations personnel. EPE will use its best efforts to ensure that not only its own interests, but also the general interests of the electric utility industry as a whole, are accommodated by its solar repowering design and demonstration. EPE would maintain a close liaison with utility industry representatives and disseminate progress results to other electric utilities and interested general public factions.

The rationale for EPE's belief in project leadership by the site owner/utiilty is that the program's ultimate goal (solar repowering commercialization) can be favorably impacted through the alignment of site owners/utility and industry in their standard post-commercialization roles. The "window" for incorporating solar repowering options is finite in size. This reflects an early need to walk the commercialization path to allow business to begin considering their solar repowering investment options and opportunities. An artificial management structure in which government is interjected between a site owner and industrial entities, situated above the site owner, or assumes a split leadership role with the site owner, may substantially delay subsequent commercialization activities.

Additionally, EPE perceives that a site owner will be making significant financial commitments to the design and construction of a solar repowered facility and would not want to jeopardize his long-term investment. The Federal government is expected to depart the project scene after several years of testing, but the site owner/utility must continue to operate and maintain the solar facility. These operations and maintenance costs may be substantial if early projections prove to be correct.

EPE has a number of preliminary thoughts on the appropriate government/DOE role in a demonstration program. The desire of DOE to protect its project investments is understood and EPE supports DOE's stated beliefs that it should "act as a partner with contractor management in key decisions." DOE must consider, though, that the cost of any delay will penalize its utility and industrial partners who will have acted in good faith in furtherance of national energy goals.

Must the government, in return for its substantial financial underwriting of a solar demonstration project, be involved in the day-to-day management and decision-making process of this project? Many electric utilities, in cooperative nuclear ventures (for example), have been involved as co-owners in power plants where the financial commitment involved is many times greater than DOE's entire current solar budget. In these cooperative ventures, management structures and relationships have been established which reasonably protect the interests of all co-owners, regardless of their percentage involvement in the facility. Concurrently, the project manager (a designated utility) is granted the authority and responsibility commensurate to ensure flexibility to accomplish design and construction activities in a timely fashion.

In this manner, a concept evolves where DOE becomes simply one of the project "owners" with rights equal to other owners through rather steadfastly defined roles. Of course, a highly positive aspect of DOE's involvement in an R&D demonstration is its (and its technical managers) vast knowledge, talent, and experience. EPE recognizes these characteristic abilities and plans to utilize them substantially to ensure program success. Thus, EPE would expect to enter into some form of cooperative agreement with DOE, rather than become a contractor to the government.

To further stress the importance of centralized management control of a demonstration program by the site owner, it can be stated that EPE's Utility Advisory Council is of the general opinion that, ideally, solar repowering should be demonstrated without any DOE/government involvement. The Council would concede, however, that due to the probable uneconomic nature of such a demonstration facility, it is appropriate for the government to assume financial and risk burdens.

There is a long history of Federal involvement and incentives to develop alternative energy technologies. It is estimated that the Federal government has provided, in many forms, as much as $130 billion in incentives for energy production from the 1920's to the mid-1970's. These Federal incentives were made primarily for two reasons. First, incentives were necessary to promote new technologies during their maturing stages. The second readily apparent reason was to appropriately assume the financial difference between the value of a technology to the private sector and the perceived value to society at large. Because of our demand for foreign oil, it is clearly in the national interest to accelerate the development and deployment of solar thermal energy technology more rapidly than it would occur with only normal market factors involved. Also, with Federal incentives (oil and gas price controls, etc) for conventional energy sources, the social value of solar may be masked and not readily perceived. Thus, to push solar energy production to the forefront, Federal support is needed and deserves to be provided for this program.

El Paso Electric Company is not precluding any particular cost/risk sharing arrangement with the Federal government in possible follow-on phases of this necessary and important solar repowering program, but instead believes DOE should look at historical governmental roles as well as the performance of and rationale for these roles.

Other than cost/risk sharing, the Federal government should perform other roles to further the solar repowering program. The government should spearhead efforts related to the Environmental Impact Statement. DOE should attempt to educate regulatory agencies, other Federal agencies, Congress, etc as to the importance of this national program in order to forestall any negative impacts these groups and others may desire to impose, and perhaps even to illicit favorable actions which will further demonstration and subsequent commercial acceptance of solar concepts. DOE should also make available the experience of its staff and laboratories to the program.

The role of the utility industry is that of a future owner/user of solar repowering technology. Gaining utility confidence, particularly in the hardware, is an essential part of the commercialization process. Because of the retrofit nature of solar repowering, a utility coalition formed to finance a demonstration on a particular utility's system will be very difficult to establish. Part of the difficulty is related to the fact that each retrofit is very site-specific and unit-specific. Another consideration is that today's financial climate is having unfavorable effects on utilities' capital structures due to commitments required to meet increasing energy demands. Even so, EPE expects that some utilities will contribute actively to the success of each demonstration.

One utility organization, the Electric Power Research Institute (EPRI), may be expected to continue taking steps to enhance utility interaction with Federal and private programs. These activities will be facilitated through the continued recognition by utilities of the need to actively involve themselves in research, development, and demonstration programs.

The role of private industry in the form of manufacturers/vendors remains an open question to El Paso Electric Company. EPE believes that the potential for equipment vendors to profit by a future solar market should make any non-standard guarantees unnecessary with respect to product suitability, reliability, or performance. Manufacturers, who have been trusted suppliers to the electric utility industry for many years, can be relied upon to correct product performance (and hence to accept technical and financial risks) if for no other reason than to receive future electric utility business. At present, it is our position that industry and utilities are best served by conducting business employing standard commercial terms, without direct governmental involvement or restrictions.

It is important that the site owner/electric utility be able to interface directly with manufacturers/vendors. This prevents either party from shifting their responsibility to some intermediary, and sets the stage for cooperation of both parties during the lifetime performance and maintenance of the equipment. Additionally, this direct interface will promote the transfer of data between suppliers and utilities, thus aiding confidence in solar technology and related equipment.

However, some form of government incentive or subsidy may be justified (directly to manufacturers) in order to promote the potential of solar energy. These incentives would recognize that suppliers are not competing in an ideal "free market" economy. Different manufacturers are confronted by differing problems; even the same manufacturer has varying needs at different stages of growth. This complication is further compounded by the fact that many new and non-homogeneous groups are involved in this development toward commercialization.

To summarize EPE's preferred roles in follow-up final design and construction activities, the site owner/utility should have sufficient authority/responsibility to provide strong leadership as overall project manager. The Federal government (i.e., DOE) should be a partner with contract management in key decisions in return for its cost/risk sharing and other project related services. EPE is precluding no institutional arrangements and expects this to be a matter of further negotiation between all parties at a later date.

☆U.S. GOVERNMENT PRINTING OFFICE: 1980-740-145/643