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NEWMAN UNIT I SOLAR REPOWERING, Volume 1A

Volume 1 Executive Summary

Final Report

July 1980

Work Performed Under Contract No. AC03-79SF10740

El Paso Electric Company
El Paso, Texas

U.S. Department of Energy

Solar Energy

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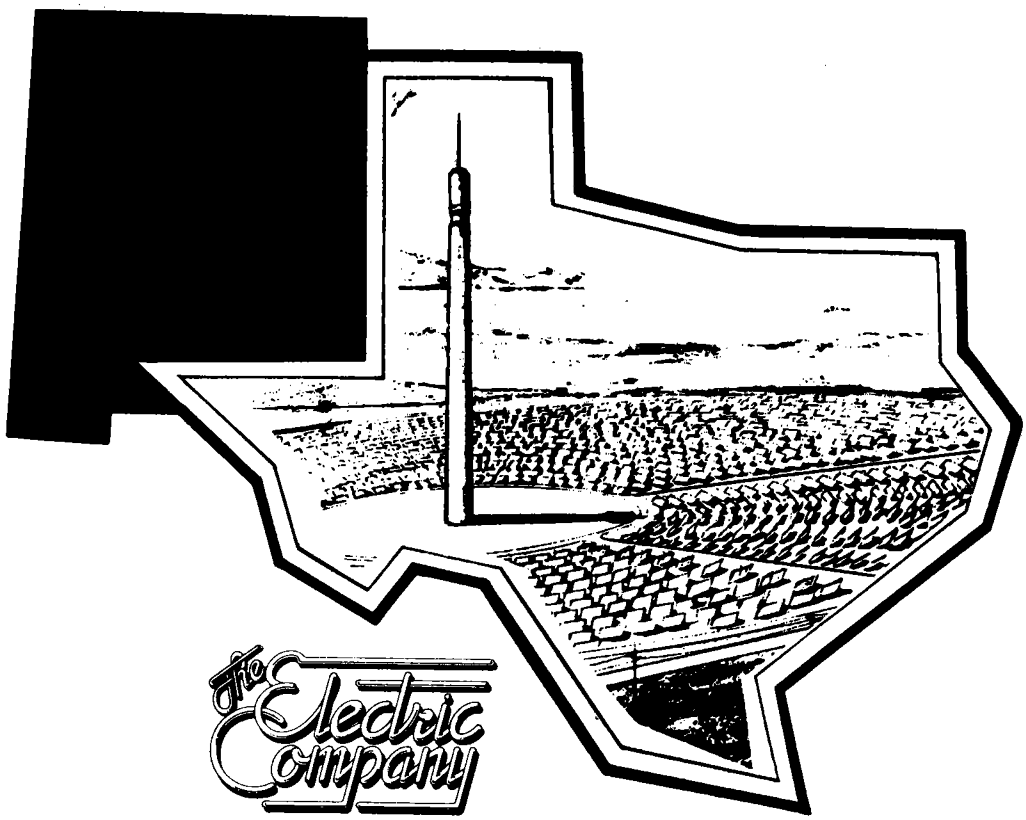

EL PASO ELECTRIC COMPANY

Newman Unit I Solar Repowering

Final Report Volume I Executive Summary

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

July 1980

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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.

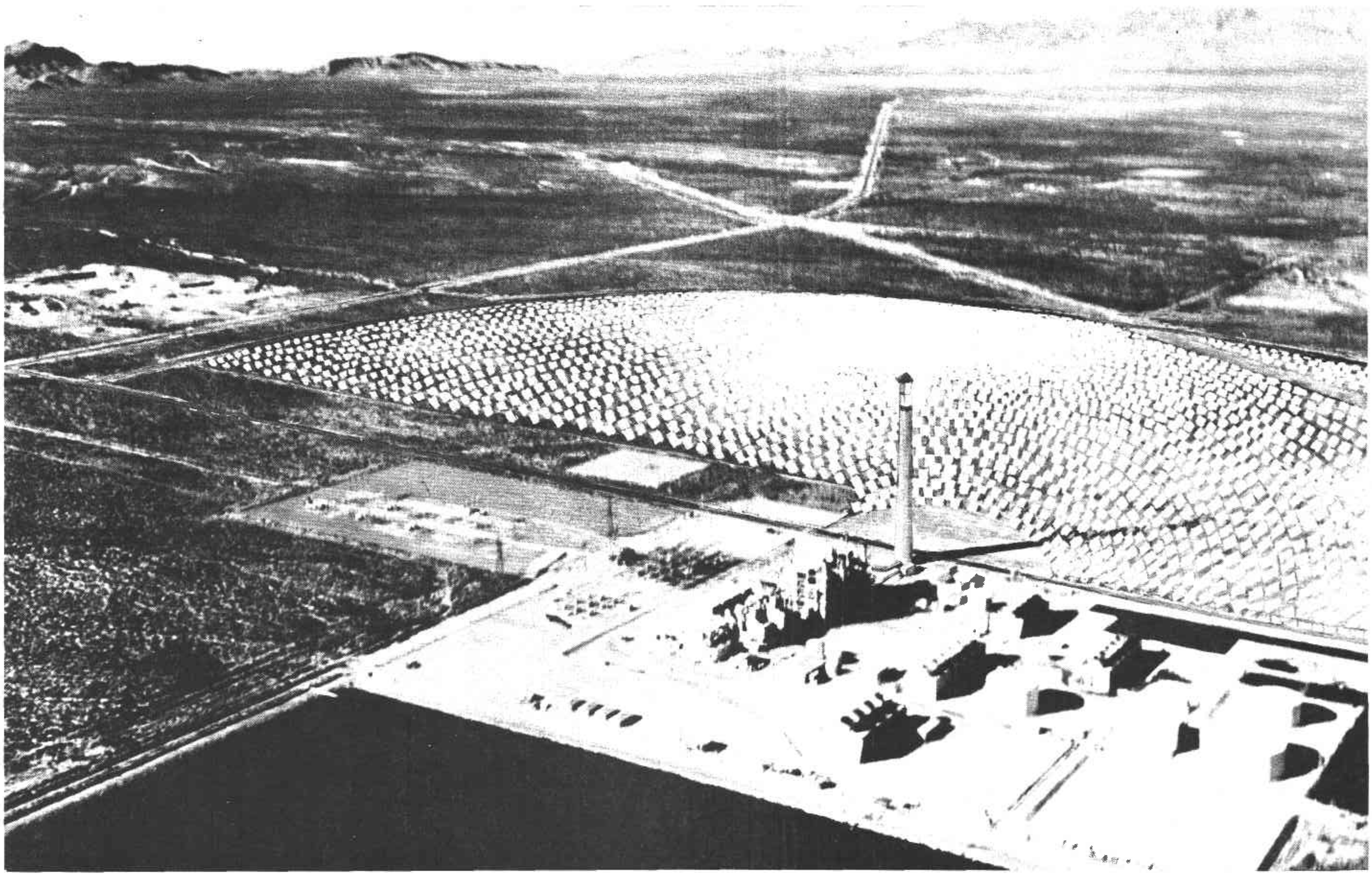


FIGURE 1.1-1
SOLAR REPOWERED NEWMAN UNIT 1

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.

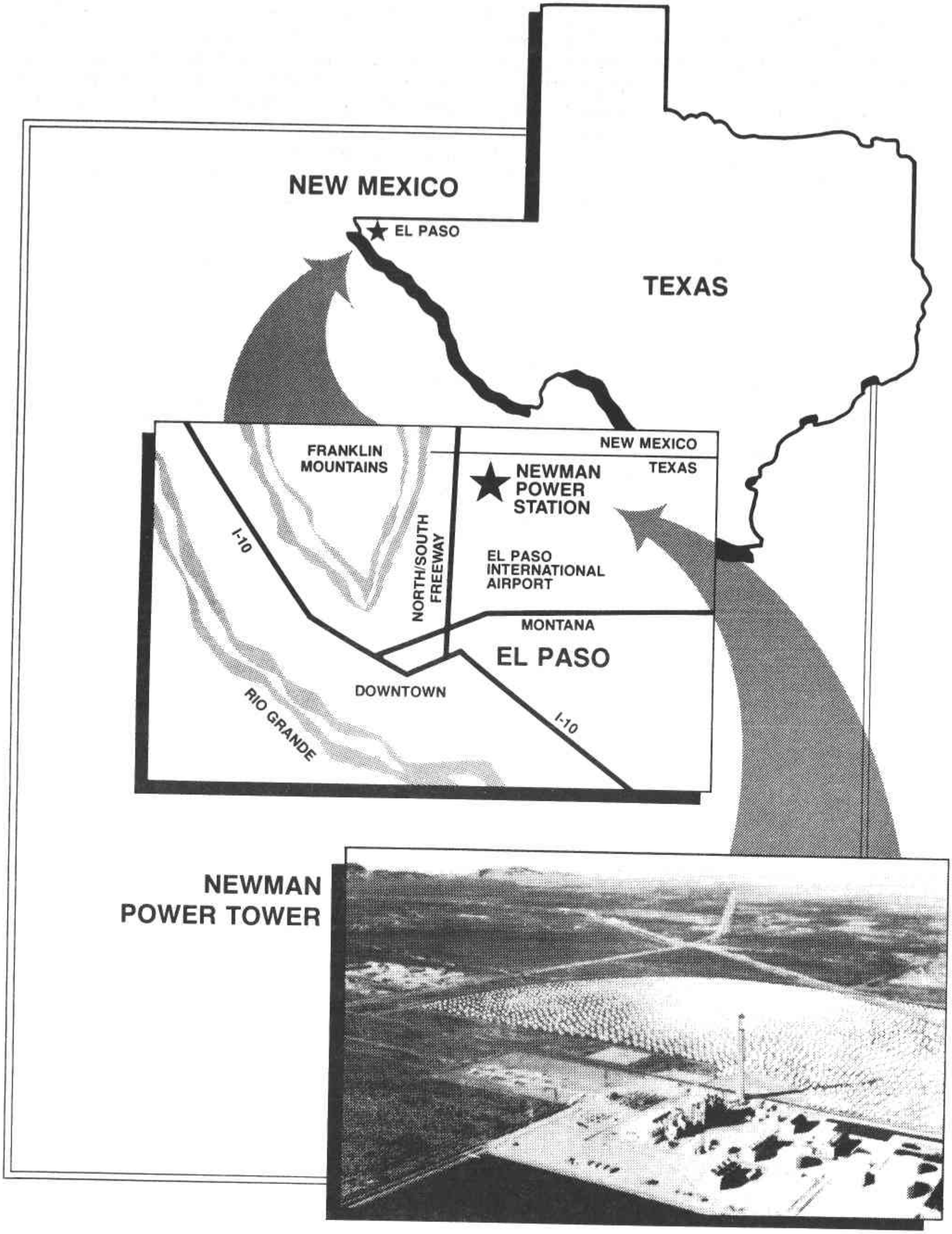


FIGURE 1.2-1
LOCATION OF NEWMAN STATION

The Electric Company
El Paso Electric

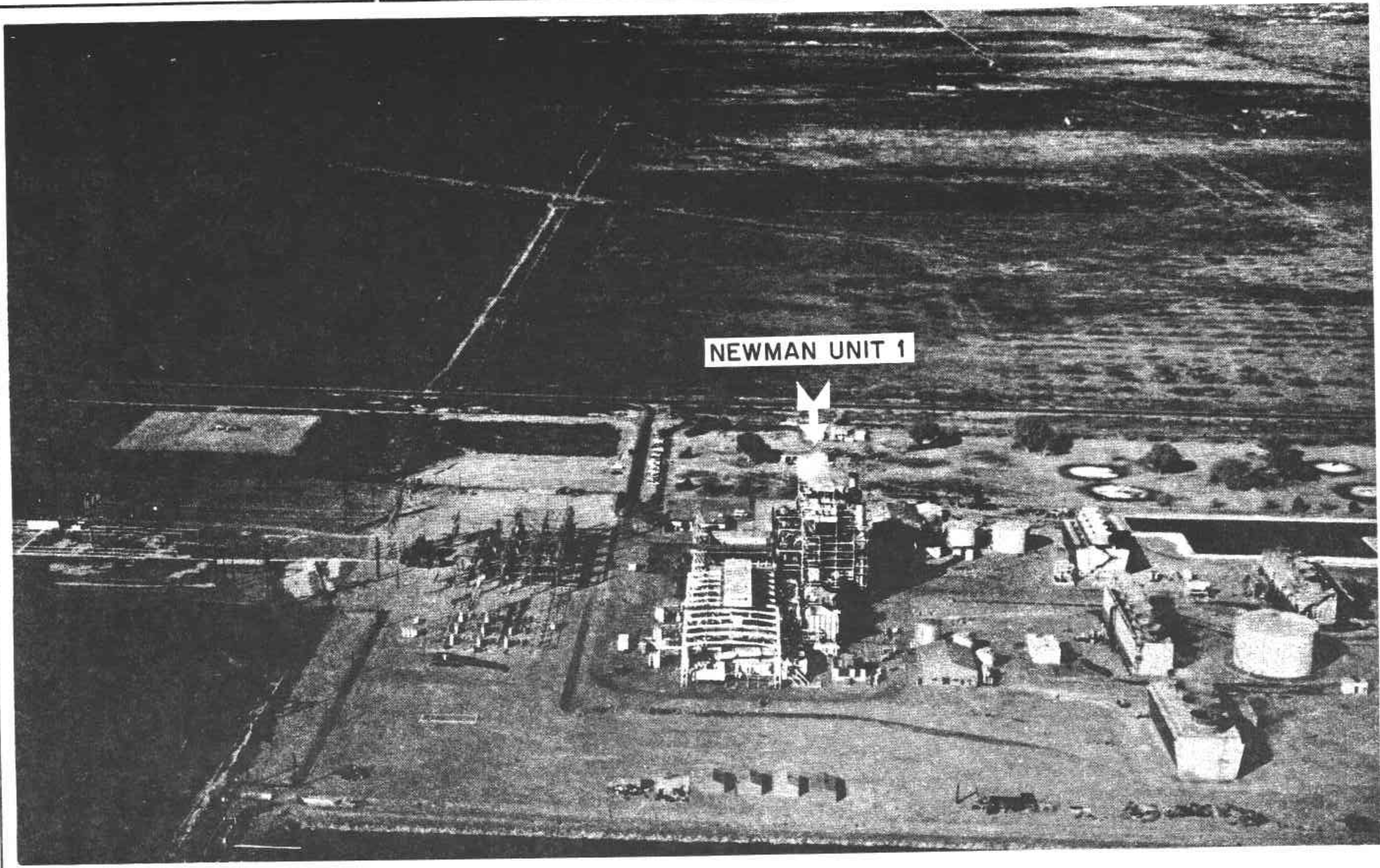


FIGURE 1.2-2
NEWMAN STATION SITE AND SURROUNDINGS

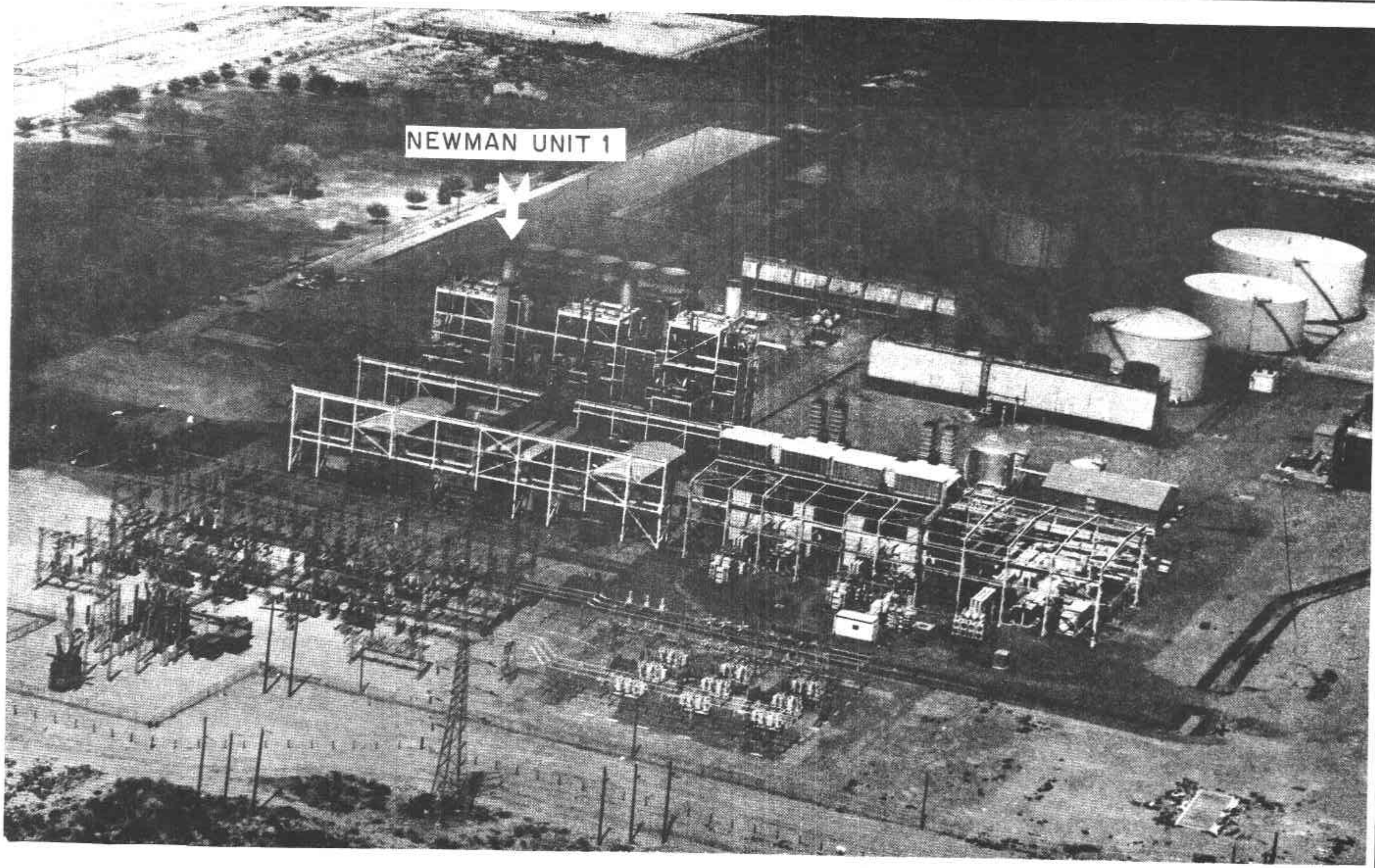


FIGURE 1.2-3
NEWMAN STATION UNITS 1-4

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

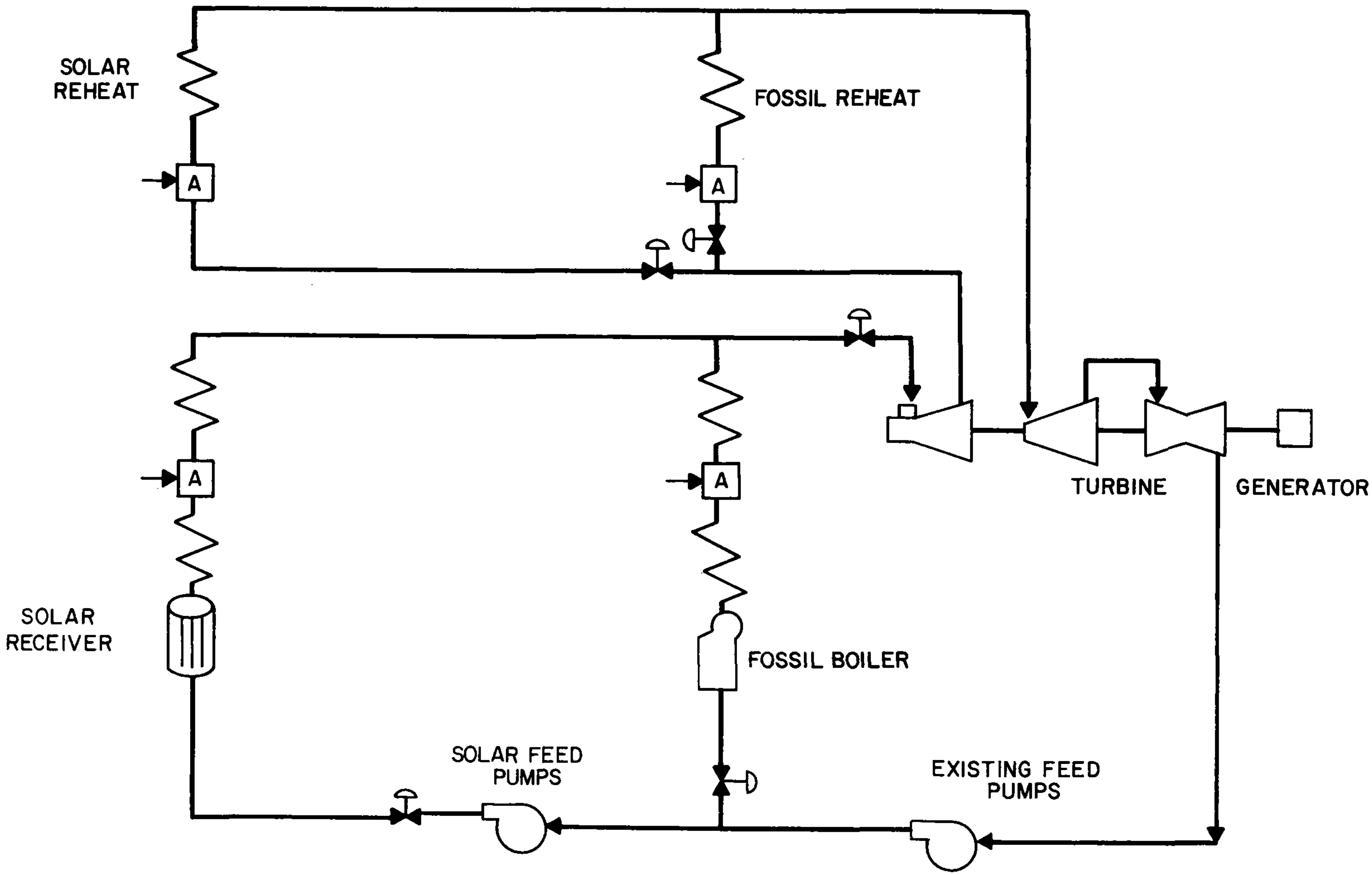


FIGURE 1.4-1
SIMPLIFIED FLOW SCHEMATIC

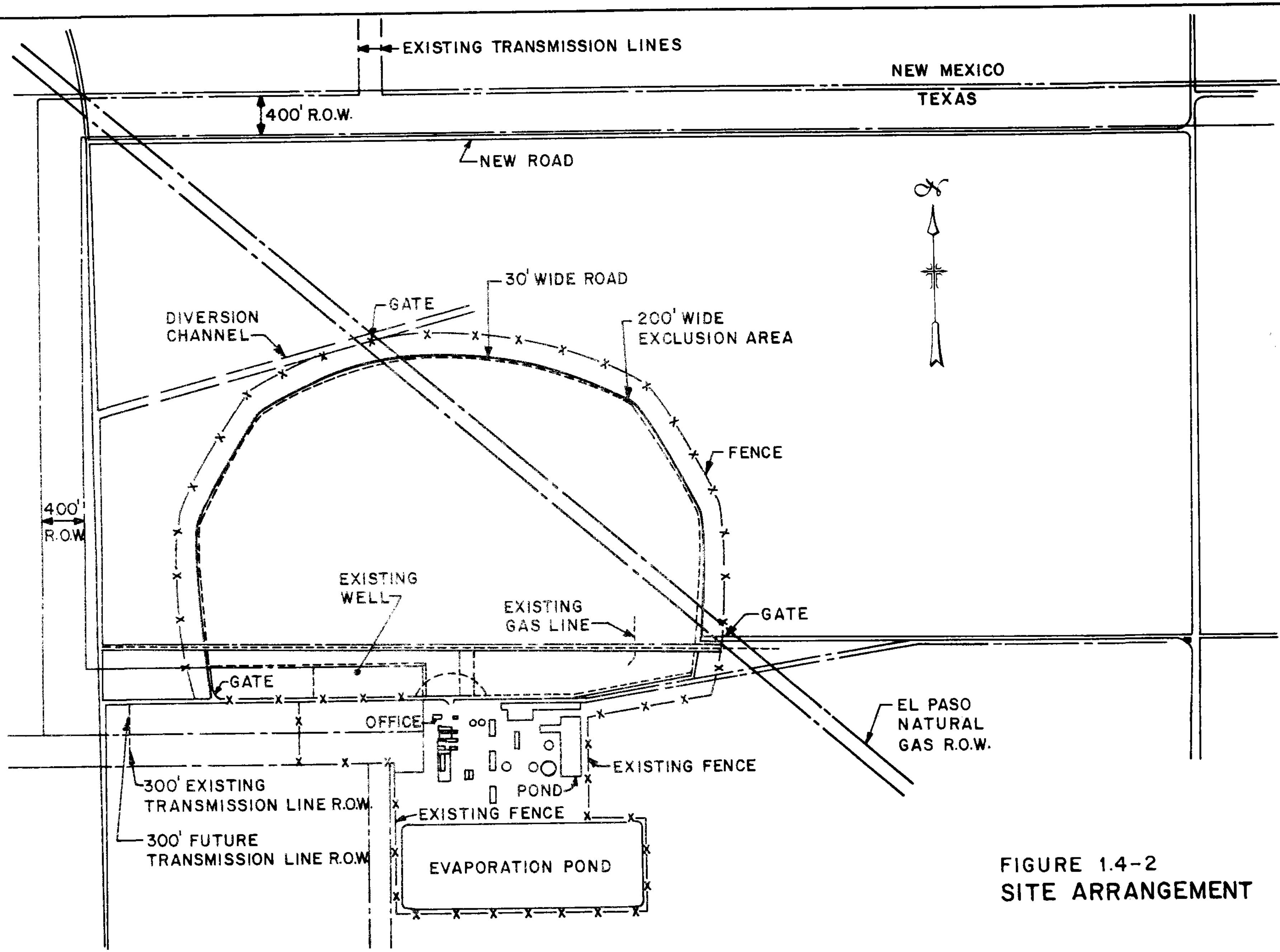
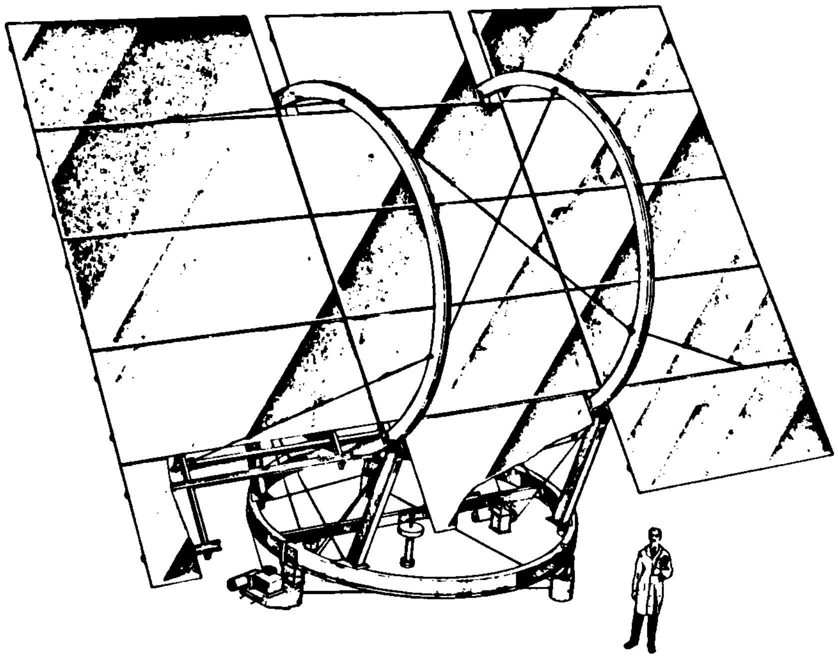


FIGURE 1.4-2
SITE ARRANGEMENT



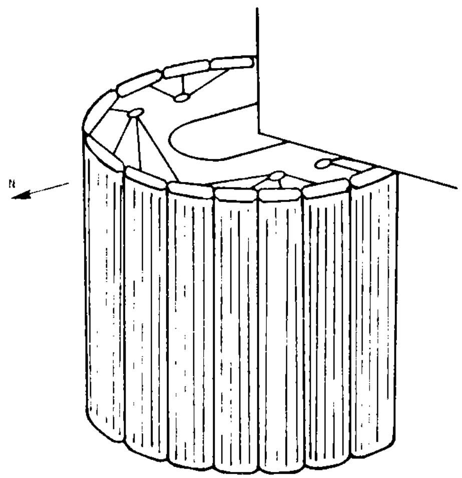
HELIOSTAT CHARACTERISTICS

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

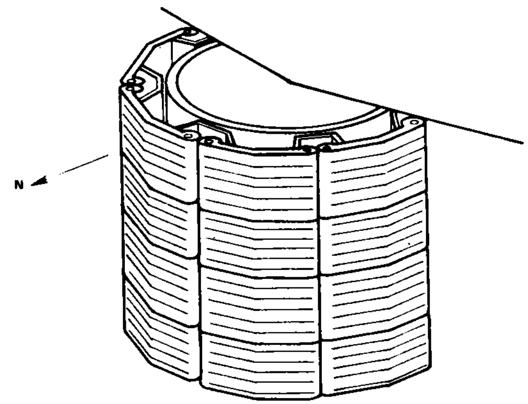
CONFIGURATION: EXTERNAL CONFIGURATION
FORCED RECIRCULATION
SCREENED TUBE CONCEPT
1 TOWER WITH PRIMARY AND REHEAT RECEIVER
160° NORTH FIELD

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

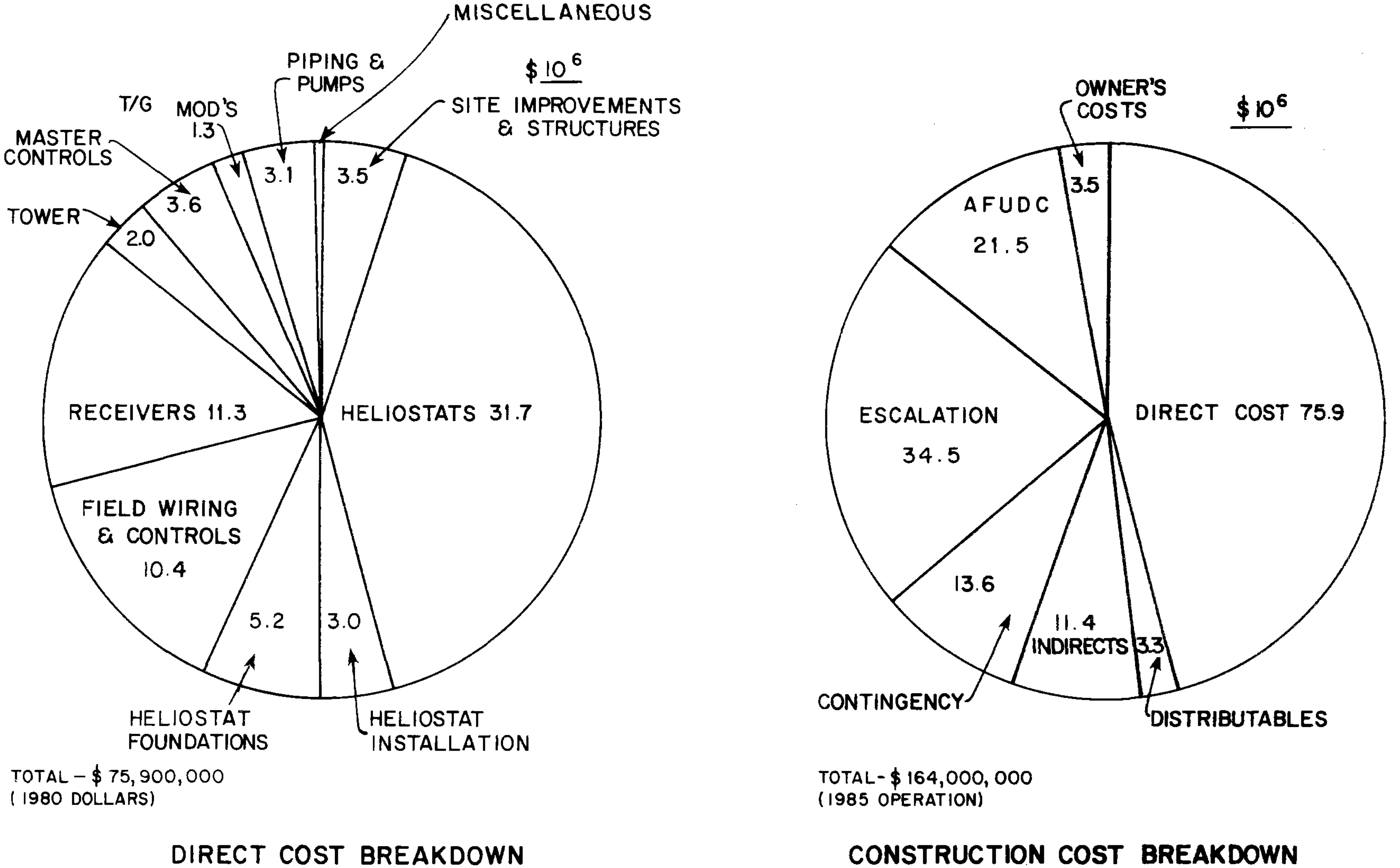


FIGURE 1.4-5
CONSTRUCTION COST BREAKDOWN

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/m²
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/m².

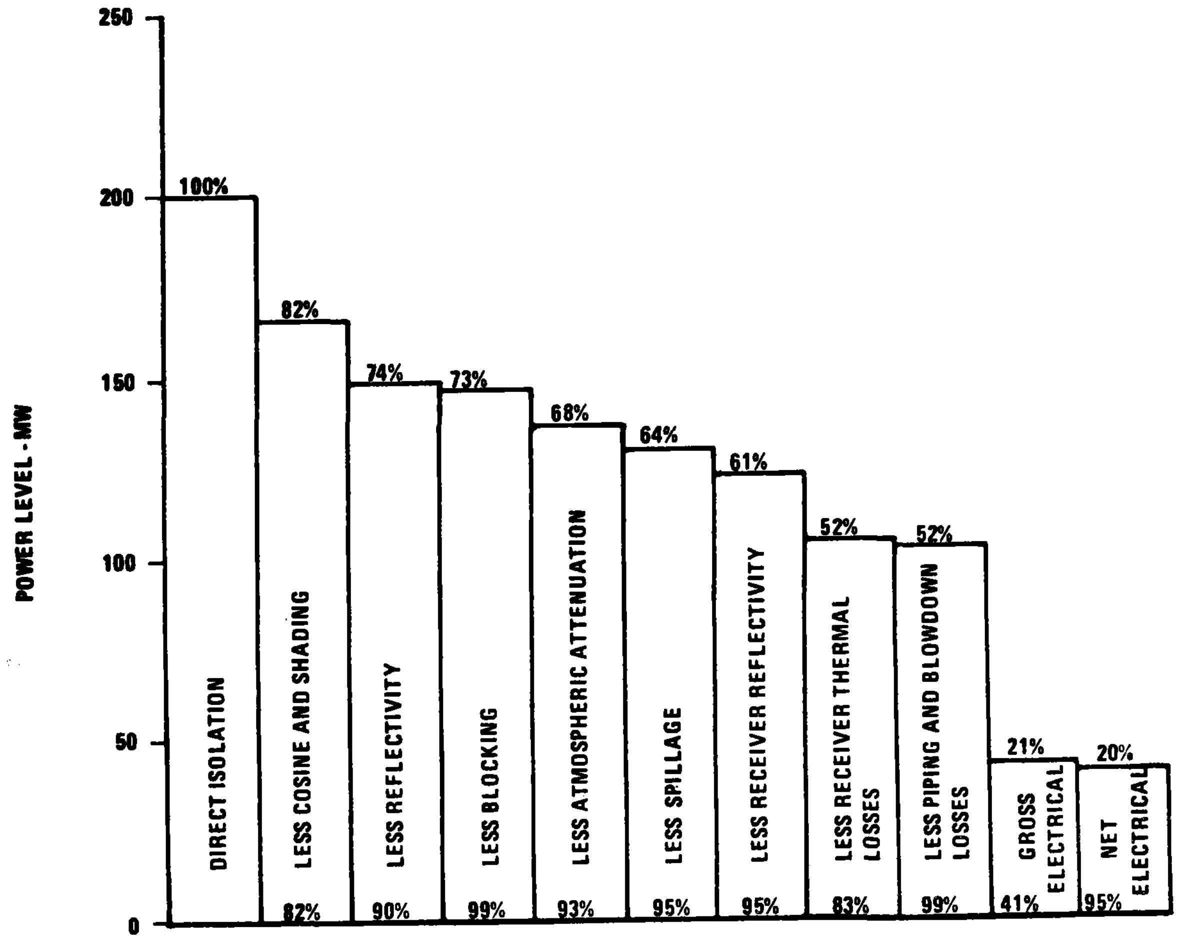


FIGURE 1.5-1
SOLAR REPOWERING NEWMAN UNIT 1 EFFICIENCY CHART (DESIGN POINT - NOON SUMMER SOLSTICE - 950 W/M^2 INSOLATION)

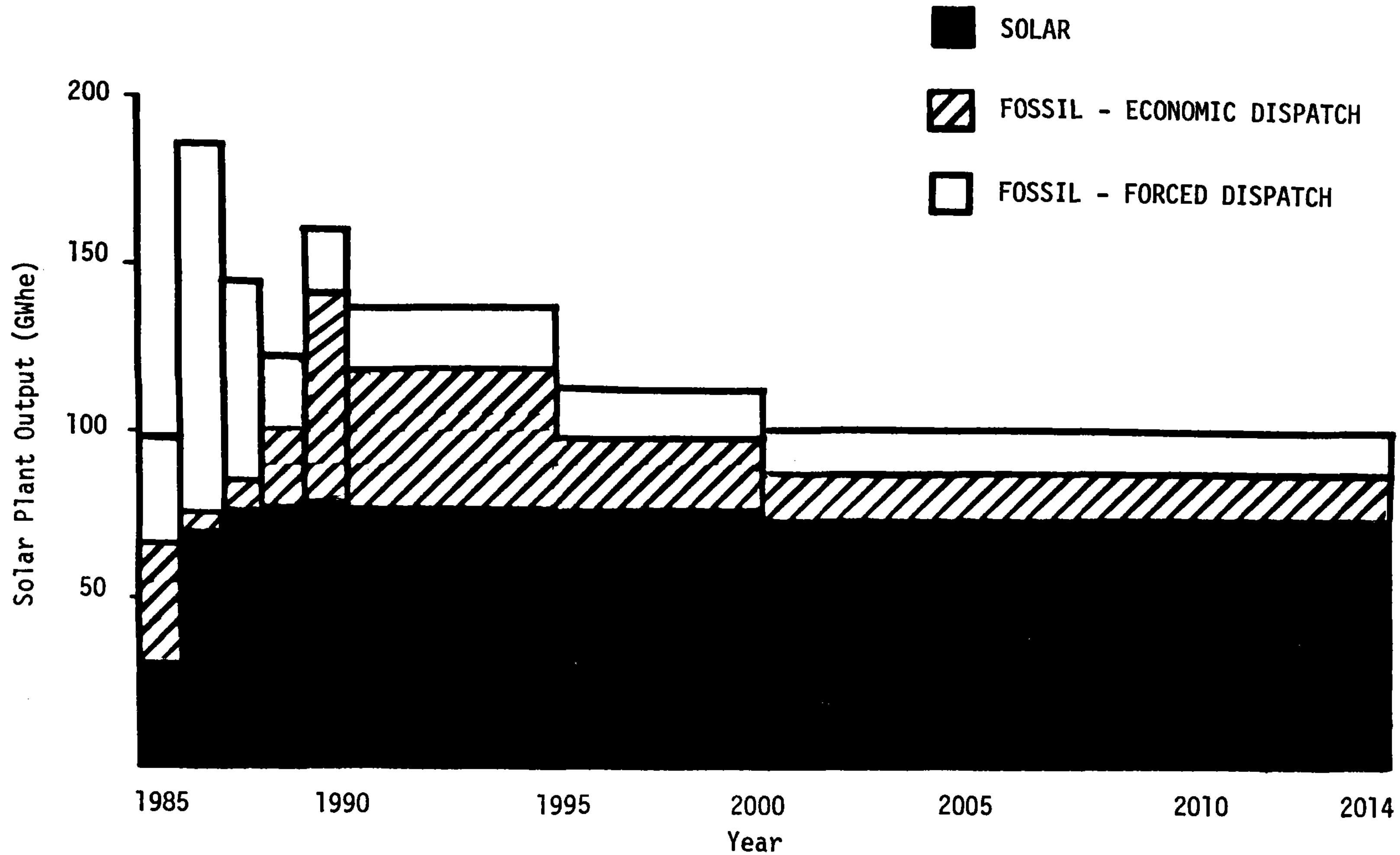


FIGURE 1.5-2
SOLAR REPOWERED UNIT ENERGY OUTPUT

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 ($28x10^{12}$ Btus) of gas/oil and $0.84x10^4$ MJ ($8x10^{12}$ Btus) coal. The solar repowered unit consumed about $1.27x10^4$ MJ ($12x10^{12}$ Btus of gas/oil over its life. Thus, the net energy displaced is $1.69x10^4$ MJ ($16x10^{12}$ Btus) of gas/oil and $0.84x10^4$ MJ ($8x10^{12}$ 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

TABLE 1.6-1

ECONOMIC SCENARIOS (1985)

	EPE Scenarios A	EPE Scenarios 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.

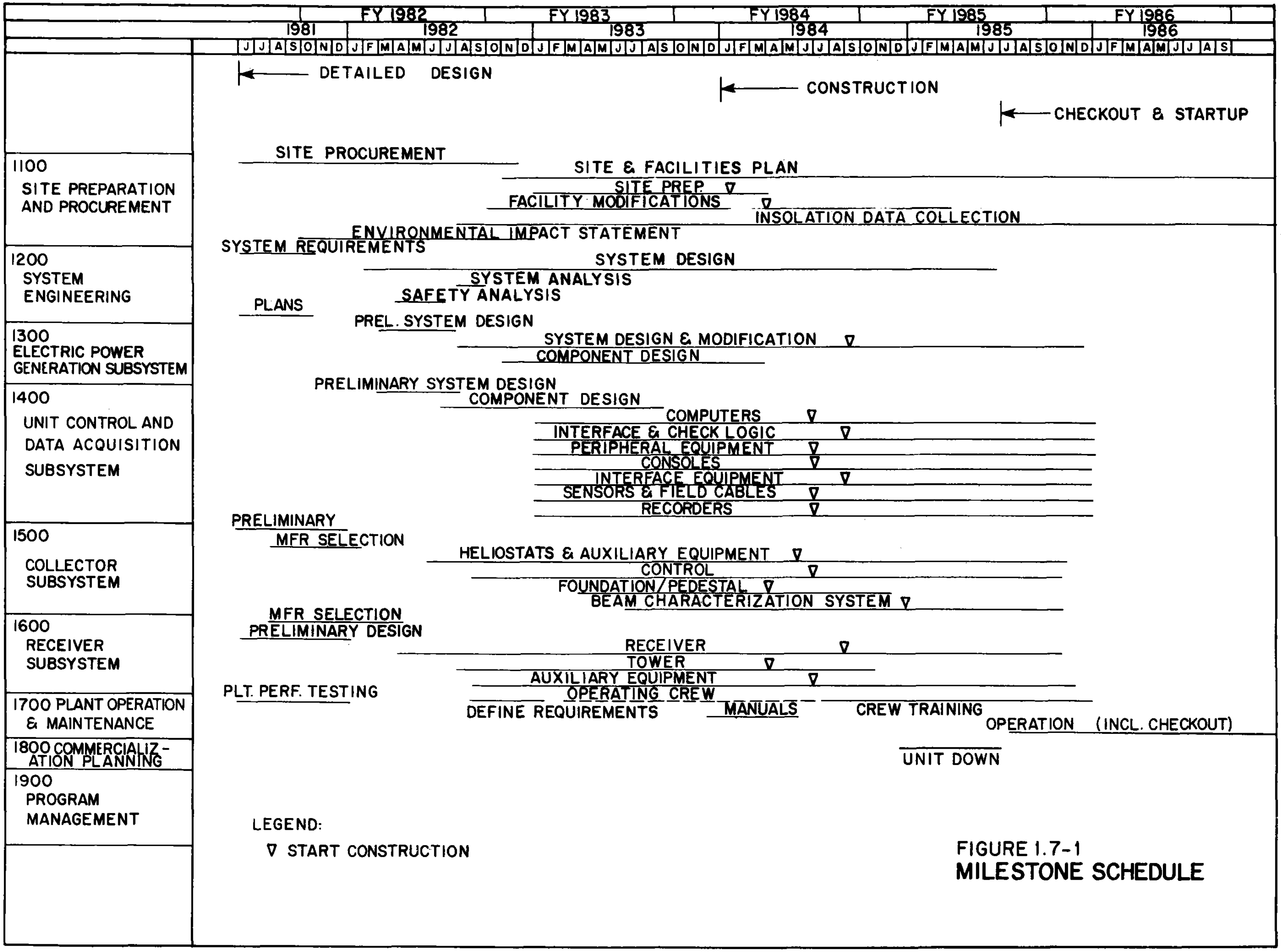


FIGURE 1.7-1
MILESTONE SCHEDULE

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.

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