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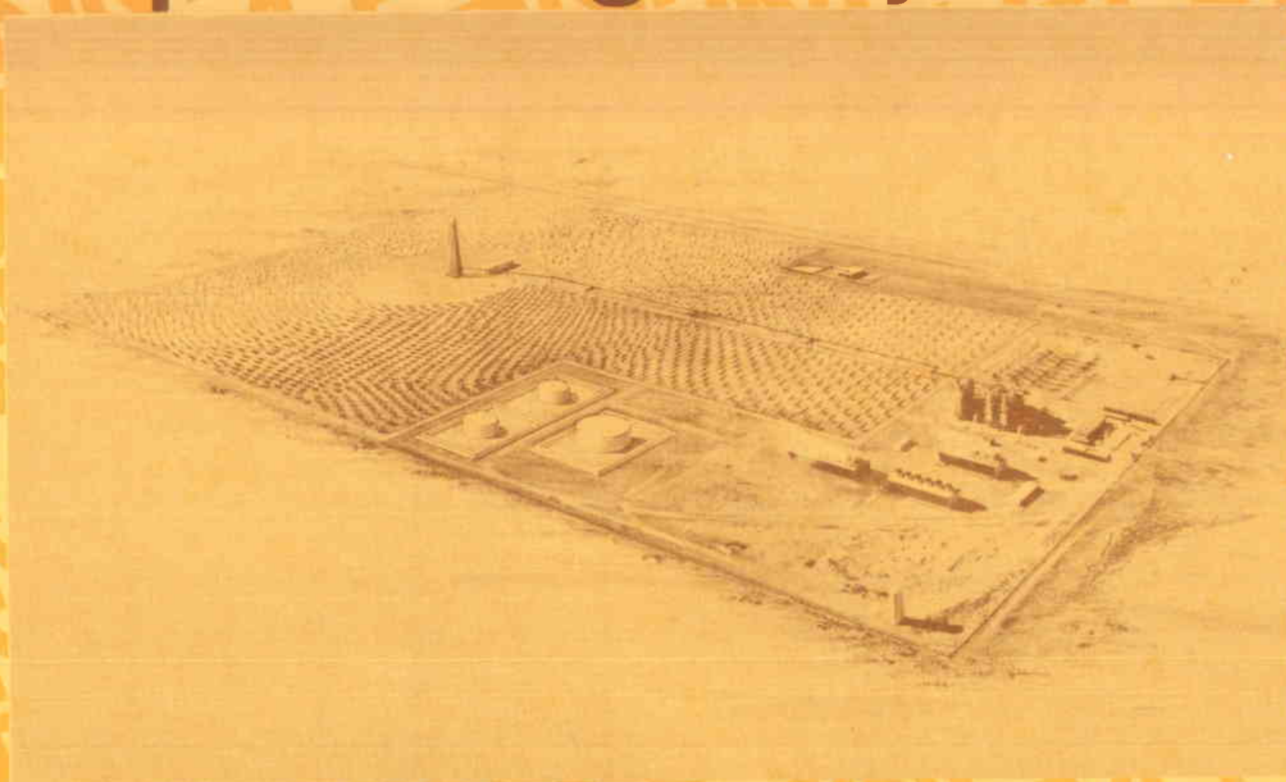
Solar Hybrid Repowering Project



a utility program for Commercializing Solar Hybrid Repowering

submitted by

PUBLIC SERVICE CO. OF NEW MEXICO

for The Department of Energy

"SUN" DAY
May 3, 1978

PNM PUBLIC SERVICE COMPANY OF NEW MEXICO
Post Office Box 2267 / Albuquerque, New Mexico 87103

May 3, 1978

Mr. John F. O'Leary
The Department of Energy
Old Executive Office Bldg.
Washington, DC 20585

Dear Mr. O'Leary:

The Public Service Company of New Mexico (PNM) is pleased to submit this proposal for the first pre-commercial construction and operation of a solar hybrid repowering plant by December 1981. PNM has also initiated a development plan linked to the participation of the major Southwestern utilities with large potential applications. These utilities will provide a market to fully commercialize the concept and lead to installation of at least 58 repowered units. The 58 candidate repowerable units identified by PNM could displace greater than the equivalent of 17 million barrels of fuel oil (0.1 quad of energy) annual consumption for boiler firing in the 1980's, greatly assisting the national energy plan in decreasing the United States' dependence on foreign oil and fossil fuels. Utility responses provided herein indicate support of the PNM design, procurement, construction, and operation of a 25 MWe pre-commercial plant. Eight potential heliostat manufacturers contacted have, or are considering, the development and testing of equipment to meet this aggressive program's heliostat manufacturing requirements and the commitment of all required front-end capital for plant construction for the market envisioned.

This project is based on PNM's origination of the concept in 1974, which led to detailed in-house investigations of the engineering and economic feasibility. Positive results prompted PNM to submit a proposal to ERDA in December 1976, which was funded by the Department of Energy (DOE) (Contract CST 2499) and initiated in September of 1977. This study, "The Technical and Economic Feasibility of Solar Hybrid Repowering," allows for a natural evolution of the study into a second phase which would include the pre-commercial plant construction and operation at the PNM Reeves Station Unit No. 2. The solar system is based on the central receiver concept, consisting of sun tracking mirrors, a central receiver support tower, and solar boiler. The conceptual design, presented herein, applies the DOE developed hardware for the 10 MWe pilot plant being constructed at Barstow, California. It is planned to utilize this technology in the proposed pre-commercial project, pending the development of more advanced and cost effective hardware, minimizing program cost and technical risk.

Two major subcontractors have been selected to assist PNM in the successful execution of the proposed program. Westinghouse Electric Corporation will provide system engineering and project integration, and

Bechtel Corporation will provide architect-engineer and construction services. Both of the highly qualified subcontractors have participated in the preparation of this proposal, are thoroughly conversant with the program, and are committed to the successful development of solar power.

Economic analyses, based on traditional utility factors, have shown that solar hybrid repowering is the most attractive near-term solar alternative for power generation. PNM has investigated progressive financing arrangements and tax incentives which could allow for commercial equivalency of the concept after construction of the fifth unit. Such a program results in the minimum direct government financial support on subsequent units. A detailed financial analysis is presented for the DOE's consideration.

As the host utility for the pre-commercial project and lead utility for subsequent regional repowering projects, PNM will commit the Reeves Station Unit No. 2, a 50 MWe gas- and oil-fired electric generating unit, for a 50 percent repowering. This unit is superior in all parameters to implement the repowering concept. The proposed power cycle will have all modifications required for cycling duty. In addition, PNM will provide the land for the solar field. We will also fund certain modifications to the unit and all operation and maintenance costs not only to the balance of plant, but to the solar system once in commercial operation. The Reeves unit meets the specific candidate unit criteria as identified in the PNM Southwestern Survey of 263 applicable units reported by utilities and closely matches the DOE design criteria for the Barstow Pilot Plant.

We believe the solar hybrid repowering pre-commercial unit is urgently needed to conserve our dwindling oil and natural gas reserves, reduce our nation's severe foreign oil dependence, achieve the earliest commercialization of solar components, introduce earliest direct utility participation in commercializing solar energy, extend the life and use of existing generation equipment, utilize present generation sites wherever adjacent land is available, reduce fossil fuel emissions at existing sites, improve present generation mix, determine hybrid operating principles, and minimize backup requirements for early solar thermal electric plants.

The above goals are exciting and challenging. PNM proposes to aid the DOE in achieving these goals. President Carter's administration goals are directed toward near-term achievements to aid the United States in reducing our increasing dependence on foreign oil sources. The necessity for immediate action is apparent, and it is believed that the program proposed by PNM will greatly assist the President in achieving those goals. Any lag will only further delay large solar application for power generation in the near-term, and regulatory hesitation will discourage utility interest.

PNM commits its full resources to this effort.

PNM has received the support of the Governor of the State of New Mexico, the New Mexico Department of Energy and Mineral Resources, and the State's Public Service Commission. PNM will work closely, as in the past, with the DOE, and will take a direct and active role in prompting other Southwestern utilities to utilize the concept.

We are pleased to participate in this exciting endeavor to rapidly commercialize the repowering of existing gas- and oil-fired power plants in the Southwest.

Sincerely,

Jerry D. Geist
President

RNR:jon

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1.0 INTRODUCTION AND SUMMARY

1.0 INTRODUCTION AND SUMMARY

The Public Service Company of New Mexico (PNM) has been actively involved in energy conservation efforts and investigations of alternate concepts for electric power generation for many years. In 1974, PNM originated a concept in which an existing power plant might be modified to operate from either fossil (oil or natural gas) or solar energy.

In this concept, the solar thermal central receiver or so-called "power tower" system which consists of sun-tracking mirrors and a steam boiler atop a tower is located adjacent to an existing power plant. During periods of adequate sunlight, the mirrors (called heliostats) focus sunlight in a concentrated form on the tower mounted boiler (called receiver). This receiver then provides steam to be piped to the power plant for operation of the steam turbines. During periods of inclement weather or nighttime operations, the existing fossil-fired boiler may be utilized to generate steam. The technical name given this concept is "solar hybrid repowering." Initial studies performed by the System Planning Department of PNM indicate that a high percentage of fossil fuel normally burned by such a repowered unit would be saved. Some analyses have shown a fuel saving potential for a particular unit to approach 95 percent of that unit's normal usage for intermediate and peaking service.

The central receiver solar power concept is currently under intensive development by DOE. A 5 MWt test facility is near completion in Alburquerque, New Mexico, and a 10 MWe pilot plant will soon be constructed in Barstow, California. Concurrently, a major EPRI program is also developing the central receiver concept for central power generation to complement the DOE effort. These major efforts, in conjunction with many other related research and engineering activities supported by DOE and EPRI are rapidly firming the technological base of the central receiver concept. PNM feels confident that this technological base can be fully utilized to achieve solar hybrid repowering.

PNM, noting the possible large scale application of the central receiver solar technology to the repowering concept, performed a utility literature survey in nine Southwestern states to identify potential units which could be solar repowered. The survey was performed in 1976, and indicated approximately 40,000 MWe of generation capacity which might be suitable for solar hybrid repowering.

Encouraged not only by the previously mentioned System Planning Department studies, but the potential widespread application of the concept throughout the Southwestern United States, PNM prepared a proposal. This unsolicited proposal, entitled Technical and Economic Assessment of Solar Hybrid Repowering, was submitted to the Department of Energy (formerly the Energy Research and Development Administration) in December of 1976. It proposed a two phased project consisting of a one year assessment study followed by an implementation of the solar hybrid repowering concept.

Phase I, the assessment study, includes an extensive market survey of the Southwestern states. It also includes a conceptual design and detailed economic analysis of both the total market benefit of the concept to utilities, as well as the specific benefits to a unit repowered in the PNM system. The proposal requested $831,000 to be expended over a twelve-month time period for the Phase I activities.

On September 30, 1977, DOE and PNM entered into a letter contract. The study is to be completed by September 29, 1978. Financial support has been committed by EPRI, West Associates and four Advisory Utilities. Fifty-five Utilities have also joined in their technical support of this project.

The primary technical tasks of the assessment study will be completed by June 30, 1978. The following output will be available to initiate the proposed project:

- A market survey and cost/benefit analysis
- A specific site selected for the project
- A conceptual design of the solar hybrid repowering unit
- A cost estimate for the unit

The assessment phase of the study is approximately 30 percent complete, and a major portion of the results of the Market Survey and Cost Benefit Analysis have been realized and are discussed in Section 2.0. Seventy-two Southwestern utilities have responded to a detailed questionnaire addressing the applicability of solar hybrid repowering to their specific systems, identifying approximately 11,000 MWe of capacity with adjacent land available, the most readily discernible criteria. A cost benefit analysis is discussed herein which determines the overall economic savings of repowering these units with solar energy versus their continued operation on natural gas or fuel oil.

PNM has been involved in selecting a power plant study unit representing a typical unit as identified in the utility survey (Section 2.0), and meeting various requirements of the PNM system. Results indicate Reeves Unit No. 2 is a desirable candidate for solar repowering. A conceptual design of a 50 percent solar repowering of this unit (25 MWe produced by the solar field for a 50 MWe total output) is also underway in the assessment to serve as a basis for a demonstration of the concept.

Parallel studies were initiated by the Department of Energy (DOE) to investigate various parameters of solar hybrid repowering not addressed by the PNM study. The contracting agencies were the Solar Energy Research Institute at Golden, Colorado; Planning Research Corporation at Washington, D.C.; and MITRE Corporation at McLean, Virginia. PNM provided input as requested by these independent agencies for their studies. However, PNM had no input in the results or the conclusions.

MITRE Corporation presented study results to Public Service Company of New Mexico officials in March, 1978. The MITRE study conclusion was reached independently of the PNM assessment: if an amount of oil displacement of 0.1 quads per year (3350 MWe and 17,640,000 barrels of oil) is to be realized by 1985 using solar thermal power generation (MITRE scenario No. III), the <u>only suitable concept</u> will be solar hybrid repowering.

The above goal is an exciting and challenging goal which the Public Service Company of New Mexico proposes to aid DOE in achieving. PNM has gained much utility interest and, DOE interest is at a high level. President Carter's energy goal is for near-term achievements to aid the U.S. in immediately reducing our increasing dependence on foreign oil sources; MITRE concludes that solar hybrid repowering is a major step to reach the goal. The necessity for an immediate pre-commercial unit is apparent. Any lag will further delay large solar applications for power generation in the near term, and regulatory hesitation about its economy and efficiency will discourage utility interest. Most importantly, foreign fossil fuel dependency will continue unless other energy sources are utilized.

Realizing a goal of displacing 0.1 quads/year by solar hybrid repowering by 1985 is an aggressive one. Mass production of heliostats is essential in achieving the goal. PNM has therefore contacted potential heliostat manufacturers. These manufacturers are very aware of the repowering concept and interested in providing the required heliostat hardware. Each heliostat manufacturer has responded in a positive fashion to commit capital for developing a manufacturing capability to meet the repowering goal. Enclosed in the Business volume of this proposal are responses received from these manufacturers indicating their willingness to commit front-end capital expenditures on their own behalf to meet the material requirements and equipment requirements should the DOE provide incentives to develop the market as identified by PNM.

A complete utility program plan for commercialization has been developed by PNM. PNM has also identified potential financial incentives from federal, state, and local governments, including a written discussion from a utility point of view, which will expedite the accomplishment of these goals. This total package will allow the DOE to proceed immediately with a plan of commercialization and enter the U.S. into a period of commercial, large-scale solar power generation with minimum risk and maximum near-term benefits.

PNM proposes to begin engineering design immediately for a 25 MWe repowering of Reeves Unit No. 2. This unit is superior in all parameters to utilize the repowering concept. The proposed power cycle will have all modifications required for cycling duty which will be performed by PNM. In addition, PNM will provide the land for the solar field, certain modifications to the unit, all upgrading features required, and all O&M not only to the balance of plant, but to the solar system once in commercial status. The Reeves unit meets virtually every specific candidate unit criteria as identified in the PNM Southwestern survey of 263 applicable units reported by utilities and matches the DOE design criteria for the Barstow Pilot Plant. This will minimize development modifications required for the solar equipment.

Conceptual design issues as understood to date are described in Section 5.0 to display the recommended modifications to this unit. Conceptual design will continue to move forward and mature into a complete detailed design.

A Southwest Solar Hybrid Repowering Implementation Plan, as presented in Section 3.0, is proposed to achieve a rapid commercialization at multiple sites. A supporting list of 55 utilities is included for the concept.

PNM has received written notice from many utilities indicating their support of the pre-commercial unit placement at PNM. Houston Lighting and Power Company, Public Service Company of Oklahoma, Arizona Public Service Company, Nevada Power Company, and others have indicated in writing their strong interest in committing units for solar hybrid repowering subsequent to the pre-commercial unit.

DOE must act in an immediate fashion to attain these aggressive goals, calling for a rapid utilization of the Department's resources. PNM will work closely, as it has in the past, with DOE. This will include close coordination with appropriate technical arms and other pertinent agencies so that the plan enclosed and, hence, the large-scale application of solar hybrid repowering, can be immediately implemented to the satisfaction of all parties. PNM, the utility leader in the solar hybrid repowering effort, welcomes this challenge.

1.1 SOUTHWEST COMMERCIAL MARKET EVALUATION

An evaluation of the near term market potential for solar hybrid repowering of existing fossil-fueled electric power generating plants located in the southwestern United States has been completed as part of the current PNM Phase I Technical and Economic Assessment Study of Solar Hybrid Repowering. Table 1.1-1 summarizes the results of this evaluation; the evaluation is discussed in detail in Section 2.0 and Appendix B.

A literature survey was performed using primarily the Federal Power Commission Form 12 data. The survey identified 755 gas and oil fueled electric power generating units located primarily in the Southwest as potential candidates for solar hybrid repowering; more than half of these units have a nameplate rating of 50 MWe or less. These units represent in excess of 40,000 MWe generating capacity, and most of them will have to be either repowered or replaced with new generating capacity within the next twenty-five years.

A data questionnaire was distributed to 78 utilities to identify interest in the solar hybrid repowering concept, to identify candidate plants for repowering, and to determine the availability of land adjacent to the candidate plants. The 78 utilities comprise most of the electric power generating capacity in the southwestern United States covering California, Arizona, New Mexico, Nevada, Texas, Oklahoma, Utah, Colorado and Louisiana. Sixty utilities responded to the questionnaire; approximately 50 utilities indicated an interest in solar repowering of their existing gas and oil fired units. As indicated in Table 1.1-1, the utilities surveyed identified 263 candidate units for solar hybrid repowering which represents, considering land availability, an effective solar repowering capacity of 10,700 MWe. A large potential market therefore exists for the solar hybrid repowering concept if the concept can be proven to be economically attractive.

Table 1.1-1

MARKET EVALUATION SUMMARY

Category	Number of Units	Total MWe
Potential Market Size (rated MWe)		
Literature Survey	755	40954
Utility Survey	263	19273
Solar Repowering Potential (effective MWe)		
Based on land availability	263	10699

The characteristics of a typical candidate unit for solar hybrid repowering were defined on the basis of the utility survey. The typical candidate unit was built between 1950 and 1960, is a steam plant, and will be retired before the year 2000. The rated power of the plant is between 10 MWe and 50 MWe. The plant has a non-reheat steam turbine with steam conditions of 850-1250 psig/900-950^{o}F. In general, all of the candidate units identified in the survey are considered by the utilities to be in good operating condition and most of the units are currently used either as intermediate or peaking units.

A cost/benefit analysis has been performed as part of the present Phase I Assessment study for the solar hybrid repowering concept for four selected Southwestern utility systems; Arizona Public Service, Public Service Company of New Mexico, Nevada Power Company, and the Electric Power Research Institute Synthetic Utility System E which is representative of utility systems in Texas, Oklahoma, and Louisiana. A reference 50 MWe solar hybrid repowering plant was defined for performing the cost/benefit analysis based on the characteristics of the typical candidate unit discussed above. The details of the cost/benefit analysis are discussed in Section 2.5. The results of this analysis to date indicate that the solar hybrid repowering concept has the potential to be economically attractive for utility applications when compared with conventional methods of electric power generation (a cost/benefit ratio of approximately 0.9 for a repowered unit operating as part of Synthetic Utility System E) and is superior from an economic viewpoint to stand-alone solar thermal electric power plants utilitizing thermal energy storage (a cost/benefit ratio of 1.35 to 1.5 for a repowered unit on the PNM system versus greater than 1.5 for a stand-alone solar plant).

1.2 SOUTHWEST REPOWERING IMPLEMENTATION PLAN

The repowering of 3350 MWe fossil fired steam electric generating units to incorporate the capability for large scale displacement of fossil fuel, during daylight hours, is a major undertaking, An investment of about $3.5 billion is required for the repowering program alone. Additional investments in manufacturing facilities will also be required.

National and utility interests provide a strong incentive to undertake the repowering program and to bring it to successful conclusion on an accelerated schedule. The major programmatic and economic benefits include:

- Large scale utilization of an alternative and non-depletable energy source, namely solar energy.

- Displacement of the progressively more expensive imported fuels with solar energy at a rate of 0.1 quads/yr in the 1980's.

- Energy displacement utilizing existing generating capacity thereby minimizing the demand for other natural resources.

- Economic benefit to the utilities by reducing their dependence on costly, and at times unavailable, fossil fuel.

Economic studies indicate that under higher projected fuel cost escalation rates and 30 year plant life, the investment in repowering and the cost of displaced fuel would reach break even with as few as 5 units.

The success of the repowering program hinges on careful unit selection, energetic management and timely action by all participants.

The implementation plan was developed with the goal of repowering 67 50 MWe modules (3350 MWe) steam electric units in the southwestern U.S., or their equivalent.

The program plan envisions that each unit repowering will be implemented as a separate project, however, a central entity would be responsible for overall program planning, implementation of generic design activities as well as preliminary commitments for procurement of generic components such as heliostats and receivers. Dissemination of technical and programmatic information and coordination of personnel training would fall within the responsibility of this entity as well.

The schedule for program implementation recognizes that the solar technology is relatively new and an orderly expansion of manufacturing facilities as well as personnel training must be taken into consideration. Consequently, two schedules have been prepared. A high risk schedule would bring about the 0.1 Q/year fuel displacement in 1985. The second schedule, achieving the same displacement capability by 1989 has significantly lower risks.

Although large quantities of materials will be required for implementing the repowering program, studies indicate that during peak construction less than 1% of the U.S. productive capacity will be utilized. It is expected that this coordinated program will result in progressively improving productivity due to improving construction expertise and innovations brought about in the course of the projects. A peak labor force of about 16,000 will be required around 1981 (assuming 1985 completion). Since concurrent projects will proceed, in most cases, at widely dispersed locations, impact of the construction labor at any location will be modest. There is relatively small demand for such scarce skills as welders and pipe fitters. However, the labor mix contains a larger than usual percentage of electricians. The program implementation will require an increase in heliostat deliveries from a 20 per day rate early in the program to more than 200 per day in the later phases, which implies a major expansion of the manufacturing and component supply capacity. Fortunately the heliostats are universally suitable for using modern mass production techniques in their manufacture.

A review of risks indicates that in the technical field the major uncertainties are associated with the central receiver and with the heliostat control systems. These uncertainties have already been recognized and development programs are under way for their resolution as part of the 10 MWe Solar Thermal Pilot Plant project.

Close coordination with these programs is required to assure compatibility with the needs of the repowering program. One of the major functions of the Utility Participant Council will be to coordinate the supply and demand for heliostats, thereby minimizing the risks of scheduling delays. Multiple suppliers must be employed to reduce scheduling risks.

It appears that the heaviest technical, schedule and economic risks are borne by the first 8 repowering projects and to some extent they will serve to prove technical and economic viability of solar repowering.

Utility participation in the repowering program is discussed in greater detail in Section 4.4. Another cardinal issue of the program is the availability of heliostats. Eight manufacturers have been contacted to solicit their expression of interest in providing heliostats for the program. All responded favorably and indications are that they would commit the initial investment in new facilities on guarantee by DOE of a utility site bank, and, if an agressive solar power utilization program (such as being proposed by PNM) is initiated to assure an adequate market.

1.3 UTILITY AND PUBLIC PARTICIPATION PLAN

The overall objective of the solar repowering program, and hence of the proposed pre-commercial project, is the rapid implementation of commercial repowering projects. PNM has initiated a utility (and public) participation plan to expedite timely dissemination of the project results and data. Utility participation will also assure a design with the least restriction as to applicability to other systems. The plan to achieve these objectives is discussed in Section 4.0.

PNM has already issued numerous invitations to utilities judged (on the basis of current assessment results) to have promising candidate units to support and join the proposed project. Response to date has been very encouraging. The invitations request an expression of support for the pre-commercial project and encourage active participation through membership on a Utility Participan Council (UPC). This council can make valuable contribution to the success of the proposed project. It can also enhance the rapid dissemination of data and information to decision makers in the utilities that are expected to implement the DOE goal of 0.1 quad/yr of repowering in the 1980's.

Utility members of the UPC will be encouraged to provide observers to the project. These personnel will receive experience vital to the formation of qualified cadres when their companies initiate repowering projects.

Dissemination of data and information will be advanced through timely report distributions, progress briefings, and site visits. PNM will recommend a plan to DOE for joint DOE/PNM execution to pursue the solar repowering program goal.

Public understanding and acceptance of solar repowering is recognized to be an important factor in a successful program. To this end, PNM proposes to build a visitor center with displays and models. Public forums are planned. News releases, literature and public ceremonies at ground breaking and initial power are recommended for joint DOE/PNM actions to enhance public awareness.

These participation activities will be pursued throughout the proposed project period.

1.4 PRE-COMMERCIAL UNIT DESCRIPTION

The so-called Pre-Commercial Unit of the Southwest Repowering Program has a significant role in establishing a secure technical base for the commercialization of solar repowering. Unit 2 of the Reeves Station located just northwest of Albuquerque, NM, will be the site of this repowering project. The station is owned and operated by Public Service Company of New Mexico. Salient characteristics of Reeves Unit 2 are given in Table 1.4-1. The selected unit is currently in baseload service, however PNM plans to initiate intermittent dispatch operation around 1980. Modifications to the turbine/generator, to permit intermittent operation will be initiated in the near future. The equipment at the Unit is in generally good condition. It is best suited for cyclic operation, characteristic for solar repowered units, by virtue of limited use of ceramic refractory materials in its boiler construction. The Reeves Station site has approximately 30 acres available for the solar subsystem. An additional 125 acres of vacant land

Table 1.4-1

PUBLIC SERVICE COMPANY OF NEW MEXICO

REEVES STATION

UNIT NO. 2

Unit Summary:		
Maximum Gas Consumption	CU FT/HR	539,500
Maximum Oil Consumption	GALS./HR	3571
Heat Rate - Net (Gas)	BTU/NKWH	11,431
Heat Rate - Gross (Gas)	BTU/GKWH	10,851
Annual Capacity Factor (1977)	%	69.4
Circulating Water Flow	GALS./HR	36,000
Efficiency	%	31.46
Turbine Generator:		
Turbine Rated Capacity	KW	44,000
Turbine Manufacturer		Westinghouse
Turbine Type		Tandem-Comp
Throttle Steam Pressure	PSIA	1250
Throttle Steam Temperature	°F	950
Boiler:		
Boiler Manufacturer		B & W
Boiler Steam Capacity	LB/HR	467,500
Combustion Fuel		Gas/Oil
Year Installed		1958
Efficiency	%	88.24

to the south of the present site boundary will be acquired for the repowering project through lease or purchase arrangements. A tentative site plan is shown in Figure 1.4-1.

Some modifications to the existing unit components will be required to interface properly with solar repowering. Major items of modification include:

- Provisions for mixing the solar and fossil boiler generated steam.

- Installation of a full flow demineralizer/polisher in the condensate return line to provide high purity feedwater required in the solar receiver.

- Provisions to direct part or all of the boiler feed water to the solar receiver.

- Redesign of the control system to permit fossil only, mixed solar/fossil and solar only operation.

The solar repowering system will provide steam to generate 25 MWe at design point insolation (2 PM, winter solstice). For Reeves Unit 2 this requires approximately 92 MWt input to the receiver. The heliostat field layout was specified using the Sandia code MIRVAL. A total of 4289 heliostats, of the McDonald Douglas design (Figure 1.4-2) will be deployed around the receiver tower. The field layout makes maximum use of the available land area and at the same time minimizes blocking and shadowing. The circular receiver is of the once through type with an active length of approximately 70 ft and a diameter of 40 ft. The receiver is constructed as a series of panels, each with 70 tubes. Both the heliostats and the receiver use the designs prepared for DOE's solar thermal Pilot Plant at Barstow, California. The receiver is mounted on a steel tower located approximately at the center of the wide portion of the heliostat field. It is tall enough to set

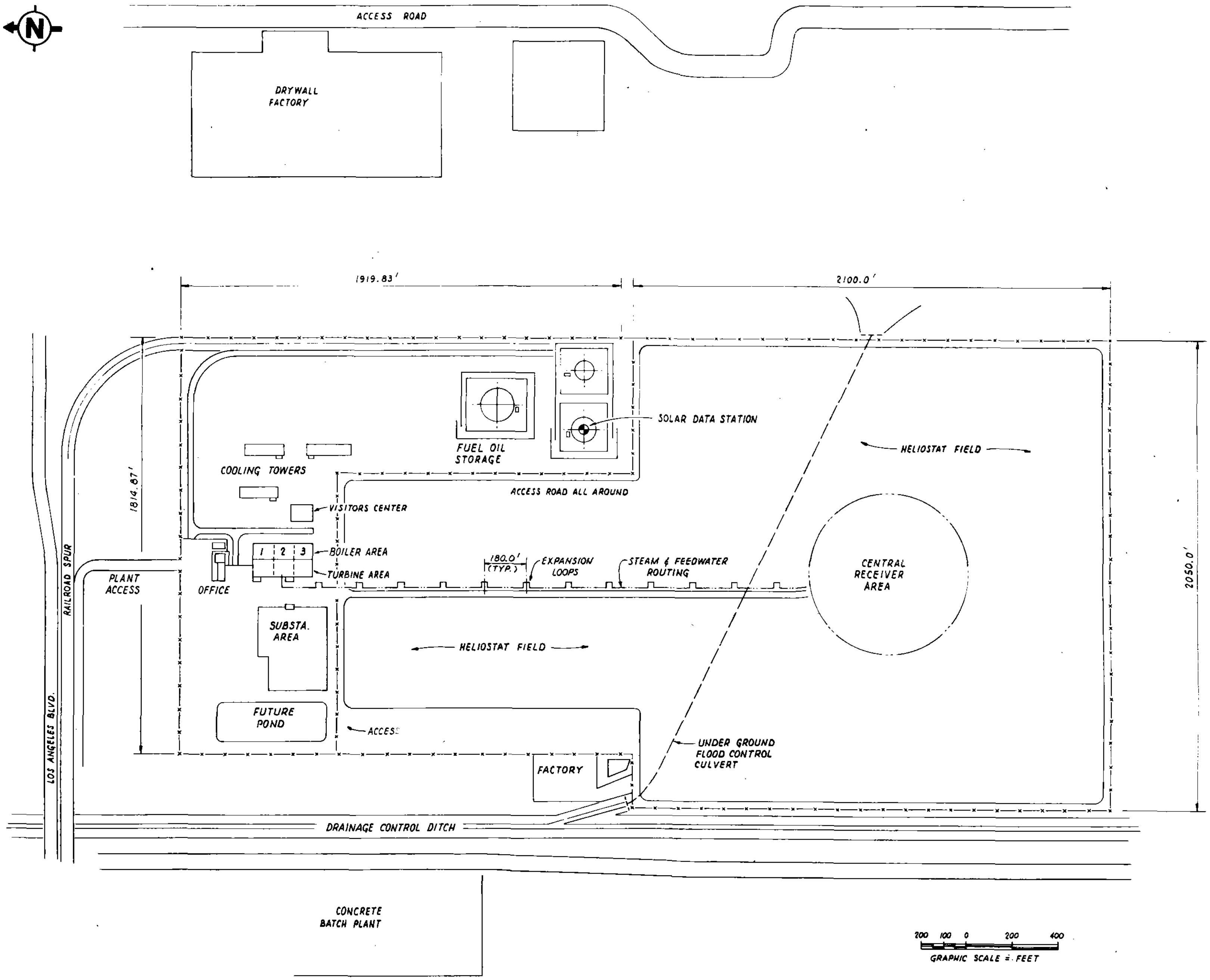


Figure 1.4-1

CONCEPTUAL SITE PLAN

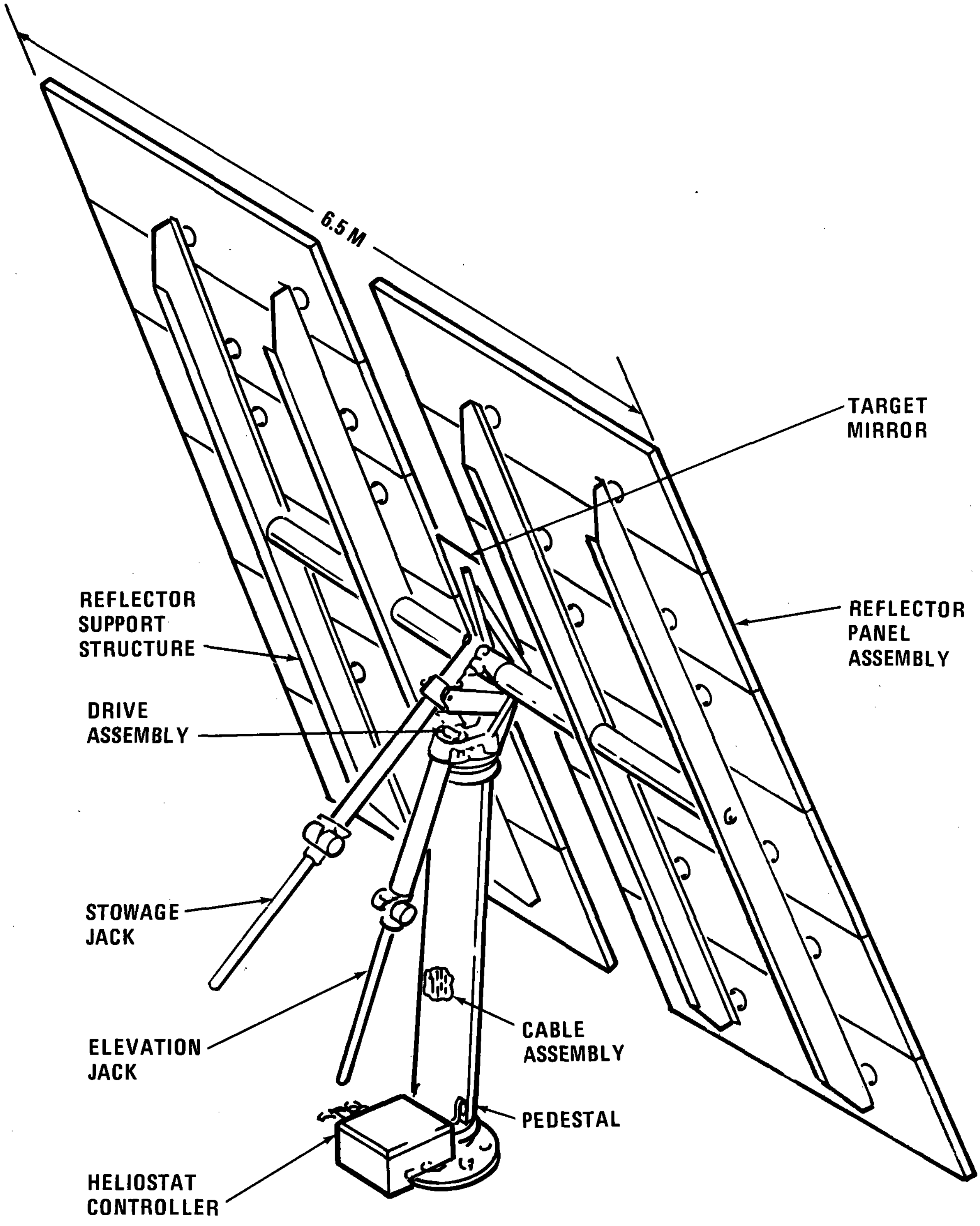


Figure 1.4-2
MC DONNELL DOUGLAS HELIOSTAT DESIGN

the receiver centerline at 500 ft above grade. The Master Control System (MCS) supervises and controls the overall solar repowering unit and each of its subsystems. The MCS also has a data acquisition and storage function, which is more extensive than will be required for future commercial repowering units, so that additional data may be secured from this first-of-the-kind installation. The proposed MCS uses a digital computer system consisting of several processing units (CPU). Positioning of the heliostats to focus on the receiver is controlled by the MCS.

The yard subsystem of the site includes the feedwater and steam connections between the receiver tower and Unit 2, extensive cable connections to supply power to the heliostat positioning motors and for control signal transmission. Extensive lighting protection is provided. The Reeves station will be surrounded with a chain link fence, topped off by barbed wire. A central road will connect the receiver tower to the power station and there will be a perimeter road. Consideration is being given to the problem of surface treatment in the heliostat field to minimize dusting problems. Heliostat cleaning provisions will be patterned after the system developed for the Barstow Pilot Plant. Facilities for the solar installations will include heliostat maintenance and assembly facilities as well as temporary construction facilities.

A preliminary environmental impact assessment identified no major adverse impacts for the region that would result from the construction and operation of the solar repowered unit. A major beneficial impact will derive from a 40% redirection in stack emissions of the repowered unit. The insolation, climate, geology and hydrology of the site is satisfactory for construction and operation of the repowering project.

1.5 PRE-COMMERCIAL UNIT PROJECT PLAN

PNM proposes the project plan outlined in Section 6.0 for this pre-commercial unit. The project plan is structured to permit the project to be conducted in a manner similar to previous successful utility-oriented pre-commercialization projects.

The primary purpose of the proposed project is the implementation of the solar hybrid repowering concept. The principal project objective is to confirm the technical viability and economic attractiveness of the solar hybrid repowering concept for widespread utility application. The specific project objectives are:

- Preparation of the design of the solar hybrid repowering pre-commercial unit at the Reeves Station.

- Construction of the pre-commercial unit.

- Successful operation of the unit for a period of two years.

- Timely dissemination of the progress and the results of the project to other utilities, industries, and government agencies to enhance the early commercialization of solar repowering.

The project to confirm the solar hybrid repowering concept was originally prepared in two principal phases:

- Phase 1 - Technical and Economic Assessment Study of Solar Hybrid Repowering

- Phase 2 - Solar Hybrid Repowering Pre-commercial Project

The Phase I effort is presently being performed by PNM under DOE sponsorship. The primary technical tasks of Phase I will be completed by June 30, 1978, and the following output will be available to initiate this proposed project:

- A market survey and cost/benefit analysis

- A specific site selected for the demonstration.

- A conceptual design of the solar hybrid repowering pre-commercial unit.

- A cost estimate for the pre-commercial unit.

This project is divided into five major tasks: Task 1 - Design, Task 2 - Procurement, Task 3 - Construction, Task 4 - Startup, and Task 5 - Operation.

A forty-one month program is proposed to engineer, procure, construct and start up the solar hybrid repowered unit. A two year operating period is also planned; the option for DOE to continue the plant operation for a longer period (to be determined) will be considered by PNM once successful operation of the unit has been demonstrated. Figure 1.5-1 presents the summary schedule and milestone chart for the project.

PNM has assembled a well qualified organization to perform the Solar Hybrid Repowering Project. PNM will be responsible for the overall project and in addition, for all utility operations. Bechtel Power Corporation and Westinghouse Electric Corporation will support PNM in the areas of architect - engineering services and systems engineering/project integration, respectively. The qualifications and relevant experience of these companies are discussed in Section 7.0. The overall project organization is shown in Figure 1.5-2.

A cooperative agreement will be executed between PNM and DOE for the direction of the project. A Solar Project Operating Committee (SPOC) will be formulated to assist the project manager in the direction of the project. Membership of the SPOC will consist of key management personnel from PNM.

PNM fully recognizes its responsibility, as a member of the electric utility industry, to assure industry-wide transfer of the experience gained from the design, fabrication, testing and operation of the solar hybrid repowering pre-commercial unit. This project represents a truly innovative endeavor, the outcome of which will have a major impact on electric utility acceptance of solar energy as a viable energy option. In addition, PNM recognizes that an important objective of the project will be to assure that the benefits, problems and characteristics of generating electricity from solar repowered plants are made known to as many segments of the public and industry as possible. A Utility Participant Council will therefore be established to advise the project manager in performing this function.

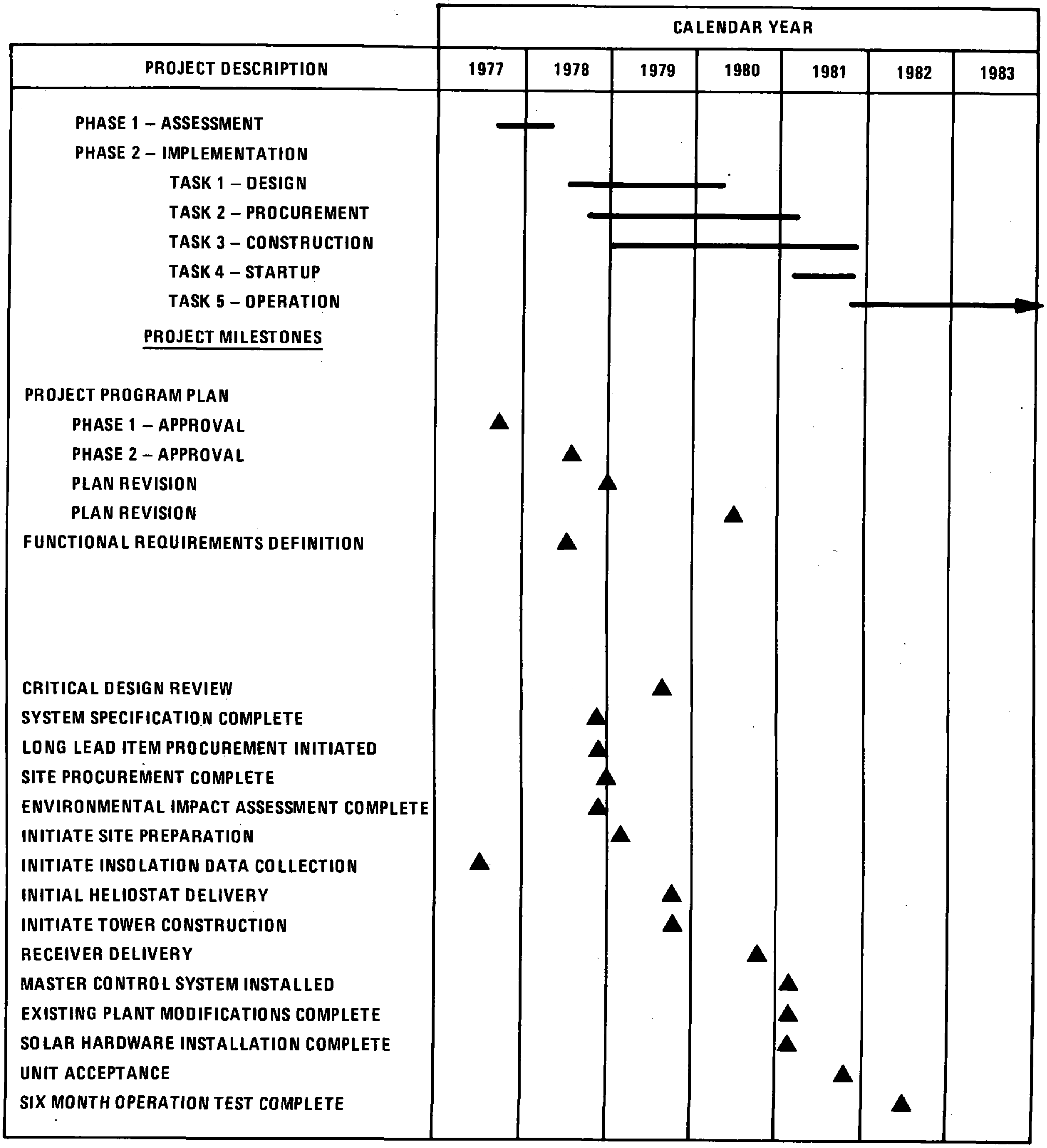


Figure 1.5-1
SOLAR HYBRID REPOWERING PROJECT SCHEDULE

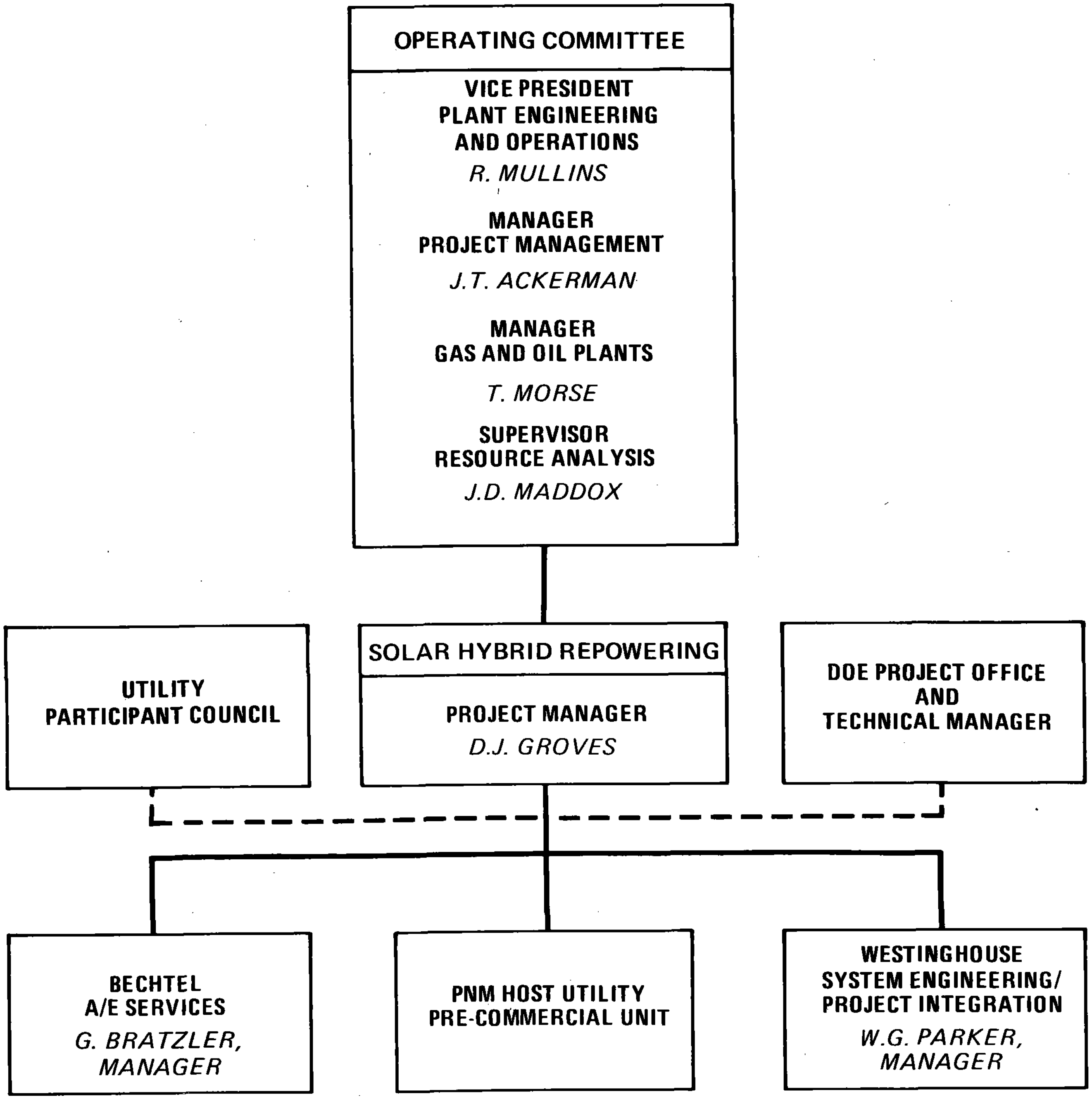


Figure 1.5-2
OVERALL PROJECT ORGANIZATION

2.0 SOUTHWEST COMMERCIAL MARKET EVALUATION

2.0 SOUTHWEST COMMERCIAL MARKET EVALUATION

An evaluation of the near term market potential for solar hybrid repowering of existing fossil-fueled electric power generating plants located in the southwestern United States has been completed. This evaluation was accomplished primarily by conducting a survey of southwestern utilities to identify potential candidate plants/units for solar hybrid repowering. In addition, the utility survey was augmented by a survey of candidate plants using Westinghouse market information and Federal Power Commission (now Federal Energy Regulatory Commission) Form 12 data. The nine state market survey included the following states in the Southwest: Arizona, California, Colorado, Louisiana, Nevada, New Mexico, Oklahoma, Texas and Utah. This survey was directed toward the potential repowering of oil/gas fired plants of less than 200 MWe in size. Environmental and safety issues were not addressed in the market survey. Finally, as part of the market evaluation, cost/benefit analyses have also been completed for the solar hybrid repowering concept as applied to selected southwestern utilities.

A description of the market survey is presented below in Section 2.1. Section 2.2 discusses the interest in the solar hybrid repowering concept as expressed by the utilities which were surveyed.

The details of the solar hybrid repowering potential in the Southwest are given in Section 2.3.

A description of the typical candidate unit for solar hybrid repowering was developed and is summarized in Section 2.4.

Presented in Section 2.5 are the results of the cost/benefit analyses which have been completed for the solar hybrid repowering concept.

2.1 MARKET SURVEY

The technical approach used in developing a comprehensive survey of the potential market for solar hybrid repowering involved the following:

- Review the results of previous PNM surveys.

- Conduct a literature survey of the utilities in the southwestern United States, based on Federal Power Commission Form 12 data and Westinghouse market information.

- Submit a data questionnaire on the PNM Solar Hybrid Repowering Project to 78 utilities in a nine state area of the Southwest.

The results from the previous PNM survey and the literature survey were used for: a) guidance in developing the utility questionnaire and b) information purposes to supplement the responses to the questionnaire.

Included in the utility questionnaire were the following three basic questions:

1) "Has your utility considered the possibility of solar power generation as a future alternative?"

2) "Would your company be interested in participating in a solar hybrid plant program if financial incentives made it equivalent or superior to existing generation alternatives?"

3) "Do you have any plans or interest in repowering any units of 200 MWe or less?"

The questionnaire also addressed the following general utility information:

- Approximate generation mix (oil/natural gas, coal and nuclear).
- Time of system peak.
- Availability requirements for peaking and intermediate units.

For each of the units less than 200 MWe owned and operated by the utility, the following information was requested:

- Rated size (MWe).
- Turbine type (Steam/reheat, Steam/non-reheat, Combustion, Combined cycle).
- Turbine inlet temperature.
- Turbine inlet pressure.
- Year built.
- Unit condition.
- Current use (Base, Intermediate, Peak, Standby).
- Estimated retirement.
- General plant location (Industrial, Suburban, Urban, or Rural).
- Land availability (Based on a requirement of approximately 6 acres of land per MWe for the solar collector field, there is sufficient vacant land near the plant to repower ____ percent of the unit).
- Distance from unit to above available land.

The above described market survey questionnaire was mailed to the appropriate investor owned, municipal, federal, state, district, and cooperative systems/utilities in the nine state area.

2.2 UTILITY INTEREST

The above market survey questionnaire was transmitted to 78 utilities in the southwestern United States. Of these 78, a total of 60 responses (77 percent) were received from the utilities. Considering the significant efforts required of these utilities to prepare the detailed information for their response to the questionnaire, including plant data on 379 units, PNM has concluded that most of the utilities in the Southwest are very interested in solar power and, in particular, solar hybrid repowering as a means to conserve dwindling fossil fuels.

As discussed above in Section 2.1, three basic questions were posed to the utilities. Shown in Table 2.2-1 are the responses to these three questions. For the first question on solar power generation as a future alternative, about half of the utilities indicated that they have considered this possibility. This response is indicative of the broad utility awareness of the solar electric power program being conducted by DOE and EPRI.

For the second question, 50 out of 53 utilities (94 percent) stated that their company would be interested in participating in a solar hybrid repowering program if financial incentives made it equivalent or superior to existing generation alternatives. This high percentage response was considered very favorable in support of the solar hybrid repowering program.

Referring to the third question on Table 2.2-1, 39 utilities out of 55 (71 percent) indicated that they do have plans or interest in repowering some of their units of 200 MWe or less. We believe this response is indicative of their recognition of the anticipated dwindling supplies of natural gas and/or fuel oil, coupled with the expected rapid escalation in the costs for these fuels. In particular, solar hybrid repowering was expressed by several of the utilities, in their comments on and cover letters to their questionnaire responses, as an attractive and logical alternative. In summary, the responses by the utilities to these three questions is very favorable in support of the solar hybrid repowering concept and indicative of the utility interest in the program.

Table 2.2-1

RESULTS OF UTILITY SURVEY QUESTIONS

Question	Number of Utility Responses*	
	Yes	No
Has your utility considered the possibility of solar power generation as a future alternative?	26	29
Would your company be interested in participating in a solar hybrid plant program if financial incentives made it equivalent or superior to existing generation alternatives?	50	3
Do you have any plans or interest in repowering any units of 200 MWe or less?	39	16

*Of the 60 utilities which responded to the survey, only 55/53/55 elected to answer these questions.

Table 2.2-2 delineates the breakdown by state of the number of utility responses, the number of candidate units of $\leq$200 MWe reported and the number of candidate units which are repowerable by solar, based on land availability. Note that the majority of the utilities are represented in the larger size and/or high population states of Texas, Louisiana, Colorado, California, New Mexico, Oklahoma and Arizona. A total of 379 candidate units of $\leq$200 MWe were reported by the 60 utilities. Of these 379 units, a total of 263 oil/gas fired units were reported as potentially repowerable to some percentage by solar, based on land availability. From the breakdown by state, Texas, California, Louisiana, New Mexico, Arizona and Oklahoma contain, in that order, the majority of the units which are repowerable. As elaborated on further in Section 2.3 below, the effective solar hybrid repowering potential in MWe and the percent repowering for each unit, based on land availability, needs to be considered in the selection of candidate units for solar repowering.

Table 2.2-2

UTILITY DATA QUESTIONNAIRE RESPONSE

State	Number of Responses	Number of Candidate Units Reported	Number of Candidate Repowerable Units
Arizona	5	30	22
California	7	122	61
Colorado	8	15	9
Louisiana	8	36	25
Nevada	2	9	9
New Mexico	6	22	22
Oklahoma	5	25	21
Texas	16	113	91
Utah	2	5	1
Others	1	2	2
Totals	60	379	263

2.3 SOLAR REPOWERING POTENTIAL IN THE SOUTHWEST

A summary of the solar hybrid repowering potential in the Southwest is presented in this section. A detailed presentation of the survey analysis and repowering potential is contained in Appendix B.

As discussed in Section 2.2, 60 utilities in the Southwest responded to the PNM utility survey questionnaire. In these responses, a total of 379 units $\leq$200 MWe were identified. Considering land availability, 263 of these 379 units were reported as potentially solar repowerable. Thus, the PNM utility survey responses for repowering covered approximately 35 percent of all the units in the data base established by the literature survey. These 263 units represent 47 percent of the total rated generating capacity in the literature survey.

The results of the literature survey and the PNM utility survey were summarized above in Section 1.1 (see Table 1.1-1) and this table is reproduced here as Table 2.3-1 for convenience. These results, coupled with the fact that approximately 77 percent of the utilities elected to respond to the survey (60 of 78 utilities), indicate a strong potential and definite interest for solar hybrid repowering in the southwestern United States.

2.4 CANDIDATE REPOWERING UNIT

Shown in Table 2.4-1 are the characteristics and general data of the typical candidate unit for solar hybrid repowering, as determined from the utility and literature surveys. The typical candidate unit is a non-reheat steam turbine with an overall power generating capacity between 10 and 50 MWe. The steam turbine inlet conditions include a throttle pressure range of 850 to 1250 psig and a turbine inlet temperature range of 900 to 950^{o}F at the nominal unit MWe rating.

For the general unit data, the typical candidate repowering unit is currently in good condition and was built (or went into initial service) between the years 1950 and 1960. Currently, the typical repowering unit is used for intermediate or peak load service and has an estimated 20 to 25 years of useful service before it's planned retirement. The typical candidate unit is located in a rural area suggesting, based on land availability, a repowering potential to a significantly high percentage (75 to 100%) of its current rating in MWe.

Appendix B summarizes the survey results which were used to derive the characteristics and general data for the typical candidate solar hybrid repowering unit.

Table 2.3-1

MARKET EVALUATION SUMMARY

Category	Number of Units	Total MWe
Potential Market Size (Rated MWe)		
Literature Survey	755	40954
Utility Survey	263	19273
Solar Repowering Potential (Effective MWe)		
Based on Land Availability	263	10699

Table 2.4-1

TYPICAL CANDIDATE UNIT FOR SOLAR HYBRID REPOWERING

• Unit Characteristics	
Type	Non-reheat Steam Turbine Unit
Rating	10 to 50 MWe
Turbine Inlet	850-1250 PSI/900-950^{o}F
• General Unit Data	
Year Built	1951 - 1960
Unit Condition	Good
Current Use	Intermediate/Peak
Location	Rural
Estimated Retirement	Before 2000

2.5 COST/BENEFIT ANALYSIS

The prospects of the integration of solar hybrid repowered plants into electric utility systems raise a number of questions as to their value, problems they might introduce, and requirements that should be placed upon them. A cost/benefit analysis is therefore being performed for selected southwestern utilities as part of the Phase 1 Technical and Economic Assessment Study of Solar Hybrid Repowering to assess the prospective value and impact of solar hybrid repowered plants upon electric utility systems. The analysis is being performed utilizing the methodology developed by Westinghouse as part of EPRI Contract RP648-1 entitled "Requirements Definition and Impact Analysis of Solar Thermal Power Plants".

Four southwestern utilities were selected for analysis on the basis of the results of the market survey. The utilities selected for analysis were:

- Public Service Company of New Mexico
- EPRI Synthetic Utility System E (Texas, Louisiana, and Oklahoma)
- Arizona Public Service Company
- Nevada Power Company

The primary effort has been directed toward the analysis of the first three utility systems listed above. The results of the analysis obtained to date are summarized below. A detailed description of the Analysis Methodology, Assumptions and results are presented in Appendix B.

Though the analysis is not yet complete, the results to-date are extremely encouraging for Solar Hybrid Repowering. The results are especially attractive on Systems where solar is displacing high cost fossil fuels such as in the case of the Texas Utility. Cost/benefit ratios for the various systems range from 1.37 to 0.91 depending on inputs.

Results from the cost benefit analyses also indicate solar hybrid repowering for the general time period from 1980-2000 is more cost effective than solar stand-alone plants.

Details of the analysis results are contained in Appendix B.

3.0 SOUTHWEST REPOWERING IMPLEMENTATION PLAN

3.0 SOUTHWEST REPOWERING IMPLEMENTATION PLAN

This section presents an implementation plan for solar repowering of existing oil- and gas-fired power plants in the capacity range of <200 MWe to achieve a fossil fuel displacement of about 0.1 quad per year by the 1980's. This plan includes the pre-commercial project proposed by PNM for implementing the solar hybrid repowering concept.

3.1 PLAN GOALS

The primary goal of this plan is to achieve early commercial status for the solar repowering technology in order that it may provide a share of U.S. energy supply commensurate with its potential. Implicit in this goal is the displacement of a significant portion of oil and natural gas fuels with solar energy at the earliest possible time. A potentially achievable goal of 0.1 quad per year displacement by the 1980's has been adopted as the immediate southwest regional repowering objective as the basis for this plan. For example, a repowering capacity of sixty-seven 50 MWe modules (3350 MWe) will be required to achieve this goal.

In addition to the above goal of energy displacement, the repowering program will also yield other benefits such as:

- Training a large number of engineering, construction, manufacturing, and operating personnel in the specialized requirements of solar thermal power plants

- Providing a significant market for heliostats and receivers, thereby creating incentives for the development of a competitive manufacturing base for solar related components and for manufacturing and design improvement which will result in lower plant costs

- Providing extensive operating experience with solar thermal hybrid plants, which will lead to design and operating improvements in future solar repowering projects and in other solar thermal power plants

- Providing the bases for standardization of performance requirements and design

- Contributing to the validation of solar power as an economic and desirable source of energy

3.2 SUGGESTED ACTIONS

The solar repowering program is an unprecedented undertaking both in scope and schedule. The achievement of 17,000,000 bbl of oil per year of fuel displacement (the equivalent of 3350 MWe) requires the repowering of 67 modules, each with an average of 50 MWe solar capacity or their equivalent at an estimated cost of about $3.5 billion. Assuming that the program is started in July of 1978, 90 months remain to accomplish the task by the end of 1985. The success of the program implementation depends on:

- Perceived sense of urgency and decisive government action

- Timely action by all participants to complete the assigned tasks

- Imaginative and innovative planning

- Energetic management of execution

PNM, assuming a utility viewpoint, has identified various actions which will enable the Solar Hybrid Repowering Plant to be implemented and achieve 0.1 Quad penetration by the end of the 1980's. Table 3.2-1 presents a matrix of group actions required for the first and second generation

Table 3.2-1

SOLAR HYBRID REPOWERING INCENTIVES

Unit Classification and Cost	Federal Government	State Government	Financial Institutions	Utilities	Consumers
Unit #1 PNM PRE COMMERCIAL 25 MWe $3000/KW	100% funding of solar increment Permit O&M charge in fuel adjustment clause (FERC)	Exemption from ad valorem tax for solar State provide land for nominal rental Permit O&M charge in fuel adjustment clause (PUC)	N.A.	Provide O&M for solar increment Provide regional representative site Upgrade and modify existing facility as necessary Exclude from rate base	Pay solar O&M vs. oil cost in fuel adjustment clause
Second to Fifth COMMERCIAL 50 MWe ea. $/KW to $/KW	Graduated funding of solar increment to meet estimated commercial $/KW Depreciation, etc. on net utility cost (federal funding handled as capital cost reduction) Permit O&M charge in fuel adjustment clause (FERC) 20% investment tax credit 15 year guideline for depreciation of 30 year operational plant Non-recourse loan guarantee Tax exempt loan (e.g. pollution control)	Exemption from ad valorem tax for solar State provide land for nominal rental Permit O&M charge in fuel adjustment clause (PUC) Investment tax credit on utility share	Slightly inverse 15 yr. operating lease on utility portion (may require IRS approval)	Provide O&M for solar increment Provide site and upgrade Determine solar plant value on specific system and fund utility portion Utility portion in rate base	Pay solar O&M vs. oil cost in fuel adjustment clause Base rate increment due to capital expenditure by utility
Units No. 6 and above until 1989[1] COMMERCIAL 50 MWe each $/KW or less	Same as above except 0% funding	Same as above on all	Same as above on all	Same as above on all	Same as above on all

[1] No credits if not installed by 1989

units, and the remaining commercial units, to reach this aggressive goal. A brief discussion of each group noted follows:

- The federal government will be required to fund the pre-commercial unit cost as it will not be cost effective to PNM and will be of a somewhat experimental nature. The solar increment of units No. 2 through 5 will be funded on a sliding scale as the DOE participation by means of federal grants approaches a minimum. O&M charges should be handled in the fuel adjustment clause. Strong financial incentives should be allowed such as 20 percent investment tax credit, 15 year depreciation (on 30 year life), nonrecourse loan guarantees, and tax exempt loans on the portion of financing similar to pollution control issues. The payback to utilities on the units requiring utility funding could be based on the cost of local generation less solar O&M at 50 percent of the solar theoretical capacity factor. Such an arrangement makes the investment more attractive. Additionally, an environmental statement with a time dependency factor, similar to the Alaskan Pipeline arrangement, will streamline environmental regulatory issues.

- The state government can aid in the financial attractiveness of solar hybrid repowering by exempting the solar increment from ad valorem taxes, as well as allowing a state investment tax credit on the solar increment. The state public utility commissions will be involved in permitting the O&M charge on the solar plant to be included in the fuel adjustment clause (versus oil cost). Equivalent value land parcels may be exchanged by the state for acceleration of the solar repowering penetration or state land adjacent to candidate units may be provided for nominal rental.

- The allowance for supplemental fuel oil firing of the unit should be permitted without further restrictions on SO_2, NO_x, or particulate emissions. This can assist the attractiveness of solar repowering as intermediate units currently burning natural gas, a majority of the time, will be penalized by pollution controls (PC) required when burning fuel oil. Fuel oil conversion of these units will require adding large oil storage capacity and possible equipment and facilities for oil blending for emission control. Additional stack interface equipment for PC may be required in certain regions.

- Financial institutions can provide assistance in commercialization by offering a slightly inverse "operating lease" for a duration of 75 percent of the solar equipment life. This will add to the financial attractiveness and reduce the apparent capital intensiveness seen in current policy. Section 3.9.2 further discusses this item. Prime loans could be provided for required manufacturing facility construction.

- Utilities must provide the required number of sites equivalent to 3350 MWe capacity with sufficient remaining life to be utilized for solar hybrid repowering. It is suggested that the utility upgrade and modify the existing facility as necessary, also providing O&M on the solar equipment. The pre-commercial unit would not be in the rate base; however, the utility funded portions of subsequent units would.

- The effect on consumers will increase in a positive fashion beginning with the pre-commercial unit and leading to a maximum at full commercialization. By paying for the solar unit O&M versus fuel oil cost in the fuel adjustment clause (FAC), it is anticipated that the overall effect on the consumer will be a large reduction in the rate of escalation for the FAC portion attributable to the repowered unit. There could be a downward adjustment in the FAC. There will be an increase in the rate base increment due to the capital expenditure by the utility; however, the overall effect of solar hybrid repowering for the commercially viable units is intended to be a reduction in the anticipated cost of generation by fuel oil and natural gas.

The intent of the guidelines noted above is to allow for the rapid commercialization of solar hybrid repowering while achieving a penetration of 0.1 quad. With such an aggressive goal, cooperation of all involved parties for implementing these items is essential, as is immediate action on the issues.

3.2.1 Program Elements

The elements essential to the program are delineated in this section.

Institutional: Prior to initiating large scale engineering and construction actions, a number of institutional issues need to be resolved. These issues include:

- Firm selection of the first five repowering units and sequencing the start of construction at these plants, which will serve as sites of the pre-commercial and commercial projects for design and construction improvements to support the subsequent projects
- Securing commitments by utility participants
- Tentative sequencing of the remaining projects
- Preparation of environmental statements and securing permits and licenses required for the program as well as for the individual repowering projects

- Organization of management and technical consulting teams including representation of utilities and the DOE

- Preparation of financial plans and negotiating the terms of government and utility contributions to financing of the program

- Negotiations with lending institutions to secure borrowed capital

Technical: This element includes those activities that will result in the construction and successful operation of the repowered units. Parts of this element include:

- Site selection and survey

- Site development

- Preliminary and detail engineering

- Procurement and expediting

- Construction and installation

- Startup and commissioning

- Technical consultation and technology transfer

Planning and Scheduling: This is a critical element consisting of:

- Careful identification of program activities and the time required for accomplishing them

- Development and upkeep of logic diagrams to sequence activities with consideration of constraining events

- Preparation and upkeep of multilevel program schedules

- Progress assessment and dissemination

Development Activities: Within the limits of time constraints, the regional solar repowering program will utilize the results of ongoing private and government sponsored development efforts. Conversely the program will result in information and data beneficial to other regional programs and to the solar thermal technology as a whole. Although no extensive development programs are possible within the tight schedule, this element contains such R&D aspects as:

- Development of generic plant and component designs with expectation of shortening the schedule of later plants by replicating the generic features as much as possible

- Development of construction and manufacturing techniques through experience in construction of the initial units that will reduce the cost and time requirement of constructing the later units

- Proof testing of heliostats, receivers, and control systems

- Use of the pre-commercial and up to four of the first commercial units, to verify operating procedures

Manufacturing and Support Facilities: Implementation of the repowering program will require approximately 500,000 heliostats. An assured supply of heliostats is obviously a major concern. This program element includes:

- Selection of a reference and a fallback heliostat design for the program

- Selection of qualified heliostat manufacturer(s)

- Securing manufacturing facilities

- Securing one or more sources of mirrors and small electric motors (this will probably involve expansion of present manufacturing facilities)

Manpower and Training: Although the solar thermal technology is, to a large extent, relatively simple, the design, construction and operation of solar hybrid units requires a degree of specialized expertise. At present, the number of skilled personnel experienced in the solar field is limited and will require expansion by a factor of about 20 to meet the needs of the solar repowering program. This element includes:

- Identification of personnel and corporate entities presently involved in solar related work
- Recruitment and training (mainly on the job) of additional technical personnel
- Retraining present plant operating personnel for solar hybrid operation (training in one of the first commercial units)
- Recruitment and training of additional operating personnel as needed.

3.2.2 Program Organization

To assure coordinated execution of a program with a large number of participants, it is essential to establish an effective central management group to which the participating utilities delegate the responsibility for plannning, technical direction and program control. The program organization is shown in Figure 3.2.2-1. A functional description of the major entities on the organizational chart is as follows:

Utility Participant Council (UPC): This group is staffed by the participating utilities for the duration of the repowering program, tentatively terminating when the last repowered units have achieved commercial operation. Through its major subdivisions, the UPC is responsible for:

- Top level planning and scheduling of the program
- Surveillance of the overall program and advice to the individual repowering projects
- Evaluation and selection of generic designs of systems or components
- Dissemination of technical information to other utility participants and to other interested parties
- Coordination of personnel training

Technical Consultants: The technical consultants are DOE, EPRI, SERI, and manufacturers representatives versed in the solar repowering and the utility power field. Their function will be to resolve technical issues as they arise during the engineering, construction, and early operating phases. It is intended that a technical representative of the operating organization of the particular utility where a repowering project is in progress serve as ex officio technical consultant on matters pertaining to that project.

Repowering Projects: Each project will be managed as a separate operation under a project manager. Since a number of these projects will proceed concurrently, particularly in the late phases of the program, it will be necessary to assemble several utility project teams early in the program. The teams will be structured to perform such functions as project management, system integration, engineering/design, construction management, etc. It is expected that the effectiveness of these teams will increase during the course of the program such that the time required for repowering

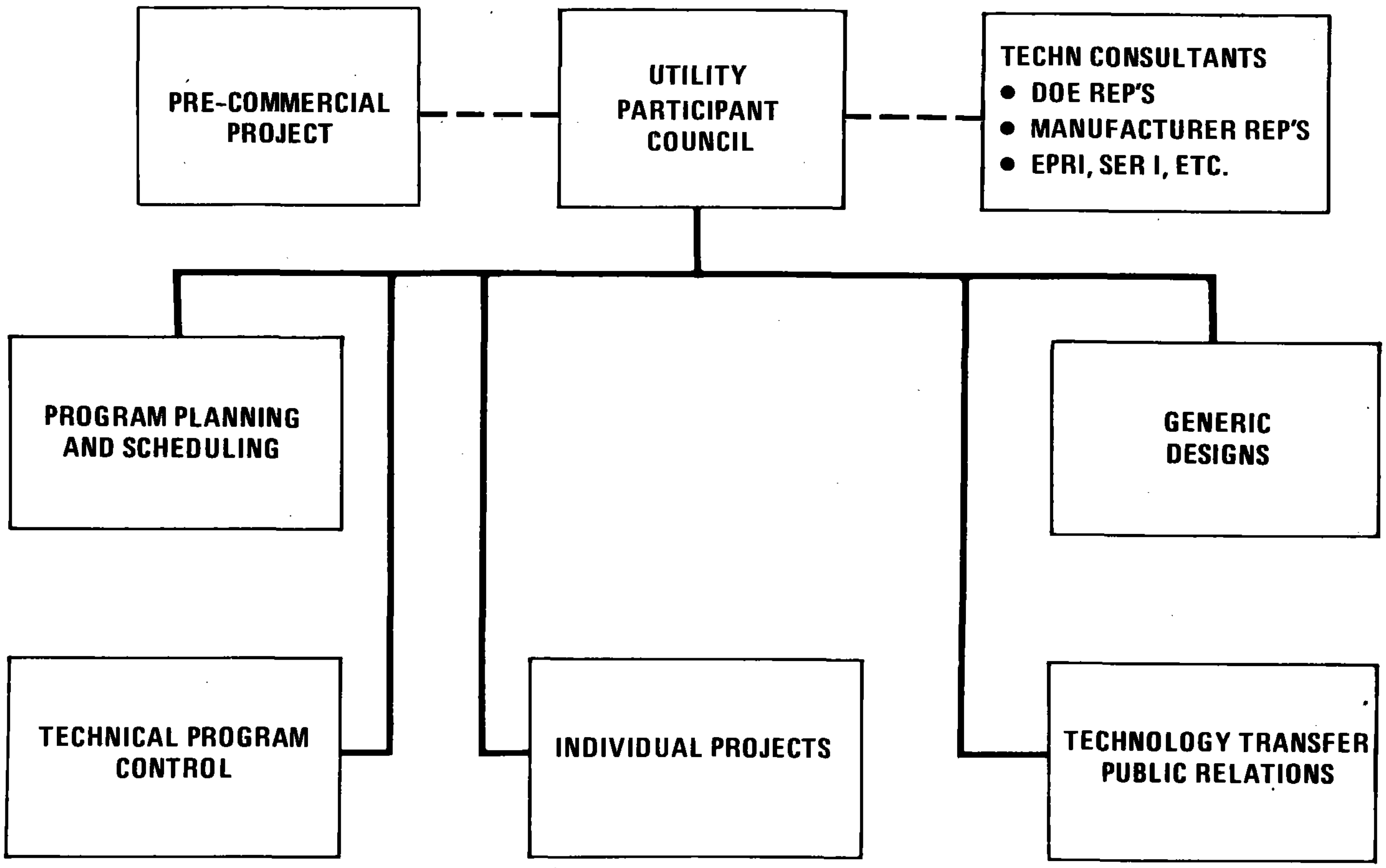


Figure 3.2.2-1
PROGRAM ORGANIZATION

a unit can be shortened in the later phases of the program. This approach to the repowering projects will:

- Maximize the use of innovative design and construction techniques developed during the course of the program
- Make best use of trained and experienced manpower
- Allow a rapid expansion of the pool of trained personnel
- Lay the foundation of an expanding national industrial potential to construct various facilities for solar energy conversion

3.2.3 Program Schedule

The schedule of the repowering program is influenced by the following considerations:

- The capability of manufacturers to satisfy the heliostat production rate requirement
- The paucity of technological bases, derived from actual construction and operating experience with solar thermal power plants (the Barstow plant will not be operational until mid 1981)
- The construction of solar repowering involves dispersed activities such as heliostat installation or pipeline construction, and concentrated activities such as the receiver tower construction and modifications to the existing fossil fired unit. This allows paralleling or "fast tracking" of the work
- The minimum disruption of the normal operation of the existing plant

- The program execution at several locations, requiring mobilization and demobilization for each project

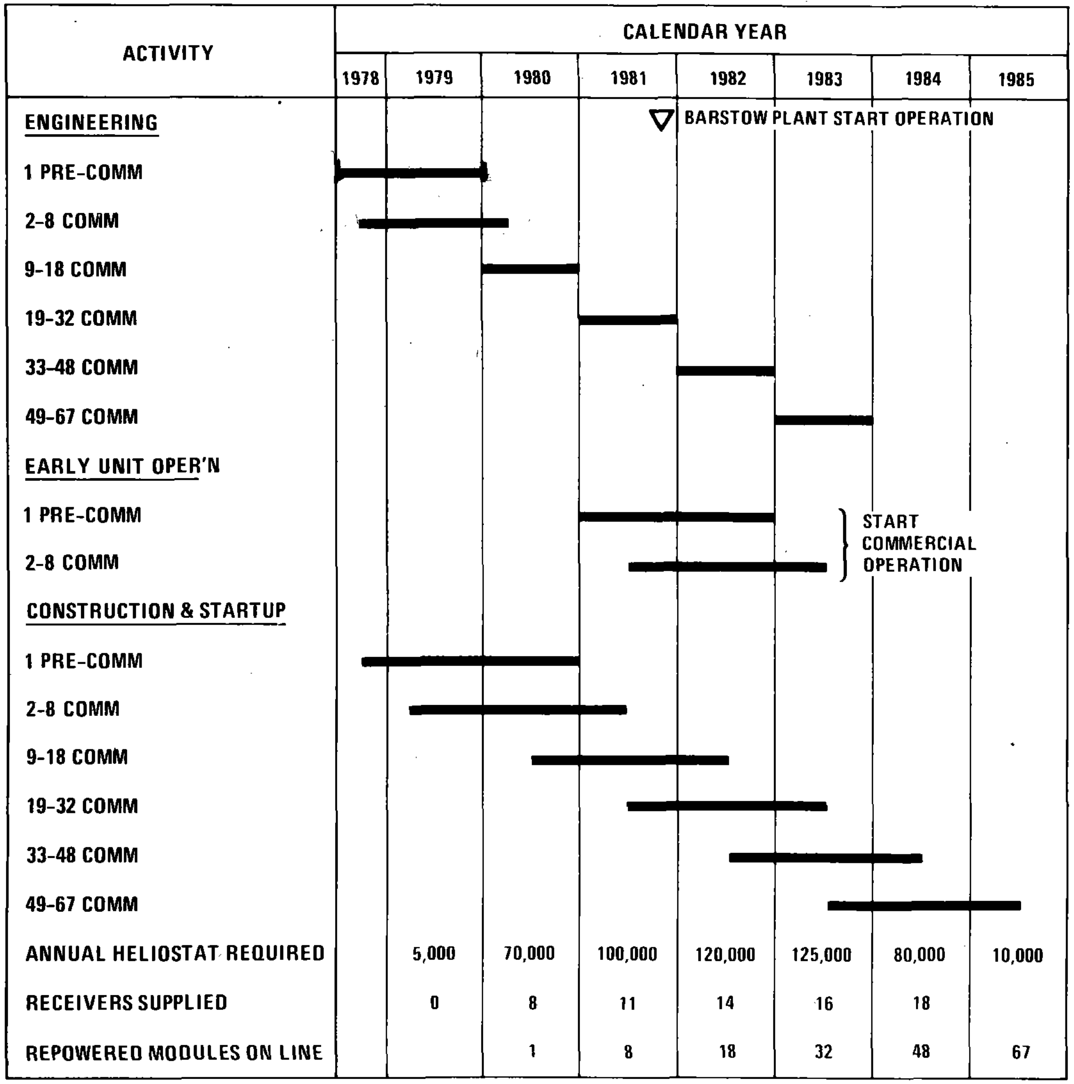
- Although the adaptability of the generic design is based on a solar displacement of 25 MWe, the program will cover a wide range of sites, plant designs, and capacities such that each repowering project will require some degree of unique engineering

Considering the degree of innovation and the technical and manufacturing uncertainties, it appears desirable to bracket the schedule spread by selecting 1985 as the target for program completion (shown in Figure 3.2.3-1). An alternative schedule, shown in Figure 3.2.3-2 leads to program completion in 1989. Both achieve the targeted 0.1 Q/year fuel displacement. Both require parallel and concurrent repowering of several units to achieve this goal. The technical, economic, and schedular risks leading to the program completion by 1985 are significantly higher as seen from these figures. One of the major tasks of the proposed implementation program will be to perform a detailed analysis of program schedule options including rigorous evaluation of the associated risks.

3.3 REPOWERABLE UNITS

PNM has identified a repowering capacity, which substantially exceeds the 3,350 MWe required to displace 0.1 Quad of fossil generation; these units are listed in Section 4. They are of the steam-electric type and were constructed in the 1950 through 1960 time period. They are generally in good condition at present, are scheduled for retirement before the year 2000, and are currently in intermediate or peak load service. The steam turbine inlet conditions vary considerably, but a typical unit would operate with an 800-1250 psi/900-950^{o}F nonreheat cycle with power ratings of 10 to 50 MWe.

PNM has also confirmed the findings of previous evaluations that solar repowering at the feedwater heaters has only limited fuel displacement



BENEFITS:

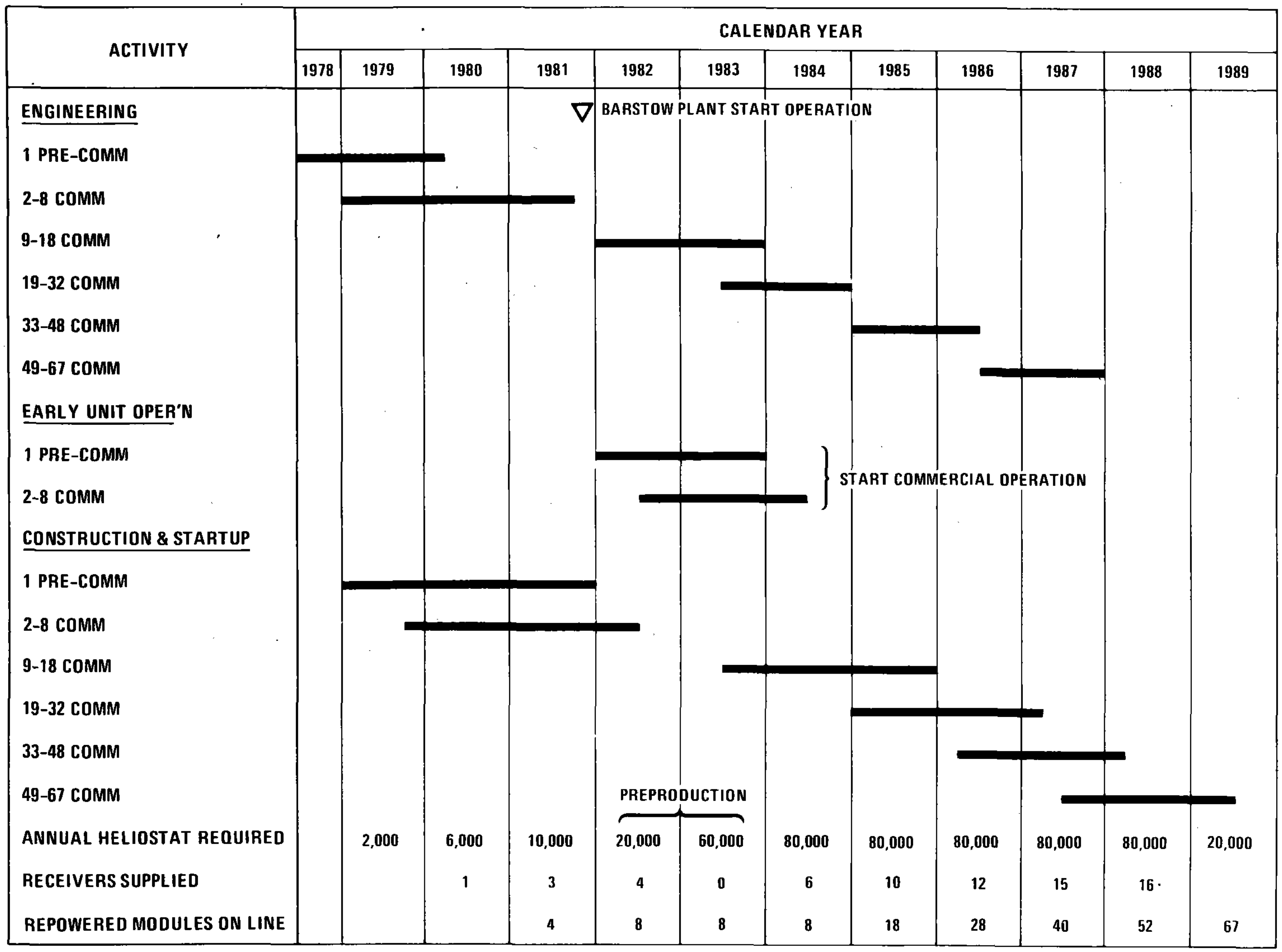
- MEETS .1Q/YEAR BY 1985 GOAL

PROBLEMS/RISKS

- RAPID HELIOSTAT MANUFACTURING CAPACITY BUILDUP
- REQUIRES RAPID MANPOWER EXPANSION
- BENEFITS OF PRE-COMMERCIAL PROJECT NOT AVAILABLE BEFORE MAJORITY OF PLANTS MUST BE COMMITTED
- MAY REQUIRE EXTENSIVE "FIXES" DURING STARTUP AND MAY NOT MEET TARGET SCHEDULE
- SIGNIFICANTLY WEAKER TECHNICAL BASIS
- RAPID INCREASE IN DEMAND FOR MIRRORS

Figure 3.2.3-1

REPOWERING PROGRAM SCHEDULE, (HIGHER RISK)
BASED ON 50 MWe MODULES



BENEFITS:

- MORE THAN 10 UNIT/YEAR EXPERIENCE BEFORE COMMITTING THE MAJORITY OF COMMERCIAL UNITS
- LESS STEEP BUILDUP OF HELIOSTAT, RECEIVER, MIRROR MANUFACTURING
- PERMITS ORDERLY AND COST EFFICIENT EXPANSION OF SOLAR POWER INDUSTRY
- MORE ASSURED ACHIEVEMENT OF .10/YEAR FUEL DISPLACEMENT

PROBLEMS/RISKS:

- DELAYS FUEL DISPLACEMENT CAPACITY (ACTUAL DELAY MAY BE LESS THAN INDICATED)
- ENGINEERING AND CONSTRUCTION MOMENTUM DISRUPTED DURING EARLY UNIT OPERATION

Figure 3.2.3-2

REPOWERING PROGRAM SCHEDULE (ASSURED APPROACH)
BASED ON 50 MWe MODULES

potential (less than 10 percent of boiler fuel input), whereas using solar energy at the boiler/ superheater could displace up to 100 percent of fossil fuel during daylight hours. Consequently, to maximize the fuel displacement potential, the generic repowered plant will have a solar central receiver operating as a boiler/superheater in parallel with the existing fossil fired boiler. Considering the compressed time frame, leaving practically no time window for development of new approaches or technologies, the repowering program will be based on the technology developed for the 10 MWe Barstow pilot plant.

3.4 DEVELOPMENT REQUIREMENTS

The major technical uncertainties of the program are associated with:

- The design and performance of the receivers.
- Performance and durability of the heliostats.
- Operation and control of the parallel fossil fired and solar steam systems.

To maximize the benefits from investment in the current development efforts in support of DOE's Solar Thermal Pilot Plant at Barstow, California, and to assure timely receipt of development results, the proof testing of the heliostats and receiver designs needed for the repowering program will be closely coordinated with the pilot plant program.

The program to develop operating procedures and a suitable control system will be conducted in conjunction with engineering and operating the proposed pre-commercial unit. The program will consist of:

- Computer simulation of various operating modes broadly categorized as fossil fired alone operation, solar alone operation, and combined solar, fossil operations to characterize system responses.

- Definition of the characteristics of a control system suitable to keep the unit parameters within safe operating limits.

- Operating the pre-commercial unit with a control system designed to meet these characteristics during the initial operation of the repowering project.

- Upgrading the system as needed based on the operating experience.

- To the extent feasible, generalizing the control system design to meet the needs of subsequent repowering projects.

It is noted that the control system requirements of solar repowering units appear to be sufficiently different from a solar stand along unit, and that this development program may best be conducted separately from the pilot plant related activities.

Although not part of a formal development program it is expected that the engineering, construction, and operation of repowered plants will inevitably result in improved designs and methodology that will permit more economical and accelerated conduct of the repowering program and will lower the cost of electricity from repowered units. Such innovations will be encouraged and information about them will be disseminated to participants in the repowering program as well as to other components of the national solar power program.

3.5 REQUIREMENTS FOR MANUFACTURING AND SUPPORT FACILITIES

This section presents the program requirements for manufacturing and support facilities.

3.5.1 Heliostat Manufacturing Facilities

Facilities for heliostat manufacturing must expand their production capacity from the projected 3,000 per year to 125,000 per year by 1983 to meet the targeted fuel displacement by 1985 or alternately 80,000 per year in 1984 to meet the 1989 targeted fuel displacement. Two potential approaches have been considered for heliostat manufacturing:

- Establishment of several central manufacturing facilities which will supply several repowering projects with assembly facilities at the site.

- Setting up temporary manufacturing facilities at the repowering project sites scheduling the availability of tooling and fixtures at each site for the duration of construction and providing replacement heliostats later on from one or more central facilities.

The former alternative was tentatively selected for this plan for the following reasons:

- The heliostat costs will probably be less since field shop labor is minimized.

- A more stable work force can be established, thus one may expect better productivity.

- Since most of the repowering projects are in rural areas the pool of labor to man the on-site fabrication facilities may be more difficult.

- Future use of abandoned fabrication facilities at each site is questionable.

It is recognized that a second tier manufacturing capability such as the production of fractional horsepower drive motors and heliostat mirrors will have to be available to furnish parts/sub-assemblies of heliostats.

3.5.2 Concrete Supply

Major amounts of concrete will be required for heliostat footings and for the receiver tower. Although heliostat foundation requirements are likely to vary from site to site, depending on soil and wind force and seismic conditions, their weights and shapes may lend themselves well for precasting at nearby concrete plants and truck transportation to the site. If the receiver towers are made of structural steel, foundation concrete can also be supplied by nearby concrete plants. If the towers are made with slip formed concrete in some locations the nearby concrete plant capacities may have to be supplemented, possibly with a batch plant at the site.

3.5.3 Other Support Requirements

It appears at this time that the industrial capacity to supply structural steel, heliostat frames, wiring, and similar construction materials may be made available without major difficulty.

3.6 MATERIAL REQUIREMENTS

Approximate annual material requirements for the repowering program assuming the 1985 completion goal are given in Table 3.6-1. When compared with the annual U.S. production of these materials it is evident that the repowering program will not require a significant portion of the U.S. productive capacity. However, the availability of low iron float glass in sufficient quantities for sixty-seven repowering modules requires further analysis.

Table 3.6-1

REPOWERING PROGRAM APPROXIMATE MATERIAL REQUIREMENTS

Material	10^3 Tons							U.S. Produced 103 Tons/Yr	Peak Program Demand % U.S. Produced
	1979	1980	1981	1982	1983	1984	1985		
Structural Steel	20	80	100	100	120	120	146	150,000	.09
Alloy Steel	.03	.12	.15	.15	.18	.18	.22	500	.04
Concrete	38	150	190	190	225	225	275	250,000	.01
Aluminum	.5	2	2.5	2.5	3	3	3.6	5,000	.07
Glass	4	16	20	20	24	24	29	4,000	.7
Insulation	.25	1	1.2	1.2	1.5	1.5	1.8	500	.4
Silver	small	.003	.004	.004	.004	.004	.0051	1.4	.4
Zinc	.5	2	2.5	2.5	3	3	3.6		small

3.7 LABOR REQUIREMENTS

The composition of the labor force required in the repowering program is significantly different from that used in conventional power plant construction. In particular, there is significantly lower percentage of such scarce skills as weldings and pipefitters in the labor force. However, the relative proportion of riggers, millwrights, and electricians is larger. The estimated manpower requirements for achieving the 1985 target are shown in Table 3.7-1. The initial manpower load per megawatt was assumed to be 75 man-years. It is expected that improvements in construction methods such as a higher degree of automation and experience factors will improve productivity and thus reduce this load by 50 percent in the year 1985. It is expected that some parts of the labor force will migrate from project to project, but a major fraction will be hired from the local labor pool. Therefore, the experience factor may be less than fully applicable. It is noted that the labor requirements for the program will remain relatively constant over the 6 year period of heavy construction.

Table 3.7-1

REPOWERING PROGRAM LABOR REQUIREMENTS

	1978	1979	1980	1981	1982	1983	1984	1985
Labor Loading (Manyear/MWe)	75	75	70	65	60	55	45	35
Work Force (Thousands)	.1	4	14	16	16	16	14	12

3.8 PROGRAM RISKS

The Solar Repowering Program will benefit the southwestern United States and the nation as a whole in terms of clean environment, job availability, industrial development, more secure energy supply, reduction of dependence on imported fossil fuels, shifting away from depletable energy sources, support for an orderly expansion and growth of local and regional economics, and increased governmental revenues. The program is not without risks, however. It represents a large scale implementation of an emerging technology, mainly solar thermal power generation. National interests require a very compressed schedule. Nevertheless, successful implementation of recent major programs employing new technologies, such as the Apollo space program, affirm the confidence in the feasibility of the proposed solar repowering program. An overview of the program risks, the consequences, and appropriate remedial actions is given in Table 3.8.1.

Particular consideration was given to the risks associated with the boot strapping nature of the project. As was indicated in Section 3.4, the program is being undertaken without the benefit of design construction and operating experience with comparable sized solar power plants. Previous investigations indicated that the greatest technical risks of the central receiver type solar systems are associated with the receiver and the heliostat control system. The schedular risks are connected to the development of adequate manufacturing capability for heliostats.

Technical Risks: The testing and development program with the once-through boiler type receiver will achieve a milestone in July 1978 with the delivery of the first panel for testing at the Solar Thermal Test Facility (STTF) near Albuquerque, New Mexico. In light of the repowering program schedule, it is probable that the receiver for the pre-commercial unit will have to be procured during the second half of 1979. The current receiver test program must, as a minimum, yield enough data by that time

Table 3.8-1

PROGRAM RISK ASSESSMENT (Sheet 1 of 2)

Risk	Remedial Action	Consequences
Technical Failures due to		
• Generic design defects	Redesign, retrofit already constructed items	Program delay, added costs, delay in achieving benefits, loss of public support and acceptance.
• Equipment failures	Repair defects, improve QA/QC program	
Schedular Delays due to		
• Inadequate planning	Revise priorities, replace program	Increased program cost, supplier financial losses, higher cost of power from repowered units, loss of public support, loss of program momentum, loss of priority status of program, delay in attaining program goals.
• Inadequate manpower	Intensify recruiting and training efforts, add incentives	
• Inadequate management	Reorganize structure, restaff	
• Inadequate financing	Rework financial plans	
• Institutional problems (licenses and permits)	Close management follow, intensified communication	
• Late equipment (heliostat, receiver) delivery	Accelerate expansion of manufacturing, multiple suppliers	
• Construction problems (weather, labor problems)	Initial agreements on jurisdiction, job definitions	

Table 3.8-1

PROGRAM RISK ASSESSMENT (Sheet 2 of 2)

Risk	Remedial Action	Consequences
Schedule Acceleration due to		
• Acute shortage of alternative fuel sources	Make program plans	Loss of efficiency due to "crash" programs
• Other, national interests		
Technological Breakthrough such as		
• Unforeseen design improvement	Adopt new technology to the extent feasible	Programmatic benefits (design innovations, etc.)
• Unforeseen advances in other energy sources	Adjust program to meet changing demand for solar power	

to support a decision whether to proceed with the receiver procurement using the current design concept. The current receiver test program may:

- Show the design to be fully acceptable for widespread use, in which case this technical risk is eliminated.

- Show that the design is acceptable but at a lower power or temperature rating, in which case the program may proceed and specify a derated system until the deficiencies are corrected, and presumably by retrofitting, the planned solar utilization can be achieved.

- Show that the design is untenable, which will result in delays to the program until a suitable alternate design becomes available.

In any case, the conclusive proof of the workability of the receivers will be furnished by actual operation in the repowering projects.

Several alternative designs have been proposed for heliostat control incorporating either central computer control or local control at each heliostat. The programmatic risks of selecting either of these concepts may be minimized by specifying different approaches for the first five units and adopting the most suitable ones for the remainder of the repowering projects. Economic risk to the program will be limited to the cost of retrofitting those units which were equipped initially with control systems which were later found to be inadequate.

Schedular Risks: The possibility of expanding the heliostat manufacturing capacity to meet the demand of the repowering program is one of the major schedular risks. Assuming that a reference and a fallback design can be selected by mid-1979, contracts must be let for supplying these heliostats at an initial rate of about 20 per day starting about May of 1979. The production rate for the repowering program must be expanded to about 200-400 per day within the next three years.

Tooling used in heliostat manufacturing is comparatively simple and no long lead machine tooling is required. Modern mass production techniques can be utilized in setting up production lines. However, assured suppliers for mirror glass and fractional horsepower motors (focusing drive motors) must be established.

The Role of Early Commercial Units in Mitigating Program Risks:

Design, construction, and operation of the first units will contribute significantly to:

- Reduction of technical risks of solar repowering as described above

- Development of new and cost effective methods to improve the probability for successful completion of the overall repowering program

To accomplish these objectives, the first units should log significant operating time before the remaining repowering projects are committed to construction. In order to fully benefit from the experience and data from the first units, the 0.1 quad per year fuel displacement target would have to be timed for 1989. This course of action would minimize the program risks. The schedule constraints of the 1985 program completion target require that some percent of the repowering projects be committed to construction before the first units achieve operating status. Data from the first units would still be of significant value but design modifications would require retrofitting of the already committed design.

3.9 FINANCIAL PROGRAM PLANNING

This section presents an evaluation of the economic incentives required to achieve breakeven through solar hybrid repowering and the development of an optimum financing package to commercialize the concept.

3.9.1 Evaluation of Economic Incentives

PNM has conducted a preliminary economic analysis to determine the capital cost of solar hybrid repowering for economic viability. The total fuel savings that could be expected over the life of the plant was calculated for 20- and 30-year plant lives and two different fuel escalation rates. Historic PNM oil fuel costs have escalated at greater than 15 percent per year since 1963. Therefore, the first escalation rate chosen for the analysis was 16 percent per year through 1985 and 7 percent per year thereafter. As a comparison, the second escalation rate chosen was a constant 7 percent per year. The average price of 217¢/MMBtu paid for fuel oil by the major solar hybrid repowering candidate units was chosen as the reference fuel cost. This cost is an average of 16 candidate units now burning fuel oil. The remaining units are now burning gas at a slightly lower cost, but they will be forced to convert to fuel oil or another source in the near future. An average heat rate 11,000 Btu/kWh was used which corresponds to the heat rate at PNM's Reeves Station.

Based on a capacity factor of 23 percent, the yearly fuel costs assuming the above escalations were calculated. These yearly costs were then present valued back to a common year at a cost of money of 11.0 percent per year. These costs represent the fuel cost savings that could be achieved with a solar hybrid repowering installation operating at a 23 percent capacity factor.

The results of the above analysis were as follows:

FUEL OIL SAVINGS BY SOLAR HYBRID REPOWERING

Plant Life (years)	Escalation (percent)	Summation of Present Worths of Fuel Savings ($/kW) 1981 $
20	7	910
30	7	1168
20	16/7	1752
30	16/7	2285

Based on an estimated operating and maintenance (O&M) cost of three mills/kWh in 1981, the total present value of the O&M costs during the life of the plant were calculated. This was done assuming a 7 percent per year escalation rate. The total present value of the O&M costs for a 20 year plant life is $87/kW (1981 dollars) and for a 30 year plant life it is $112/kW (1981 dollars).

Using the PNM Minimum Revenue Requirements Discipline (MRRD) computer program, the summation of the present worth of the minimum revenue requirements for an operating lease was calculated. The PNM developed MRRD program computes the year by year revenue requirements given various financial and tax data. The runs were completed using a base case of $1,000/kW, including AFDC of $90/kW, as the capital cost. The program also present valued the yearly revenue requirements back to a common year at a cost of money of 11.0 percent.

Section 3.2 presented various incentives identified by PNM to allow for financial equivalency or superiority for the concept as compared to other alternative generation sources. These factors were assumed applicable in this analysis. The total State and Federal investment tax credit was varied between 20 to 25 percent. No property tax was included and two costs of money were analyzed. The first cost of money used was very low which approximates a tax exempt bond type of financing. The second cost of money used was higher and approximated a loan guarantee type of financing.

As a comparison, present generating plant capital expenditure calculations are based on a Federal Investment tax credit of 10.0 percent and a mill levy property tax based on the assessed value of the plant. This capital structure can provide for a cost of money of approximately 11.0 percent.

Based on this information the results were as follows:

Plant Life (yrs)	Type of Financing	Combined Federal and State Investment Tax Credit (%)	Summation of Present Worth ($/kW) 1981
20	Tax Exempt	20	739
20	Loan Guarantee	20	803
20	Tax Exempt	25	682
20	Loan Guarantee	25	742
30	Tax Exempt	20	739
30	Loan Guarantee	20	816
30	Tax Exempt	25	686
30	Loan Guarantee	25	759

The respective O&M total present worths were then added to these present worths and compared to the respective total present worth figures of the fuel cost savings. By comparing the total present worth of the fuel savings to the total present worth of the O&M and capital cost, the breakeven capital cost figures were calculated and are presented in Table 3.9.1-1.

The MITRE Corporation of McLean, Virginia completed a study on March 3, 1978, which equates the capital cost of a solar hybrid repowering installation to the number of modules installed. The MITRE costs were in 1976 dollars; therefore, the above costs were de-escalated at a rate of 7 percent per year to 1976. These costs are plotted on the curves developed from the MITRE study in Figures 3.9.1-1 and 3.9.1-2. The results show that with additional financial incentives, such as a high investment tax credit and a low cost of money, the capital cost of solar hybrid repowering could equal the calculated breakeven cost at less than five units. Assuming a plant life of 20 years and low future fuel escalation, the additional incentives explored resulted in a capital cost represented at module 60 or greater on the MITRE curve.

Table 3.9.1-1

BREAKEVEN CAPITAL COSTS FOR SOLAR HYBRID REPOWERING

Plant Life (yrs)	Fuel Escalation (%)	Type of Financing	Combined ITC (%)	Breakeven Cost ($/kW) 1981$	Breakeven Cost ($/kW) 1976$
20	7	Tax Exempt	20	1113	790
20	7	Tax Exempt	25	1207	857
20	7	Loan Guarantee	20	1025	728
20	7	Loan Guarantee	25	1109	788
20	16/7	Tax Exempt	20	2250	1604
20	16/7	Tax Exempt	25	2448	1738
20	16/7	Loan Guarantee	20	2073	1472
20	16/7	Loan Guarantee	25	2244	1593
30	7	Tax Exempt	20	1429	1014
30	7	Tax Exempt	25	1539	1093
30	7	Loan Guarantee	20	1298	921
30	7	Loan Guarantee	25	1391	987
30	16/7	Tax Exempt	20	2940	2087
30	16/7	Tax Exempt	25	3167	2250
30	16/7	Loan Guarantee	20	2650	1890
30	16/7	Loan Guarantee	25	2863	2033

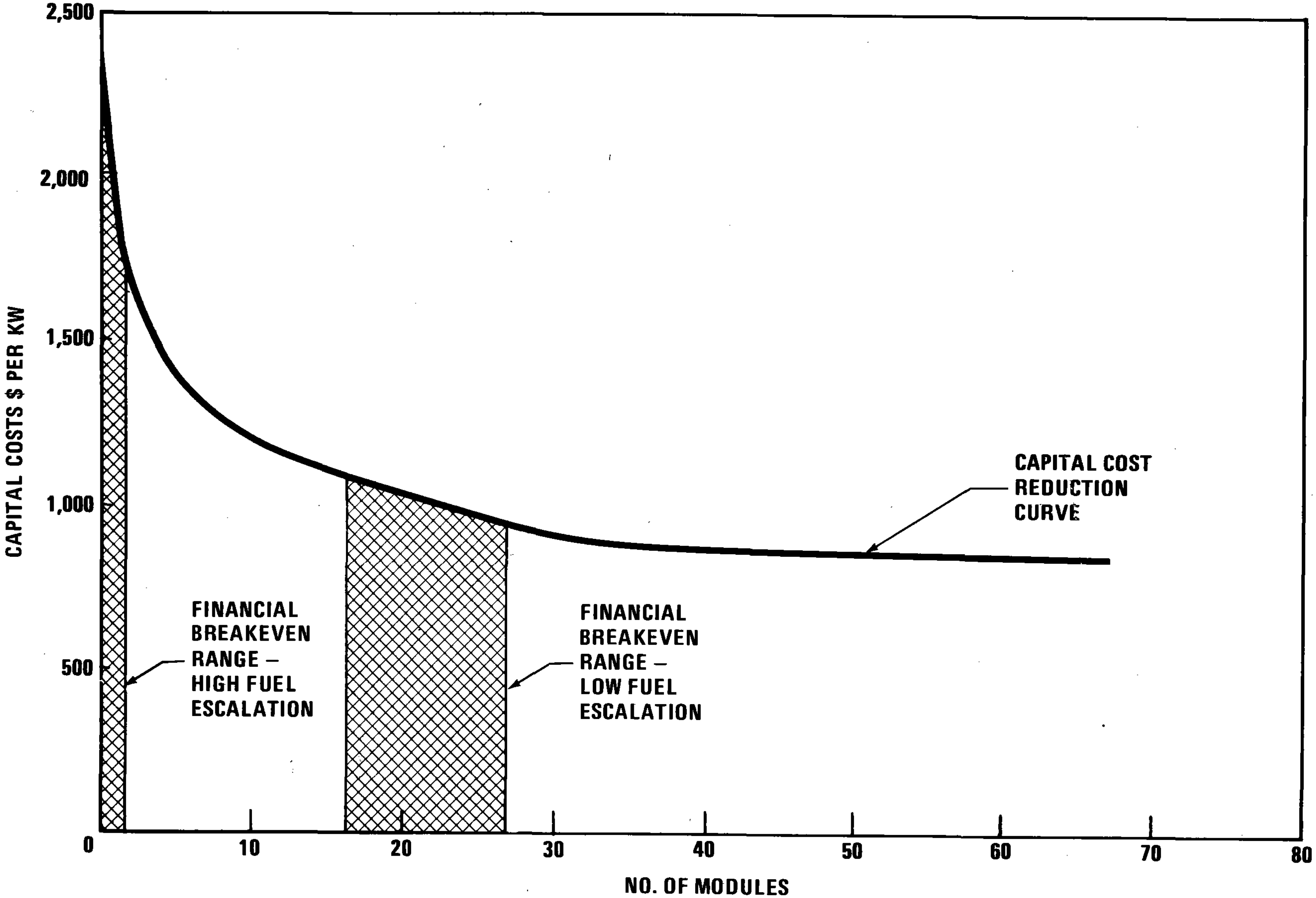


Figure 3.9.1-1
30 YEAR PLANT LIFE "BREAKEVEN" COSTS

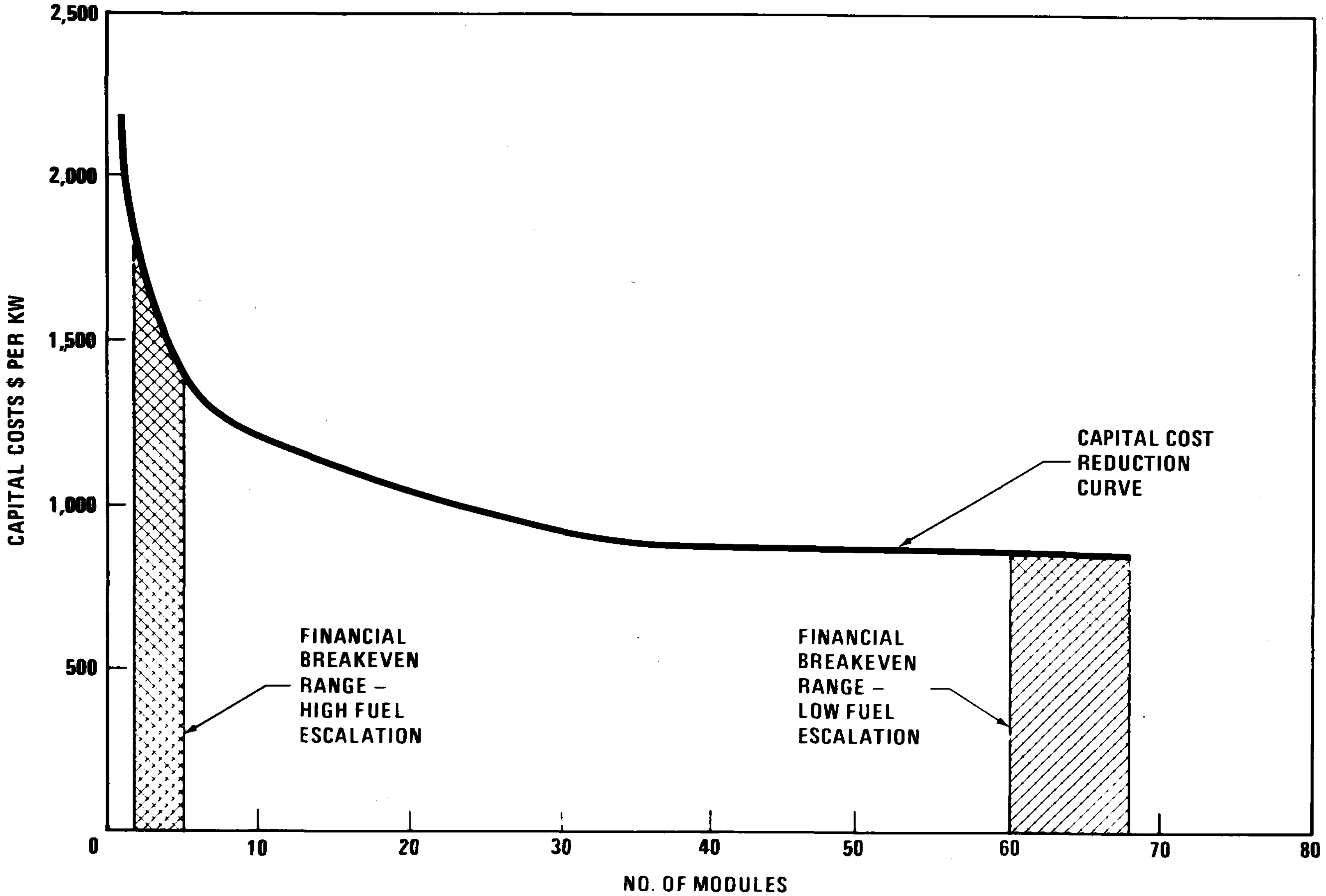


Figure 3.9.1-2
20 YEAR PLANT LIFE "BREAKEVEN" COSTS

3.9.2 Optimum Financing Package

The successful commercial application of solar hybrid repowering will require the development of an optimum financing package. In the early phases of the commercial project, PNM will investigate such a financing program.

Initial studies indicate that while incentives in various forms may be required, a major goal will be to fully investigate project leveraged leasing. In a leveraged lease, the equipment is purchased by a financial institution, acting as an equity investor, or by a group of such institutions, which advance approximately 25-40 percent of the total cost of the equipment. The equity investors are also variously called the "owners" or the "equity-participants." The remainder of the purchase price is raised through the sale of fixed interest rate long-term mortgage debt, usually to institutional investors such as life insurance companies or employee pension funds. The equity-participants are not liable on the debt, the mortgage lender being secured by a lien on the equipment and a pledge of the rents. Tax-exempt bonds should be considered to provide the debt portion of a leveraged lease. This would reduce the cost because of leverage, that is the ratio of debt to equity investment, may vary but could be expected to be about three-to-one. The tax benefits of ownership, including Investment Tax Credit and accelerated depreciation based on the total cost of the equipment, including that financed by the debt, are available to the equity-participants. In addition, the equity-participants may deduct the interest expenses on the mortgage debt. By making the tax benefits of ownership available to the equity-participants, the Leasee can obtain an extremely attractive financing rate (in the form of a low rental rate)--a rate that is less than the interest rate payable under a conventional bank term loan or the interest rate payable when funds are raised in the public or private debt market.

In a leveraged lease the yield to the equity-participants is derived to a considerable degree from the tax benefits such as Investment Tax Credit and depreciation. It is essential to structure the transaction so that the Internal Revenue Service will be willing to rule that the transaction constitutes a "true lease" in which the equity-participant is the original owner of the equipment and the Leassee, that is, the user of the equipment, is entitled to expense the rent. It is necessary to avoid having the IRS consider the transaction a constitional sale, i.e., tantamount to ownership by the utility. Failure to establish that the transaction is a "true lease" produces precisely the opposite of the desired result, that is, it leaves the equipment user with the unwanted tax benefits and turns the equity-participants into lenders. Therefore, it may be necessary to seek Federal Legislation to insure Solar Hybrid Repowering Projects will be treated as special case "true leases."

A further advantage to an operating lease is that the utility does not have to raise the capital and include a large capital expenditure in its rate base. This is an attractive arrangement from the standpoint of the Public Utility Commissions. As a result of this type of arrangement, customers would pay less today for their electric power than future customers. This is because a lower priced fuel would be displaced today than would be displaced in the future. Matching the timing of the costs and benefits is additionally attractive.

3.10 UTILITY INVOLVEMENT/COMMITMENTS

A utilities participation plan has been implemented by PNM to achieve the objectives of the solar repowering program presented in the above sections. The details of the plan are discussed in Section 4.0.

3.11 HELIOSTAT MANUFACTURING COMMITMENT

The ambitious but attainable goal for the installation of approximately 3,500 MWe of solar hybrid repowering capacity will require a large commitment by the manufacturing community. The implementation of the program plan presented herein will require the utilization of a substantial amount of materials, labor, and capacity. The pacing item, in terms of meeting the market requirement, is currently considered to be the heliostat.

Five hundred thousand heliostats are required for meeting the 0.10 Quad oil displacement goal. The cost of heliostats based on typical industrial cost reduction learning curves for this production volume (heliostats could constitute 50 percent of the solar repowering unit capital investment) has been studied. The results indicate that a significant commitment of government capital might be necessary to promote installation of the required manufacturing capacity.

PNM directly contacted eight potential heliostat manufacturers (Table 3.11-1) to explore these questions:

1. Would you commit the required capital for heliostat plant(s) construction if the market previously noted was guaranteed by the DOE?

2. If not, how much front-end capital from DOE would be required for your committal? At what production level would you commit?

3. Address any material and/or labor shortages you might envision with such a rigorous schedule and output.

4. What are the heliostat costs you predict for this scenario, as close to total installed in $/m2 as currently available?

PNM established the basic volume production ground rules noted in Table 3.11-2. The only variance from the previously mentioned study is the 1981 production rate was modified to reflect a more realistic 25 MWe unit evolving from the 10 MW Pilot Plant design. Site information was identified by state as noted in Table 3.11-3.

Table 3.11-1

POTENTIAL HELIOSTAT MANUFACTURERS CONTACTED

Boeing
Ford
General Electric
Lockheed
MDAC
McDonnell Douglas
Solaramics
Westinghouse

Table 3.11-2

HELIOSTAT PRODUCTION RATE

0.1 QUAD PER YEAR DISPLACED BY 1985

-35 m^2 glass mirror design heliostat

-7,500 heliostats = 50 MWe repowering

Year	Production Rate[1], 103/Year	
1981	4.300	*
1982	15 000	**
1983	38 000	**
1984	113 000	**
1985	330 000	**

*Installation begins January 1980, ends January 1981, at PNM Reeves Station for 25 MWe facility.

**Average production for year.

[1]Linear increase in production rates - used as extreme case

Table 3.11-3

SITES BY STATE FOR SHIPPING/
MANUFACTURING ESTIMATES

Arizona	7
California	2
Louisiana	6
Nevada	6
New Mexico	3
Oklahoma	3
Texas	27
Utah	1

These sites are assumed to be greater than 50 MWe in size and less than 200 MWe. They are assumed to be random over the commercialization time frame.

Seven manufacturers elected to respond. Their specific replies are provided to DOE in the Business Volume of this proposal. These responses are to be considered as confidential, proprietary information and not distributable outside of DOE and its reviewing agencies.

The heliostat manufacturers indicate if the DOE guarantees the utility site bank already identified by PNM, and initiates the progressive program plan noted herein to attain rapid financial competitiveness of the concept, manufacturers would commit the front-end capital required for construction of the required manufacturing facilities, and little or no DOE front-end monies would be required. It is also indicated that the commercial application of heliostats can be accomplished, with anticipated labor and material supplies, at a cost as low as $84/m2 installed. The manufacturer survey results, therefore, indicate the DOE should proceed with the program plan noted herein and obtain a commitment of various utility sites for the concept demonstration and commercial applications.

PNM will issue a standard utility bid request for heliostats, and procure them for the project from the most technically capable and cost effective manufacturer. The bid guidelines can be provided as a standard to other commited utilities to streamline their procurement procedures and, hence, the rapid commercialization of solar repowering. DOE or their technical advisor's assistance will be requested for this procurement.

4.0 UTILITY PARTICIPATION PLAN

4.0 UTILITY PARTICIPATION PLAN

PNM has initiated an implementation plan to achieve the goal of 0.1 Quads/year fossil fuel displacement through solar hybrid repowering by the late 1980's through participation of utilities located primarily in the southwestern United States. The plan will involve the greatest number of utilities directly in the pre-commercial project and thereby minimize the commitment time for additional solar repowering of existing gas- and oil-fired units. The proper financial incentives must (as described in Section 3.0) be provided by the government to assure the economic competitiveness of the concept. The plan provides for utility participation in the proposed pre-commercialization project in either the "Supporting Utility Program" or as members of the "Utility Participant Council."

PNM recognizes that one of the most important objectives of the pre-commercialization project is the timely dissemination of the progress and results of the project to the utilities committed to the solar repowering program. The direct participation by the utilities in the project will assure that the required technical expertise within the utility industry exists in order to achieve this aggressive fossil fuel displacement goal. In addition, direct utility participation, particularly during the engineering stage, is mandatory to assure the design of the pre-commercial unit does not restrict its applicability to other utility systems.

This section of the proposal presents the utility participation plan being implemented by PNM. The rationale for selecting specific utilities to participate in the program is discussed. The responses PNM has obtained to date by contacting the various utilities are presented. The plan for obtaining utility commitments to the solar repowering program is outlined, and the Supporting Utility Program and the Utility Participant Council Program are described in detail. In addition, PNM recognizes the importance of disseminating information to the related industries and to the public. A plan is presented to achieve this objective.

4.1 UTILITY SELECTION

PNM desires to provide any interested utility with the opportunity to participate in the solar hybrid repowering program and, in particular, the Pre-commercialization Project. The market evaluation discussed in Section 2.0 identified a number of specific utilites located in the Southwest having candidate units for solar repowering. Table 4-1 summarizes the utilities by state and the candidate units (>50 MWe) for the solar hybrid repowering program. Many of these utilities have already indicated their interest by virtue of their response to the data questionnaire submitted as part of the market evaluation. These utilities, therefore, are the basis for the current list of utilities from which PNM is actively seeking commitments. PNM has contacted the following utilities to participate in the program:

- Arizona Public Service Co.
- Central and Southwest Services
- El Paso Electric Co.
- Gulf States Utilities
- Houston Lighting and Power
- Nevada Power Company
- Oklahoma Gas and Electric
- Pacific Power and Light
- Public Service Company of Oklahoma
- Public Service of Colorado
- Salt River Project
- San Diego Gas and Electric
- Sierra Pacific Power Co.
- Southern California Edison
- Southwestern Public Service Company
- Texas Utilities Co.
- Tucson Gas and Electric
- Utah Power and Light Company

A number of responses have already been obtained. The letters which follow are indictive of the strong support for this program. Additional responses received to date are included in Appendix A.

Houston
Lighting
& Power
Company

Electric Tower
P.O. Box 1700
Houston, Texas 77001

APR 2 4 1978

April 19, 1978

Mr. J. D. Geist, President
Public Service Company of New Mexico
P. O. Box 2267
Albuquerque, New Mexico 87103

Dear Jerry,

As you know, Houston Lighting & Power Company has long been interested in Solar Hybrid Repowering concept. We have appreciated your efforts in this area of solar energy application with the Department of Energy.

Because of the groundwork which your company has laid and the extreme constraints required, the placement of the first demonstration site within the PNM system seems not only logical but necessary if the 1985 guidelines are to be met.

Houston Lighting & Power has existing gas fired facilities which may be conducive for the conversion to a solar powered operation. Because of our commitment to Solar Hybrid Repowering, we would wish to take part in an advisory council with respect to the conversion of your existing gas and oil fired generating unit. We would do this with the prospect of considering the conversion of one of our existing facilities whenever this seems feasible and acceptable terms, conditions, and costs are defined.

Sincerely yours,

D. D. Jordan
President and Chief Executive Officer

DDJ:lw

NEVADA POWER COMPANY
FOURTH STREET AND STEWART AVENUE
P.O. BOX 230 • LAS VEGAS, NEVADA • 89151

April 17, 1978

APR 2 1978

Mr. J. D. Geist
President
Public Service Company
of New Mexico
Post Office Box 2267
Albuquerque, NM 87103

Dear Mr. Geist:

Our Company has been interested in Solar Hybrid Repowering and appreciates the opportunity to participate and thereby accelerate the commercialization of solar energy by way of your ongoing study for the Department of Energy.

Knowing the significant groundwork Public Service of New Mexico has laid and the time constraints required, the placement of the first demonstration site within your Company's system seems logical and necessary. As you are aware, our Company has existing oil and gas steam units (Clark Station and Sunrise Station) which could be converted for solar repowering operations.

Because of our interest in Solar Hybrid Repowering, we again reiterate our desire to take part in an advisory council on conversion of one of your existing oil and gas fired generating units.

We do this with the prospect that our existing units may some day be converted for a demonstration or commercial solar repowering, when conditions and costs are better defined.

Solar repowering appears to be viable; however, numerous questions must be answered by demonstrations before significant amounts of oil and gas can be replaced by solar energy.

Sincerely,

A. E. Pearson
President

JWA:sm

PUBLIC SERVICE COMPANY OF OKLAHOMA
A CENTRAL AND SOUTH WEST COMPANY

P.O. BOX 201 / TULSA, OKLAHOMA 74102 / (918) 583-3611

Martin E. Fate, Jr.
Executive Vice President

APR 24 1978

April 21, 1978

Mr. J. D. Geist, President
Public Service Company of New Mexico
P.O. Box 226
Albuquerque, New Mexico 87103

Dear Mr. Geist:

Public Service Company of Oklahoma has maintained an interest in the efforts toward Solar Hybrid Repowering since its introduction. Even by our limited participation, we feel we have, at least to some extent, enabled the early commercialization of the use of solar energy in electric generation. New Mexico is to be congratulated on your ongoing study for the Department of Energy.

If solar power is to become a viable alternate energy source, it is crucial that we capitalize on the groundwork PNM has laid to move toward a pre-commercial application in the very short term.

As you may be aware, Public Service Company of Oklahoma may have present facilities which would lend themselves to a solar repowering application. Because of this, we would like to continue to take part in an advisory council concerned with the conversion of existing fossil-fired generating units in order to be aware of the conditions and costs of solar repowering as they become better defined through the pre-commercial project contemplated by PNM. This then would provide us with a substantial understanding, enabling a thorough evaluation of any conversion potential that our company may have.

With the apparent long-term development needed to utilize solar energy in providing electricity, it appears that the solar hybrid repowering concept is the most viable near-term technology available.

Sincerely,

Martin E. Fate Jr.

MEF:lh
cc: R.O. Newman

Table 4-1

MAJOR SOLAR HYBRID REPOWERING CANDIDATE
UNITS ≥50 MW BY STATE (Sheet 1 of 4)

State	Utility	Total Repowering Capacity	Unit	Size* (MWe)	Location
Arizona	Tucson Gas and and Electric	580.0	Irvington 1	75	Tucson, Arizona
			Irvington 2	75	
			Irvington 3	75	
			Irvington 4	165	
	Arizona Public Service Co.	189.0	Saguaro 1	99	Red Rock, Arizona
			Saguaro 2	99	
	Arizona Electric Power Cooperative	75.0	Apache 1	75	Cochise, Arizona
California	Southern California Edison	218.6	Coolwater 1	65	Dagget, California
			Coolwater 2	81	
Louisiana	Gulf States Utilities	492.0	Nelson #1	114	Westlake, Louisiana
			Nelson #2	114	
			Nelson #3	163	
			Willow Glen #1	163	St. Gabriel, Louisiana
	Cajun Electric Power Cooperative	230.0	Cajun No. 1 Unit No. 1	115	New Roads, Louisiana
			Cajun No. 1 Unit No. 2	115	
Nevada	Sierra Pacific Power Co.	387.8	Tracy #1	55	Sparks, Nevada

*Units >50 MWe only

Table 4-1

MAJOR SOLAR HYBRID REPOWERING CANDIDATE
UNITS >50 MW BY STATE (Sheet 2 of 4)

State	Utility	Total Repowering Capacity	Unit	Size* (MWe)	Location
Nevada, (cont'd)			Ft. Churchill #1 Ft. Churchill #2	114 114	Yerington, Nevada
	Nevada Power Company	278.0	Clark #2 Clark #3 Sunrise #1	72 73 85	Las Vegas Nevada
New Mexico	Public Service Company of New Mexico	297.0	Reeves #1 Reeves #2 Reeves #3	50 50 75	Albuquerque, New Mexico
Oklahoma	Western Farmers Electric Cooperative	421.0	Mooreland #1	50	Mooreland, Oklahoma
	Public Service Company of Oklahoma	334.5	Northeastern #1	170	Oolagah, Oklahoma
	Oklahoma Gas and Electric	115.0	Arbuckle	74	Sulphur, Oklahoma
Texas	Houston Lighting and Power	1232.3	Deepwater #7 Sam Bertron #1 Sam Bertron #2 W. A. Parrish Green Bayou #4 Green Bayou #1	177 177 177 177 112 72	Houston, Texas Richmond, Texas Houston, Texas

*Units >50 MWe only

Table 4-1

MAJOR SOLAR HYBRID REPOWERING CANDIDATE
UNITS $\geq$50 MW BY STATE (Sheet 3 of 4)

State	Utility	Total Repowering Capacity	Unit	Size* (MWe)	Location
Texas, (Cont'd)	West Texas Utilities	921.5	Paint Creek Unit 3 Paint Creek Unit 4	53 110	Stamford, Texas
			Oak Creek #1	81	Bronte, Texas
			Ft. Phantom #1	155	Abilene, Texas
			Rio Pecos #6	95	Girvin, Texas
	City Public Service Board of San Antonio	575.0	Leon Creek #3 Leon Creek #4 W. B. Tuttle #1	60 100 60	San Antonio, Texas
	El Paso Electric Co.	407.9	Newman #1 Newman #2 Newman #3	105.6 86.4 82.3	El Paso, Texas
	Texas Power and Light	372.0	Lake Cr. #1	87	Waco, Texas
			Rivercrest	110	Bogota, Texas
			Valley #1	175	Savoy, Texas
	City of Garland Power and Light	341.6	Olinger #1 Olinger #2 Olinger #3	75 110 156.6	Garland, Texas

*Units >50 MWe only

Table 4-1

MAJOR SOLAR HYBRID REPOWERING CANDIDATE
UNITS ≥50 MW BY STATE (Sheet 4 of 4)

State	Utility	Total Repowering Capacity	Unit	Size* (MWe)	Location
Texas, (Cont'd)	Southwestern Public Service Company	158.8	Unit 1 Cunningham	80	Hobbs, New Mexico
			Unit 1 Plant X	52.5	Earth, Texas
	Lubbock Power and Light	98.0	Holly Ave. Power Station Unit 2	54	Lubbock, Texas
Utah	Utah Power and Light Company	66.0	Gadsby 1	66	Salt Lake City, Utah
			TOTAL	5758.4	

*Units >50 MWe only.

4.2 PLAN FOR OBTAINING UTILITY COMMITMENTS

The formal commitments of the utilities to the solar repowering program must be obtained by DOE. However, PNM will initiate the program outlined below for obtaining the formal utility commitments following DOE's indicated acceptance of the proposed program. PNM will cooperate with DOE for securing the formal utility commitments. In addition, PNM welcomes the participation of the utilities in the pre-commercialization project. The plan to obtain utility commitments is outlined as follows:

- PNM will continue to identify utilities with candidate units for participation in the program.
- PNM will study and report on possible financial incentives required for solar repowering to be attractive to the utilities. This is discussed in detail in Section 3.
- PNM will continue to solicit utility support for the program.
- PNM will host a regional meeting for DOE and invite utility executives indicating an interest in the program to Albuquerque, New Mexico. In addition, PNM will also invite state and local government officials. PNM will present the following at the meeting:
  - A description of the solar repowering concept
  - An identification of candidate units for solar repowering
  - An economic evaluation of solar repowering
  - The financial incentives needed for the solar repowering program to be economically attractive
  - A description of the pre-commercial project.

At the meeting, DOE will present the following:

- The solar repowering implementation plan

- The government-provided incentives to make the program economically attractive

- The manufacturing facilities to support the program

- Following the meeting, PNM will prepare a data package on solar repowering to be submitted to the utilities by DOE.

- DOE will contact each utility to discuss solar repowering; in particular, to review the data packages prepared by PNM.

- DOE will establish a site data bank for repowering based on the data package prepared by PNM and the previous DOE contacts.

- DOE will establish a program and definitive schedule for the first five commercial units. The program will include the government-provided financial incentives.

- DOE will formally contact each utility for a unit commitment to the solar repowering program. DOE will follow up on the commitment letters. PNM will assist DOE by responding to utility technical and economic questions on solar repowering.

- PNM will establish the program discussed in Section 4.3 for the utilities to participate in the pre-commercial project.

4.3 UTILITY PARTICIPATION IN THE PRE-COMMERCIAL PROJECT

PNM has established two programs for the utilities to participate in the Pre-commercialization Project. These programs are discussed below.

4.3.1 Supporting Utilities Program

The utilities can elect to participate in the supporting utilities program. The utilities in this program will receive a description of the project, a periodic bulletin on the progress, and a copy of the interim and final reports documenting the Project. Supporting utilities will be encouraged to provide the PNM Project Manager with written comments on the Pre-commercialization Project.

A number of utilities are participating in the Phase 1 Technical and Economic Assessment Study of Solar Repowering as part of the Supporting Utilities Program. These utilities are listed in Table 4.3-1. It is anticipated that most of these utilities will want to continue to participate in the Pre-commercialization Project in either the Supporting Utilities Program or the Utility Participant Council Program discussed in the next section.

4.3.2 Utility Participant Council Program

The Utility Participant Council Program (UPC) has been formulated to enable the participating utilities to have considerable involvement in the project. A Utility Participant Council is presently participating in the Phase 1 Technical and Economical Assessment Study of Solar Repowering.

The Utility Participant Council is providing valuable support to the conduct of the assessment study.

The objectives of the UPC will be:

- To inform the electric utility industry regarding the status of the Solar Hybrid Repowering Pre-commercialization Project.

- To provide direct participation in program activities.

Table 4.3-1

UTILITIES PARTICIPATING IN THE SUPPORTING UTILITIES PROGRAM (Sheet 1 of 3)

Arizona
Arizona Electric Power Cooperative, Inc.
Arizona Public Service Company
Salt River Project Agricultural Improvement & Power District
Tucson Gas & Electric Company
California
Burbank Public Service Department
Glendale Public Service Department
Los Angeles Department of Water & Power
Pacific Gas and Electric Company
Pasadena Water and Power Department
Southern California Edison Company
Colorado
Colorado Springs Department of Public Utilities
Colorado Ute Electric Association, Inc.
Lamar Light & Power Department
Public Service Company of Colorado
Southern Colorado Power Division Central Telephone & Utility Corporation
Trinidad Municipal Power & Light Department
Hawaii
Hawaiian Electric Company, Inc.

Table 4.3-1

UTILITIES PARTICIPATING IN THE SUPPORTING UTILITIES PROGRAM (Sheet 2 of 3)

Louisiana
Cajun Electric Power Cooperative Inc.
Central Louisiana Electric Company, Inc.
Lafayette Utilities System
Louisiana Power & Light Company
New Orleans Public Service, Inc.
Ruston Utilities System
Southwestern Electric Power Company
New Mexico
Farmington Electric Utility
Gallup Electric Department
Lea County Electric Cooperative, Inc.
Los Alamos County Utilities
Plains Electric Generation and Transmission Cooperative, Inc.
Nevada
Nevada Power Company
Sierra Pacific Power Company
Oklahoma
Grand River Dam Authority
Oklahoma Gas & Electric Company
Ponca City Municipal Water & Light Department
Western Farmers Electric Coop.

Table 4.3-1

UTILITIES PARTICIPATING IN THE SUPPORTING UTILITIES PROGRAM (Sheet 3 of 3)

<u>Oregon</u>
Pacific Power & Light
<u>Texas</u>
Brazos Electric Power Cooperative, Inc.
Central Power & Light Company
Texas Power and Light Co.
City Public Service Board of San Antonio, Texas
Dallas Power & Light Company
Denton Municipal Utilities
El Paso Electric Company
Garland Electric Department
Greenville Municipal Light & Power Department
Houston Lighting and Power Company
Lubbock Power & Light Department
Brownsville Public Utilities Board
South Texas Electric Cooperative, Inc.
Southwestern Public Service Company
Texas Electric Service Company
Texas Power & Light Company
West Texas Utilities Company
<u>Utah</u>
Provo City Power Department
Utah Power & Light Company

- To establish the broadest possible dissemination of technical information on plant design, construction, startup, operation, performance, and economics.

- To advise the project on applicable general utility practices.

- To assure the design of the pre-commercial unit is applicable to other utility systems.

The proposed plan for technology transfer to potential utility users is shown in Figure 4.3-1 and described in the following individual elements of the plan:

- Progress Reports--Progress reports provided on a quarterly basis and summarizing the status of project activities will be distributed to all UPC members.

- Progress Briefings--As key program milestones are reached, UPC members will be invited to seminars in which the nature and significance of these milestones are reviewed. Briefing charts will be provided to all participants. For milestones highlighting completion of a particular construction or operational phase, seminars will include tours of the site and facilities as appropriate. Seminar/tours are anticipated to include the following:

    - Site Selection--The basis for selection of the pre-commercialization unit site will be reviewed, site geographical and environmental characteristics described, the location of main plant components identified, and a tour of the site conducted. This briefing will take place in Albuquerque, New Mexico, as soon as feasible after contract initiation.

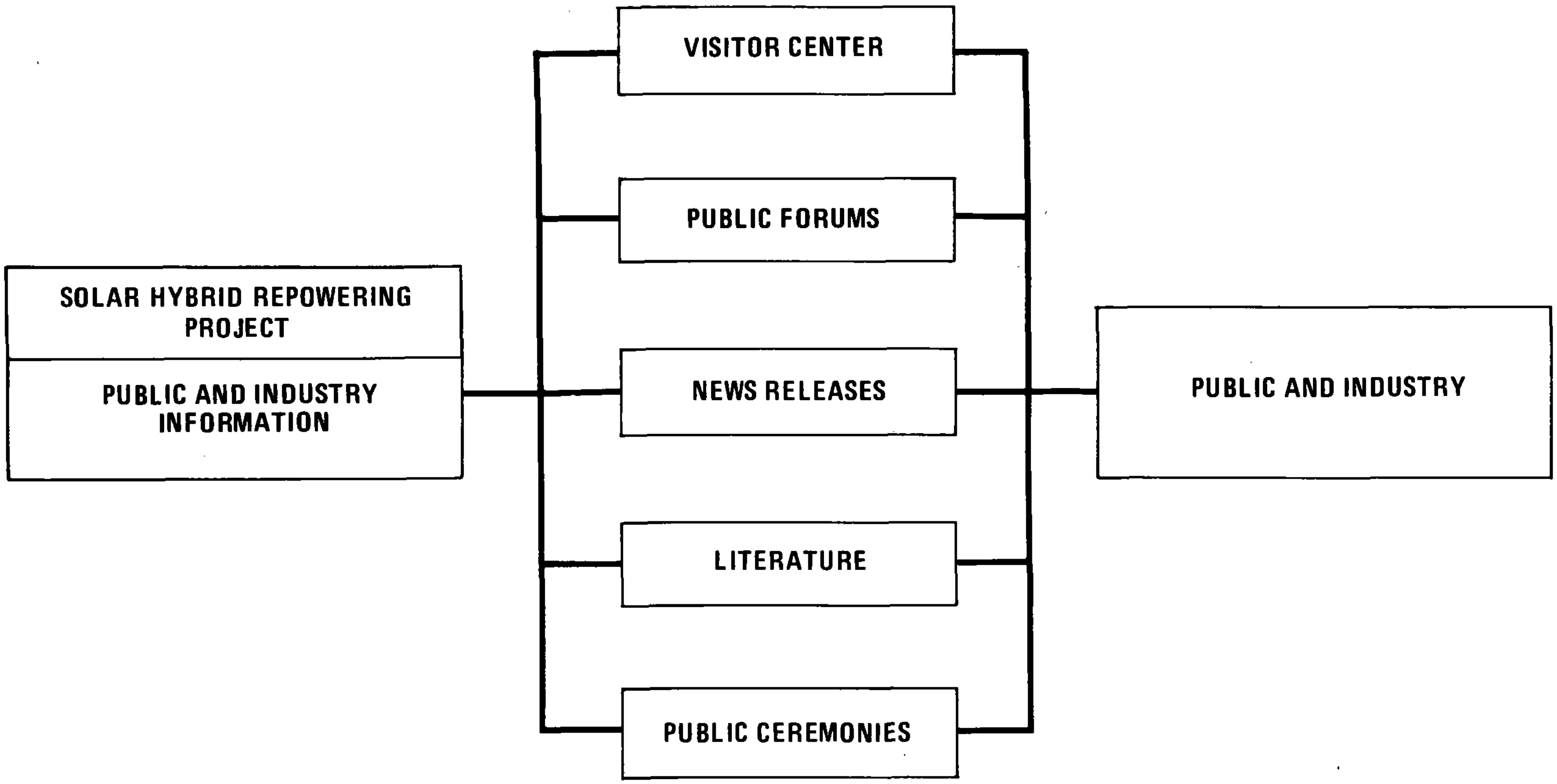


Figure 4.3-1
PUBLIC AND INDUSTRY TECHNOLOGY TRANSFER

- Unit Component Selection and Design Review--After the solar components have been selected and again after detailed plant design (i.e., solar, EPGS, and balance of facility) has been completed, plant features and design details will be reviewed for UPC with special emphasis on the nature of utility network tie-in and on operational considerations arising from the transient nature of the solar insolation.

- Prestartup Unit Description and Tour--After unit construction has been completed, a briefing will be held in Albuquerque, New Mexico, at the unit site, reviewing overall plant layout and design and describing principal plant components and functions. A tour of the unit site will emphasize principal plant components and features. A description of unit startup, test and maintenance operations, the test data to be acquired and the test instrumentation to be used are also included in the briefing.

- Unit Operational Review--After the unit has been in operation for approximately one year, a briefing to review unit operational experience will be conducted at the plant site. Comparisons of predicted versus actual performance, operational problems, and overall effectiveness of tying plant output into the utility network will be included.

- Testing Completion--When testing of the unit is concluded at the end of the two-year period, a briefing to provide a general overview of the entire Solar Hybrid Precommercialization Project will be held at the unit site. An assessment of operational and economic feasibility of the basic unit concept, proposed design and operational modifications for the next generation commercial units, and an account of plans for its disposal or continued operation will be included.

- Informal Briefings--In addition to the formal briefings described above, provision will also be made to accommodate requests of individual members of UPC for informal briefings and unit tours.

4.4 PUBLIC AND INDUSTRIAL INFORMATION DISSEMINATION PLAN

PNM also recognizes the importance of the timely dissemination of the project progress and results to the public and related industries. PNM, therefore, proposes the following:

4.4.1 Visitor Center

A special visitor center will be planned adjacent to and in full view of the Solar Hybrid Repowered Pre-commercialization Unit. The center will include displays designed to enhance public awareness and understanding of the nature and benefits of solar energy in general and of the Pre-commercialization Unit in particular. The center displays will include, for example, the following items:

- A visual display illustrating the principle of generating electricity from solar thermal power.
- A model of the Solar Hybrid Repowered Pre-commercialization Unit.
- Examples of actual solar thermal unit hardware in partial or full scale as appropriate such as the receiver and the heliostats.

4.4.2 Public Forums

A series of public forums will be conducted periodically at the plant site to inform the public of various aspects of the Solar Hybrid Repowering Pre-commercialization Unit and to provide the opportunity for a direct interchange with the public on questions of potential concern to safety and environmental aspects of plant operation. It is anticipated that the following topics will be included in forum presentation:

a. A description of the solar repowering plan, its significance, and its relation to other solar electric RD&D programs.

b. A discussion of unit design and operational features.

c. A discussion of unit safety and measures to assure safe unit operation.

d. A discussion of environmental aspects of unit operation.

4.4.3 News Releases

News releases on significant aspects of program progress will be prepared for release to the nation's communications media, subject to the DOE's prior review and approval.

4.4.4 Literature

Literature describing the Solar Hybrid Pre-commercialization Unit and various aspects of plant design and operation will be prepared for free distribution on request to individual members of the public, to public organizations, and to industrial organizations.

4.4.5 Public Ceremonies

Special ceremonies will be planned, with the DOE participation, to commemorate significant milestones in the program. These ceremonies will include a unit site groundbreaking ceremony, a unit completion ceremony, and an initial power generation ceremony. Prominent government personnel who have played major roles in conception and implementation of the program will be invited to participate in these ceremonies, along with the news media and the general public.

5.0 PRE-COMMERCIAL UNIT DESCRIPTION

5.0 PRE-COMMERCIAL UNIT DESCRIPTION

The Reeves Unit No. 2 has been selected by PNM for the pre-commercial solar hybrid repowering unit and is described in this section. The proposed expansion of the station to accommodate the heliostat field and solar receiver tower, is discussed. The subsystems of the repowered unit are described. Finally, site operation and environmental considerations are presented.

5.1 PLANT FACILITIES

The pre-commercial unit is the Reeves Unit No. 2 which is located just northwest of Albuquerque, New Mexico, owned and operated by the Public Service Co. of New Mexico. The Reeves Station has three oil/gas fired steam electric units with evaporative type cooling towers. The nameplate capability of the selected unit is 44 MWe

The major plant components of the existing station are as follows.

- Electric Power Generating Subsystem
- Gas/oil fired steam boiler
- Cooling towers
- Switch yard
- Fuel Oil Storage
- Office and Administration Building

The area of the existing site is approximately 60 acres of which approximately 30 acres is available for the added solar facility. An additional 125 acres to the south of the present site is available and options are being obtained for the additional land required for solar repowering, as shown in Figure 5.1-1. The immediate surroundings of the site are used for light industrial purposes and will not restrict locating a solar repowering unit.

5.1.1 Existing Facilities

Reeves Unit 2 was selected as the pre-commercial unit for the repowering program because:

- The unit is representative of the typical candidate unit defined as a result of the market survey.
- The estimated earliest retirement date of 1996 is representative of the units identified on the basis of the market survey.
- Present condition of the boiler is good. It has minimal brick refractory, thus it will be less affected by the expected temperature transients of hybrid operation.
- Present condition of the boiler auxiliaries is good.
- The turbine generator is generally in good condition and will be modified by PNM for load cycling duty in 1979.
- The location of the unit at the station is immediately adjacent to the Control Room, thus making operator attention more readily available during times of boiler ramping, upset, etc.
- The current minimum load the unit may carry with all boiler controls in full automatic operation is 20 MW. (6 burners in service.) The practicality of further reduced minimum loads is being studied.

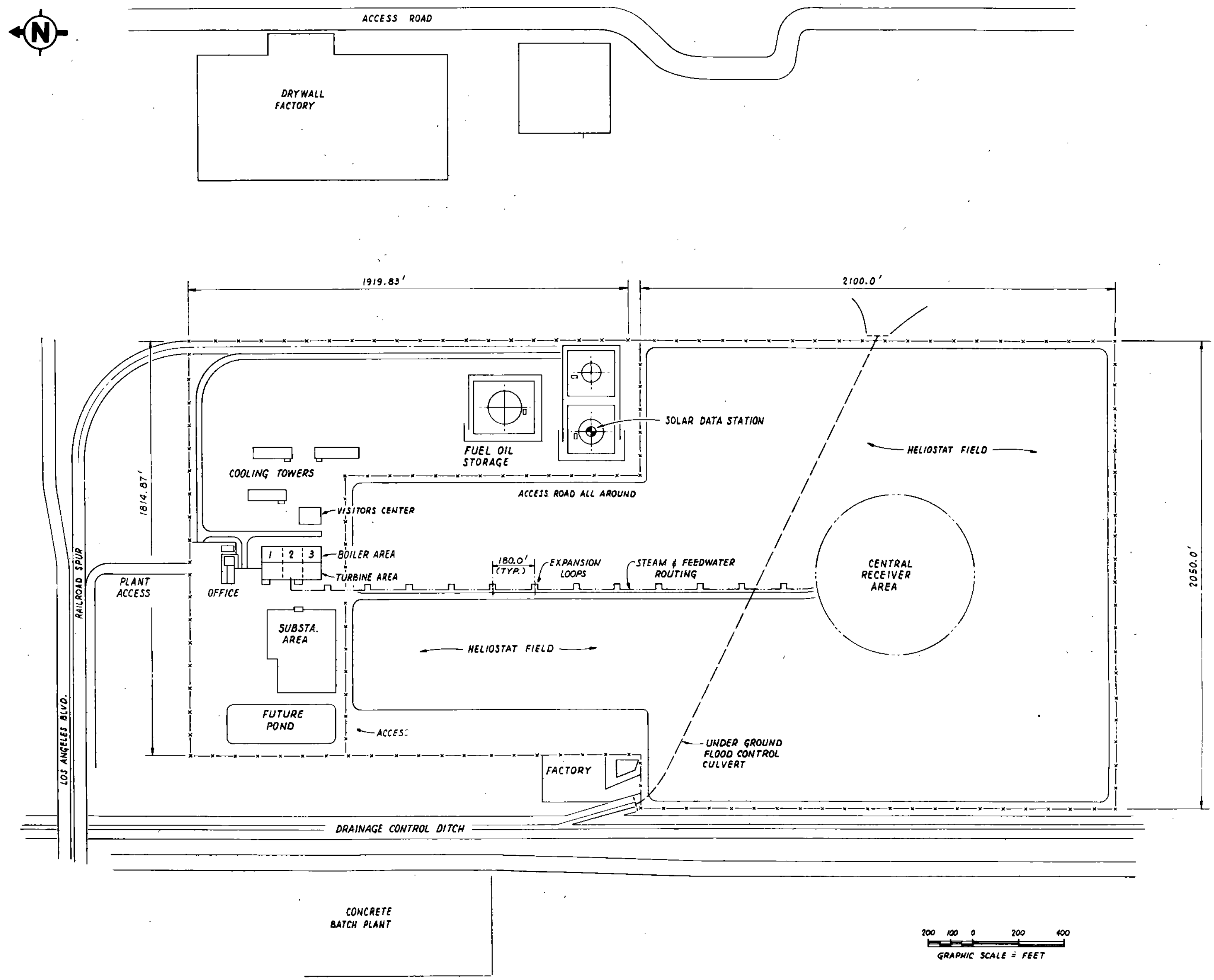


Figure 5.1-1
CONCEPTUAL SITE PLAN

- It is expected that this unit will operate with fuel oil as a primary boiler fuel after the year 1981.

A brief specification of the major plant components of the Reeves Unit No. 2 is as follows:

GENERATOR:

Make: Westinghouse	Volts: 13800
Serial: 1S-59P72	KW: 44000
Power Factor: 85%	Speed: 3600

TURBINE:

Make: Westinghouse	Steam Pressure: 1250 psig
Serial: 13-A-1671-1	Steam Temperature: 950 Deg. F
KW: 44000 Nameplate	Exhaust Pressure: 1.5" Hg
50000 Rated	
Speed: 3600 RPM	

BOILER:

Make: Babcock & Wilcox	Capacity: 467,500 #/Hr
Serial: RB-323	Heating Surface: 7882 Sq. Ft.
Steam Temperature: 960 Deg. F	Economizer: 11608 Sq. Ft.
Steam Pressure: 1475 psig	

STATION TRANSFORMER:

Make: Westinghouse	Volts: 115,000 GRD Y - 13200
Serial: 6537053	Type: 3 Phase Class OA/Fa

NO. 1 H.P. HEATER:

Make: Griscom-Russell
Serial: 79444A
Size: 23-5-311

NO. 2 H.P. HEATER:

Make: Griscom-Russell
Serial: 79447A
Size: 23-5-358

STEAM CONDENSER:

Make: Westinghouse
Serial: 16A1144-1
Surface: 37,500 Sq. Ft.

PERFORMANCE DATA (by actual test)

Generator Load	-	52626 KW
Auxiliary Power	-	2270 KW
Net load	-	50356 KW
Cycle Heat Rate	-	8645 Btu/kwhr
Net Plant Heat Rate	-	11007 Btu/kwhr
Condenser Pressure	-	1.8" Hg abs

5.1.2 Proposed Site Arrangement

The repowering of Reeves Unit No. 2 will add two major features to the site. Namely:

- Heliostat field
- Receiver/Tower structure.

The heliostat field requires approximately 150 acres which in part are provided by the present site and in part by adjacent land area south of the present site. The adjoining property is relatively level, however it contains a wash, which drains into a concrete lined drainage control ditch, running along and near the west boundary of the plant site property.

The present site boundary of the Reeves Station will be expanded by the acquisition of properties immediately adjacent and to the south of the existing property line. By making use of the unused area west of the fuel oil tank and developing a symmetric heliostat field it will only be necessary to acquire an additional 120 acres (2100 ft x 2500 ft) in order to construct a heliostat field requiring 150 acres, overall. In order to be able to most efficiently develop the new facilities (heliostat field, central receiver, and piping) which will be located in the newly acquired area an existing flood control culvert will be moved underground. The entire area will then be free of obstructions to the flow of vehicles to all of the heliostats.

The Reeves Station site and the new property is characterized by a 3.6 percent slope with soils of moderate erosion potential. Drainage to the canal along the west boundary will be provided during development of the heliostat field. Sufficient area will be obtained at the existing Reeves site to permit construction of maintenance and warehouse facilities for the heliostats and the solar receiver and expansion of the administration building to accommodate the additional personnel during construction and operation.

In the layout of the heliostat field care was taken to not encroach on the drainage control ditch and to facilitate the natural drainage of the wash. A catch basin at the east boundary of the new property and an underground flood control culvert (running southeast, northwest and draining into the drainage control ditch) will be installed.

The receiver/tower structure is located approximately in the center of the new property. The heliostat field is completely surrounded by a security fence and a setback from the fence for roads is provided for service and inspection access.

An access road through the center of the field provides access to the receiver/tower structure and also facilitates the routing of the steam line, steam line drains, feedwater line and lines for other services.

5.1.3 New Facilities

The primary major components of the new solar repowering system are:

- Heliostat field
- Central Receiver/Tower
- The Master Control System (described in section 5.2.2.5)

The pre-commercial unit heliostat field layout is based on:

- The design power of 25 MW(e) at 2 p.m. winter solstice.
- The assumed solar insolation of 950 w/m^2.
- The heliostats being placed in a radial stagger arrangement and located to allow complete freedom of motion, and the minimization of blocking and shading.
- The number of heliostats required to yield 25 MW(e) from the solar plant is 4289.

The heliostats have been placed in the modified rectangular land area shown in Figure 5.1.3-1. Radii of the rows and the number of heliostats up to and including a given row, along with the coordinates of the individual heliostats, have been determined.

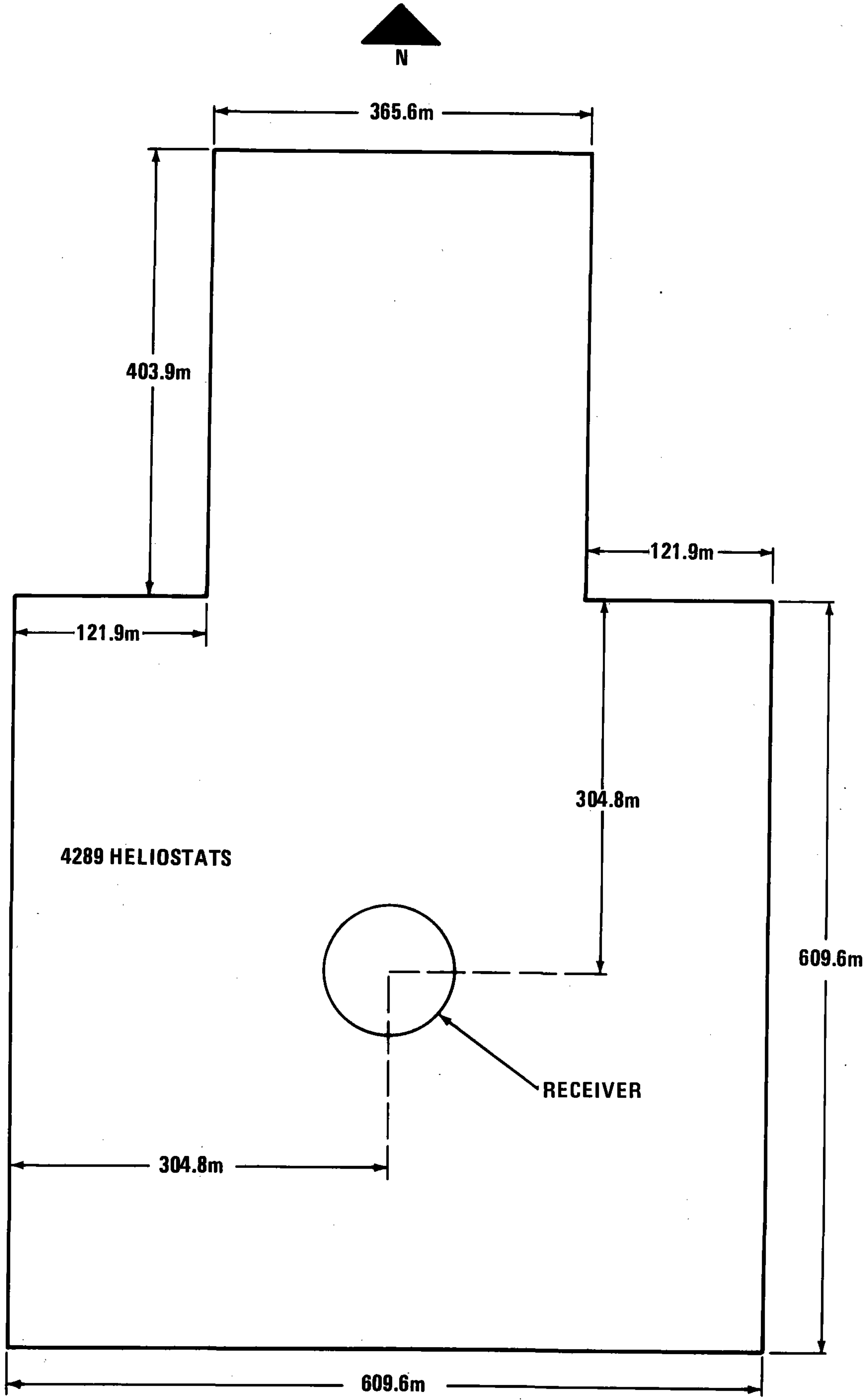


Figure 5.1.3-1
HELIOSTAT ARRANGEMENT FOR CONCEPTUAL
DESIGN OF PNM REEVES UNIT 2

The receiver dimensions are:

Length = 21.0 m (69 ft)

Diameter = 12.0 m (40 ft)

Centerline Elevation = 150 m (402 ft)

The circular exclusion area at the base of the tower is approximately 38,000 m^2, corresponding to a radius of 110 m (360 ft).

5.1.3.1 Civil-Structural

Site and Foundations - The heliostat field will require the removal of vegetation and grading to provide a relatively flat area upon which to locate the heliostats and the receiver structure. The surface will be treated with a cover of gravel or other means to control blowing dust or erosion and to control vegetation growth. A 20-foot-wide inspection and service road will be constructed around the perimeter of the site immediately inside the perimeter fencing. Access is provided as required to service the heliostats and the receiver structure. Chain link fencing will be installed along all the boundaries of the site and access to the site will be controlled at gates on the north side of the fence. For the present, it is considered that the bearing capacity of the soil at the site is sufficient to support the individual footings of the heliostats and the receiver tower base. A complete soils investigation will be conducted prior to the design of the foundation systems.

Each of the heliostats is supported by a pedestal anchored to a concrete footing which will be sized and buried deeply enough to withstand the dead loads as well as the expected maximum wind or other dynamic loading.

Central Receiver - The central receiver will be a commanding feature of the site in that it is a rather large structure supported by a free-standing tower approximately 450 feet high. The receiver includes the absorber panels, water distribution systems, steam downcomer, flow and temperature control apparatus. The free-standing tower is a space frame make up of structural steel shapes of low or intermediate grade members, shop welded and field bolted. The tower will be anchored to and supported by reinforced concrete spread footings. The tower will be wider at the base and gradually taper to a smaller width at the top. The tower will also contain within its dimensions, structures and support for access, equipment and piping. The structure and the foundation will be designed for expected maximum wind loads, seismic loads and operating loads in addition to the static loads. On the site, in close proximity to the receiver tower, a maintenance shop will be constructed in which the normal maintenance and warehousing of the equipment is conducted. The warehouse will be placed on a reinforced concrete slab. Construction of the shop will be a steel frame, concrete block wall and a steel deck roof.

5.1.3.2 Utilites

Water Supply - Approximately 65,000 gallons of water per month will be required for washing heliostats. Recycling of this water is under consideration. Requirements for service water are minimal for this facility, however service water to the maintenance shop may be desirable. The source of supply for the service water will be tied into the existing Reeves Station Water System.

Fire Protection - The noncombustible nature of the structures and equipment at the site requires minimal fire protection, however, electrical wiring and motors and high temperatures generated at the receiver are considered. A system of hydrant and hose houses will be located as necessary along the perimeter road at the heliostat field. The fire line will be tied into the existing Reeves Station fire protection system. In addition chemical fire extinguishers will be located as necessary for electrical fire protection.

Waste Disposal - A chemical toilet will be located near the maintenance shop. In general, the facilities of the Reeves Station will be used to dispose of solid wastes from the repowered plant.

Drainage - Onsite drainage will be adequately handled by grading and channelizing where necessary to control runoff and erosion.

Offsite drainage will be intercepted on the east side of the site and a culvert will be installed through the heliostat field to direct the offsite runoff from the interceptor, through the culvert and into the drainage canal on the west side of the site.

Underground Utilities - The fire protection pipe lines, service water and electrical service will be provided as necessary in buried conduits from the existing Reeves Station to the points of service.

5.1.3.3 Security

The solar hybrid repowering addition to the existing Reeves Station will be entirely enclosed with chain link security fencing. Access into the heliostat field will be provided through a locked man gate and a locked vehicle gate in the fencing on the north side of the field facing the main access road entering from the existing power plant property.

Access to the heliostat field will be provided for authorized operating and maintenance personnel only and every entry will be registered in the plant guard station.

Immediately inside the new perimeter fence a 20 foot wide patrol and service road will be constructed to provide for periodic inspection and servicing of the heliostat field.

5.1.3.4 Visitor Center

PNM will provide a visitor center, anticipating that the interest in this concept will be very high both in the private and utility sector. The staff at the center, in conjunction with the project manager's office, will disseminate information to interested parties. It will contain graphic displays on the concept, how and where the committed regional utilities will implement future plants, and include a scale model of the existing plant and solar unit, a scale heliostat and receiver.

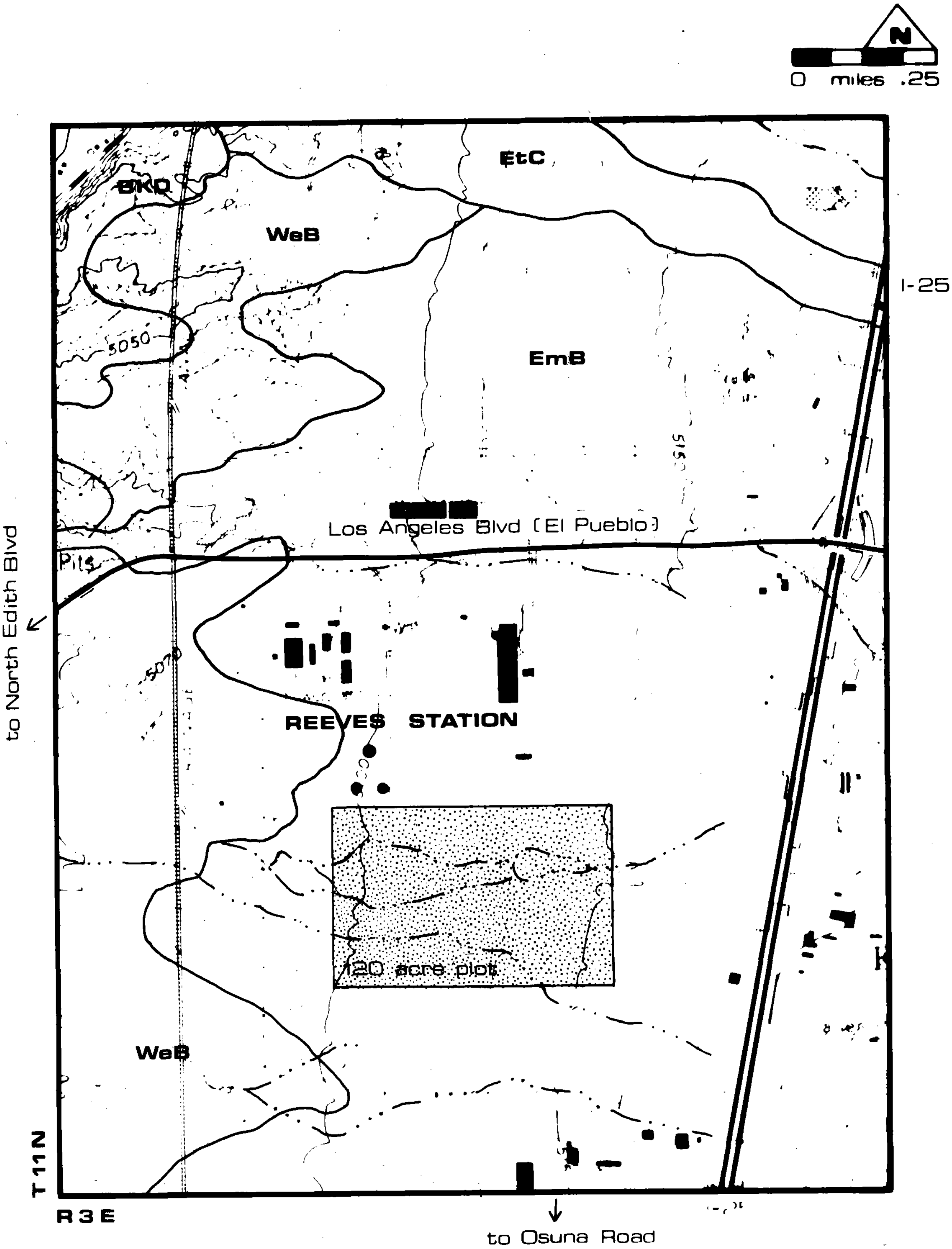
The orientation of the site allows for the visitor center's southern wall to view from a distance the north field boundary and the central tower. The southern wall will therefore be constructed primarily of glass to allow general viewing of the project. This exposure will allow the building to be partially solar heated by a passive mechanism. New Mexico's traditional pueblo architecture will be the basis for design, including adobe stuccoed walls with an exposed wood beam ceiling.

The City of Albuquerque is constructing, in the early 1980's, an exit from Interstate 25 to Los Angeles Blvd.; Reeves Station is located 1 mile west of I-25 on Los Angeles Blvd, as shown in Figure 5.1.3.4-1. The accessibility for all cross country travelers is excellent, as the site is less than 5 miles from the western U.S.'s major interchange of Interstate 40, the east/west artery and Interstate 25, the north/south artery.

5.1.4 Solar/Fossil Interface

The principal interfaces between the existing fossil fired thermal unit and the solar steam generating facility are:

- Steam supply from each steam generator to turbine.
- Feedwater supply to each steam generator from the turbine condenser.
- Control interactions between fossil plant and solar systems.
- Power supply to the heliostat field and central receiver.



BcA, WeB, etc. = soil types

Figure 5.1.3.4-1
REEVES STATION VICINITY

Steam generated by the solar energy can be mixed with the steam provided by the fossil steam generator prior to admission into the steam turbine. Attemperation of the solar steam will insure that the temperatures are maintained within turbine limits. Solar generated steam will be used to provide the "base-load" with fossil steam generation to pick-up the steam flow reduction due to intermittent cloud covers and at night.

It will first be treated in a common mixed-bed demineralizer to insure the required water purity. The feedwater supplied to each steam generator will match the steam flow and pressure requirements of each unit by means of a coordinated control system.

The control system of the existing fossil fired unit will be modified and interfaced with the solar steam generator control system by means of a master control system which will be arranged so that the required fossil firing rate will be anticipated and controlled as necessary to maintain turbine load and maximize solar steam generation.

5.2 SUBSYSTEM DESCRIPTION

The solar repowering concept requires the addition of new solar subsystems to an existing plant along with the modification of some subsystems of the existing plant. These new and modified subsystems are discussed in this section and are indicated schematically in Figure 5.2-1.

5.2.1 Solar Hardware

A conceptual design for the solar subsystem is being prepared as part of the Phase 1 Technical and Economic Assessment Study of Solar Hybrid Repowering. The solar subsystem conceptual design utilizes as a design basis

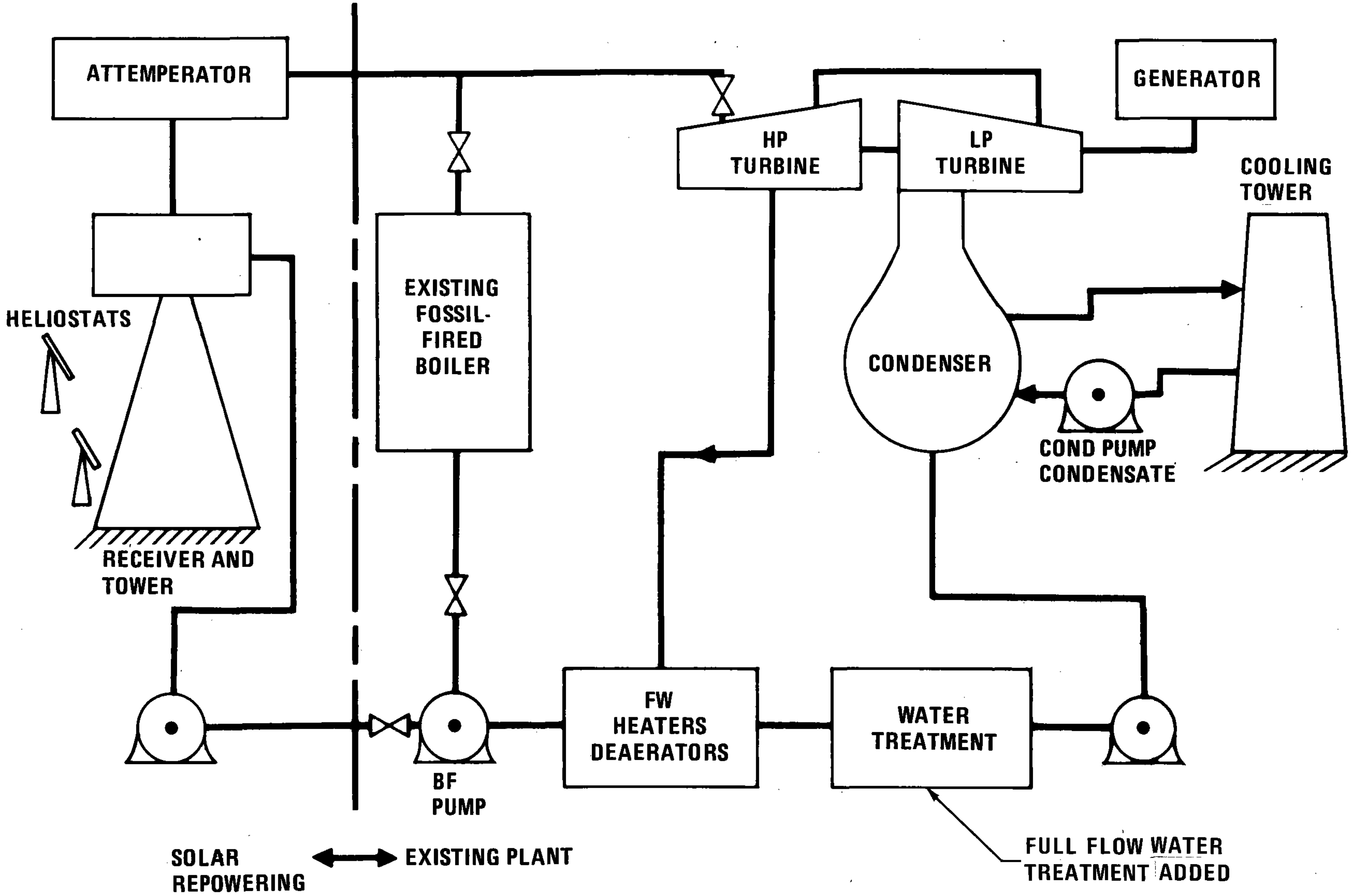


Figure 5.2-1
SCHEMATIC OF A GENERIC SOLAR THERMAL
REPOWERING PLANT

stipulated by DOE, the technology being developed for the 10 MW(e) solar thermal central receiver pilot plant to be constructed at Barstow, California. The basic heliostat configuration and the basic receiver configuration, (a once thru boiler) therefore, are based on concepts developed by the McDonnell Douglas design team as part of the DOE Phase 1 Central Receiver Program. The design for the heliostat field and the receiver is currently in progress; however, the results of the design effort to date are summarized in the following sections.

5.2.1.1 Heliostat Field

The conceptual design, sizing and layout of the heliostat collector field for the 25 MW(e) solar hybrid repowered plant Reeves Unit 2 was accomplished with the use of the MIRVAL computer code. MIRVAL is a Monte Carlo program in which the interaction of light rays from the sun with an arbitrary array of mirrors and a solar energy receiver is simulated. Phenomena whose effects are simulated include shadowing, blocking, mirror tracking, detailed optics of the reflective surfaces, insolation, and the angular distribution of incoming sun rays. The MIRVAL computer code, along with two preprocessor codes, was developed at Sandia (Livermore) Laboratories.

The heliostat and central receiver employed in sizing the collector field are McDonnell Douglas Astronautics Company designs. The heliostat simulated is shown in Figure 5.2.1.1-1. It should be noted that the heliostat as modeled by MIRVAL is simply a (6-faceted) square with a side length of 6.5 m. However, account was taken for light rays falling between facets, and hence the total mirror area of a single heliostat is 38 m^2.

The heliostats have been placed in a radial stagger arrangement as computed by the preprocessor code developed by Sandia. For a fixed heliostat deployment, the sun can be in a position such that one mirror shadows another or perhaps so that some of the light which reflects from one mirror strikes the back of a neighboring mirror (blocking). Hence, the heliostats have

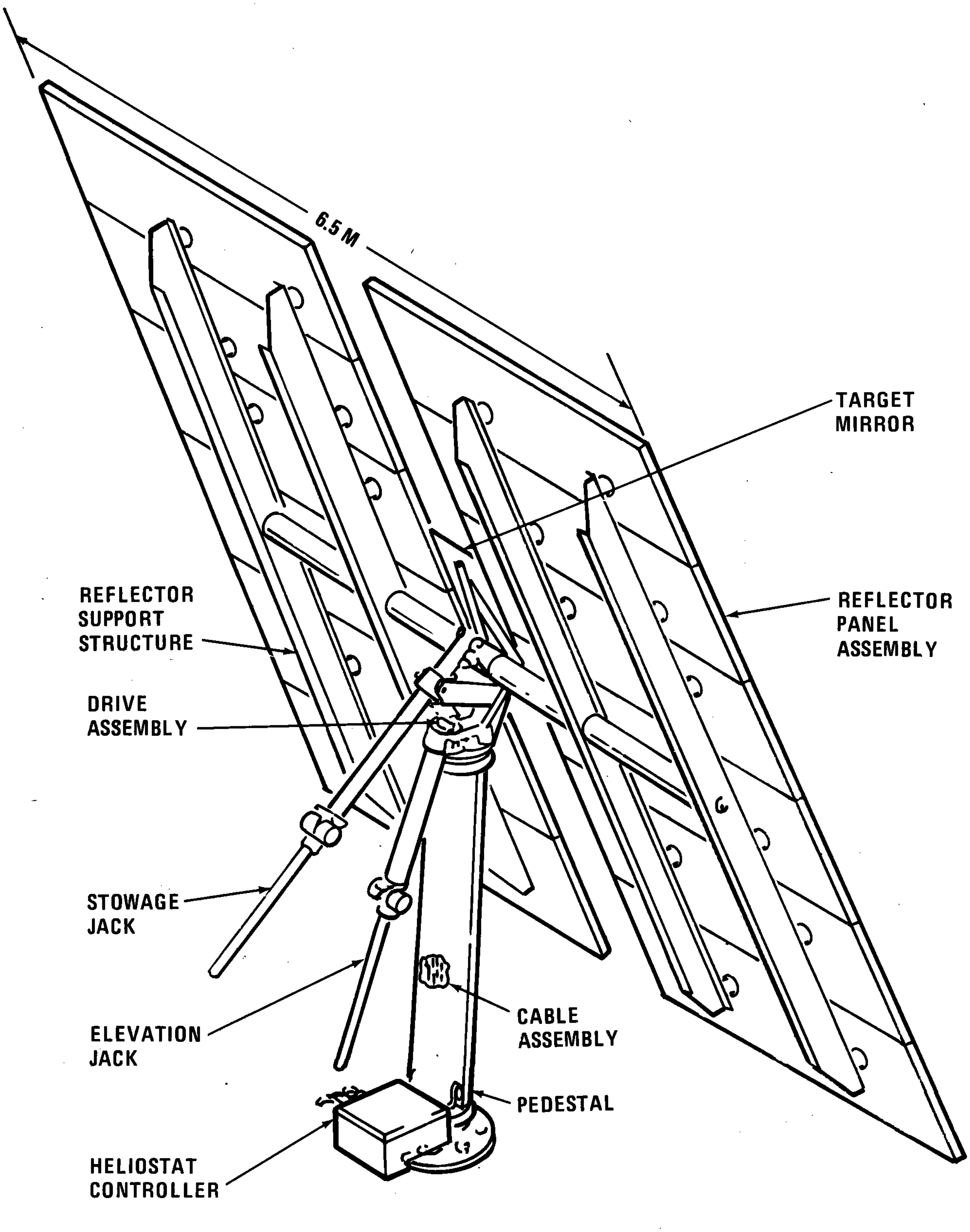


Figure 5.2.1.1-1
MC DONNELL DOUGLAS HELIOSTAT DESIGN

been located so as to minimize the effects of shadowing and blocking and also to allow complete freedom of motion, i.e., no interference. The heliostats have been placed in the modified rectangular land area shown in Figure 5.1.3-1. The circular exclusion area at the base of the tower is approximately 38,000 m^2, corresponding to a radius of 110 m. Radii of the rows and the number of heliostats up to and including a given row, along with the coordinates of the individuals heliostats, have been calculated.

The design power is 25 MW(e) at 2 p.m. winter solstice. The number of heliostats required to produce 92 MW(t) at the receiver, which in turn will yield approximately 25 MW(e) from the solar plant, is 4289. The solar insolation has been assumed to be 950 W/m^2.

The central receiver length is 21.0 m and the diameter is 12.0 m. The height to the centerline of the receiver is 150 m.

A summary field performance is given in Table 5.2.1.1-1.

Table 5.2.1.1-1

POWER INCIDENT ON RECEIVER AT SELECTED TIMES OF THE YEAR

Time of Year	Power (MW)
2 p.m. Winter Solstice	92.2
Noon Winter Solstice	102.8
Noon Summer Solstice	114.0
Noon Vernal Equinox	112.8
Annual Average	100.5

MIRVAL is a Monte Carlo code which is used to trace a suitably large number of rays from their origin about the sun to either a non-useful absorption event or to the receiver. A simple bookkeeping procedure leads to estimates of the power for each event. Table 5.2.1.1-2 is a detailed field performance table that shows the power associated with each event after incoming rays strike the mirrored surface of the field.

Table 5.2.1.1-2

DETAILED FIELD PERFORMANCE

Description of Ray	Power (MW)			
	2 p.m. Winter Solstice	Noon Winter Solstice	Noon Summer Solstice	Noon Vernal Equinox
Incoming Ray Hits Mirror	108.2	121.2	134.7	133.0
Reflected Ray Absorbed	10.5	12.1	13.5	13.2
Reflected Ray Hits Back of Mirror	1.0	1.2	1.9	1.7
Ray Clears Mirrors	96.7	107.9	119.3	118.1
Ray Absorbed Between Mirror & Receiver	4.3	4.9	5.1	5.1
Ray Hits Receiver Plane Properly But Misses Receiver	0.2	0.3	0.2	0.2
Ray Enters Receiver	92.2	102.8	114.0	112.8

5.2.1.2 Receiver

As noted in Section 5.2.1.1, the central receiver employed is the McDonnell Douglas Astronautics Company (MDAC) design, shown in Figure 5.2.1.2-1. The receiver subsystem absorbs the solar insolation reflected from the collector subsystem, and converts water into superheated steam for delivery to the turbine of the electric power generation system. The receiver subsystem consists of the receiver unit, the tower on which the receiver is mounted above the collector field, and the supporting control and instrumentation equipment.

The receiver length for the PNM Reeves Unit 2 solar hybrid repowered plant is 21 m and the diameter is 12 m. The height to the centerline of the receiver is 150 m. The receiver is modeled by the MIRVAL computer code and is a right circular cylinder. The aimpoint for a mirror lies on the cylinder and in the vertical plane through the center of the mirror and the receiver centerline. The aimpoint for the mirror lies 3/4, 1/4, or 1/2 of the way up the cylinder in this plane, representing an overall 3-point aiming strategy. This serves to distribute the power incident on the receiver more evenly so as to avoid any local hot spots.

The receiver must safely and efficiently absorb incident solar radiation at a maximum flux of 0.3 MW/m^2. As seen in Figure 5.2.1.2-2, which is a MIRVAL generated power flux map on the receiver for the PNM Reeves Unit 2 solar repowered plant, a maximum of 0.32 MW/m^2 is incident on the receiver. This is at noon summer solstice for a solar isolation of 950 W/m^2. If necessary, a slight increase in the receiver size will lower this value to the design limit of 0.30 MW/m^2.

5.2.1.3 Tower

The tower, shown in Figure 5.2.1.2-1 is the most dominant visual feature of the repowered plant site. It is located south of the existing power

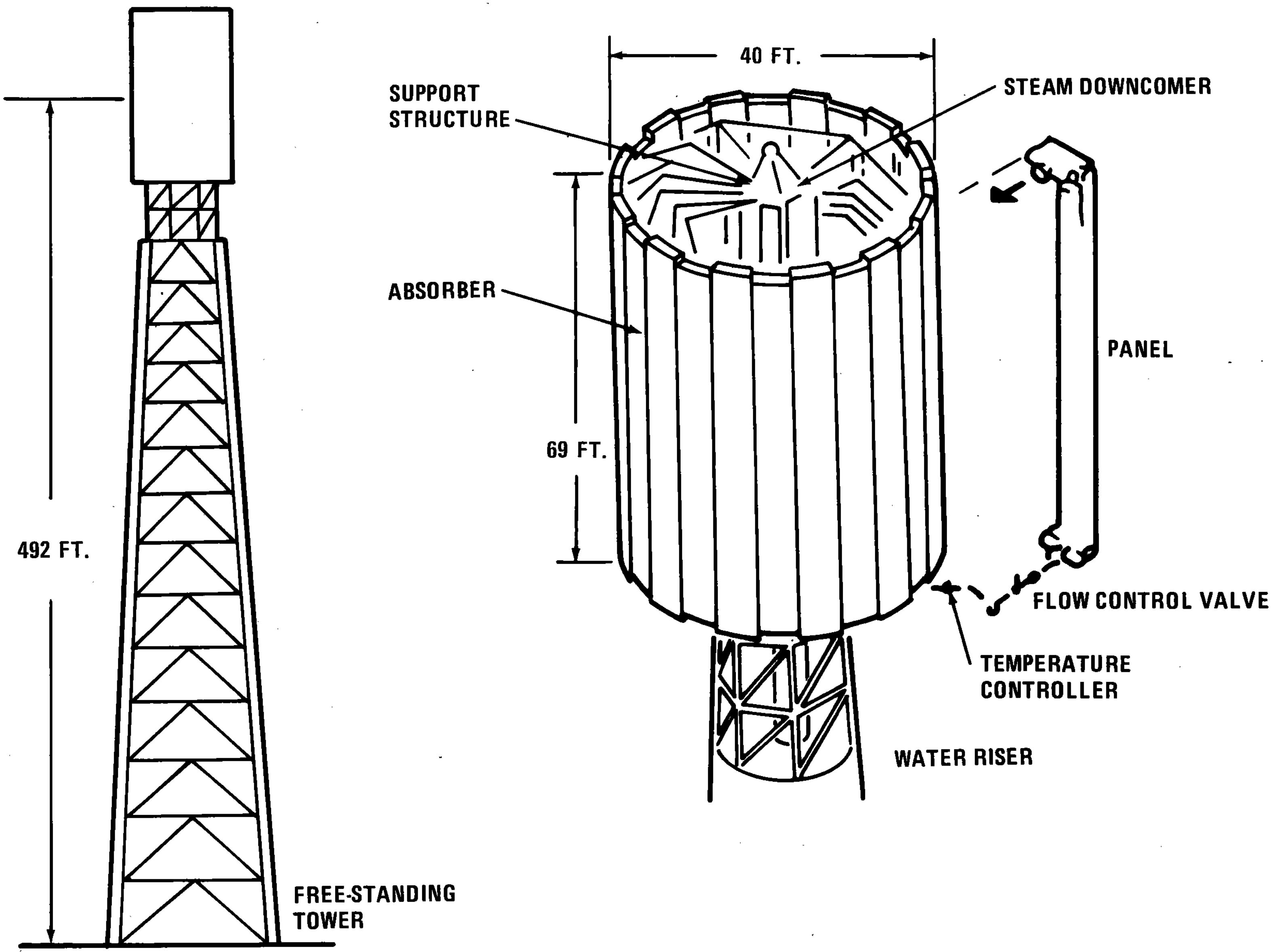


Figure 5.2.1.2-1
McDONNELL DOUGLAS TOWER AND RECEIVER DESIGN

FLUX ON MC DONNELL DOUGLAS RECEIVER

0.01	0.02	0.02	0.05	0.05	0.02	0.02	0.01
0.13	0.14	0.15	0.27	0.26	0.15	0.13	0.13
0.13	0.14	0.16	0.30	0.29	0.16	0.14	0.13
0.14	0.15	0.17	0.31	0.31	0.16	0.15	0.15
0.13	0.14	0.15	0.30	0.30	0.15	0.14	0.13
0.14	0.15	0.17	0.31	0.32	0.16	0.15	0.13
0.12	0.13	0.13	0.25	0.25	0.13	0.12	0.11
0.01	0.01	0.01	0.03	0.04	0.01	0.01	0.01

(m): 20, 16, 12, 8, 4

-16 -12 -8 -4 0 4 8 12 16
(m)

Figure 5.2.1.2-2
ENERGY FLUX (MW/m^2) ON THE MC DONNELL DOUGLAS RECEIVER ON NOON SUMMER SOLSTICE

plant complex and is surrounded by the heliostat field. The functions of the tower are to:

- Support the receiver mounted on the top of the tower.
- Provide space and supports for the water feed pipe and for the returning superheated steam pipes/
- Provide work space for maintenance of equipment located in the tower.
- Provide anchor and support for rigging external hoisting equipment (to lift receiver panels in place).
- Provide safe access for maintenance personnel to work platforms on the tower.
- Protect equipment and personnel from accidental damage resulting from impingement of concentrated solar radiation.
- Provide space and shelter for the heliostat control system components.

The tower will meet the design criteria listed in Table 5.2.1.3-1. Conceptually the tower is a octagonal vertically tapered steel structure resting on an octagonal concrete foundation. The levels near ground serve as:

- Control and cable spreading rooms for the heliostat field.
- Ground level terminal of the elevator and ladder.
- Entry points for the water and steam piping as well as electrical power.

TABLE 5.2.1.3-1

RECEIVER TOWER DESIGN CRITERIA

Receiver Center Line Elevation	492 ft
Receiver Weight	500,000 lbs
Receiver dimensions	
diameter	40 ft
height	69 ft
Design basis wind velocity at ground level	7 mph
Wind pressure variation with height	per ANSI A-58.1-72
Gust factor	TBD
Soil Bearing Capacity	TBD K/ft^2
Seismic Design Basis	UBC Zone 2
Permissible Horizontal Deflection at Receiver Center Line (operating condition)	TBD ft
Hoist capacity at receiver top	10 tons
Passenger elevator capacity	1 ton

Space in the remainder of the tower to the receiver platform is occupied by the steam and water pipes, power and instrument cable trays, the elevator, and the emergency personnel ladder. The piping runs will be designed to accommodate thermal expansion. Conventional power plant type thermal insulation is used on the pipes. At the receiver, elevation structural members are provided to support and stabilize receiver panels. A network of distribution piping and headers for water and steam connections to the panels are also provided together with the required service, shutoff and control components. Catwalks and platforms will be installed at locations requiring manned access.

The tower structural steel and the equipment and personnel occupying the tower during solar operation will be protected from accidental exposure to concentrated solar radiation by a thin stainless steel or aluminum shield designed to provide the necessary protection and at the same time permit front to back wind pressure equalization (slotted design). To permit stallation of receiver panels during construction and the replacement of defective units during the operating phase, a boom-type hoist is provided. The hoist will be designed to cover the full receiver circle and will be used to lift the panels and move them into the required installation position.

5.2.2 Power Cycle

5.2.2.1 Fossil Boiler System

- Description

Reeves Unit 2, has a gas fired natural circulation boiler with oil backup. A superheating section delivers steam to the turbine-generator. Two full capacity condensate pumps, one on standby, are used to pump condensate from the condenser to a deaerator tank for air removal after passing two low pressure heaters located in the condenser neck. Two full capacity boiler feed pumps, one on standby, are used to pump the feedwater to the gas fired boiler after passing through two high pressure heaters. The low pressure and high pressure heaters have Cu-Ni tanks.

Extraction steam from the turbine is used to heat the condensate and feedwater in the low pressure and high pressure heaters. Drains from the low pressure heaters are pumped by a low pressure heater drain pump back to the condenser. Drains from the high pressure heaters are routed to the deaerator tank by a pressure differential. Air and noncondensible gases in the condensate and feedwater train are removed by the air ejector and the deaerator.

- Modifications

Repowering of Reeves Unit 2 will require certain modifications as outlined below. Physical arrangement of these modifications and the location of added equipment are shown on Figures 5.2.2.1-1 through 5.2.2.1-5.

  - Feedwater Modifications

    The addition of a solar receiver, requires new equipment. The equipment includes one feedwater booster pump to supply feedwater to the solar unit and a full flow polisher, with a

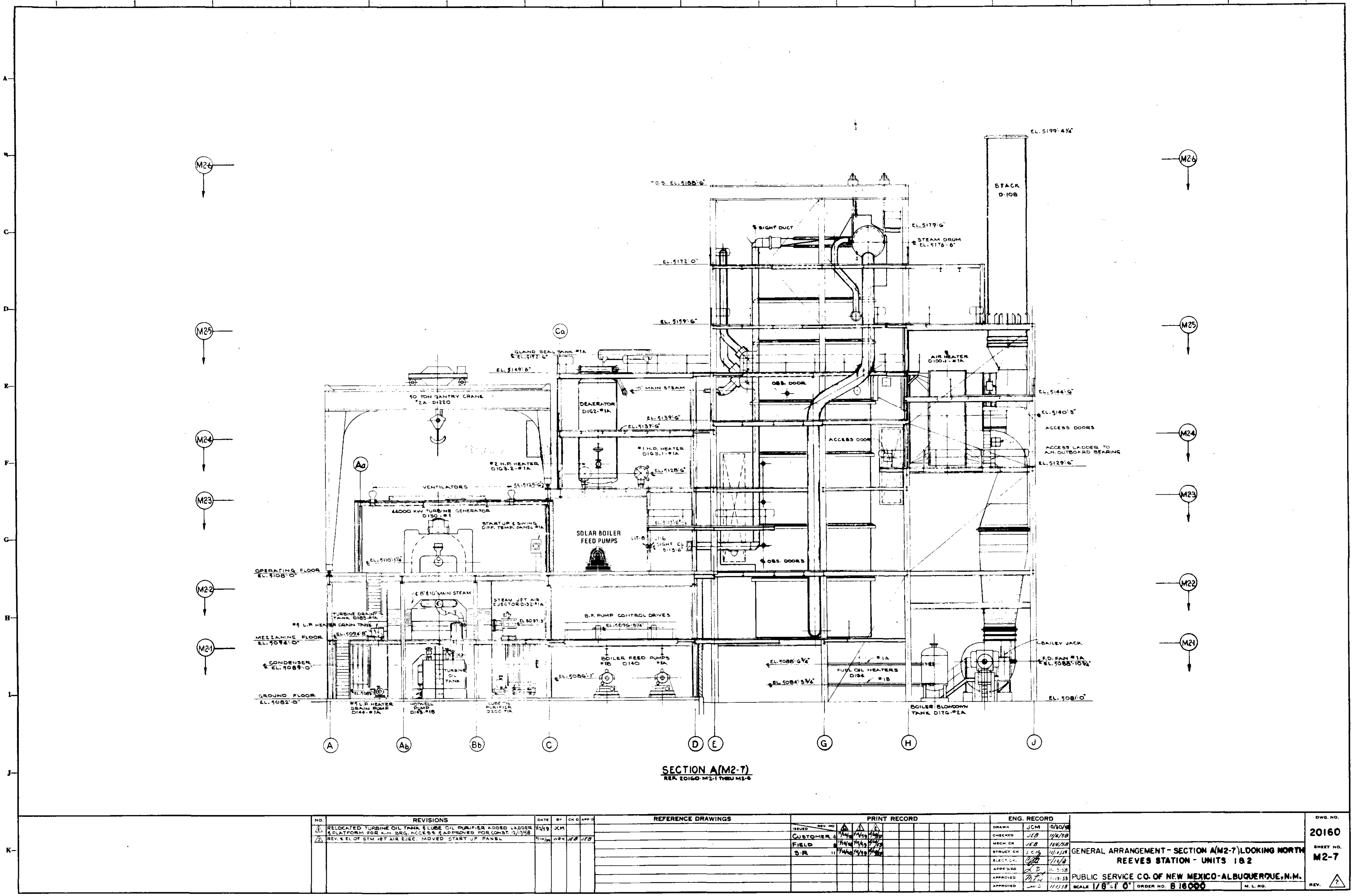


Figure 5.2.2.1-1 REPOWERED REEVES UNIT 2 SOUTH ELEVATION

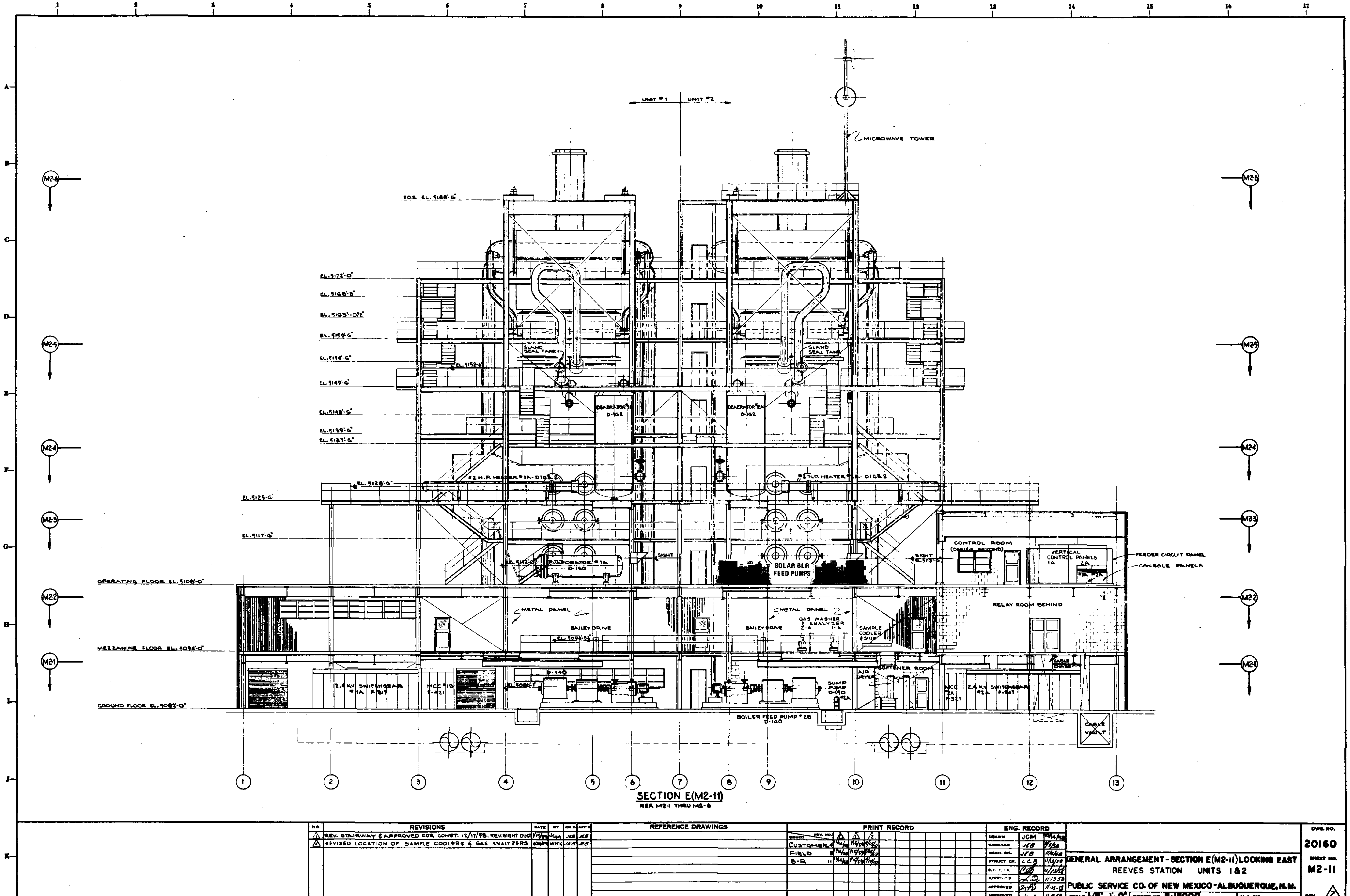


Figure 5.2.2.1-2 REPOWERED REEVES UNIT 2 WEST ELEVATION

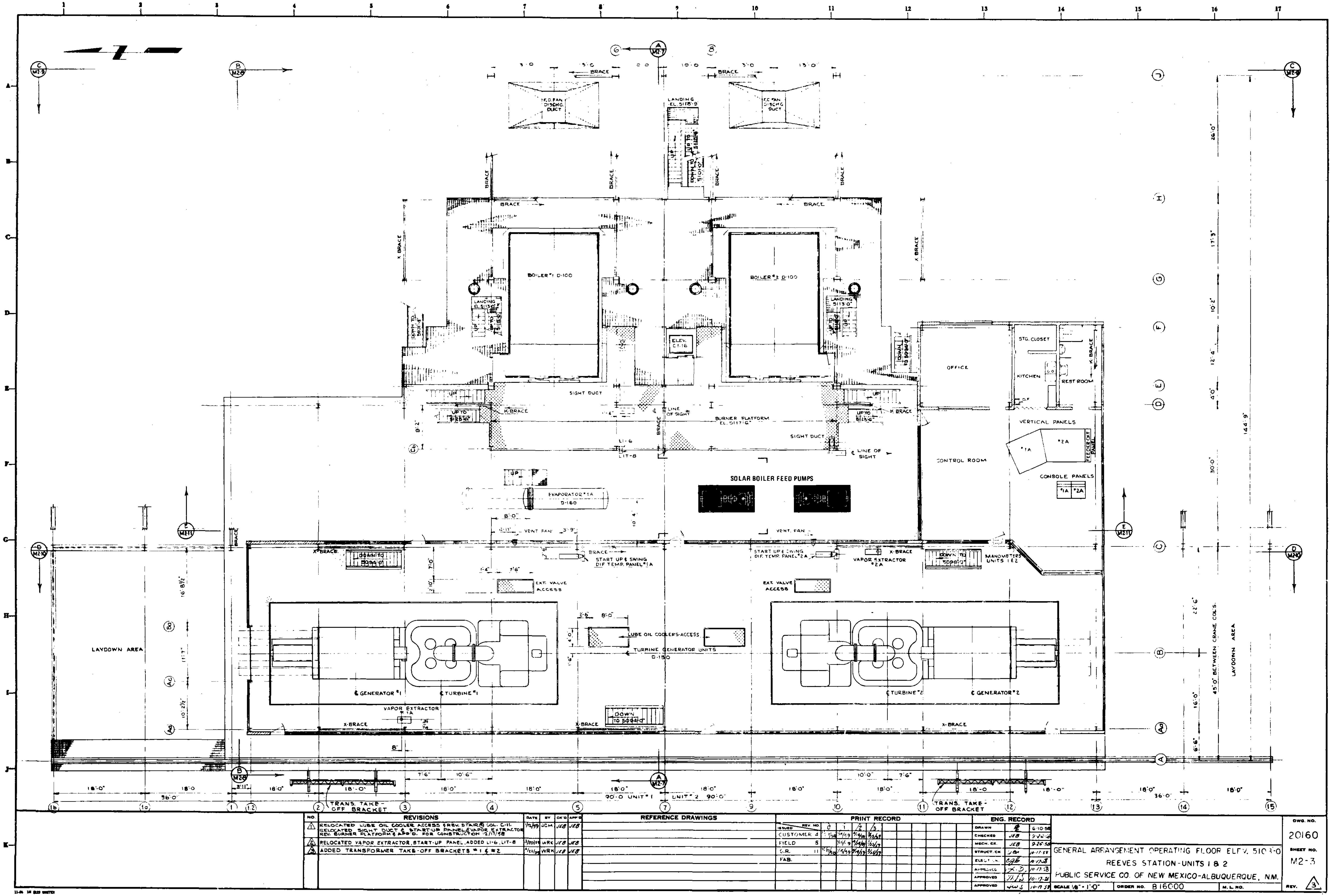


Figure 5.2.2.1-3 REPOWERED REEVES UNIT 2 PLAN AT OPERATING FLOOR

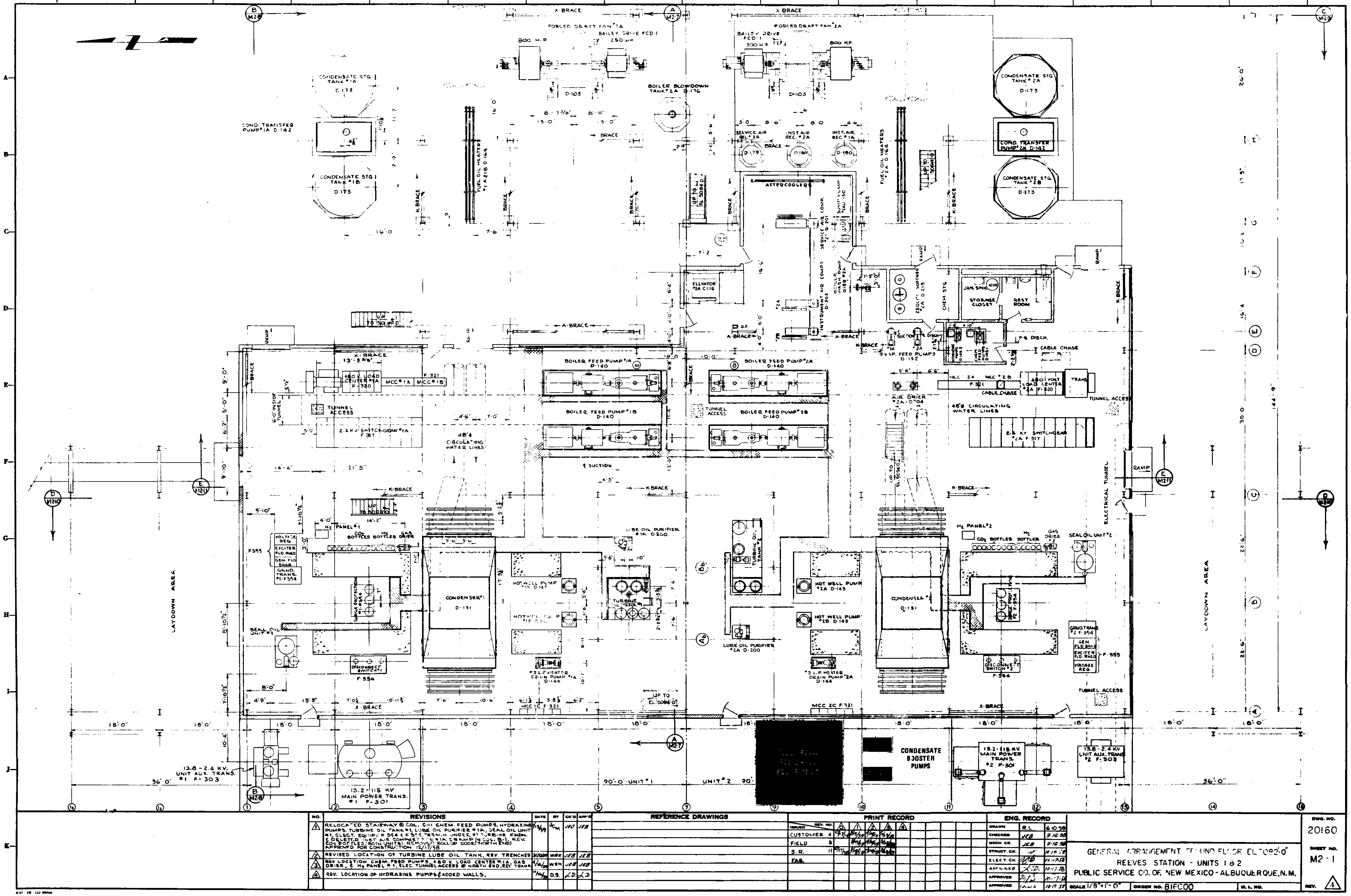


Figure 5.2.2.1-4 REPOWERED REEVES UNIT 2 PLAN AT 5082 ELEVATION

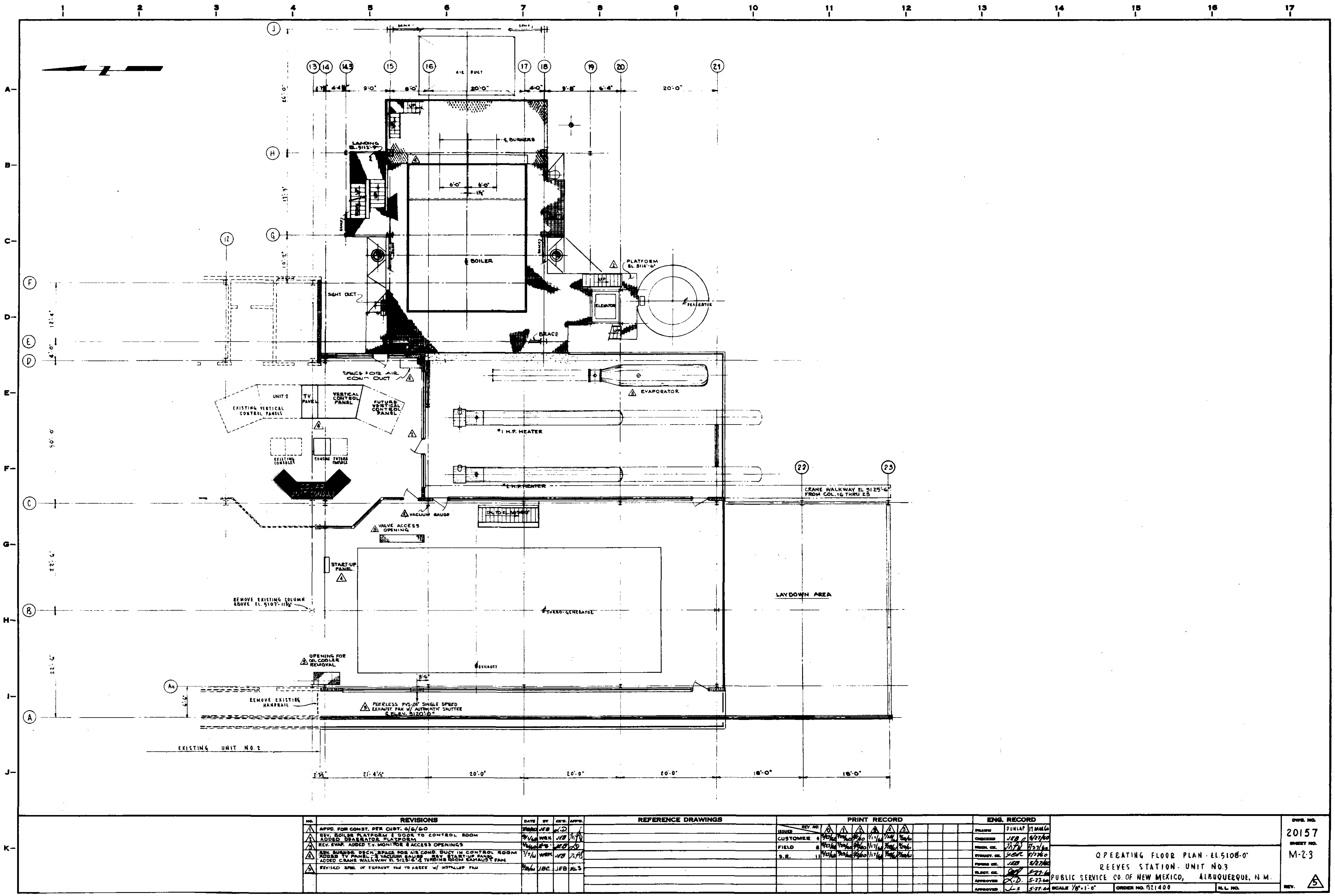


Figure 5.2.2.1-5 REPOWERED REEVES UNIT 2 PLAN AT CONTROL ROOM

condensate booster pump to supply purified water to the system.

The receiver is a once through boiler and requires a very high quality water. The use of a full flow polisher and a chemical injection system for removing oxygen will provide the high purity water. The receiver, being a once through boiler, has no blowdown. The introduction of a full flow polisher, which will be located between the existing condensate pumps and the low pressure heaters, will add to the condensate system pressure drop. The pressure drop through the full flow polisher will be overcome by adding a new condensate booster pump downstream of the polisher. The feedwater, after leaving HP heater No. 1, will split into two streams. One stream, through a feedwater control valve actuated by the steam provides the suction of the new feedwater booster pump which pumps the feedwater to the receiver. A control valve and recirculation will be provided to control flow to the receiver. A branch line, taken from a point downstream of the boiler feed pumps, will provide water to the attemperator to control steam temperature. A schematic diagram of the modified steam/water system is shown on Figure 5.2.2.1-6.

The control system would be modified to place the existing boiler feed pumps on a total unit demand (sum of solar and fossil boilers). The existing fossil boiler drum level controls will now regulate the aforementioned feedwater valves.

- Main Control Room Modifications

The existing control room will be utilized to house the additional control panels and operator consoles. Only minor room modifications such as new baseplate bolting and floor penetrations will be required. It is expected that the present boiler control system will be replaced in part by an

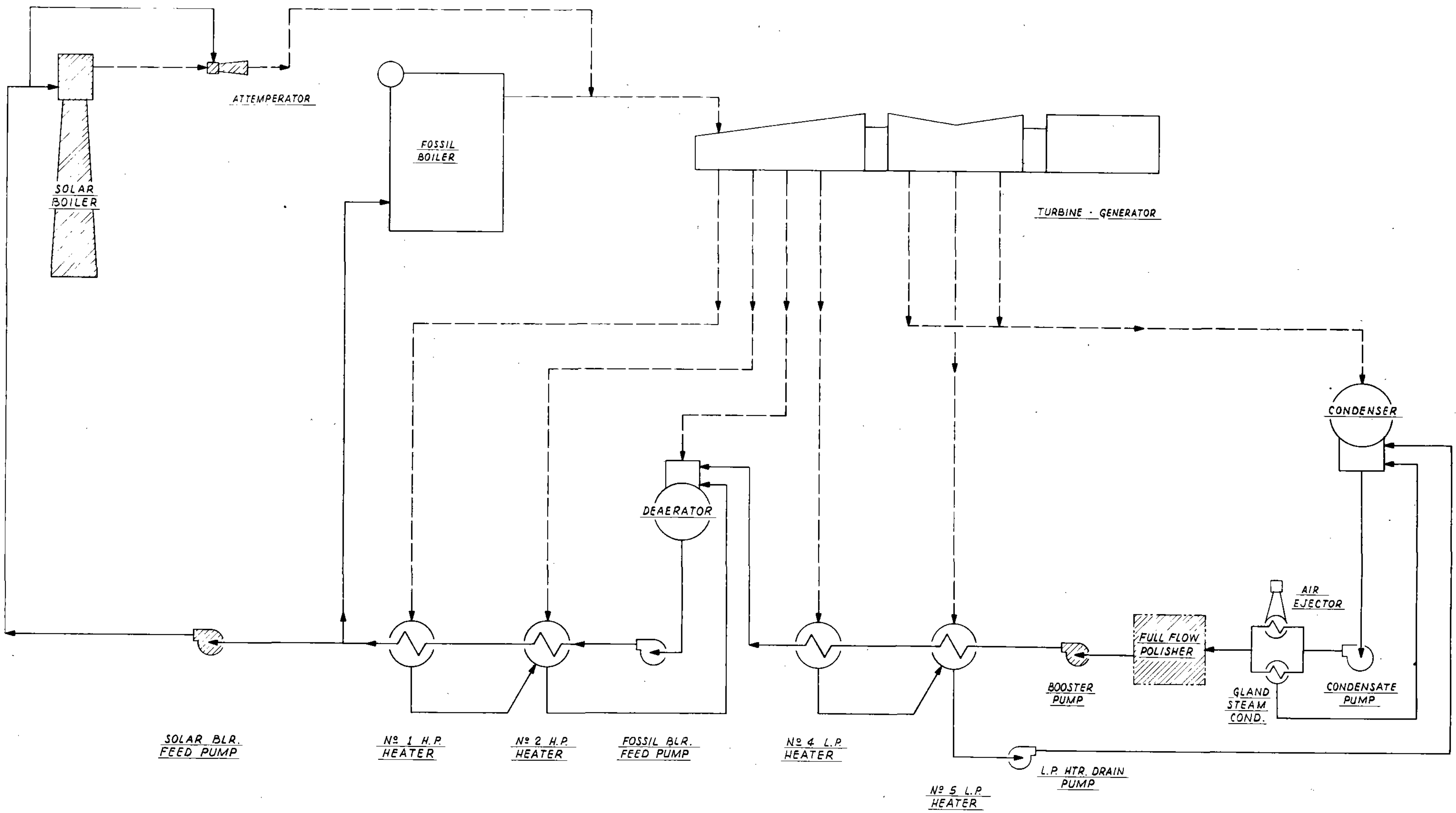


Figure 5.2.2.1-6

CONCEPTUAL FLOW DIAGRAM

electronic system compatible with the solar subsystem controls. This new electronic system will require mounting on the Unit 2 control panel. In addition, the sophistication of both the new electronic Boiler Control System and additional control equipment supplied for the Solar Unit may dictate a new Unit 2 control panel or panel addition to existing panels. Additional control equipment such as remote burner controls, CRT (Cathode Ray Tube) information centers, additional turbine and balance of plant controls, etc., are visualized as mounted on the new panel. Additional control consoles are also to be located in the control room. These consoles will be utilized for the Solar Unit Master Control System.

- System Auxiliary Room

The addition of the solar subsystem controls and new electronic boiler controls requires modifying the existing facility to provide a separate auxiliary room to house the electronic cabinets. The room will require a temperature and humidity controlled environment. The room is expected to house the following:

12 Bays - Solar Unit Master Control System Cabinets

4 Bays - Combustion Control System Cabinets

4 Bays - Burner Control System Cabiners

4 Bays - Turbine Control Cabinets

Each bay is expected to be roughly 30 inches wide.

The additional air conditioning equipment required for the controlled environment is expected to be located adjacent to the existing HVAC equipment.

- Electrical Modifications

  The existing station battery system will be increased. Additional cable trays will be required to accommodate the new electronic systems. An additional motor control center will also be required.

- Boiler Hardware

  A new burner control system will be considered for monitoring boiler safety and assisting in igniting and shutting down the six burners. This new system could facilitate in quick load changes in case of disruption in the Solar Unit with minimum adverse effect on electrical production.

- Unit Software Makeup

  A water softener system will be required in washing the mirrors. The water softener will treat water supplied from an off plot location or from the raw water storage tank and the purified water will be then stored and used when required by the mirror spray wash system or plant makeup. Interconnecting piping and valves will be required to convert the new equipment identified above including the feedwater line to the receiver and the steam line from the receiver to the existing steam line leading to the steam turbine.

5.2.2.2 Turbine Generator

- Description

  Reeves Unit No. 2 is a 44 MW capacity, two casing, tandem, 3600 rpm, double flow, AIEE-ASME preferred standard turbine designed for operating steam conditions of 1250 psig, 950°F and 1.5 in.-hg-abs exhaust pressure. The turbine is guaranteed for 44 MW(e) with rated steam inlet conditions with 3.5 in-hg-abs exhaust pressure, five stages of feedwater heating and 3% makeup.

The Reeves Unit No. 2 has two combination stop and throttle valves, one mounted on each side of the steam chest which includes the following:

- Provision for testing each throttle valve while unit is in operation.
- Solenoid trip device for remotely tripping throttle valves and closing control valves.
- Two signal switches on each throttle valve for remote indication of throttle valve position.
- Signal switch on each throttle valve, when connected in series, will trip the main circuit breaker when both throttle valves are closed.
- Removable steam strain in each throttle valve body.

A separate over-speed governor will trip the throttle valve in the event of 10% over-speed and a provision is included to test the over-speed trip while it is operating without over-speeding or tripping the turbine. The steam chest is integral with cylinder cover containing multiple governor control valves.

A hydraulically operated governing system controls the position of the governor control valves. The system has adequate response to prevent over-speed trip in the event of a sudden loss of load. The speed regulation is 2% for a gradual change in load equal to 1/2 the unit rating. The system is provided with a hand-operated steam flow limit devices. The speed changer is suitable for hand and motor operation; speed changer range is ±5 percent of rated speed.

The complete oil system contains an oil reservoir, main oil pump mounted on turbine shaft, twin oil coolers, auxiliary oil pumps mounted on oil reservoir, and vapor extractor mounted on oil reservor.

The thrust bearing is a pivoted shoe-type. Two thermometers are mounted on the exhaust hood. The turning gear is motor operated.

Tripping devices are provided for low vacuum and excessive thrust loading. Exhaust relief diaphragms are provided in exhaust hoods.

The Reeves Unit No. 2 performance specification is summarized as follows:

The heat consumption, when operating under design conditions will not exceed the quantities specified below. These quantities include steam used and consumed by the turbine, and losses in the generator including energy required in the field for excitation, and the losses of the exciters.

kW	P-f	Heat Rate (Btu/kWh)
44,000	0.935	8,955
40,000	0.85	8,964
30,000	0.85	9,095
20,000	0.85	9,485
10,000	0.85	10,618

The unit has been operated as a base-loaded unit except at night or during the noon hour.

The following repairs were made during an outage of April 1971:

1) Lower pressure blades were modified to include stellite strips

2) Cracks on the high pressure outer casing and main steam connections at horizontal joint were welded

3) Magnaflux test performed on the bottom half of low pressure blade ring - found no defects

4) Cracks in nozzle chamber were removed by grinding

5) One small surface crack from shroud of Row #28 was removed

6) The high pressure rotor expansion groove near control stage was machined

- Modifications

  As previously noted, PNM will modify this unit for cyclic operation in preparation for planned intermediate dispatching in 1980. All major turbine components will be investigated and upgraded where appropriate as recommended by the manufacturer for optimum thermal cycling durability. PNM plant engineering and operational personnel are continuing to assess required modifications, and will complete these actions by the end of calendar year 1979.

The following control system modifications are planned.

1) Replace the existing 150-lb mechanism Hydraulic Control System with a Digital Electro-Hydraulic (DEH) Control System.

2) Replace the existing Turbine Supervisory Instruments (TSI) with a Bently Nevada design.

3) Add all turbine generator sensors required by the DEH for Automatic Turbine Control (ATC).

4) Provide necessary sensors for the Steam & Metal Temperature Recorder.

The above recommendations are based on the following reasons:

1) The DEH System provides valve management which will permit greater capability for handling load cycling with minimum rotor stress.

2) The DEH System provides Automatic Turbine Control which will permit start-up and load changing while automatically controlling rotor stress as well as considering all significant T-G conditions. This provides the capability of handling unexpected main steam conditions which can occur in any plant using new technology.

3) The DEH is a proven state-of-the-art system which is, both esthetically and functionally, most compatible with the Digital Plant Control System. A Data Link can be provided for DEH/Plant Control communication.

4) The DEH System provides maximum flexibility for modifying control functions as operation philosophy evolves during the design and early operational stages.

5) The DEH System with Remote and Operator Adjustable Throttle Pressure Control option provides maximum turbine protection against water carry-over. Throttle pressure variation will be a normal operating condition.

6) The DEH provides faster response than the existing mechanical control system as well as repsonse to system frequency fluctuations.

7) The DEH includes an over-speed protection control (PC) function in addition to the centrifugal trip weight presently provided.

8) New Supervisory Instruments are provided as well as other primary measurement devices to insure that the DEH as well as the operator has reliable data, to base operating decisions on.

5.2.2.3 Heat Rejection

- Description

  Steam from low pressure turbine is exhausted to the shell side of the unit condenser. The condenser is a Westinghouse surface type condenser, with a capacity of condensing 360,000 lb/hrs of 1080 BTU/lb steam. The steam passes over 37,500 sq ft of cooling tubes and the resulting condensate is collected in a hotwell for distribution back to the boiler.

  Circulating water pumps pass the cooling water medium through tubes of the condenser to the cooling towers. The cooling towers are designed to distribute the water so as to achieve maximum contact with ambient air thereby rejecting the heat content, accumulated from the condenser, to the atmosphere.

- Modifications

  No modifications to the heat rejection system are required for the repowering project.

5.2.2.4 Water Treatment Modifications

The once-through boiler design for solar firing requires feedwater of high purity since there is no fixed steam-water separation point for blowing down. A full flow condensate polishing system and a chemical feed system is used in order to maintain the necessary purity with minimum corrosive effects in the feedwater. The full flow condensate polishing system consists of:

- Precoat prefilters to remove particles larger than 1/10 micron.

- Mixed-bed demineralizers to remove dissolved solids.

- Cartridge post filters to trap resin particles or other suspended solids.

- Pumps to convey the water to and from points in the system.

- Chemical feed system to introduce hydrazine and ammonia for pH control and oxygen removal.

Although the water polishing is only required for the feedwater piped to the once-through receiver boiler, the treatment package is connected to the feed water stream just upstream from the No. 5 low pressure feed water heater to permit operation at lower pressure.

The polishing system will be designed to permit various modes of operations including:

- Demineralized water storage tank polishing.
- Makeup water polishing operation.
- Normal plant operation.
- In-stream polishing operation.

During normal operation, only the low pressure heater drains and the sample drains will be sent to the bitter storage tank for polishing.

At boiler start-up all water will be polished from start-up through partial load. During this, so called, "in-stream" polishing all flow returning from the boiler and turbine will be sent from the hotwell to the low pressure heater drain tank for processing through the bitter storage.

5.2.2.5 Unit Control

The plant control consists of the independent control systems for the individual subsystems, and the Master Control System (MCS) that supervises and coordinates the control of the total plant. Part of the plant is existing, the fossil boiler and turbine generator, with an existing control system that will be modified, and part is the new solar equipment. The controls will be coordinated to allow interface between all of the control systems and operator through the master control system.

- Existing Control System Design

  The existing boiler control system is a Bailey Meter Co. pneumatic control system. Turbine first stage pressure is used as an indication of turbine steam flow. This turbine flow is used as an index of what steam flow is required from the boiler. The boiler control uses this index as a feedforward demand signal for boiler firing rate through positioning of the gas feed valve. The actual turbine throttle pressure is then compared with the throttle pressure setpoint and the error signal is used to generate a correction signal to trim the gas valve demand position signal. Thus, the boiler firing rate responds to steam flow changes and any error in the calibration or non-linearities in the system are corrected by the throttle pressure correction trim signal.

  The drum level is controlled with a three element feedwater control and steam temperature is controlled through superheater attemperator sprays. The automatic controls maintain the correct ratio of fuel to air flow.

  The control system is set up in such a way as to allow automatic operation only at loads above approximately fifty percent of rated steam flow. This is due to a low limit signal on the automatic position demand for the gas flow valve.

  The turbine control system is a Westinghouse 150 lb. hydraulic system. Basically it uses turbine speed as its only feedback. Load changes can only be achieved through manual changing of the inlet valves position to admit more or less steam. A protection system against a low throttle pressure setpoint is also on the turbine. In the event of low throttle pressure, the inlet valves are closed until some minimum position is reached or until throttle pressure is restored. This is an attempt to protect against water in the steam entering the turbine, due to rapid flow rate changes in the fossil boiler.

- Modifications to Existing Systems

The turbine control system will be modified to include a modern turbine controller that will interface with the master control system and will handle automatic matching of the solar and fossil boiler steam. This will resolve problems that would exist with the present system.

During intermittent cloudy days, the fossil boiler must operate with the solar boiler to compensate for transients in the solar boiler output. Since the solar boiler will deliver up to sixty percent of the unit's rated steam (at summer solstices), the fossil boiler must run below fifty percent rated load. With the existing control system, the fossil boiler can only be operated at this level in manual, and thus no automatic transient compensation can occur.

Obviously, this limitation will be unacceptable for the operation of the Solar Hybrid Repowered Unit. Thus, the boiler control must be modified to allow for automatic operation at lower load levels. In addition, the master coordinated control system must be able to adjust the fossil boiler output temperature and pressure so that it can be matched to the header steam conditions from the boiler. This requires the ability for the fossil boiler control to respond to a remote steam temperature and throttle pressure setpoint. Finally, the firing rate index must now take into account the solar boiler output beside the steam flow, and also the desired plant load.

In the solar only mode of plant operation, the only way to control throttle pressure is with the turbine inlet valves since the solar firing rate cannot be controlled. This is not possible with the present turbine control. Also, no remote automatic load setpoint is available for the turbine control. This makes a coordinated startup without operator intervention impossible.

The modification will provide the ability to monitor turbine steam temperature, and recommend the correct load rates and steam temperatures to minimize thermal stress on the turbine. Such a controller will provide coordinated control, add operating life to the turbine and provide detailed comprehensive monitoring.

All of the above will require modifications to the existing fossil boiler control. The extent of such modifications will be determined during the design stage.

5.2.2.6 Master Control System

The Master Control System (MCS) supervises and controls the overall Solar Hybrid Repowering plant operation by coordinating the independent control systems of each of the individual subsystems. The purpose of the MCS is to provide an operational mode where the operator can communicate with all the plant control systems through a single point of entry. The MCS translates the operator's desired plant operating state into setpoints and control commands for each of the individual control systems. These systems will be for the Collector System (CS), Receiver System (RS), Steam Header System (SHS), Turbine-Generator System (TGS), Fossil Boiler System (FBS), and Balance of Plant (BOP). In addition to this control function, the MCS will collect data on the entire plant and make this information available to the operator through one central communications port.

In addition to performing the functions described above, for the precommercial unit only, some other requirements will be considered. Larger data collection and storage may be needed since detailed plant evaluation will be desired. In addition, off-line manipulation and analysis of this data through digital techniques may be required to permit long term storage and economical transmission of the data. The means of easily changing the MCS system at the plant site should be incorporated into the original design.

The basic tasks to be performed by the MCS involve performing complex sequencing and logic decision making, calculation of setpoints based upon plant conditions and the collection, display, storage and retrieval of plant operating data. All of these functions are best suited to a digital computer and would be much harder to do in an analog control system. Therefore, the hardware will be of a digital design.

The MCS should be as cost effective as possible and should use proven techniques. Both these motives point to using a standard, typical power plant data acquisition and control system adapted to the Solar Hybrid Repowering Plant. This adaptation will be achieved by writing programs (in a high level language) for the unusual control and sequencing functions, but using standard proven data base management, data collection and operating system programs. Thus, a majority of the hardware and software will be tested and proven and a minimum amount of new software will be required.

The MCS should also be reliable. Some degree of reliability will be achieved through the use of proven hardware and software. However, to further enhance the reliability, more than one Central Processing Unit (CPU) should be available for use by the control and supervisory functions of the MCS. This implies either the use of a standby redundant CPU or a more cost effective solution, building the MCS with multiple mini-computer CPU's. In this system several mini-computer CPU's, using multiple accessed "shared" core (and storage to permit rapid reload and restart) for information transfer and switchable I/O busses for process I/O communication perform all the functions of the MCS system. Then, in the event of any CPU failure, the total MCS gracefully degrades itself to a predetermined mode where the important functions such as control and supervision run and some of the lesser important functions such as logs are discontinued. Thus, no CPU sits idlely for most of the MCS operating life and if a CPU fails, the system reverts to a known effective operating mode.

Since the MCS system will be a multiple CPU configuration, then it is easy to add on a dedicated CPU for the precommercial plant detailed data storage and manipulation. The advantage is that this CPU can obtain its information from the rest of the MCS and thus save the added expense of duplicating process I/O hardware.

Also, the flexibility required for the control and supervisory system will be obtainable. Programming changes, to solve unexpected conditions that arise, can be made through the use of the high level language compiler. This compiler will run in one of the multiple CPU's which will have "batch", i.e., programming capabilities. This will require some input/output mode, i.e., punched cards, magnetic tape cassettes, etc. and bulk stored memory devices.

Communications to the system should be compatible with present day standard power plant digital computer systems. This implies communication should be through interactive English language CRT commands, entered through a keyboard, and output displays should make maximum use of colored graphic CRT's. The communications will be centralized to one area and the MCS will lead the operator through the communications steps via fill-in-the-blank type interchanges. Again all these communication programs will be in standard, proven software to increase reliability and cut cost.

By using the above described configuration, maximum reliability will be obtained. Since each individual system has its own control and most have both auto and manual control levels, a total MCS failure will still leave the operator with control of the plant. Single point failure within the MCS has been virtually eliminated since the failure of a single CPU will merely cause the system to degrade to a mode where some extra functions are dropped but important control functions will still remain.

The MCS will be distributed functionally through the multi-CPU hierarchy as shown in Figure 5.2.2.6-1. The number of mini-computer CPU's shown is determined with the information available at this time.

The Control and Supervision System (CSS) which would perform the logic for startups, shutdowns, and normal plant operation and generate the setpoints for the individual subsystem control elements will reside in a CPU separate from the Plant Information Collection System (PICS) which collects and displays data to the operator on the plant's operating status. However, through shared memory the two systems will maintain communications. In addition, a third CPU will function to support and collect data from the PICS to perform MCS diagnostics, and for use in plant evaluation calculations and manipulations. This CPU will also contain the redundant Plant Protection System which will provide protection for each element of the plant. This protection will be in addition to the individual element's protection controls such that a total MCS failure will still leave the plant with a protection system.

The fourth CPU will only be needed for the precommercial plant and not for normal Solar Hybrid Repowering systems. It will contain the Plant Evaluation and Programming System (PEPS); programs for plant evaluation data manipulation and storage. In addition, it will be used for a programming "batch" system upon which programming changes can be performed at the plant site.

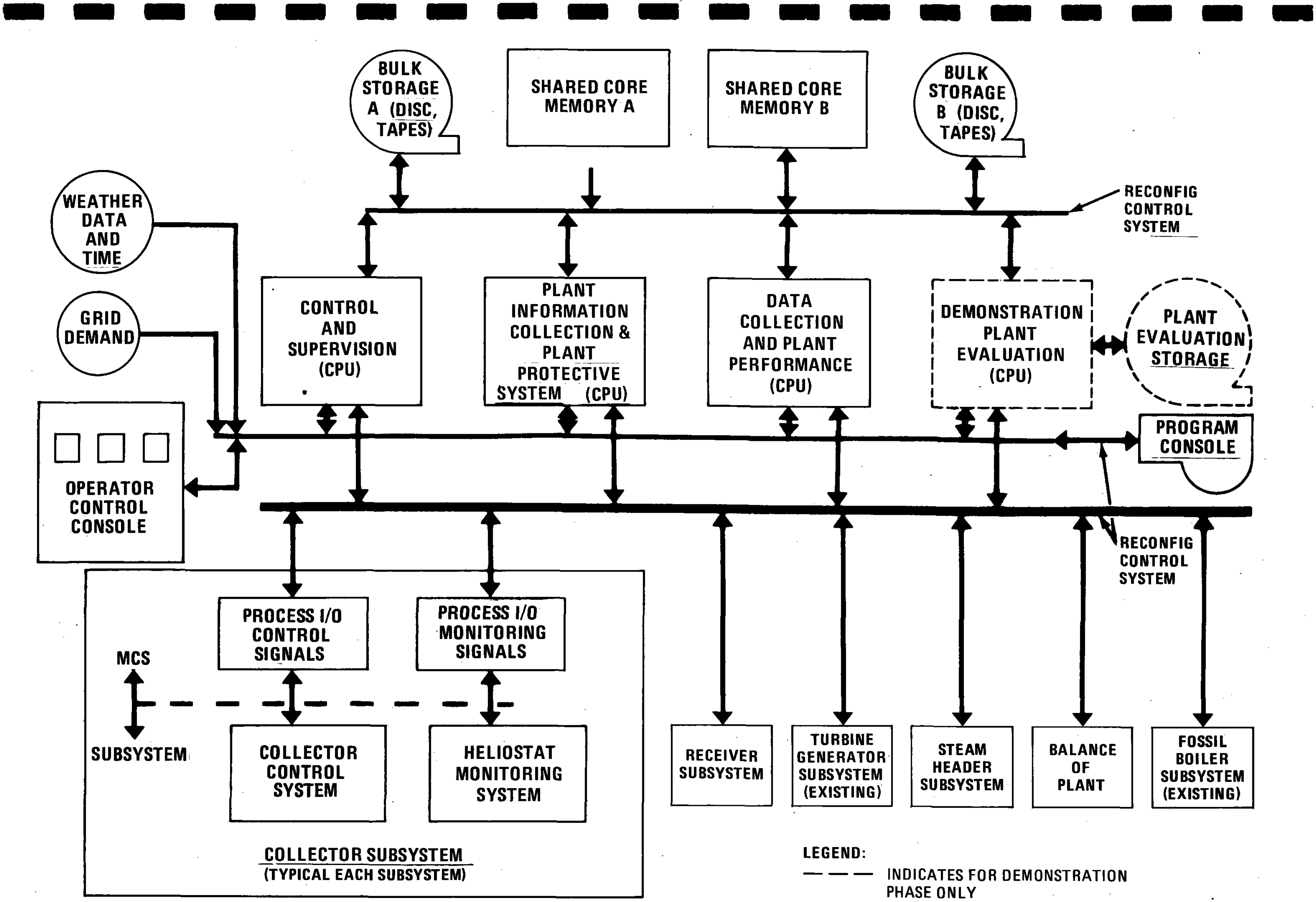


Figure 5.2.2.6-1
MCS HIERARCHY

A Reconfiguration System communicates with all the CPU's. Upon a failure in the system it allows for automatic or operator controlled reconfiguring of the system to a different allocation of the available resources. This allows the MCS to gracefully degrade itself and the important functions such as Control and Supervision continues running and the things of lesser importance such as Plant Evaluation Programs are temporarily shut-down until a repair can be made.

The MCS interfaces to the individual elements of the plant in the following manner:

Collector Subsystem Control

The Collector Subsystem controls will be based upon a central CPU which then feeds the individual heliostat positioner controls. During phases of Solar Boiler startup and shutdown varying quantities of steam will be required from the Receiver System which will be a function of the thermal heat being delivered by the heliostats. The thermal energy delivered will be a function of the solar insolation, time of day, and number of heliostats focused. Therefore, to translate the required steam in terms of desired output megawatts, to number of heliostats focused requires information that will already be needed by the Collector Control System. Therefore, rather than duplicate this information and programs in the MCS and thus complicate the interface, the MCS will give a setpoint in terms of level of thermal energy required. This might be in discreet steps such as startup, minimal load, quarter load, half load, full load or might be a continuous signal. This is to be determined during final design.

Information from the collection field that is determined of interest to the operator for display will be received by the PICS portion of the MCS. Likewise, information just for plant evaluation will be received by the Plant Evaluation System.

Receiver Subsystem Control

The Receiver System will provide its own automatic control of the steam temperature and flashtank bypass valves. The MCS system will supply this control with proper setpoints for these control variables so that steam conditions can be matched to turbine and header conditions and an orderly shutdown or startup will take place. In addition to this control interface, information will be collected and displayed by the PICS section of the MCS.

Fossil Boiler Control

The FBS will have its own independent automatic control system. The MCS will provide to the FBS control system a setpoint for throttle pressure, and steam temperature to match fossil boiler outlet conditions to the solar boiler and turbine. In addition, the MCS will provide a load demand signal which will be the index for required plant load and available solar boiler steam flow.

By manipulating these setpoints the MCS will startup and shutdown the fossil boiler while not upsetting steam conditions on the steam header. Also, the MCS will maintain constant unit load by manipulating the fossil boiler to make up for changes in solar boiler output due to transients in the solar insolation.

Turbine Generator Control

The MCS will give the DEH system a setpoint for load and the DEH will open the turbine governor valves correspondingly. The MCS system then will use this setpoint to manipulate the valves and thus control steam header throttle pressure. In addition, the MCS can monitor metal temperatures and recommend load and acceleration rates.

Balance of Plant Control

The MCS will interface with the balance of plant equipment by reading sensors and status contacts into the MCS. Outputs to the balance of plant will be in the form of logic command contact outputs and setpoints for the individual elements control.

Operator

The MCS system will provide the operator with a point of communication. This interface will consist of pushbutton keyboards for operator inputs and color graphic CRT displays for MCS outputs. Commands to the Control and Supervisory System of the MCS will be activated by dedicated start-stop type buttons for actions, with fill-in-the-blank communication with the MCS for startup sequence, etc.

The operator will have various plant information displays available to him. These will be both of the on-demand and periodic type and will use tabular word form of display as well as pictorial graphic flowcharts and bargraph type displays. The operator will request these displays through a conversational, self-instructing, fill-in-the-blank CRT input. The following are the functions available to the operator:

- Display/Print Point.
- Add/Remove Point to Scan.
- Sensor Calibrate.
- Value Enter (limit assignment and changes, control parameters, etc.).
- Analog Trend Pen Assign/Scaling.

- Alarm Review Display/Print.
- Change Point Scan Frequency.
- Point Repeat Display (Immediate Scan-Update).
- Assign Points to Special Log.
- Initiate Special Log.
- Review Point Values.
- Update System Time.
- Scan Removed Review Display/Print.
- Limit Check Removed Review Display/Print.
- Value Entered Review Display/Print.
- Review Points Off of Normal Scan.
- Bad Input Review Display/Print.
- Post Trip Demand Display/Print.
- Peripheral Device Transfer/Restore.
- Post Operative Review.
- Logs - Free Format Logs consisting of up to ten pages, 16 process points per page.

Control Levels

The MCS system provides a fully automatic level of plant operation. Based upon operator input, the MCS runs the plant through logic commands and setpoints to the individual control systems.

A second level of operation involves the MCS supervising and monitoring the plant operation, with the operator, through the MCS console, providing the commands to the plant. In this control level, one central point of communication exists and the operator receives recommendations, but still retains the final command.

The final level is manual where all inputs must be made to the individual control system by the operator(s). MCS alarms and monitors would still be available.

All three levels of operation will track each other and the transfer between levels will be "bumpless", i.e., no change shall be seen by process. The individual protection systems will always be in service, no matter what the level of the MCS and the additional MCS protection system will act automatically in the Automatic mode and produce alarms in the other two levels.

Plant Evaluation System

For the pre-commercial plant only, the MCS includes a Plant Evaluation system. This system consists of a CPU with capacity for large data storage including a 40M word moving head disc and mag tape cassette capacity. Information passed from the other sections of the MCS concerning weather data, plant operating conditions and control system performance can be stored and kept for research and evaluation of the plant's concepts.

In addition to storing the information, off-line statistical analysis programs can be generated for the plant site computer. In addition, programs to reduce, compact and format the information for transmittal to off-site computers for detailed analysis or other uses can also be generated. All programming will be in a high level (Fortran-like) language.

5.3 SITE CONDITIONS AND OTHER CONSIDERATIONS

- INSOLATION

The Reeves Station of the Public Service Company of New Mexico system is an excellent choice for location of a Solar Hybrid Repowering Pre-Commercial Plant since:

- the insolation level is relatively high for most of the year enhancing the potential for demonstrating economically competitive and useful commercialization of solar hybrid repowering,

- most of the reliable direct normal insolation data available in the United States has been accumulated for Albuquerque, New Mexico and will thus permit a high level of confidence to be achieved in the design of and the performance predictions for the plant.

- an instrument package for recording direct normal insolation data has been installed at the station as part of the WEST Solar Resource Evaluation Study, and measurements (every 15 minutes) of direct normal insolation has been recorded since June 1977; thus, providing a site specific data base for verification of the plant design.

Figure 5.3-1 shows the predicted geographic variations in direct normal insolation for the United States(1). These data indicate that the yearly average day values for the direct normal insolation varies from approximately 5.6 $KW\text{-}h/m^2$ day for the Texas/Oklahoma region of the country to 7.2 $KW\text{-}h/m^2$ day for the Arizona/Nevada region. The value for Albuquerque,

(1)Insolation and Climatological Analysis Task Report prepared by Arthur D. Watt as part of EPRI Research Project 648-1. Prime Contractor is Westinghouse Electric Corporation, Pittsburgh, Pennsylvania.

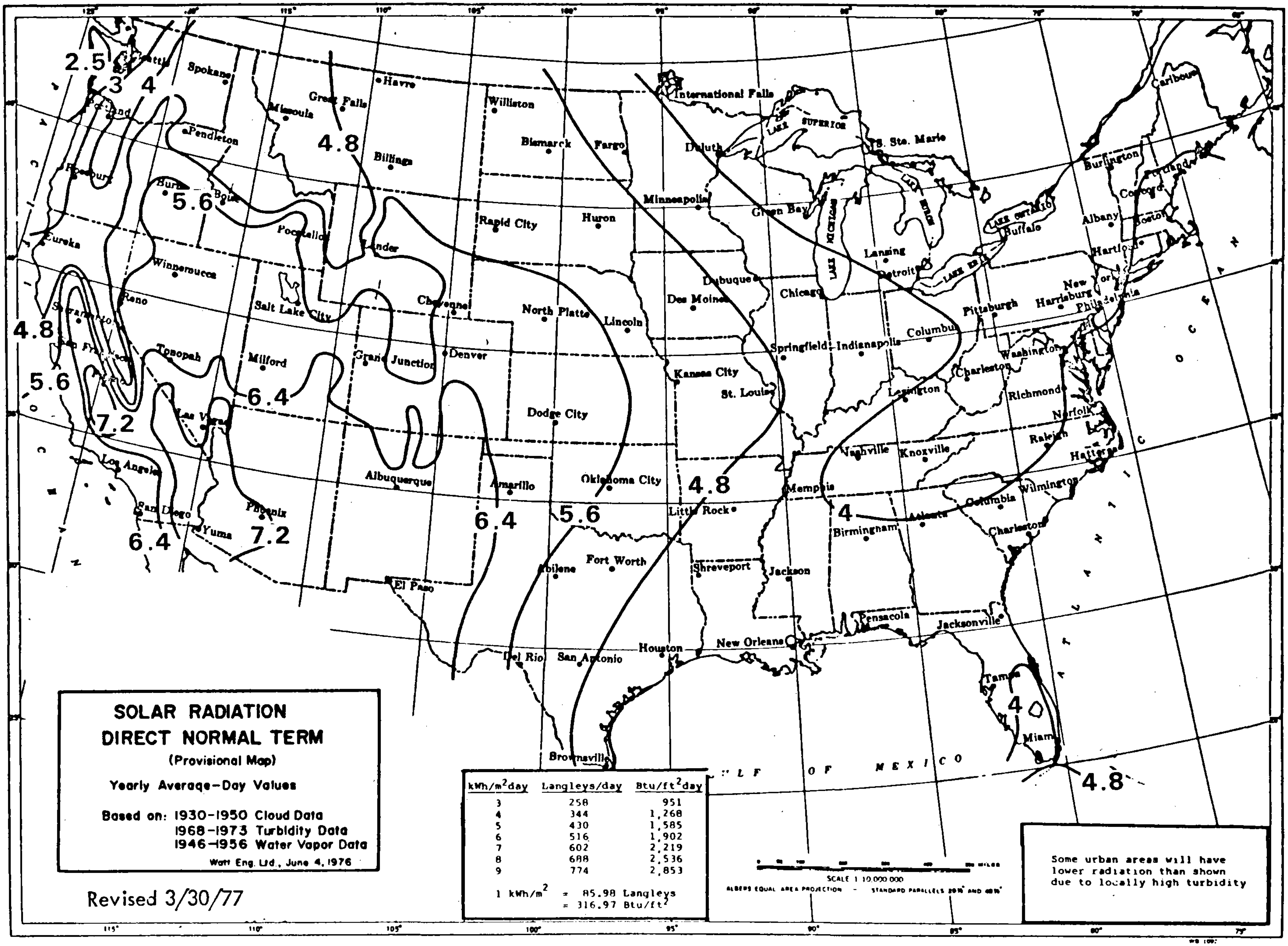


Figure 5.3-1 SOLAR RADIATION - DIRECT NORMAL TERM

New Mexico is approximately 6.6 kW-h/m^2 day. Therefore, it can be expected that the data obtained from a demonstration program for solar repowering performed in New Mexico from an insolation level standpoint will be representative of what can be achieved through solar repowering of other units located in other regions of the Southwestern United States.

Table 5.3-1 presents the monthly and annual average direct normal insolation values for Albuquerque, New Mexico for the years 1961 through 1964; the average annual values range from 6.59 to 7.08 KW-h/m^2 day for these four years. These data were obtained from ten-minute digitized records available for Albuquerque, New Mexico from the National Environmental and Climatic Data Center. The variation in direct normal insolation on a day-by-day basis for June 1962 is given in Figure 5.3-2. The data presented in this figure indicate that solar energy could be used to displace a significant portion of the fossil fuel required to operate a power plant at Albuquerque during every day of June 1962. In addition, "clear day" insolation profiles were observed for approximately 50 percent of the time during June indicating the potential of the solar hybrid repowered plant to displace in excess of 90 percent of the fossil fuel normally used during these days. Likewise, as indicated for the year 1962 (see Section 2.5) solar energy has the potential to displace significant portions of the fossil fuel that would normally be consumed during more than 300 days of plant operation.

o PRECIPITATION

Normal precipitation totals for the year average about eight inches at 5,000 feet. Departures from the yearly normals can range from half to double the normal. Usually such departures are widespread. Droughts, which can last months, even years, are more persistent than wet periods. Snow covers rarely last more than a few days below 7,000 feet. Winter precipitation is mostly associated with polar pacific airmasses and occasionally arctic airmasses. The onset of the summer thundershower season is a result of a monsoon type circulation which imports a greatly modified tropical maritime airmass. Rather dependably this occurs about July] and ends in late September. Temperature and precipitation data are shown in Table 5.3-2 below.

Table 5.3-1

DIRECT NORMAL INSOLATION FOR ALBUQUERQUE, NEW MEXICO
MONTHLY AND ANNUAL VALUES, kW-h/m^2 DAY

Month	1961	1962	1963	1964	Average
January	6.26	4.87	6.06	5.61	5.70
February	6.05	6.21	6.32	5.75	6.08
March	5.76	5.99	6.16	5.66	5.89
April	8.09	7.15	6.92	6.99	7.29
May	7.52	8.85	7.51	7.50	7.85
June	8.54	9.82	8.80	9.35	9.13
July	8.21	6.98	7.03	7.49	7.43
August	6.84	8.78	6.23	7.25	7.28
September	7.43	5.67	6.88	6.05	6.51
October	7.69	7.28	6.09	7.69	7.19
November	4.75	6.47	5.23	5.97	5.61
December	5.37	6.88	6.17	3.75	5.54
AVERAGE	6.88	7.08	6.61	6.59	6.79

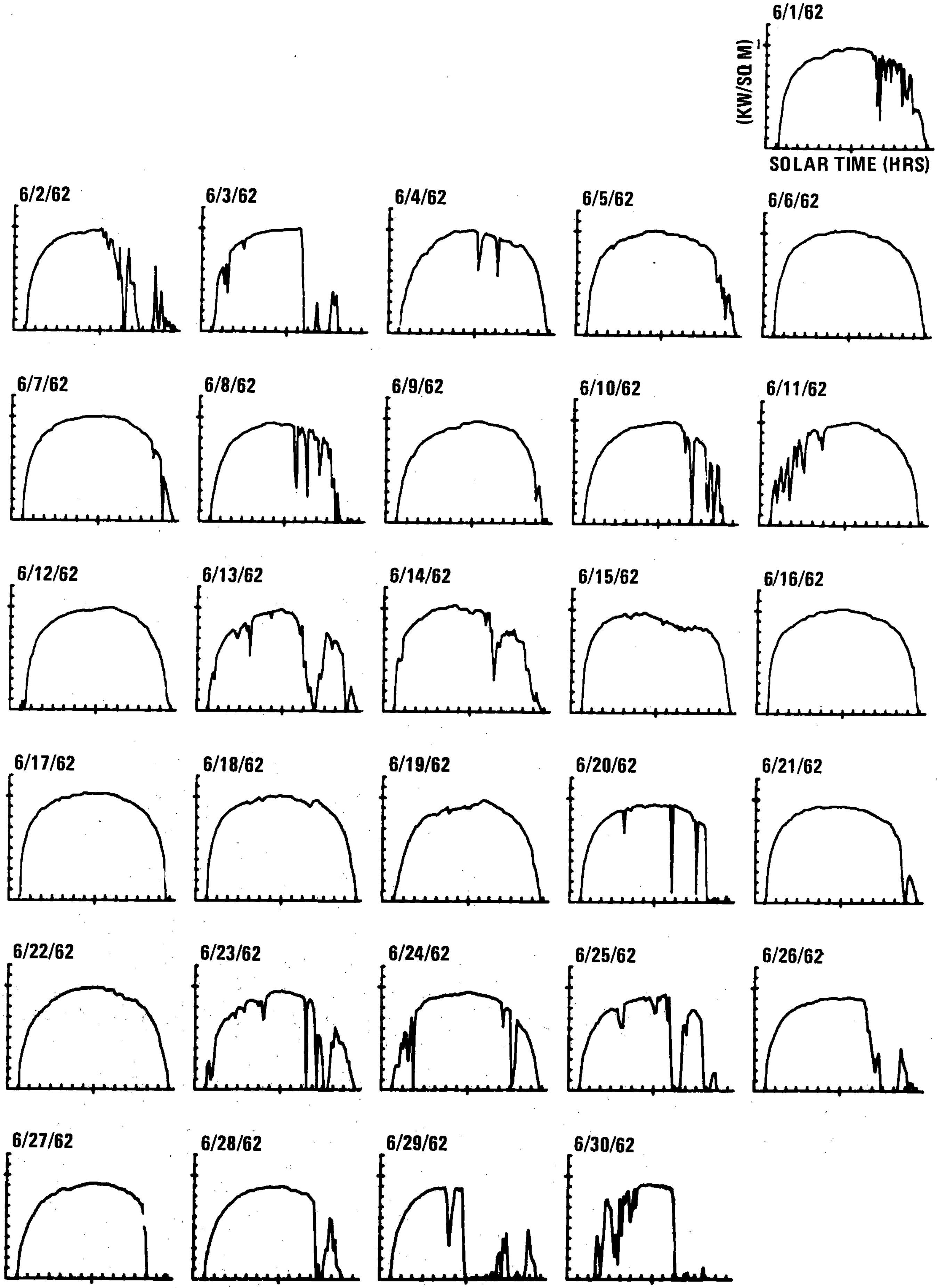


Figure 5.3-2
DIRECT NORMAL SOLAR RADIATION OBSERVED AT ALBUQUERQUE, NEW MEXICO

Table 5.3-2

CENTRAL RIO GRANDE VALLEY REGION

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures (F°)												
Average daily maximum	47	53	59	70	80	89	92	90	83	72	57	48
Average daily minimum	24	27	32	41	51	60	65	63	57	45	32	25
Daily mean	35	40	46	56	65	75	79	77	70	58	44	37
Extreme maximum	68	72	81	89	98	102	104	104	100	98	74	72
Extreme minimum	-7*	-5	8	19	28	43	54	52	37	25	10	3
Precipitation												
Average (inches)	.31	.40	.47	.47	.56	.53	1.37	1.38	.83	.78	.34	.52
Average days 0.10 in. or more (no.)	1	2	2	2	2	1	4	4	2	2	1	2
Average snowfall	1.8	1.7	1.7	0.3	T	0	0	0	T	T	1.2	2.6

T = Trace, less than 0.05 inch

For period of record August, 1939, through December, 1970.
Recording Station: Albuquerque Airport, Bernalillo County, New Mexico

*An extreme minimum of -17 was subsequently recorded on January 7, 1971.

• WINDS

Winds and wind storms occur mainly in the spring with thunderstorms. Both types of winds can exceed 60 MPH but most average 25 to 35 MPH. Spring winds usually diminish after sunset and blow out of the quadrant from south to west. Table 5.3-3 shows mean wind speeeds and prevailing directions by month.

Dust and dust storms are an unattractive feature of the arid southwest. The following discussion is taken from the New Mexico State Planning Office publication The Climate of New Mexico (Tuan, et al) concerning the nature of such storms and their occurrence in Albuquerque:

> "The basic conditions for blowing dust are the presence of wide areas of exposed dry topsoil and strong, turbulent wind. In New Mexico, dry soil with scantly vegetation cover is widespread in areas that average less than ten inches of rain a year (in the trough of the Rio Grande). The large tracts of sand hills, one series to the east of the Pecos River and another on the Staked Plains to the south of Clovis, are evidence of the effect of wind action on loose soils in the south-eastern sector of New Mexico.
>
> Dust Streams
>
> Given the presence of loose soil, the severity of blowing dust depends on the strength and turbulence of the wind. In the dry months of late fall, winter, and early spring, a common phenomenon (not dignified by the name "dust storm") is the swift motion of dust and sand in wandering sheets and narrow streams. The dust and sand bounce and skip along the surface, and the mass of material appears to be concentrated in a shallow layer less than two feet in thickness. Such local dust movements are caused by sudden, horizontal sweeps of air moving at speeds of fourteen to eighteen miles per hour.

Table 5.3-3

MEAN SPEED AND PREVAILING DIRECTION
AT ALBUQUERQUE SUNPORT

	Mean Speed (mph)	Prevailing Direction*	Fastest Wind Speed Recorded		
			Speed (mph)	Direction	Year
January	8.0	N	61	E	1949
February	8.8	N	68	NW	1944
March	10.1	SE	80	NW	1943
April	11.0	S	72	S	1946
May	10.5	S	72	W	1950
June	10.0	S	82	SE	1946
July	9.1	SE	68	E	1945
August	8.1	SE	61	SE	1951
September	8.6	SE	62	SE	1945
October	8.3	SE	66	N	1959
November	7.8	N	57	NW	1948
December	7.6	N	90	SE	1943
YEAR	9.0	SE	90	SE	Dec. 1943

*Wind direction divided into sixteen 22.5° sections.

Source: Weather Service, Albuquerque Airport

Dust Devils

In contrast to the ground-hugging dust streams are the vertical dust devils. The small vortices of rapidly moving air, made visible by the dust and loose organic matter they sweep up, are especially common in sparsely vegetated, flat and open parts of southern New Mexico during the summer half of the year.

Dust Storms

Widespread and thick drifts of dust affecting the entire state or a large portion of the state are associated with the passage of cyclones, and in particular, cyclones with sharp, cold fronts. Dust storms caused by general cyclonic winds tend to develop gradually, and the life of the typical cyclonic duster is limited to daylight hours.

One especially severe dust storm occurred at 2:30 p.m., local time, on April 2, 1956, and brought complete darkness to Midland, Texas.

Statistical information is lacking as to the seasonal distribution, intensity, and duration of dust storms for New Mexico as a whole. Von Eschen has compiled data for Albuquerque, of which Table 5.3-4 is a summary. The information is based on sixteen years (1945-1960) of hourly weather observation made at the Municipal Airport (Sunport) in Albuquerque. Dust storms are divided into three categories; severe, moderate, and light, defined as follows:

> Severe: Continuous blowing dust for three hours or more with the visibility restricted to one mile or less at some time during the storm;
>
> Moderate: Continuous blowing dust for two hours or more and visibility four miles or less during the storm (but not qualifying as severe);

Table 5.3-4

DUST STORMS IN ALBUQUERQUE*
(16-YEAR PERIOD 1945-1960)

Month	Total Number of Days With Blowing Dust	Storms Classified		
		Severe	Moderate	Light
January	14	4	3	7
February	26	7	11	8
March	44	15	12	17
April	75	18	21	36
May	55	2	8	45
June	56	5	6	45
July	38	1	2	35
August	10	0	1	9
September	8	0	2	6
October	15	0	5	10
November	13	1	2	10
December	10	3	3	4
TOTAL	364	56	76	232
AVERAGE YEAR	23	3	5	15

*After Von Eschen

Light: All other dust storms during which the visibility was restricted to six miles or less (but not qualifying as moderate or severe).

Spring months have the most dust storms, with an average of about five days in April when some blowing dust will occur. Fall and early winter months have the least dust, with September recording some dust on an average of every other year. Although April averages more dust storms than any other month, March storms normally last somewhat longer. September has the least number of dust storms but those in July and August are usually of shorter duration."

It is not anticipated that any mitigation measures are required other than protective heliostat stowage during periods of high winds. Station personnel will notify the project coordinator of any unusual occurrences involving this issue in the future.

- TOPOGRAPHY AND HYDROLOGY

Terrain

The 120 acre rectangular plot for the solar hybrid facility is located in the area south of the existing Reeves Station.

The slope of the 120 acre rectangular plot is 3.6 percent and is comprised of the Wink fine sandy loam and Embudo gravelly fine sandy loam soil types. Very little dissection of the site is present, except for a shallow drainage running east-west through the site. Drainage flows into the major drainage canal (AMAFCA North Diversion Channel) to the west of the site.

Vegetation

Vegetation at the site is characterized by black grama, sand dropseed, three-awn, bush muhly, Indian ricegrass, fluffgrass, broom snakeweed, prickly pear, and cholla cactus, tansymustard, Russian thistle and bladderprod.

During construction all animals will be displaced and the native vegetation removed.

Hydrologic Conditions

For Embudo gravelly fine sandy loam, 0 to 5 percent slopes, runoff is medium and the hazard of water erosion is moderate.

For Wink fine sandy loam, 1 to 5 percent slopes, runoff is medium. The hazard of water erosion is slight to moderate and the hazard of soil blowing is moderate.

Since the slope of this site is not great and the soil type has moderate absorption qualities, the erosion potential is moderate.

The site slopes gradually from east to west toward the drainage canal to the west of the site. Offsite drainage will be intercepted on the east side of the site and a culvert installed to conduct the flow across the site discharging into the drainage canal. The intercepter and the culvert will be sized to handle 1125 c.f.s. which is the runoff calculated for a 100-year storm. In addition the drainage through the site will be channelized to control erosion. With the above features the site and the surrounding area will be adequately protected from flooding and erosion.

- SEISMIC STABILITY

Estimate of Seismic Risk in the Area of Study

The instrumental data since 1962 indicate that the strongest shock in a 100 year period for the entire region (including the 100 km wide buffer zone) should not exceed Richter magnitude 4.9. On the other hand, the reports of felt shocks for the 94 year period prior to 1962 indicate six shocks had magnitudes greater than 5. On the basis of this data, the strongest shock in a 100 year period is likely to have a magnitude near 6.

The discrepancy in these estimates of seismic risk can be explained in two ways. Activity during the past 11.5 years was lower than normal or the activity in the 94 years prior to 1962 was higher than normal. With the short time history of seismic activity available, one cannot determine which of these two interpretations is correct. Therefore the safest procedure at this time is to assume that a magnitude 6 shock is possible somewhere in the region (including the buffer zone) during the next 100 years.

Variations of Seismic Risk Within the Area of Study

The vicinity of the Reeves site has been divided into three regions: Region 1 lies mostly in the Rio Grande Valley south of Bernalillo, Region 2 is mostly in the Rio Grande Valley north of Bernalillo, and Region 3 is located to the east of the Manzano and Sandia Mountains.

Seismicity in Region 3 appears very low inasmuch as very few epicenters or recent faults lie within or near its boundaries. The strongest shock in this region in a 100 year period is estimated to be so weak that it constitutes no danger whatever to well-built structures. On the other hand Regions 1 and 2 do have a potential for moderate shocks. Of these two, Region 1 appears to have the highest seismic risk because it has had the largest number of shocks within or adjacent to its boundaries. In addition, faults that cut late Tertiary or Quaternary rocks in Region 1 appear to be geologically younger than those in Region 2.

The strongest earthquakes in a 100 year period in Regions 1 and 2 are estimated to be of magnitudes 6 and 5-1/2, respectively. Shocks of this magnitude are considered moderate and will not damage well-built structures unless they occur beneath or very near these structures. In the latter case, damage is generally minor to properly designed power distribution equipmen, e.g., transmission lines and sub-stations (Steinbrugge et al. 1970; San Fernando, California Earthquake of February 9, 1971; 1971).

• ACCESSIBILITY

Railroad

The existing Reeves Station has a railroad spur served by the Atchison, Topeka & Santa Fe line that serves Albuquerque. Amtrak service is also available in Albuquerque.

Air Service

The largest and most active airport in the state is Albuquerque International. In 1969 the FAA reported that it ranked 47th in the United States in terms of volume of passengers. Also, the airport ranked 22nd in operations of civilian and military aircraft. In the 1972 State Airport System Plan, the north-south runway was listed as 8,993 feet in length with a 1,000-foot overrun. This length is sufficient to land almost any commercial aircraft. This airport is within ten miles of the Reeves Station.

Highways and Roads

Extensive improvement and expansion of transportation networks are planned for northwest Albuquerque. Within the vicinity of Reeves Station, the Frontage Road will be improved, running in a north to south flow west of I-25, and a south to north flow east of I-25. An I-25 interchange will be constructed at Los Angeles Boulevard. A major improvement will be the construction of a North Valley River Crossing which will follow the alignment of either Montano Road, Los Angeles Boulevard (El Pueblo Road) or Richfield Avenue. At the present time Montano Road is the favored alignment. If Montano is not feasible Los Angeles Boulevard is the likely alternative. All of these improvements to the circulation system will increase the opportunities for large scale development in the early to mid-1980's for this area through increased accessibility and visibility of the area.

- AVAILABILITY OF CONSTRUCTION MATERIALS

Based on experience on construction projects in New Mexico, no difficulty is foreseen in obtaining general materials for construction purposes or consumable supplies from local distributors or suppliers. It is most likely that local suppliers will be able to furnish most of the construction equipment such as long boom cranes, compressors, compaction equipment and other special equipment and materials required for the project on a rental or purchase basis. Suppliers of most bulk consumables, such as fuel, industrial gases, etc., and concrete supplies will usually establish satellite depots for their products in or near the project site so that adequate supplies will be available at all times. Due to the proximity of the project site to Albuquerque, supply sources are deemed readily available with a minimum of hauling distances.

- AREA (LAND AVAILABILITY)

A search has been conducted as to the availability of lands immediately adjacent to the Reeves Station and an effort to determine the approximate values of these lands has also been completed. Figure 5.1.3.4-1 presents Reeves Station and the surrounding areas.

The required rectangular area of approximately 120 acres adjacent to the Reeves Station appears to be readily available.

Options to use the land for the Solar Hybrid Program are under consideration.

- ZONING AND LAND USE

The solar hybrid facility will require 120 acres of land and would preclude use of this acreage for other purposes.

This site is located in an area of rapid urban development activity. The Metropolitan Areas and Urbans Centers Plan of the City's Comprehensive Plan classifies the area of the proposed Reeves site as established urban land. Established urban land is land suited for development as there exists financing and public services which will permit higher densities.

The Reeves site is bounded by two established industrial parks, Academy Industrial Park to the south and Loop Industrial Park north of Los Angeles Boulevard. The area between these two industrial parks is vacant land with the exception of the heavy industry activity of PNM's Reeves Station and American Gypsum, both located south of Los Angeles Boulevard. The other principal land use in the area is the Coronado Mobile Home Park (Los Angeles and I-25). To the west of Reeves Station, between the AMAFCA North Diversion Channel and North Edith Boulevard, the land is classified as developing urban which is land that has not been plotted extensively and is presently acceptable for low level urban development. Albuquerque Gravel Products occupies most of this land. Small portions of land adjacent to Edith Boulevard are designated as semi-urban and rural, with low density residential development.

Most of the projected industrialization in this area will be related to Loop Industrial Park and a speculative and yet to be designed industrial community east and south of Reeves Station. Development of a solar hybrid repowering facility is considered compatible with future activities in this area.

- SOILS INVESTIGATION

The soil types described in the vicinity of the Reeves Station, north of Albuquerque, are as follows:

EmB - Embudo gravelly fine sandy loam

WeB - Wink fine sandy loam

This description is quite general and was used in the past by the Public Roads Administration and Highway Research Board, and used for highways, airfields and dams.

During the design of the proposed structures, an appropriate foundation investigation program will be performed, developing this portion of the design criteria for the project. For the purpose of this study, assumptions were made which will be confirmed prior to the design of the project.

It is assumed that the EmB type soils are transported or alluvial soils overlying the WeB type soils of undefined thickness. The drainage of the area is to the west toward the Rio Grande. The descending-in-elevation contours and drainage paths from east to west also suggest this condition. Accordingly, for the purpose of this study, the EmB, or gravelly fine sandy loam is assumed to be the foundation materials for the proposed structures.

The term "loam," no longer used in geotechnical and foundation engineering, suggests a mixture of sand silt and clay, and, for the purpose of this study, the following engineering properties are assumed:

Solar Hybrid Repowering Study - Reeves Station

- Allowable bearing capacity of compacted material - 1 to 2 tons per S.F.
- Dry unit weight - 80-100 lb lb pcf
- Optimum moisture - 22%-30%
- Frost action - Susceptible
- Compaction required - 100% Std. Proctor ASTM 698

• Compaction methods	- Tamping or Rubber Tire Roller
• Drainage characteristics	- Relatively impervious characteristics
• Shrinkage and expansion characteristics	- High Susceptibility
• Value as roadway	- Poor, granular base and sub-base coarse materials probably required

Current engineering practice dictates that for the design of any structures sensitive to settlement and loading conditions, appropriate foundation investigations and analysis must be performed as part of the design. The investigation program designed for each project is usually performed by firms knowledgeable in the engineering properties of the foundation materials and experience in construction in the immediate vicinity of the proposed project. The results of this foundation investigation will provide the designer with basic criteria for site preparation, foundation design, construction criteria and related engineering tasks.

For the purpose of this study, assumptions were made with the conclusion that a safe and reliable foundation system can be designed for the structures associated with the proposed project, based on the results of an appropriate foundation investigation program.

5.4 PLANT OPERATION

Since this unit is a pre-commercial unit, consideration should be given to allowing as much flexibility and experimentation as possible in the operation of the unit. The following is the proposed plan for operating this unit.

5.4.1 Fossil Only

During conditions of limited or non-existent solar thermal energy, the plant can be run as a fossil plant. The existing fossil boiler would provide the steam for the turbine generator and the plant would operate the same as any conventional fossil boiler power plant.

5.4.2 Solar/Fossil

The solar and fossil boiler can be both operating producing steam for the turbine. On an intermittent cloudy day, this would be the normal operating mode. The following is the description of plant operation in this solar/ fossil combined mode:

5.4.2.1 Solar/Fossil Startup

One of the two boilers would be started up as if it was to operate the turbine alone. With the turbine at some load level, the other boiler would be started. Steam would be bypassed to the condenser from that boiler until steam conditions could be matched to the existing steam conditions in the header. When the match was acceptable the outlet valve to the header would be opened while the bypass valve is closed. If the fossil is coming on line second, then the turbine throttle pressure setpoint would have to be increased and the turbine load allowed to increase. If the solar boiler is coming on second, then the fossil boiler could be cut back to maintain turbine load while the solar boiler steam picks up flow to arrive at the operating condition where the solar boiler is providing most of the flow.

5.4.2.2 Solar/Fossil Normal Operation

During normal operation, the most economical way to run the plant is to use whatever solar boiler steam that is available and make up the difference in required load with the fossil boiler. In this mode, the fossil boiler will fire to achieve a load based upon the required plant load and the solar boiler output. The fossil boiler will control the turbine throttle pressure by manipulating its steam output. Thus, during solar insolation transients the fossil boiler will change its load to correct for changes in the solar boiler output.

5.4.2.3 Fossil/Boiler Shutdown

Plant shutdown will be achieved by first lowering the boiler and turbine load, and then opening the boiler steam bypass system and closing the output to the steam header. In the case of the solar boiler, the heliostats can be defocused and the boiler completely shutdown. In the case of the fossil boiler, the boiler can be tripped and shutdown or banked and bottled up.

5.4.3 Solar Only

With the fossil boiler shutdown for maintenance or efficiency reasons, the plant can run as a solar boiler within the restrictions of section 5.4.1.

5.4.3.1 Solar Only Startup

The solar boiler feedwater system would circulate water up the receiver tower through the receiver boiler panels into the flash tank and from there back to the water treatment system, thus flushing the receiving. Based upon time of day and solar insolation conditions, some sections of heliostats will be focused upon the receiver. The circulating water will absorb heat from the boiler panels and begin flashing steam into the flash tank to the condenser or atmosphere. When correct steam conditions matched to the turbine metal conditions are reached, the steam will be admitted from the flash tank to the steam header to warm the lines and turbine. When proper steam conditions are achieved, the turbine inlet valves will be opened to roll the turbine.

The turbine will be brought up in speed, synchronized, and minimum load reached using steam from the flash tank. At this point another section of heliostats will be focused, producing more thermal energy in the boiler, and the steam bypass valves to the flash tank will be closed as the main receiver outlet valve is opened. This will be done while maintaining constant throttle pressure.

With full steam flow through the receiver outlet valve, the remaining heliostats will be focused. The solar boiler will control steam temperature, and the steam flow to the turbine will ramp up until the turbine reaches required load.

5.4.3.2 Solar Only - Normal Operation

The receiver control system will maintain steam temperature at the setpoint by manipulating the feedwater flow to the boiler panel through the control valves. As the thermal energy available varies as the day progresses, the steam flow from the solar boiler and thus the total available turbine electrical load will vary.

5.4.3.3 Solar Only - Shutdown

The shutdown will be initiated by defocusing a section of heliostats. This will reduce the available thermal energy and thus the steam flow to the turbine and ultimately electrical load. The bypass valves to the flash tank and out of the flash tank to the steam header will be opened. Another section of heliostats will be defocused again reducing steam output and the throttle pressure control setpoint will be ramped down. This action will cause the main outlet valve to close and the flash tank to be the main steam supply source.

When the electrical load reaches minimum on the turbine, it will be tripped and all steam will be bypassed through the flash tank, to the condenser or atmosphere. The remaining heliostats will be defocused and when the required heat is removed from the receiver the water circulation system will shutdown.

5.4.3.4 Emergency Conditions

Some emergency conditions must be allowed for and protective action provided. In the event of loss of feedwater to the receiver, the heliostats will have to be defocused and the turbine tripped. If the breaker opens or the steam turbine trips, steam will be vented through the relief valve to atmosphere, while sections of the heliostats are defocused. Upon achieving allowable steam conditions, the bypass to the flash tank will be opened and steam will be bypassed through the flash tank to the condenser. Finally, if a sudden drop in steam temperature and pressure occurs due to loss of heat input, then the bypass to the flash tank must be brought immediately into service and the steam turbine will close its inlet valves to protect against water carrying over into the turbine.

In the event that the solar boiler begins operation on a full solar day which develops into an intermittent cloudy day, then either the solar boiler must be removed from service or the fossil boiler brought on-line. This will be an operator decision, based upon anticipated operation plans and the state of the fossil boiler.

5.4.4 Operation Plan/Options

The unit consists of three main parts, the solar boiler, the fossil boiler and the steam turbine generator. Steam may be produced from either boiler or from a combination of both. The unit itself will either be in a condition of both boilers shut down, no electrical load being produced or in a steady state operating mode with the turbine generator on-line producing electricity with steam supplied by one or both boilers. The unit transitional states are the transition from a unit shutdown mode to an on-line mode (Plant Startup) or the reverse (Plant Shutdown). In addition, the unit can be in transition from one boiler operating to both boilers operating, (Plant Operating with Startup of a second boiler, solar or fossil) or vise versa (Plant Operating with Shutdown of one boiler). If we disregard the mode of all units being shutdown, then five possible unit operating modes exist; Plant Normal Operation, Plant Startup, Plant Shutdown, Plant Operating with Startup of a second boiler, Plant Operating with the Shutdown of one of the boilers.

Within these plant modes each part can be in various states. The operating solar boiler can be defined in terms of the day's solar insolation condition. Basically three types of insolation exist; full, a cloudless sunny day, low, an overcast or hazy day with constant cloud cover and intermittent, cloudy day with broken transient clouds causing relatively rapid transition in solar insolation. The starting conditions of the solar boiler are either cold; where the boiler has been shutdown within the last two days and no extra water treatment must be done or colder where the unit has been shut-down for more than two or three days and the feedwater requires extra treatment which requires the fossil boiler to be running.

The fossil boiler and steam turbine both have two operating states during startup. These are the hot and cold condition based upon metal temperature. A startup varies in time and method for both depending on whether they are hot or cold.

Finally, two other conditions affecting plant operation must be considered. First, the plant can be operating in a mode trying to maintain some fixed value of load based on an operator set load demand or it can be responding to the demand as received from some remote dispatching system (Variable Dispatch). Finally, the plant can be shutting down equipment in a normal fashion or in an emergency mode of operation.

Table 5.4.4-1 summarizes the probable combinations of unit conditions in tabular form. Reviewing the table, certain operating states are not felt to be valid operating states (particularly for the solar subsystems) and the plant will not be allowed to run in those modes. They are as follows:

During Plant Normal Operation with only the solar boiler producing steam, the unit will not respond to electrical grid dispatching requests but instead will make whatever electrical load is available based upon solar thermal energy available. Therefore, modes I-4, I-5 and I-6 are invalid. Also the plant cannot be reliably controlled during solar insolation transients if the solar boiler alone is producing steam. Therefore, Mode I-3, Solar Boiler Only on an Intermittent Cloudy day is an invalid normal operating mode.

Table 5.4.4-1

COMBINATIONS OF UNIT CONDITIONS (Sheet 1 of 3)

STATE	ID	SOLAR BOILER						SUN			FOSSIL BOILER						TURBINE		LOAD		SHUTDOWN		NOT ALLOWED OPERATING MODE
		OFF	RUNNING	START	SHUT-DOWN	COLDER	COLD	FULL	LOW	INTER CLOUD	RUNNING	START	SHUT DOWN	OFF	COLD	HOT	COLD	HOT	VARIABLE (DISPATCH)	BASE	EMER-GENCY	NORMAL	
NORMAL OPERATION (TURBINE RUNNING NOTHING STARTING UP OR SHUTTING DOWN)	I-1		X			–	–	X						X	–	–	–	–		X	–	–	
	I-2		X			–	–		X					X	–	–	–	–		X	–	–	
	I-3		X			–	–			X				X	–	–	–	–		X	–	–	X
	I-4		X			–	–	X						X	–	–	–	–	X		–	–	X
	I-5		X			–	–		X					X	–	–	–	–	X		–	–	X
	I-6		X			–	–			X				X	–	–	–	–	X		–	–	X
	I-7	X				–	–	–	–	–	X				–	–	–	–		X	–	–	
	I-8	X				–	–	–	–	–	X				–	–	–	–	X		–	–	
	I-9		X			–	–	X			X				–	–	–	–		X	–	–	
	I-10		X			–	–		X		X				–	–	–	–		X	–	–	
	I-11		X			–	–			X	X				–	–	–	–		X	–	–	
	I-12		X			–	–	X			X				–	–	–	–	X		–	–	
	I-13		X			–	–		X		X				–	–	–	–	X		–	–	
	I-14		X			–	–			X	X				–	–	–	–	X		–	–	
PLANT STARTUP (STARTING THE TURBINE)	II-1			X			X	X						X	–	–	X		–	–	–	–	
	II-2			X			X		X					X	–	–	X		–	–	–	–	
	II-3			X			X			X				X	–	–	X		–	–	–	–	X
	II-4			X			X	X						X	–	–		X	–	–	–	–	
	II-5			X			X		X					X	–	–		X	–	–	–	–	
	II-6			X			X			X				X	–	–		X	–	–	–	–	X
	II-7			X		X		X						X	–	–	X		–	–	–	–	X
	II-8			X		X			X					X	–	–	X		–	–	–	–	X
	II-9			X		X				X				X	–	–	X		–	–	–	–	X
	II-10			X		X		X						X	–	–		X	–	–	–	–	X
	II-11			X		X			X					X	–	–		X	–	–	–	–	X
	II-12			X		X				X				X	–	–		X	–	–	–	–	X
	II-13	X				–	–	–	–	–		X			X		X		–	–	–	–	
	II-14	X				–	–	–	–	–		X			X			X	–	–	–	–	
	II-15	X				–	–	–	–	–		X				X	X		–	–	–	–	
	II-16	X				–	–	–	–	–		X				X		X	–	–	–	–	
	II-17			X			X	X				X			X		X		–	–	–	–	
	II-18			X			X		X			X			X		X		–	–	–	–	
	II-19			X			X			X		X			X		X		–	–	–	–	
	II-20			X			X	X				X			X			X	–	–	–	–	
	II-21			X			X		X			X			X			X	–	–	–	–	

Table 5.4.4-1

COMBINATIONS OF UNIT CONDITIONS (Sheet 2 of 3)

STATE	ID	SOLAR BOILER						SUN			FOSSIL BOILER						TURBINE		LOAD		SHUTDOWN		NOT ALLOWED OPERATING MODE
		OFF	RUNNING	START	SHUT-DOWN	COLDER	COLD	FULL	LOW	INTER CLOUD	RUNNING	START	SHUT DOWN	OFF	COLD	HOT	COLD	HOT	VARIABLE (DISPATCH)	BASE	EMER-GENCY	NORMAL	
PLANT START UP – (CONT) (STARTING THE TURBINE)	II-22			X			X			X		X			X			X	–	–	–	–	
	II-23			X			X	X				X				X	X		–	–	–	–	
	II-24			X			X		X			X				X	X		–	–	–	–	
	II-25			X			X			X		X				X	X		–	–	–	–	
	II-26			X			X	X				X				X		X	–	–	–	–	
	II-27			X			X		X			X				X		X	–	–	–	–	
	II-28			X			X			X		X				X		X	–	–	–	–	
	II-29			X		X		X				X			X		X		–	–	–	–	
	II-30			X		X			X			X			X		X		–	–	–	–	
	II-31			X		X				X		X			X		X		–	–	–	–	
	II-32			X		X		X				X			X			X	–	–	–	–	
	II-33			X		X			X			X			X			X	–	–	–	–	
	II-34			X		X				X		X			X			X	–	–	–	–	
	II-35			X		X		X				X				X	X		–	–	–	–	
	II-36			X		X			X			X				X	X		–	–	–	–	
	II-37			X		X				X		X				X	X		–	–	–	–	
	II-38			X		X		X				X				X		X	–	–	–	–	
	II-39			X		X			X			X				X		X	–	–	–	–	
	II-40			X		X				X		X				X		X	–	–	–	–	
PLAN SHUTDOWN (TURBINE SHUTTING DOWN)	III-1				X	–	–	X						X	–	–	–	–	–	–		X	
	III-2				X	–	–		X					X	–	–	–	–	–	–		X	
	III-3				X	–	–			X				X	–	–	–	–	–	–		X	X
	III-4				X	–	–	X						X	–	–	–	–	–	–	X		
	III-5				X	–	–		X					X	–	–	–	–	–	–	X		
	III-6				X	–	–			X				X	–	–	–	–	–	–	X		
	III-7	X				–	–	–	–	–			X		–	–	–	–	–	–		X	
	III-8	X				–	–	–	–	–			X		–	–	–	–	–	–	X		
	III-9				X	–	–	X					X		–	–	–	–	–	–	X		
	III-10				X	–	–		X				X		–	–	–	–	–	–	X		
	III-11				X	–	–			X			X		–	–	–	–	–	–	X		
	III-12				X	–	–	X					X		–	–	–	–	–	–		X	
	III-13				X	–	–		X				X		–	–	–	–	–	–		X	
	III-14				X	–	–			X			X		–	–	–	–	–	–		X	

Table 5.4.4-1

COMBINATIONS OF UNIT CONDITIONS (Sheet 3 of 3)

STATE	ID	SOLAR BOILER						SUN			FOSSIL BOILER						TURBINE		LOAD		SHUTDOWN		NOT ALLOWED OPERATING MODE
		OFF	RUNNING	START	SHUT-DOWN	COLDER	COLD	FULL	LOW	INTER CLOUD	RUNNING	START	SHUT DOWN	OFF	COLD	HOT	COLD	HOT	VARIABLE (DISPATCH)	BASE	EMER-GENCY	NORMAL	
PLANT RUNNING WITH STARTUP (STARTING SECOND BOILER)	IV-1			X			X	X			X				–	–		X		X	–	–	
	IV-2			X			X		X		X				–	–		X		X	–	–	
	IV-3			X			X			X	X				–	–		X			–	–	
	IV-4			X			X	X			X				–	–		X	X		–	–	
	IV-5			X			X		X		X				–	–		X	X		–	–	
	IV-6			X			X			X	X				–	–		X	X		–	–	
	IV-7			X		X		X			X				–	–		X		X			
	IV-8			X		X			X		X				–	–		X		X			
	IV-9			X		X				X	X				–	–		X		X			
	IV-10			X		X		X			X				–	–		X	X				
	IV-11			X		X			X		X				–	–		X	X				
	IV-12			X		X				X	X				–	–		X	X				
	IV-13		X			–	–	X				X			X			X		X			
	IV-14		X			–	–		X			X			X			X		X			
	IV-15		X			–	–			X		X			X			X		X			X
	IV-16		X			–	–	X				X			X			X	X				X
	IV-17		X			–	–		X			X			X			X	X				X
	IV-18		X			–	–			X		X			X			X	X				X
	IV-19		X			–	–	X				X				X		X		X			
	IV-20		X			–	–		X			X				X		X		X			
	IV-21		X			–	–			X		X				X		X		X			
	IV-22		X			–	–	X				X				X		X	X				
	IV-23		X			–	–		X			X				X		X	X				
	IV-24		X			–	–			X		X				X		X	X				
PLANT RUNNING WITH ONE BOILER SHUTDOWN	V-1				X	–	–	X			X				–	–	–	–		X			
	V-2				X	–	–		X		X				–	–	–	–		X			
	V-3				X	–	–			X	X				–	–	–	–		X			
	V-4				X	–	–	X			X				–	–	–	–	X				
	V-5				X	–	–		X		X				–	–	–	–	X				
	V-6				X	–	–			X	X				–	–	–	–	X				
	V-7		X			–	–	X					X		–	–	–	–		X			
	V-8		X			–	–		X				X		–	–	–	–		X			
	V-9		X			–	–			X			X		–	–	–	–		X			X
	V-10		X			–	–	X					X		–	–	–	–	X				X
	V-11		X			–	–		X				X		–	–	–	–	X				X
	V-12		X			–	–			X			X		–	–	–	–	X				X

During Plant Startup, since operation with solar boiler only on an intermittent cloudy day is not permitted, then neither will a plant startup with solar boiler only on an intermittent cloudy day be permitted. Thus, Modes II-3 and II-6 are invalid. Also, since if the solar boiler is in the "Colder" mode (having been shutdown for more than two or three days) extra water treatment requiring the fossil boiler to be in operation must be present, then Modes II-7 thru II-12 are not valid since the fossil boiler is not running. Also, Modes II-29 thru II-40 which involve the starting of both boilers simultaneously does not seem to be practical but is included as part of the pre-commercial phase of this unit.

During Plant Shutdown the only mode that is not valid is III-3 which would be a normal shutdown with only the solar boiler operating on an intermittent cloudy day. This mode of operation is invalid and if the weather changes while operating the solar boiler, the shutdown, if chosen, would be an emergency shutdown or Mode III-6.

In the Plant Running with Startup of a second boiler operating state, all modes are valid except IV-15 thru IV-18. Mode IV-15 represents the starting of the cold fossil boiler while the solar boiler is running on an intermittent cloudy day. If the solar boiler is on line and weather conditions change to an intermittently cloudy day then the solar boiler must either be shutdown, taking the plant off line or the fossil boiler must be started up. However, with a cold fossil boiler the startup time of six to nine hours necessitates that the solar boiler be shutdown. Modes IV-16 thru IV-18 would be invalid modes since the plant will not run in a variable dispatch mode with only the solar boiler operating.

Finally, in the Plant Running with Shutdown mode V-9 thru V-12 will not be permitted since after shutting down the fossil boiler the plant will be in an invalid operation state. For Mode V-9 the solar boiler only would be on-line under intermittent cloudy conditions, and in Modes V-10, V-11 and V-12 the solar boiler only would be running with variable load dispatch. Both of these conditions represent invalid operating modes.

5.5 ENVIRONMENTAL IMPACT

A preliminary environmental impact assessment of solar hybrid repowering of Reeves Unit No. 2 is being performed as part of the Phase I Technical and Economic Assessment Study of Solar Hybrid Repowering. This section of the proposal summarizes the results of the impact assessment established to date.

Based upon a preliminary environmental assessment, it appears that there will be no major environmental impacts resulting from construction and operation of the Solar Hybrid Repowered Reeves Station (Unit No. 2) at Albuquerque, New Mexico.

The environmental impact on air is:

- For both normal and adverse operating conditions, the maximum calculated ground-level concentrations are well below the State of New Mexico and National Air Quality Standards.
- The proposed solar/oil facility does comply with Class II significant deterioration increments for SO_2 under both normal and adverse operating conditions.
- The emissions produced by the solar/oil facility are approximately 40% lower than the emissions produced by a facility operating on oil alone.

The environmental impact on water is:

- Water Use - Water needs for this facility are expressed in the need for approximately 15 gallons of water per heliostat per month for washing and rinsing the heliostats during the operation phase and drinking water for the construction crew during the construction phase. Water needs are anticipated to be met without affecting local water users. Conservation and recycling will be practiced wherever feasible.

- Water Quality - Operation of the solar hybrid repowering facility will produce discharges of cooling waters and discharges of the heliostat washing solutions. Neither should have a significant effect on local surface or groundwater resources. During construction, runoff could have a temporary effect on the local streams.

The environmental impact on terrestrial is:

- Vegetation - No significant loss of grassland.

- Wildlife - No significant habitat loss; site not in direct migratory corridor.

- Endangered Species - No known endangered plants; some endangered animals may migrate through area.

- Soils - Medium runoff poses moderate erosion hazard.

- Land Use - Land could be used for power generation, industrial park or housing. Land is not fit for other uses. Proximity of two small locally used airports may pose some hazard to pilots due to glint, glare and tower height. This may be worked out with FAA authority.

- Mineral Resources - No impact to existing resources.

- Seismology - Slight to moderate damage could occur, depending on location of epicenter of earthquake. Historically, no known earthquakes occurred on site or immediate vicinity.

- Demographic-Socioeconomic - No significant demands on schools, housing or municipal services. Some temporary increase in traffic congestion and increased demands on retail services in immediate site vicinity only during construction period.

6.0 PRE-COMMERCIAL PROJECT PLAN

6.0 PRE-COMMERCIAL PROJECT PLAN

The project plan presented in this section includes the objective, project and major task description, the management plan and work breakdown structure.

The Public Service Company of New Mexico (PNM) proposes to implement these plans during the design, construction and early operation of the Solar Hybrid Repowering Project. This proposed effort will be performed by PNM with the support of Bechtel Power Corporation for the Architect-Engineering services and Westinghouse Electric Corporation for Systems Engineering and Project Integration. The project plan is structured to provide appropriate visibility and control of all technical effort, schedules and costs. It utilizes the Work Breakdown Structure approach and anticipates control documents, such as design requirements and interface control drawings to assure a successful pre-commercial unit. It recognizes and accommodates the acquisition, analysis and reporting of data vital to the repowering program.

6.1 OBJECTIVE

The principal objective is to establish the technical viability and economic attractiveness of the solar hybrid repowering concept and widespread utility application. The specific objectives are:

- Preparation of the design of the pre-commercial unit.
- Construction of the pre-commercial unit.
- Successful start-up and operation of the unit for a period of two years.
- Timely dissemenation of the progress and the results of the project to other utilities, industries, and government agencies to enhance the early commercialization of solar repowering.

6.2 PROJECT AND MAJOR TASK DESCRIPTION

The project to implement the solar hybrid repowering concept is divided into two principal phases:

Phase 1 - Technical and Economic Assessment Study of Solar Hybrid Repowering

Phase 2 - Solar Hybrid Repowering Pre-commercial Unit

The Phase 1 portion of the project is presently being performed by PNM under DOE sponsorship. The primary technical tasks of Phase 1 will be completed by June 30, 1978 and the following output will be available to initiate the proposed Phase 2 project:

- A market survey and cost/benefit analysis.
- A specific site selected for the solar repowering project.
- A conceptual design of the pre-commercial unit.
- A conceptual cost estimate for the unit.

The Phase 2 project is divided into five major tasks:

Task 1 Engineering
Task 2 Procurement
Task 3 Construction
Task 4 Startup
Task 5 Operation

The first four tasks of Phase 2 are scheduled over a 41 month period commencing in July of 1978. A two year pre-commercial operating period (Task 5), starting in December, 1981 is also planned; the option for DOE to continue the pre-commercial operations period for a longer time period will be considered by PNM once successful operation of the plant

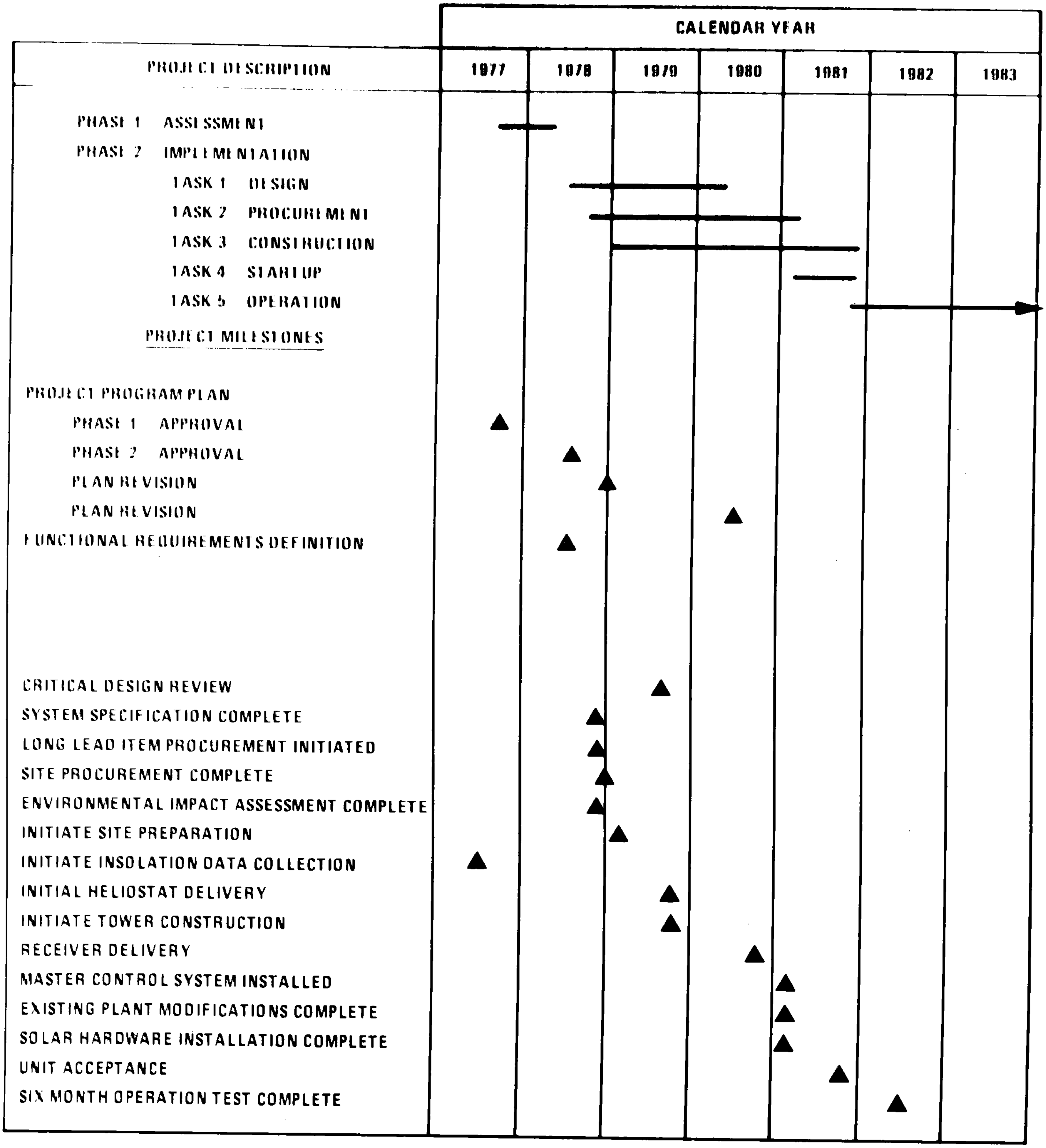


Figure 6.2-1
SOLAR HYBRID REPOWERING PROJECT SCHEDULE

has been achieved. The pre-commercial operating period will be considered the unit acceptance testing period for the project. Figure 6.2-1 presents the summary schedule and milestone chart for the Phase 2 project. A more detailed schedule for the project is presented in Figure 6.2-2.

The foundation of the proposed project is Task 1 - Design. The pre-commercial unit located at the Reeves Station (Unit 2) will be designed, fabricated and constructed on the basis of the solar central receiver technology. Major components such as the heliostat system, the reciever system, and potentially the master control system will have been operationally demonstrated to varying degrees of maturity as part of the solar central receiver 10 MW(e) Pilot Plant Program. Successful and timely accomplishment of project objectives requires detailed technical and programmatic coordination during the project and, in particular, during the Task 1 Engineering. A project management organization will, therefore, be established at project initiation to provide necessary technical and programmatic coordination.

Stringent adherence to the milestones in Figure 6.2-1 is mandatory to assure successful full power operation of the unit by December 1981. Early in the third quarter of 1978, the Project Plan, which includes the Work Breakdown Structure (WBS) will be finalized and submitted to DOE for approval. The Project Plan will be updated/revised during the performance of the project. As a minimum, the plan will be updated at the end of preliminary engineering prior to the start of construction and prior to unit startup.

An option for the necessary adjacent land at the recommended Reeves Station is being secured to support the submittal of this proposal. This option will be executed during Task 1, as an agreement prepared and executed for PNM/DOE use of the site during the life of the project. The necessary plans, including site preparation and site access will be formulated. An effort to establish and measure the direct normal insolation and other climatological data at the site has been initiated in conjunction with the WEST Solar Resources Study. This effort will be continued and it is further planned that all data collected will be transferred to the SERI data bank for utilization and integration into that program.

DETAIL ENGINEERING AND CONSTRUCTION SCHEDULE

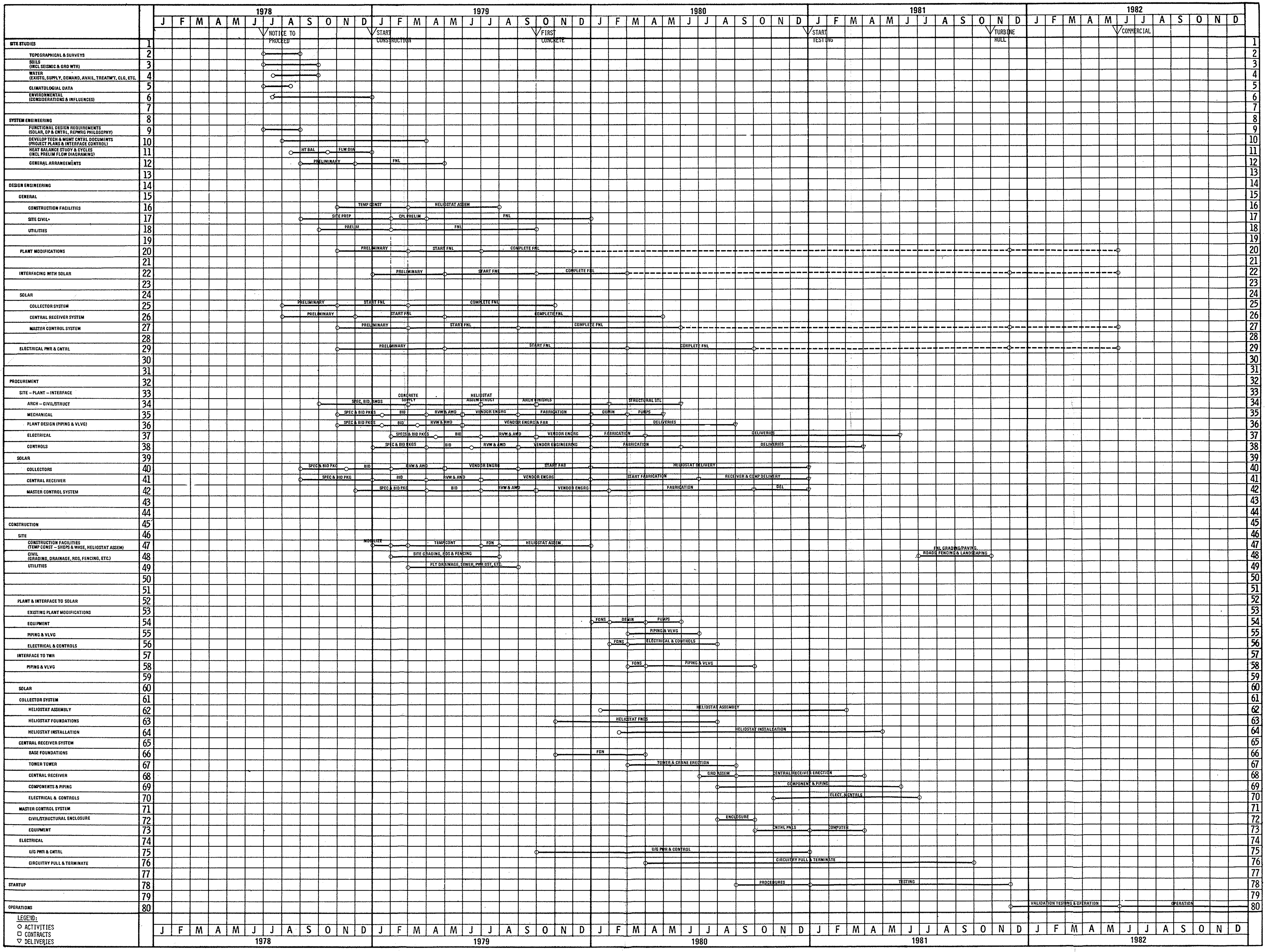


Figure 6.2-2

The preliminary design for the solar subsystem, the master control subsystem, the modifications to the existing plant equipment, and support facilities is to be prepared during Task 1; this effort will require coordination with the DOE, 10 MW(e) Pilot Plant design teams throughout this project, particularly during preparation of the preliminary design description document. Two preliminary design reviews are contemplated during Task 1 to afford DOE the maximum project visibility. Specifications parameters for the plant equipment and support facilities will be defined.

A pre-commercial unit layout will be prepared based on the conceptual design resulting from the Phase 1 Assessment. The preliminary design requirements for the plant and support facilities will be defined. A preliminary system design will be prepared from which design specifications for the component hardware can be formulated. An interface control drawing will be maintained throughout the project and will be modified to incorporate mandatory plant design changes.

An environmental assessment will be made within the scope of Task 1.

Furthermore, during Task 1, all aspects of the solar plant designs and development data of the 10 MW(e) Pilot Plant will be considered. The findings at this review will be utilized in the selection of components and systems for the design of the pre-commercial unit.

Task 2 will commence with preparation of specifications of the solar subsystem, the master control subsystem, the modification to existing plant equipment, and the support facilities.

Procurement will be initiated early to allow for long lead times. Activities will include vendor surveys, bid package preparation, vendor selection, purchasing, expediting, inspecting, and quality assurance. Special attention will be given to the procurement of such, potentially long lead items as heliostats, receiver and control system components.

Task 3 encompasses the construction which is scheduled to start in January 1979. A detailed construction schedule for Task 3 will be prepared to cover the solar subsystem, the master control subsystem, the modifications to existing plant equipment and support facilities. Principal items of work will be incorporated in this schedule. Additional charts will be prepared, as considered necessary. To schedule the construction of particular areas in greater detail.

Task 4 involving startup of the unit and all support subsystems, is scheduled to occur during the second and third quarter of 1981. The solar subsystems will be checked out during this time. The unit startup tests will be performed during the third quarter of 1981.

The pre-commercial unit, although intended to operate as an on-line power unit in the PNM electric supply network, is a first-of-a-kind system. In formulating this project plan, therefore, a number of tests have been identified which encompass the regime from component and subsystem operation verification to unit startup test and to normal and emergency operating performance tests. A test plan will be prepared with appropriate revisions being incorporated as required during subsequent phases. The test plan, for example, will include:

- Startup tests and checkout, acceptance tests for the solar subsystem, data acquisition system validation and/or modification of computer simulation model, steady state and transient performance tests.

Task 5, Pre-commercial Unit Operation, will be defined during Task 1 of the project. However, the operation task of the project has been considered in sufficient detail to permit base estimates of manpower requirements to summarize the effort needed during the initial project tasks.

Personnel for the operation and maintenance crews will be selected, utilizing a thorough screening and testing process. The test engineering team, a necessary requirement during the operations task will be selected from Westinghouse and Bechtel personnel having extensive backgrounds in the startup and testing of a first-of-a-kind power plant. Training of supporting PNM personnel will be an objective of the team effort.

The operation and maintenance and testing crews will be given thorough training and testing during the startup task in preparation for their responsibilities. The actual equipment manuals and technical personnel will assist the operators in the preparation for initial startup and checkout as well as plant operation, 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 are made operational and until the total pilot plant has been carried through the checkout and startup mode, the operation crew will be assuming greater responsibility and acquiring full 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.

The WBS includes an additional task, Number 6, which is not solely associated with the engineering and operation of the unit. It involves implementation of the commercialization plan, which initiates utility planning for the commercial units. A southwestern cost/benefit analysis of widespread implementation of solar repowering utilizing the pre-commercial unit design will be performed. It will analyze a commercial size system (50 MWe nameplate capacity) in sufficient depth to permit the regional impact of solar repowering to be assessed. Additionally, four individual utility systems will be modeled to assess in detail the impact of the four commercial units installed subsequent to the pre-commercial plant. This will better define the government/host utility cost sharing rolls. Technology transfer, Public Relations, and other like functions assisting and promoting the commercialization effects are also included.

6.3 MANAGEMENT PLAN

Public Service Company of New Mexico will manage the Solar Repowering Project with the objective of:

- Full compliance with contractual and reporting commitments.
- Implementation of the technology of solar repowering.
- Strict cost and schedule control.
- The widest practical dissemination of results and data.

A PNM Project Manager will provide the single point responsibility and authority throughout all phases of the project. Bechtel and Westinghouse will provide project managers with similar responsibility and authority over their respective scopes of work. Work efforts by appropriate PNM departments will be directed by the PNM Project Manager.

Major functions of project management are:

- Project Plan
- Work Initiation
- Monitoring of Project Progress
- Variance (from Plan) Resolution
- Reporting (to DOE)

These principal elements of successful project management are performed in accordance with the logic illustrated in Figure 6.3-1. The Project Plan provides definition of the project effort in detail in the Work Breakdown

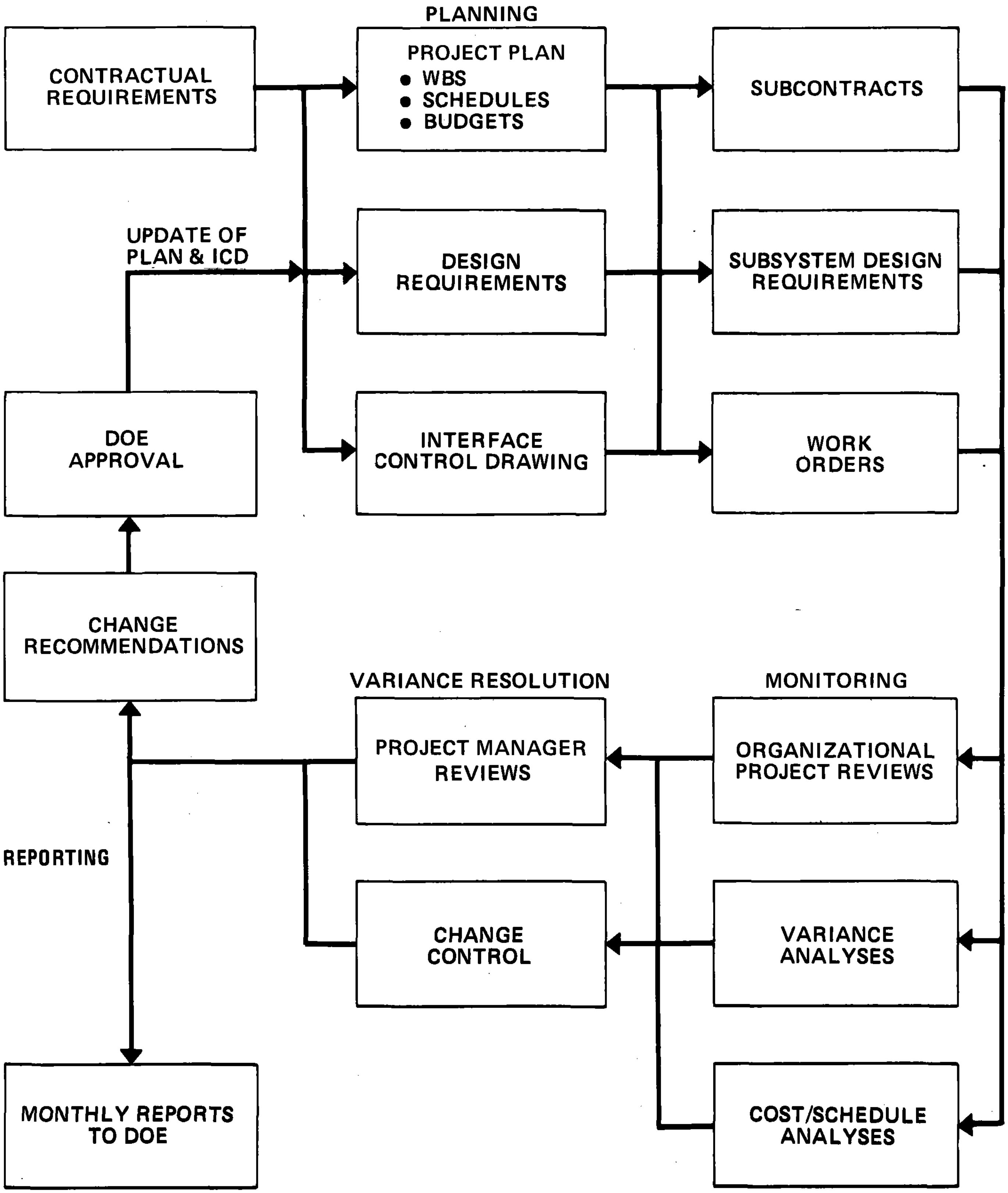


Figure 6.3-1
PROJECT MANAGEMENT AND CONTROL LOGIC

Structure. This, along with the schedules and budgets for these subtasks, will provide a consistent set of directions for all project participants.

There also will be related technical direction and control documents that are important parts of the planning element. These include the Design Requirements, which translate the contractual requirements into design directives, and the Interface Control Drawings, which define the physical and other interrelationships between subsystem responsibilities. These also become control documents and are updated, as required, as the project proceeds.

The technical work will be initiated by contracts with Bechtel and Westinghouse. The Project Managers will use similar orders to initiate work and establish financial data control. The Design Requirements will be further defined to the subsystem level for participant technical direction.

The monitoring effort by PNM will encompass management reviews at each organization, analysis of technical progress against the Project Plan and Design Requirements to identify any variance, and cost/schedule analysis against the Project Plan milestones and budgets. The results of the monitoring activities will be provided to the Project Managers.

The results of the monitoring activity will be reviewed at Project Manager review meetings. In addition to a project status review, the Project Managers will take action to resolve the delinquent items. In the event that the needed corrective action impacts the contract requirements, schedule or budget; the recommended change will be submitted to DOE. On receipt of DOE approval, the Project Plan and other affected control documents will be updated and the change will be implemented.

6.3.1 WORK BREAKDOWN STRUCTURE

A preliminary Work Breakdown Structure (WBS) is provided in Table 6.3-1 to define the participant responsibilities for major tasks and substasks of

TABLE 6.3-1
WORK BREAKDOWN STRUCTURE (Sheet 1 of 9)

Tasks			P	B	W
1.0 DESIGN	1.1	Finalize Design Require- and Technical Site Data	R	X	X
• Preliminary Design	1.2	Permits and Approvals	R	X	X
	1.3	Land Acquisition	R		
	1.4	Finalize Assessment of Solar Hardware (Helio- stat and Receiver)		X	R
	1.5	Finalize Assessment of Reeves Station, Unit 2 Modification	X	R	X
	1.6	Finalize Interfaces	X	R	X
	1.7	Basic Flow Diagrams - Receiver			R
	1.8	Basic Flow Diagrams- Existing Unit 2		R	
	1.9	Steady State and Tran- sient System Analysis			R
	1.10	Prepare Solar Hardware Design Requirements		X	R
	1.11	Finalize Receiver Design Type	X	X	R

Remarks

General Organizational Responsibilities:

PNM
- Project Management and Technical Direction
- Land Acquisition
- Cost and Schedule Control
- Plant Operation and Maintenance
- Utilities Participation Program

Bechtel
- All A/E Services
- Detailed Design
- Procurement
- Facility Layout and Arrangement including Piping
- Construction Management/Construction
- Modifications to Existing Plant and Facilities
- Project Integration
- Start-up
- Quality Assurance
- Project Planning & Schedule

Westinghouse
- Technical System Requirements and Integration
- Solar System Design Coordination
- Test Engineering
- Master Control and Data Acquisition System Design
- EPGS/Control System Design Modification

WORK BREAKDOWN STRUCTURE

Tasks		P	B	W
	1.12 Finalize Tower Type Design		R	X
	1.13 Finalize Heliostat Type and Field	X	X	R
	1.14 Finalize Equipment Specification Parameters		R	X
	1.15 Finalize Site Arrangement Plan		R	X
	1.16 Finalize Unit 2, General Arrangement Modifications		R	
	1.17 Finalize Master Control Design Approach/Data Acquisition		X	R
	1.18 Preliminary Design Description		R	X
	1.19 Prepare Preliminary Cost Estimate		R	X
• Environmental Assessment	1.20 Prepare Site Data	R		X
	1.21 Perform Environmental Assessment	R		X
	1.22 Prepare Impact Assessment	R		X

Remarks

- Assist Project Integration

Specific Responsibilities

- Solar Hardware:
  W Technical requirements during preliminary design
- Solar Hardware:
  B- Procure and incorporate system in detail design with technical assistance from Westinghouse
- Tower:
  B- Technical requirements, procure and incorporate in detail design
- Master Control System
  W- Technical requirements during preliminary design
  B- Procure procedure and incorporate system in detail design with technical assistance from Westinghouse
- Existing Reeves Station Unit 2 Modifications:
  B- Technical requirements, procure and incorporate in detail design

WORK BREAKDOWN STRUCTURE

Tasks		P	B	W	Remarks
• Quality Assurance for Design, Manufacture of Heliostats, Receiver, Receiver Downcomer and Riser Piping, and Tower and Tower Facilities	1.23 Prepare Quality Assurance Plan	X	R	X	• Site: <u>B</u>- Technical requirements, procure and incorporate in detail design
	1.24 Issue Quality Assurance Plan to Vendors		R		
	1.25 Monitor Compliance with Quality Assurance Plan		R		
2.0 PROCUREMENT • Detail Design, Specifications and Procurement	2.1 Establish Procurement Procedures and Format	X	R		
	2.2 Qualify Vendors and Contractors	X	R	X	
	2.3 Prepare Equipment Specifications		R	X	
	2.4 Specification Approvals	R			
	2.5 Issue Specifications for Bid		R		
	2.6 Receive Bids		R		
	2.7 Evaluate Bids		R	X*	*(Except master control system)
	2.8 Recommend Vendor		R	X*	
	2.9 Approval of Vendor	R			

WORK BREAKDOWN STRUCTURE

Tasks	P	B	W	Remarks
2.10 Award Vendor		R		
2.11 Vendor Drawings		R	X	
2.12 Integrate Vendor Equipment Data and Drawings in Detail Design		R	X	
2.13 Liaison Requirements in Detail Design	X	R	X	
2.14 Prepare Construction Drawings	X	R	X	
2.15 Prepare Construction Specifications	X	R	X	
2.16 Construction Specification Approval	R			
2.17 Issue Construction Specs for Bid		R		
2.18 Receive Bids		R		
2.19 Evaluate Bids		R	X	
2.20 Recommend Contractor		R	X	
2.21 Approval of Contractor	R			
2.22 Award of Contractor		R		

WORK BREAKDOWN STRUCTURE

Tasks	P	B	W	Remarks
2.23 Issue Construction Drawings	X	R		
2.24 Acquire Equipment Data Manuals		R		
2.25 Finalize Detail Design		R	X	
2.26 Recommend Design Change Notices		R	X	
2.27 Approve Design Change Notices	R			
2.28 Issue Design Change Notices		R		
2.29 Update Construction Drawings		R		
2.30 Prepare and Issue Systems Operation Description		X	R	
2.31 As-Built Drawings & Design Documents to PNM		R	X	
2.32 Monitor Engineering and Procurement Cost	R	X	X	
2.33 Monitor Engineering and Procurement Progress	R	X	X	

WORK BREAKDOWN STRUCTURE

Tasks		P	B	W	Remarks
	2.34 Report Engineering and Procurement Cost and Progress	R	X	X	
	2.35 Inspection for Equipment Quality		R	X	
	2.36 Expediting Equipment Deliveries		R	X	
3.0 CONSTRUCTION	3.1 Prepare Construction Management Plan	X	R		
	3.2 Prepare Quality Assurance Plan for Construction	X	R		
	3.3 Approve Construction Management Plan & Quality Assurance Plan	R			
	3.4 Monitor and Enforce Construction Safety Requirements		R		
	3.5 Monitor Construction Cost	R	X		
	3.6 Monitor Construction Progress	R	X		
	3.7 Report Construction Cost & Progress	R	X		

WORK BREAKDOWN STRUCTURE

Tasks		P	B	W	Remarks
	3.8 Mobilize Contractors		R		
	3.9 Coordinate Work of Contractors		R		
	3.10 Contract Compliance		R		
	3.11 Monitor Quality Assurance for Heliostats and Field		R	X	
	3.12 Monitor Quality Assurance for Receiver		R	X	
	3.13 Monitor Quality Assurance for Tower		R	X	
	3.14 Arrange for Construction Utilities (Power and Water)	X	R		
	3.15 Monitor Contractor's Systems Check-out		R	X	
	3.16 Turn Systems over to Start-Up		R	X	
4.0 START-UP	4.1 Prepare Start-up Plan and Schedule	X	R	X	
	4.2 Mobilize	X	R	X	

WORK BREAKDOWN STRUCTURE

Tasks		P	B	W	Remarks
	4.3 Verify Systems Check-out		R	X	
	4.4 Flush and Clean Systems (Existing and New)	X	R	X	
	4.5 Check out Equipment Operations		R	X	
	4.6 Verify Safety Valve Settings		R	X	
	4.7 Turbine Roll	X	R	X	
	4.8 Steady State Performance Testing	X	R	X	
	4.9 Transient State Performance Testing	X	R	X	
	4.10 Acceptance Testing	X	R	X	
5.0 OPERATIONS	5.1 Prepare Operations Plan	R	X	X	
	5.2 Prepare Plan for Data Collection	X	X	R	
	5.3 Plan for Data Dissemination			R	
	5.4 Select Operating Crew	R			

WORK BREAKDOWN STRUCTURE

Tasks				P	B	W	Remarks
		5.5	Train Operating Crew	R	X	X	
		5.6	Train Maintenance Crew (Solar)		X	R	
		5.7	Performance Testing	X		R	
		5.8	Data Collection	X		R	
6.0	COMMERCIALIZATION PLANNING	6.1	Implementation Plan	R			
		6.2	Utility Participation	R			
		6.3	Perform Regional Impact Analysis			R	
		6.4	Perform Utility Analysis			R	
		6.5	Technology Transfer/ Information Dissemination	R		X	
		6.6	Public Relations	R		X	

the Solar Hybrid Repowering Project. PNM has overall responsibility for all work performed as previously indicated in the project organization. The breakdown is to level three to avoid unnecessary detail for purposes of the proposal. PNM has also prepared a detailed WBS by subsystem (i.e., heliostat, receiver/tower, etc.) to level 4 and has utilized this for estimating purposes. PNM will utilize either WBS format per direction from DOE, noting that either representation will require refinement and substantially more detail for project implementation.

6.3.2 PROJECT PLAN

PNM will prepare a Project Plan reflecting the contractual commitments as negotiated. The Project Plan will consist of the management plan, the work breakdown structure, the schedule and milestone chart, and the cost, schedules, and manpower control plan. The Plan will be submitted to DOE within 45 days after contract initiation. When approved by DOE, the Plan will be utilized as a "controlled document" under which the project will be executed. The Plan will be updated, as required, through the procedure described in Subsection 6.3.5. The Plan will define the Work Breakdown Structure, schedules and milestones, and budgets for each level two WBS tasks. Further detail breakdowns into manageable work packages (levels three and four) will be implemented for internal management and control of the work.

6.3.2.1 Schedule and Milestones

The project schedule, along with significant milestones is presented in Section 6.2. A further breakdown of schedules and milestones will be prepared, as necessary, for use in managing and controlling the project.

Both Bechtel and Westinghouse will implement systems and services to provide to PNM timely analysis of project progress and any variance from the Project Plan. PNM will combine these with analyses of PNM work and provide to the Project Manager a Monthly Variance Report.

PNM will hold periodic project review meetings with Bechtel and Westinghouse. These meetings will include discussions of the project status relative to achieving the milestones, the technical status including the resolution of interface problems, and a detailed review of the technical work completed. In addition, the PNM Project Manager will hold project review meetings as required to resolve major issues impacting the milestones schedule.

6.3.3 VARIANCE RESOLUTION

The Monthly Variance Report will be used in the Project Managers' review meeting and in resolution of any problems through change control recommendations. Resolution of problems that can be implemented within the framework of the prime contract will be acted upon by the project management team.

For problems that impact performance under the prime contract recovery plans will be forwarded to DOE. Upon receipt of DOE approval, the change will be implemented. The plans will be updated in accordance with such changes.

6.3.4 REPORTING

PNM will provide to DOE monthly reports on the technical and financial status of the project. The first report will be provided within 60 days of contract initiation. The format of these reports will include:

- A cover page designating the contract, the contract number, and the period covered by the report.
- A brief statement of the contract content.
- A summary of technical progress during the report period.
- An update of the schedule and milestone chart.

- A discussion of any anticipated problems along with a summary of action for their resolution.

- A financial tabulation comparing cost to budget for each of the nine WBS tasks.

PNM will also provide topical reports as may be required to document significant project accomplishments. In addition, PNM will provide a report summarizing the results of each of the major tasks.

6.4 NEW MEXICO STATE GOVERNMENT LETTERS OF SUPPORT

On March 3, 1978, PNM held a briefing for New Mexico State Government officials on the Solar Hybrid Repowering Program. Representatives of the Governor's office as well as the Public Service Commission and Department of Energy and Minerals were in attendance. The outcome of the meeting included overwhelming support for PNM's initiative in offering their existing Reeves Station for the Pre-Commercial Unit as part of an overall Solar Hybrid Repowering Program. The letters received subsequently by PNM are included in Appendix A.

7.0 ORGANIZATION AND PERSONNEL

7.0 ORGANIZATION AND PERSONNEL

This section of the proposal discusses the overall project organization for accomplishing the Solar Hybrid Repowering Pre-Commercial Project. The project organizations of the participants are also presented, as well as their related experience. Personnel resumes are also included.

7.1 OVERALL PROJECT ORGANIZATION

Public Service Company of New Mexico has assembled a well qualified organization to perform the Solar Hybrid Repowering Project. The organization structure for performing the project is shown in Figure 7.1-1. The Public Service Company of New Mexico will be responsible for the project and will conduct the project in a manner consistent with other successful utility oriented development projects. The Project Manager for PNM, Mr. D. J. Groves, will be responsible for the technical and programmatic direction of the project through all aspects. He will be directly supported by Westinghouse and Bechtel project managers. Mr. Groves will be responsible for all utility operations which will primarily include the preparation of functional design requirements, the preparation of the environmental impact, and the overall project technical, cost and schedular control. Mr. Groves has single-point management responsibility and commensurate authority for the project. His responsibilities are to meet all technical, cost, and schedular objectives. Within the scope of the contract, he has complete freedom and flexibility to allocate his assigned resources to meet project goals, and he is the principal PNM decision-maker for daily project activities. Bechtel will be responsible for the architect-engineer services which will include the preparation of the engineering design (including site preparation, facility layout, civil structural work, balance of plant, and arrangement/piping), equipment procurement, construction management/construction, modifications to the existing plant and facilities, plant startup, quality assurance, and project planning and scheduling.

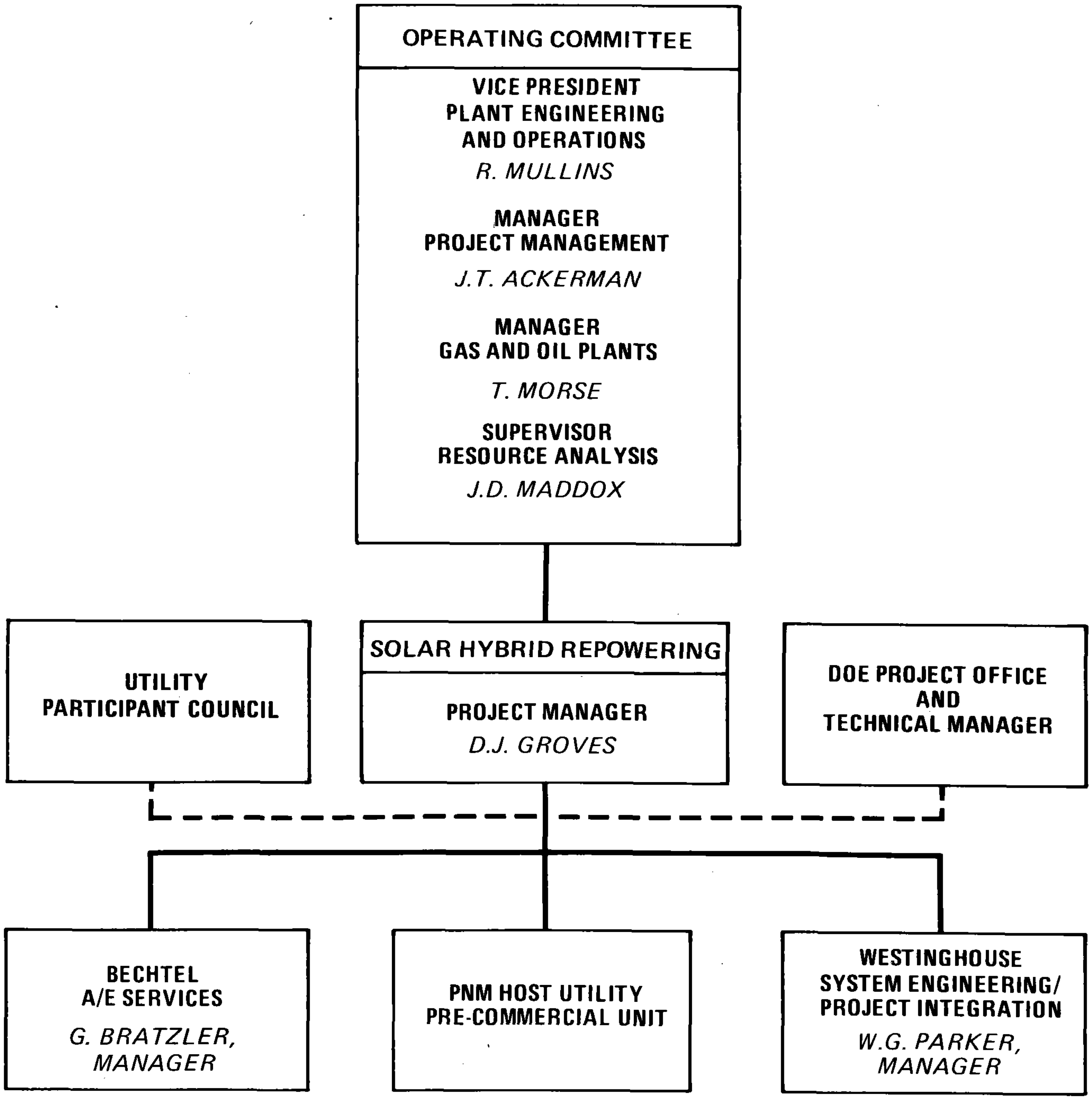


Figure 7.1-1
OVERALL PROJECT ORGANIZATION

Westinghouse will be responsible for the system engineering and project integration which will include the system design and integration, the solar system design coordination, technical inputs to the master control and data acquisition system design, the turbine generator and turbine generator control system design modification, the performance of impact assessments including safety, operational, and network, the test engineering in support of the unit operation, and the project integration including maintaining the work breakdown structure.

A cooperative agreement will be executed between PNM and DOE for the direction of the project. A Solar Project Operating Committee (SPOC) will be formulated as part of the cooperative agreement to assist Mr. Groves in his direction of the project. Membership of the SPOC will consist of key management personnel from PNM. The SPOC is responsible for the overall project as a joint DOE-utility endeavor in accordance with the terms of the contract. It is the executive decision-making authority for all matters not specifically delegated and entrusted to the PNM Project Manager. The committee, in addition to its role to direct, advise, and counsel, represents the project administratively to other functional elements of PNM. The committee is the decision-making authority for the project on all matters referred to it, including those which cut across functional or departmental lines. The Operating Committee will receive periodic reports from the Project Manager and will regularly review project progress.

The project organizations of the three companies are discussed in the following sections.

7.1.1 Public Service Co. of New Mexico (PNM)

The PNM organization selected to carry out the project is shown in Figure 7.1.1-1. Basically it is a functional organization, created ad hoc from the present PNM organization, and charged with the planning, engineering, construction, and operating tasks of the project. Because it is project-centered, the organization features central lines of communication and authority between the task managers and the operating committee for carrying

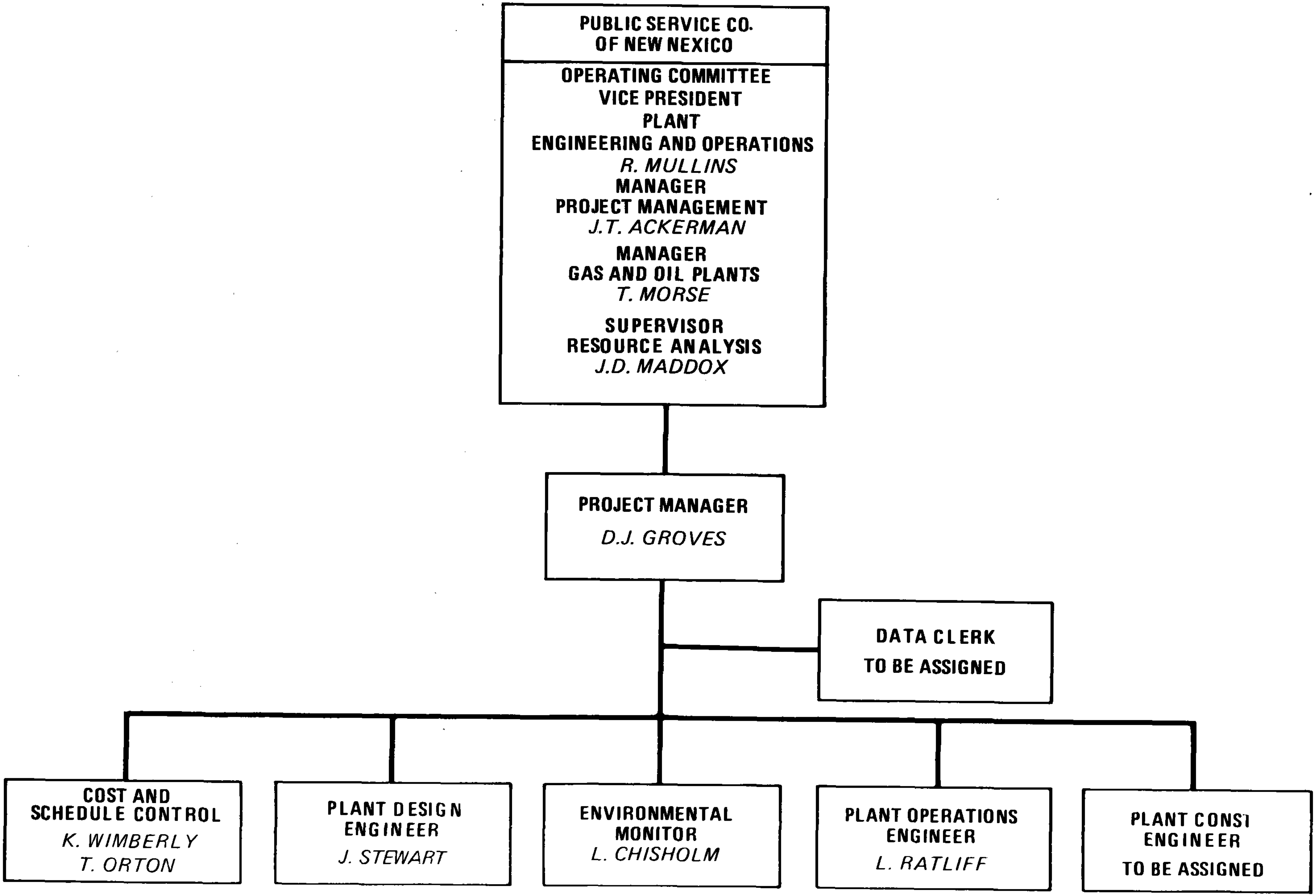


Figure 7.1.1-1
PNM SOLAR HYBRID
REPOWERING PROJECT ORGANIZATION

out assignments. At the same time, the task managers retain access to the supporting line departments wherein the contract is performed. Thus, this "matrix" technique allows immediate response to changing project needs while drawing upon the full technical experience and judgemental capabilities resting within PNM.

As shown in Figure 7.1.1-1, executive control of the project is vested in an operating committee composed of both technical and executive managers. This operating committee has as its charter the successful execution of the project in accordance with the contract between PNM and DOE.

Below the operating committee, and reporting directly to it, is a Project Manager, Mr. D. J. Groves, who oversees the daily activities of the project. The Project Manager has total responsibility and commensurate authority for all technical, cost, and schedule aspects of the project within the scope of the contract. He has complete freedom to allocate his resources to meet project exigencies, and he may take any other actions he deems appropriate to fulfill project goals, so long as those actions are consistent with operating policies and procedures of PNM and the contract with DOE.

Below the Project Manager, tasks for the project have been assigned to specifically identified PNM Departments on a functional basis. The personnel assigned for these departments have equal reporting access to project management. Each department is responsible for executing the assigned tasks within that area in accordance with the contract. Each assigned person is "matrixed" against the ad hoc project organization and the permanent line organization which be represents. Consequently, each of the assigned personnel reports functionally to the Project Manager for the execution of his assigned task, and administratively to the respective department.

Section 7.3 contains resumes of the key personnel that will be assigned to the project.

Westinghouse Electric Corporation

Power Systems Company

M T Johnson
General Manager
Advanced Energy Systems Division

Box 10864
Pittsburgh Pennsylvania 15236

.April 18, 1978

Mr. J. D. Geist
President
Public Service of New Mexico
P.O. Box 2267
Albuquerque, New Mexico 87103

Dear Mr. Geist:

In December of 1976, Mr. Gordon Hurlbert, President, Westinghouse Power Systems Company, indicated the commitment of Westinghouse to the success of the then proposed program to ERDA on Solar Hybrid Repowering. The results of the first phase of this program have vindicated this commitment by Public Service of New Mexico and it's partners as well as the various funding agencies.

As you are aware from the prior conversations and correspondence on the subject of solar hybrid repowering, Westinghouse continues to maintain a strong belief in the potential of this technology in contributing to the solution of the energy needs of the southwestern region of the United States.

We pledge the support of our Advanced Energy Systems Division and other branches of the corporation, as necessary, that can make a contribution to the successful demonstration of Solar Hybrid Repowering.

Sincerely,

M T Johnson

7.1.2 Westinghouse Electric Corporation

The Westinghouse Electric Corporation, since its incorporation in 1896, has placed major corporate emphasis in product areas associated with electric power production for the utility industry. The Westinghouse Electric Corporation is organized in company-like units, each of which is headed by a president who reports to the Chairman of the Corporation. The corporate organization chart is shown in Figure 7.1.2-1. The proposed Westinghouse function of Systems Engineering and Project Integration will be implemented by the Westinghouse Advanced Energy Systems Division.

The Advanced Energy Systems Division is organized as shown in Figure 7.1.2-2. The functional subdivision of activities within the Division is designed to facilitate effective response to the technical, programmatic, and managerial requirements of complex engineering programs.

In addition to the talents and facilities available within the Advanced Energy Systems Division, a wide diversity of corporate capability is also available and will be called upon to support the proposed project. It is a matter of corporate policy to encourage the interchange of technical information and assistance between divisions on government as well as commercial projects. The following divisions have thus far been identified to support the project: Westinghouse Steam Turbine Division in the area of turbine generator and turbine generator controls design modification, the Westinghouse Industry Systems Division in the area of technical inputs design for the master control system, and the Westinghouse Advanced Systems Technology Division in the area of utility system/network and economic analysis.

The proposed project organization is shown in Figure 7.1.2-3. Upper management visibility and support for the proposed project is reflected in the approved selection and assignment of personnel to perform the project. The management and technical personnel assigned to the project cover the full range of administrative and technical specialties required for the successful execution of the proposed program.

Management Organization

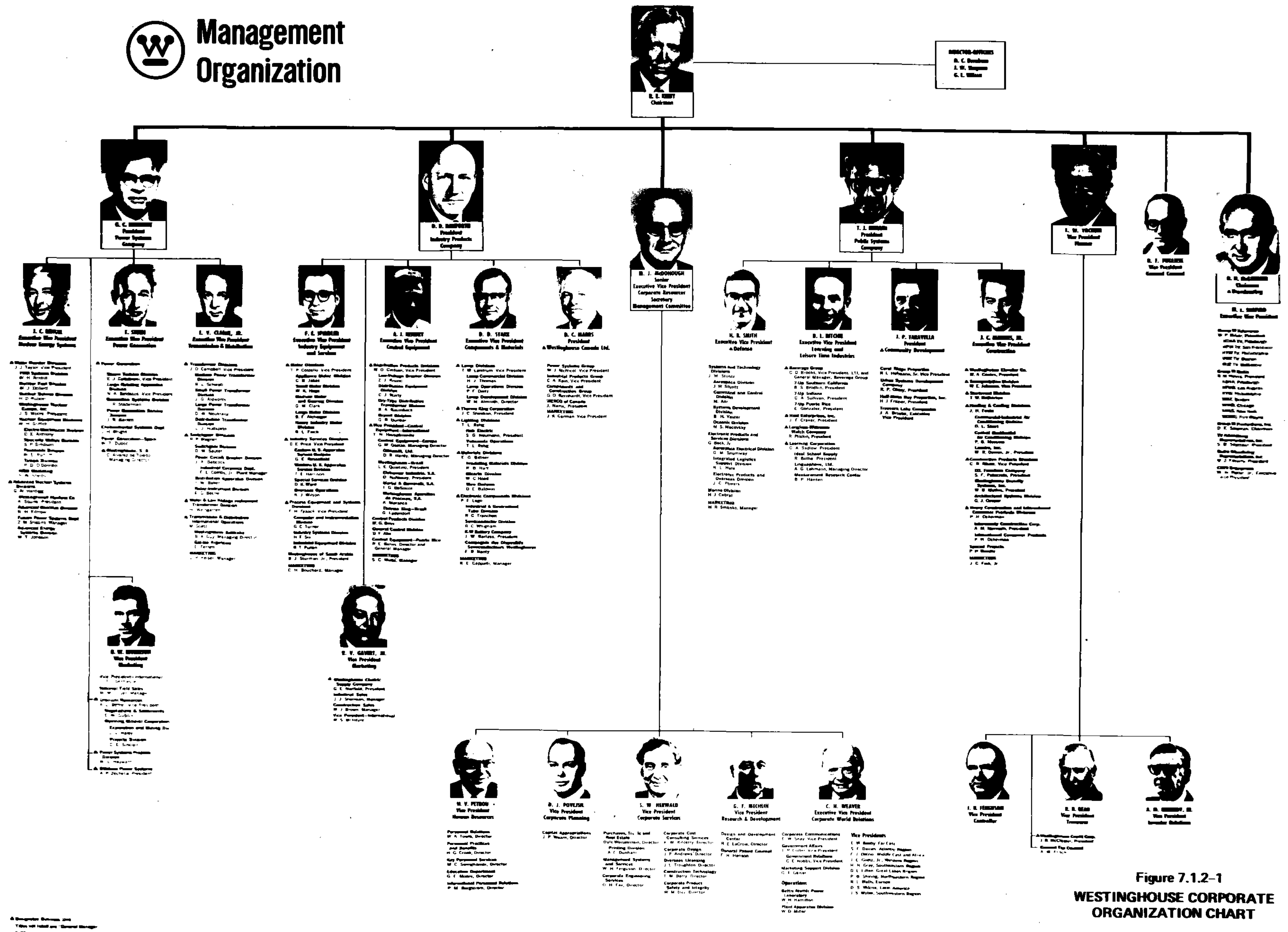


Figure 7.1.2-1
WESTINGHOUSE CORPORATE ORGANIZATION CHART

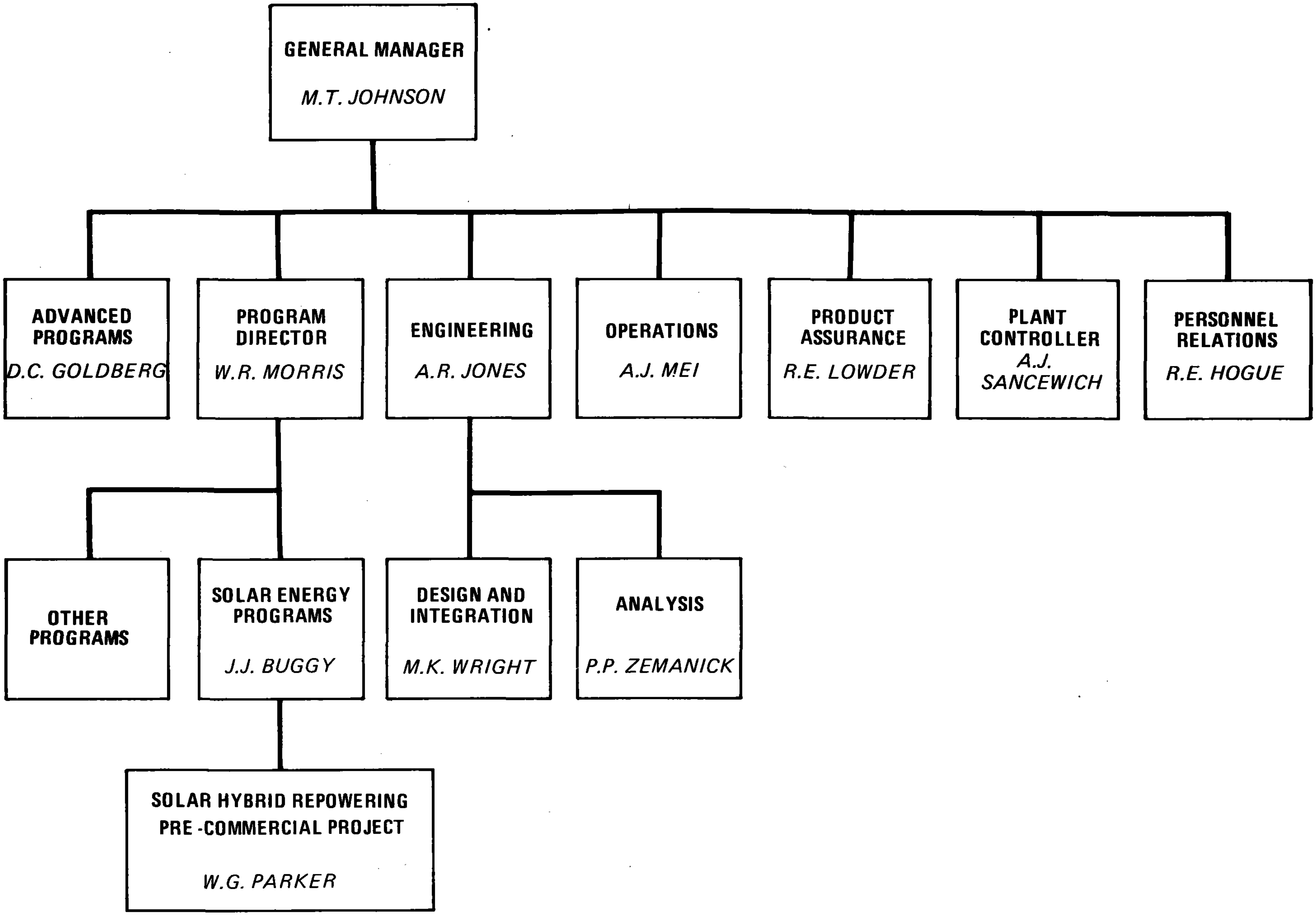


Figure 7.1.2-2
WESTINGHOUSE ADVANCED ENERGY
SYSTEMS DIVISION ORGANIZATION

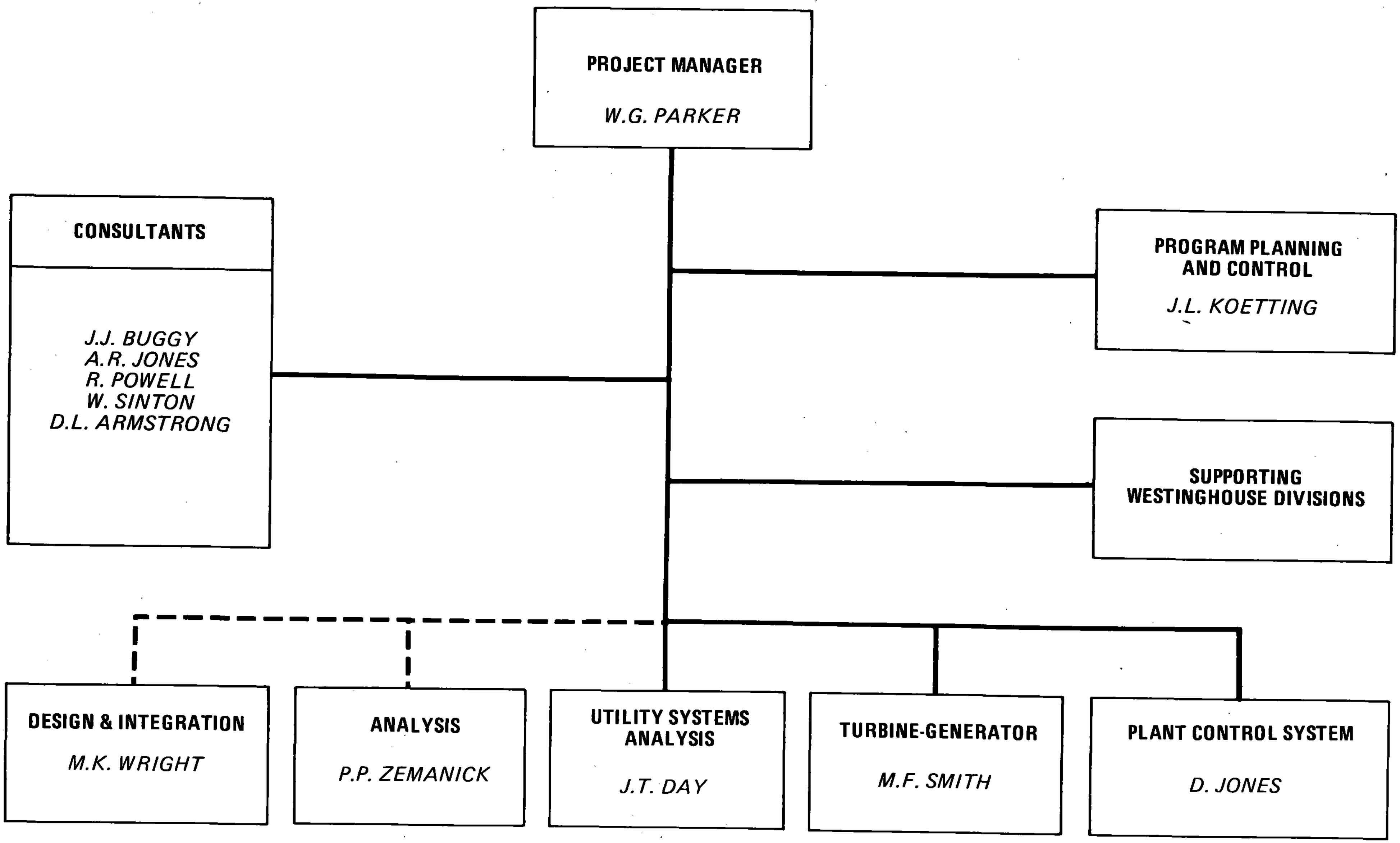


Figure 7.1.2-3
WESTINGHOUSE ELECTRIC CORPORATION
PROJECT ORGANIZATION CHART

The Westinghouse Project Manager is Mr. W. G. Parker, presently Project Integration Manager for the Phase I-Technical and Economic Assessment Study of Solar Hybrid Repowering. Mr. Parker has acquired considerable engineering and project management experience which will be of direct benefit to the proposed project, and has demonstrated all the necessary management, technical, and administrative skills to successfully manage and direct all of the activities on the project to assure the successful attainment of all objectives.

As Project Manager, Mr. Parker will have responsibility for all of the Westinghouse technical and administrative functions and decisions on the project. Mr. J. L. Koetting, Manager of Program Planning and Control, will be assigned to assist Mr. Parker, as required, on project administrative matters, such as scheduling, budgeting and report preparation. As shown on the project organization chart, Figure 7.1.2-3, the project personnel will be responsible directly to Mr. Parker for the completion of their assigned tasks. In addition, the support personnel required from the supporting divisions will be assigned well-defined tasks for their portion of the work to be executed. They will also be responsible to Mr. Parker for the satisfactory performance of their assignments. In addition, Mr. Parker will also have clear control over all aspects of relationships with Public Service Company of New Mexico.

The technical team is organized as shown in Figure 7.1.2-3 with five key technical investigators. Mr. M. K. Wright will be responsible for the design and integration effort which will include for example, the preparation of the preliminary system design.

Dr. P. P. Zemanick will be responsible for all analysis efforts on the project which will include the system analysis, the heliostat field analysis, the receiver analysis, and the preparation of the overall state point system flow diagram. Mr. M. F. Smith will be responsible for the turbine-generator design modification which will include the potential upgrading of the turbine control system. Mr. D. Jones will be responsible for the technical design inputs for the Master Control System. Mr. J. T. Day will be responsible for the utility system analysis which also includes the regional cost/benefit analysis of the solar hybrid repowering concept.

I. R. Caraco
Vice President

Bechtel Power Corporation
Engineers - Constructors
12400 East Imperial Highway
Norwalk, California 90650

April 28, 1978

Mr. J. D. Geist
President
Public Service Company of New Mexico
P.O. Box 2267
Albuquerque, New Mexico 87103

Dear Mr. Geist:

Bechtel Power Corporation welcomes the opportunity to perform the Architect-Engineer-Constructor services for the Solar Repowering Project, as described in the accompanying Technical Proposal. Moreover, Bechtel is dedicated to bring to bear all the required talents and resources of the company for satisfactory completion of the Project.

Sponsorship and primary responsibility for the performance of the work will lie with Los Angeles Power Division, and I pledge my personal attention and that of Vice President and Domestic Operations Manager Loren Hinkelman to the Project, through periodic progress review meetings with the Project Management. LAPD has had considerable experience with application of new technology in power plant work and recognizes the challenges presented by this important pre-commercialization Project. Bechtel's Research and Engineering operation has been leading the way in Solar Power Technology and their experienced personnel will participate with LAPD as necessary to provide the best team of specialists and experienced power plant engineers and constructors.

Our interest is based on a combination of enthusiasm for the future of the Solar Power Repowering concept and of a desire to continue to serve the Public Service Company of New Mexico in its electric power endeavors. It, therefore, gives me great pleasure to present to you this dedication of participation.

Sincerely yours,

I. R. Caraco

I. R. Caraco

7.1.3 Bechtel

Bechtel is organized into eight operating divisions and a Research and Engineering Operation, which, together, are staffed by about 12,000 technical personnel. This figure includes engineers serving in other technical functions, such as estimating, scheduling, purchasing, or administrative and support functions. When a project calls for technologies beyond the scope of any single office, the capability of other offices and divisions is made directly available.

Bechtel's Los Angeles Power Division (LAPD) office in Los Angeles has the primary responsibility of serving the Public Service Company of New Mexico. LAPD was established in the 1940's to serve clients in the fields of electrical power, heavy industry, and land planning. The staff at LAPD has an extensive background in the power field, gained while conducting projects ranging from site analysis and selection to detail design of power plants, substations and transmission lines.

Bechtel's Research and Engineering Operation (R&E) is located in San Francisco. It is organized to pursue Bechtel in-house research activities, to provide specialized technical support to other Bechtel entities such as LAPD, and to perform contract research and engineering for clients. These efforts focus heavily on promising emerging technologies significant to major engineering and construction projects.

The overall responsibility for this project will be assigned to the Los Angeles Power Division of Bechtel Power Corporation. This project will be implemented by an integrated LAPD-R&E Project Team under a well qualified Bechtel Project Manager, Mr. Glen Bratzler, who will be fully responsive to PNM's Project Manager for the requirements of the project.

Figure 7.1.3-1 shows the reporting relationship for the Project. The individuals comprising this team have successfully worked on previous projects. This integrated team of personnel drawn from both LAPD and R&E allows the utilization of Bechtel's extensive experience in both solar energy and power plants.

Glen Bratzler has the authority and responsibility to organize the company's resources as necessary to completely control Bechtel's project performance including cost, schedule and technical excellence. Glen's activities are closely monitored by corporate management via his reporting relationship with Loren Hinkelman, Vice President and Manager of Domestic Operations. Mr. Hinkelman also holds a monthly assessment meeting of the Project to review costs, schedule and customer satisfaction. Mr. Hinkelman reports to Ike Caraco, Vice President and Division Manager.

Reporting to Mr. Bratzler are the Project Engineer, John Bouma, the Project Construction Superintendent, the Project Start-Up Engineer, the Project Cost and Scheduling Supervisor, and the Project Procurement Manager. As shown in Figure 7.1.3-1, the Project Quality Assurance Engineer reports to Division Quality Assurance while coordinating his efforts with the Project Manager.

Engineering is organized within Bechtel on a project basis as indicated on Figure 7.1.3-2. This team of engineers are all well qualified and experienced in the field of power plant design. This team has single point responsibility and will be headed by the Project Engineer, John Bouma. Mr. Bouma will receive technical guidance from George Wang, Engineering Manager, and Bill Homer, Manager of Division Engineering. Mr. Bouma will be supported by an engineering staff of R&E under the responsibility of Ernie Lam. Dr. Lam, who has served as Project Engineer and Project Manager on a number of solar power projects at Bechtel, will coordinate project tasks assigned to R&E to facilitate the utilization of previous project experience in solar power to this repowering project.

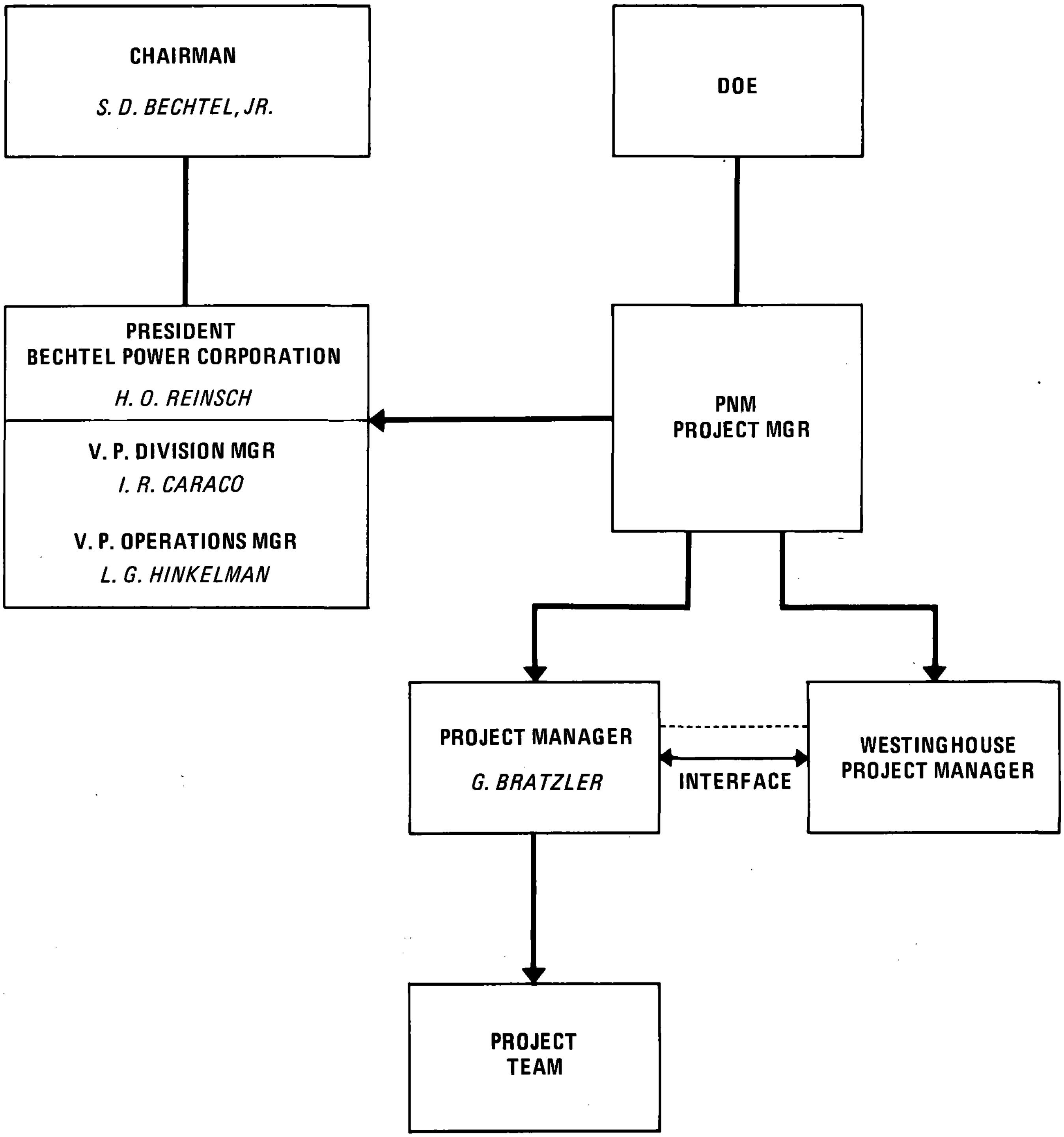


Figure 7.1.3-1
BECHTEL PROJECT REPORTING RELATIONSHIP

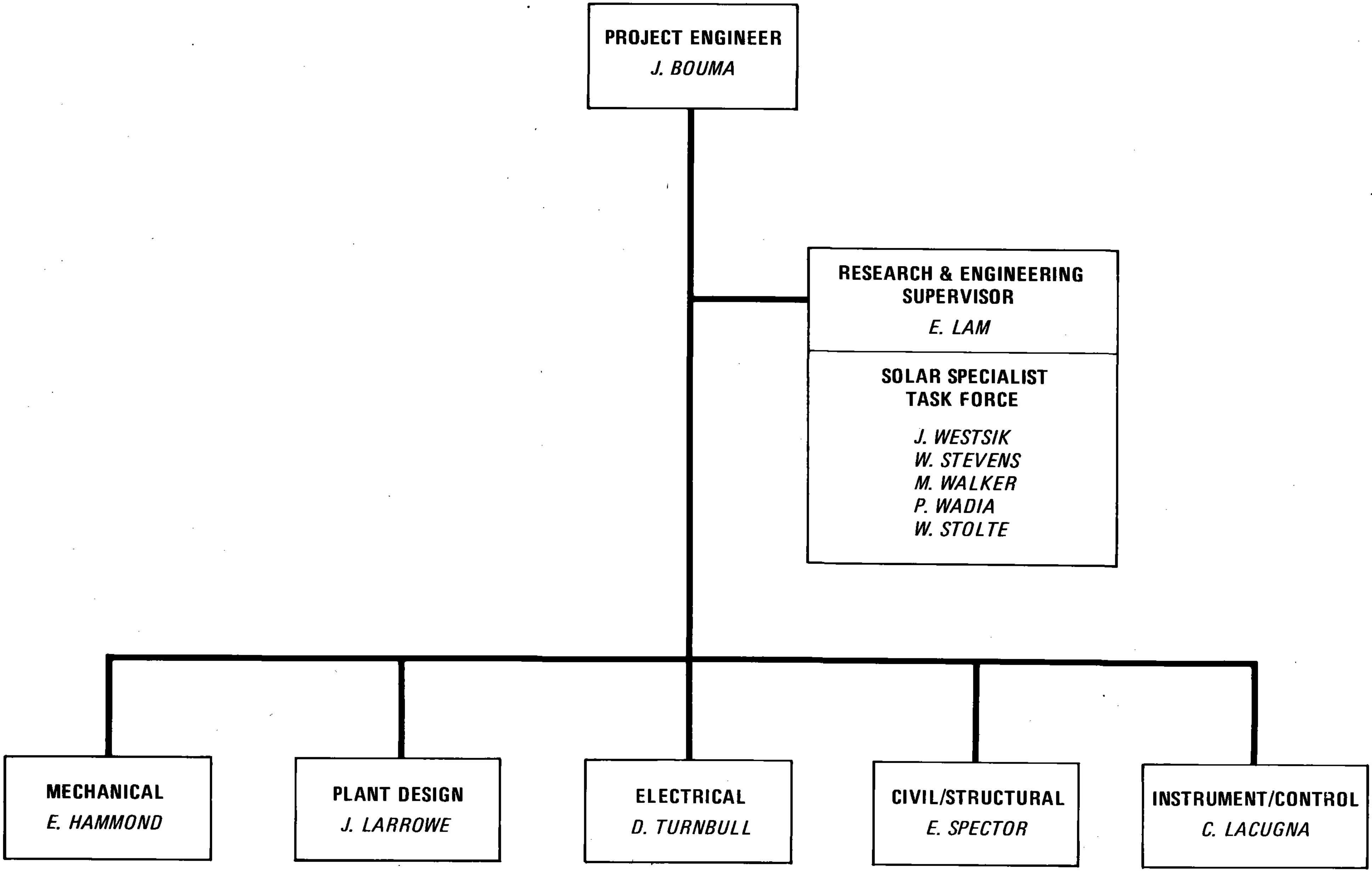


Figure 7.1.3-2
BECHTEL PROJECT ENGINEERING ORGANIZATION

7.2 RELATED EXPERIENCE

The technical experience of each of the participating organizations relating to the proposed project is presented in this section.

7.2.1 Public Service Company of New Mexico

PNM is recognized as one of the most progressive and innovative electric utilities in the United States. PNM management has recognized that the coming electric economy will present many challenges and will require new and creative approaches and methods in all areas, including the generation, transmission and distribution of electricity, and equally important, reducing the cost of this energy. PNM maintains a continuous program to recognize, evaluate, develop and place new ideas into operation.

Examples of PNM Project Leadership

Flue Gas Desulfurization - In a continuing effort to provide an adequate electrical energy supply without permanent environmental damage, PNM is installing on its San Juan Plant Unit Nos. 1 and 2 a Davy Powergas SO_2 removal system. PNM is the first utility in the United States to build a commercial size unit of this type on a coal fueled generating unit. The unit will remove SO_2 from the flue gas produced from the generation of about 700 MW of electricity. The SO_2 recovered from the Davy unit will be used as a feedstream to an Allied Chemical Company Claus sulfur recovery unit where the SO_2 will be converted to saleable liquid sulfur.

Cost of Service Indexing - In 1975, an innovative rate making approach was approved by the Public Service Commission of New Mexico. This new procedure, called Cost of Service Indexing, provides for a quarterly review of PNM's operations to determine the return on common equity applicable to the New Mexico electric operations. Indexing allows PNM to maintain stable and reliable earnings within fairly narrow parameters on either side of a 14 percent rate of return.

Wastewater Treatment - PNM was the first electric utility to purchase and install a Resource Conservation Corporation brine concentration unit. This concentrator has proven its capability to reclaim 97 percent of the wastewater in the cooling system in quantities up to a quarter of a million gallons per day. In this function, the concentrator allows for lower demands on fresh water supplies and lessens the impact of wastewater disposal into holding ponds.

Water Conservation through the Use of Parallel-Path Wet/Dry Cooling Towers - Since water may be the limiting factor in the development of new power generation facilities, PNM has specified that wet/dry water conservation towers be used at the San Juan Plant Unit Nos. 3 and 4, using 80 percent less water than do conventional all wet cooling towers. PNM was the first utility in the United States to specify this type of cooling system.

Examples Illustrating PNM Project Management Capability

Because of the magnitude of the projects in which PNM is involved, a great deal of project management experience has been developed. Projects which are either in the planning or construction stage are as follows:

San Juan Project - PNM is participating with Tucson Gas and Electric in construction of a coal-fired, steam turbo-electric generating station in San Juan County, New Mexico. PNM is acting as the project manager and will operate the station. Ultimate plant capacity will be approximately 1,600 MW. The first unit went online in 1973 and all four units will be on-line by 1981. PNM has a 50 percent interest in the station with expenditures through 1980 estimated to be approximately $329 million.

Palo Verde Nuclear Generating Station - PNM's first venture into nuclear power is its participation in three 1,270 MW units of the Palo Verde Nuclear Generating Station which will be located in the Phoenix, Arizona area. Participation will be with Arizona Public Service Company, project manager, Arizona Electric Power Cooperative, Salt River Project and Southern California Edison Company. As a participant, PNM serves on committees which make all the major decisions associated with the project. PNM owns a 10.2 percent interest with expenditures through 1980 estimated to be $202 million.

Geothermal - PNM has been investigating the potential of using New Mexico's geothermal resources for base load power generation since 1969. In 1974, these investigations led to discussions with Union Oil for the development of a geothermal field in Northern New Mexico. Since then, the reservoir has been drilled and tested. Currently, funding is being sought from the Department of Energy for a 50 MWe Geothermal Demonstration Power Plant.

Pumped Storage Hydroelectric Peaking Unit - PNM commenced studies for a pumped storage hydroelectric unit in 1975. Feasibility studies and site selection have been successfully completed, and commercial operation is scheduled for mid 1985.

Examples of PNM Research and Development Projects

PNM is involved in several research and development projects, both solar and non-solar related. The energy crisis has focused attention towards finding and developing methods to produce and conserve energy. The management at PNM encourages participation in projects which will help develop these methods and put them into commercial operation. A group has been established within the Company to coordinate R&D activities to increase the efficiency of research and development projects.

PNM actively participates with private, state, and federal organizations on energy related matters. The following is a brief summary of some of these activities:

<u>Edison Electric Institute - Electric Power Research Institute</u> - As a member of the Edison Electric Institute, PNM makes significant contributions to the Electric Power Research Institute (EPRI). The PNM participation in EPRI is not limited only to monetary contribution. EPRI has set up several task forces to allow industry input to their programs and PNM has several employees serving as members of these task forces. Objectives are: to set the general EPRI program guidelines; set budget priorities and judgments; and make recommendations on specific proposal recommendations.

<u>Western Energy Supply and Transmission Associates</u> - PNM is a member of the Western Energy Supply and Transmission Associates (WEST). WEST is an organization consisting of several western utilities which was formed for interchange of information on problems which would be specific to the western United States. WEST has set up several task forces for dissemination of information and to manage R&D projects proposed by member utilities; PNM is represented on all WEST committees.

<u>Gulf-Atomic Breeder</u> - PNM has been a financial contributor to the General Atomic Gas Cooled Fast Breeder Reactor program for the past nine years.

<u>New Mexico Energy Resources Board</u> - The State of New Mexico has established the New Mexico Energy Resources Board (ERB) to create and implement a statewide energy plan. PNM loaned one of its key employees to the ERB on a full-time basis for one year. Also, the ERB has set up energy research institutes to be the focal points for energy related R&D. PNM has several employees which serve as technical advisors to these institutes.

Los Alamos Laboratories Information Exchange - PNM and the Los Alamos Scientific Laboratories are participating in an Information Exchange Program. Meetings are held alternately in Albuquerque and Los Alamos which allow for the interchange of information on programs that are of mutual interest. Special concentration is in the fields of solar and geothermal energy, as well as advanced DC transmission.

Sandia Solar Total Energy Program - Sandia Laboratories in Albuquerque is working on a concept termed the "Solar Total Energy Program" (STEP). The Sandia STEP is intended to develop the technology required for application of a solar total energy system for both commercial and residential applications. PNM has an information exchange agreement with Sandia on STEP, providing guidance on proper design for grid integration, customer interface, etc.

Solar Energy Experience

PNM is a utility industry leader in the solar energy field. This can be seen by the many solar projects with which PNM is involved. The following are projects which are directly related to research in the solar energy field:

Solar Hybrid Repowering

In 1974 PNM originated the concept of solar hybrid repowering in which an existing power plant is modified for operation on fossil or solar energy. A nine state in-house survey in 1976 identified approximately 40,000 MWe of generating capacity to which the concept might be applied. Considering the large potential, PNM submitted an unsolicited proposal to ERDA for funding a two phased assessment and demonstration. Phase I, extending over a twelve month period, is currently underway and terminates in September 1978. To date, approximately 55 utilities have expressed support of the project, and PNM has identified and selected a 50 MWe power plant as a suitable candidate for repowering which closely represents the identified southwest repowering market.

PNM has led the nations' utilities in investigating and disseminating information on the solar hybrid repowering concept; also working closely with DOE, their technical advisors, and many other interested parties.

Southwest Project - PNM is participating with ten WEST Associates Utilities in a project funded by the Department of Energy and the Department of the Interior. This study will supply analyses of the technical, legal, regulatory, and institutional requirements from a utility perspective for accelerating the commercialization of solar electric power in the Southwestern United States. PNM will provide input data and guidance to the project and review and comment on the progress of the study.

Definition and Impact Analysis of Solar Thermal Power Plants - This EPRI sponsored project will provide electric utilities with a more complete basis for evaluating solar thermal power plants. PNM is one of three utility systems upon which effects of solar plants will be evaluated. PNM will provide all necessary data pertaining to their system and review results of the analyses for technical accuracy.

Solar Resource Data Evaluation Project - PNM is currently expanding its instrumentation of insolation measurement systems to evaluate the solar resource within its service territory. The most current addition is a direct and total radiation data station which is installed at Reeves Station, the candidate plant for repowering. These data will also be utilized for the WEST Solar Resource Data Evaluation Project which will correlate insolation measurements for the Southwest by drawing from a large standardized utility instrumentation base.

7.2.2 Westinghouse Electric Corporation

The Westinghouse Electric Corporation support to the proposed project will be coordinated by the Westinghouse Advanced Energy Systems Division located at Pittsburgh, Pennsylvania. The Advanced Energy Systems Division will be responsible for the Systems Engineering and Project Integration activities which will include efforts in turbine-generator design modification and analysis and turbine generator control systems design and analysis by the Westinghouse Steam Turbine Division, in master control system technical inputs design, by the Westinghouse Industry Systems Division, and in the utility systems economic and network analyses by the Westinghouse Advanced Systems Technology Division.

PNM, at the outset of the current Phase 1 Technical and Economic Assessment, selected the Westinghouse Electric Corporation to assist PNM in executing the systems project integration activities. This selection was based on the results of intensive interviews with a number of candidate companies. PNM proposes to continue to use Westinghouse in this role because:

- Westinghouse performance during the assessment phase has been of a consistently high quality, contributing significantly to the project success to date.

- The Advanced Energy Systems Division, which executes this activity for Westinghouse is well qualified to carry out the systems engineering and project integration aspects of the demonstration program. The Advanced Energy Systems Division has past and current experience in integrating new technology projects as well as in interfacing with DOE and utilities.

- Westinghouse is committed to provide the required support to this project. This has been expressed through top management attention by Mr. Gordon Hurlbert, President of the Westinghouse Power Systems Company. It has been demonstrated by the actions of the Division in providing appropriate skills on short notice to resolve problem areas.

- Continuation of this established, smoothly functioning, cooperation between PNM and Westinghouse will be an important factor in achieving the DOE/PNM goal of a successful project, on schedule and within budget.

The ability of Westinghouse to perform the proposed project has been further demonstrated through continuing Westinghouse management of major research and development projects and experimental facilities for industry and the government. Like the proposed repowering project these activities include design, operation and management of efforts such as:

Bettis Atomic Power Laboratory
Idaho Naval Reactor Facility
Hanford Engineering Development Laboratory
Fast Flux Test Facility
Carolina/Virginia Tube Reactor
Saxton Prototype Pilot Plant
BR-3, Mol, Belgium
Low Btu Gas Process Development Unit
Materials Research and Development
Polaris/Poseidon Launch Test Facility
Radar and Related Electronic Systems
NERVA Nuclear Rocket Test Program

From 1961 to 1972, the Westinghouse Advanced Energy Systems Division, formerly the Astronuclear Laboratory, was engaged in the development and production of a nuclear propulsion system for the Nuclear Engine for Rocket Vehicle Application (NERVA) program. Successful demonstration of this system for space propulsion was achieved in 1968 with full power testing of the NERVA XE Engine. Other specific programs with first-of-a-kind, experimental research development and demonstration criteria similar to those anticipated in the proposed program were the Low Btu Gas Process Development Unit, the Polaris/Poseidon Submarine Missile Launch Test Facilities and Materials Research and Development Laboratory at Wright Patterson Field.

During these programs, Westinghouse Advanced Energy System Division engineers and scientists gained and demonstrated their extensive experience in the major power system disciplines, including:

- System Engineering
- Heat transfer systems
- Health hazards and safeguards
- System modeling and data processing
- Structural mechanics
- Instrumentation and control
- Quality and reliability

Solar Energy Development - Active involvement in widely diverse research and development programs that cover the spectrum of solar energy development is shown by current corporate participation in the following studies.

Of particular relevance to this program, is Westinghouse present participation in the Phase 1 - Technical and Economic Assessment of Solar Hybrid Repowering. In addition, Westinghouse is performing an extensive electric utility requirements assessment study of solar thermal power plants under EPRI contract. This survey is an extension of the earlier Aerospace Corporation mission analysis studies and assesses the electric utility economics and operational requirements of a variety of solar thermal power plant concepts operating in real and simulated electric utility grids. The three utilities selected for this study are Public Service Company of New Mexico, Arizona Public Service and Utah Power and Light Company.

The Westinghouse Advanced Energy Systems Division was recently awarded a contract for the Large Scale Experiment No. 1 (LSE-1). The objective of this contract is to accomplish the preliminary design of a solar total energy complex that will supply a significant portion of the annual energy for the Fort Hood 87000 Troop complex. The preliminary design effort will finalize the baseline DOE-concept design which was selected during the previous conceptual design. The preliminary design will include, but not be limited to, design specifications, interface requirements, process flow diagrams, heat balances, energy budgets, preliminary engineering drawings, reliability analyses, operation plans, and cost estimates. Each system, subsystem, and component will be characterized by specific design features required for this application.

The LSE-1 contract was the outgrowth of a competitive conceptual design study for a solar total energy system to provide power to five buildings in an existing barracks complex at Fort Hood. It is an energy system designed to maximize the overall use of collected solar energy by meeting both the low grade and high grade needs of the site.

The complete study was performed within cost and on schedule by Westinghouse Advanced Energy Systems Division with subcontracts to Heery and Heery, Georgia Institute of Technology and Scientific-Atlanta and as a result of team performance during the conceptual design phase, Westinghouse as previously mentioned, was selected as the design contractor for the following work during the definitive design phase.

Westinghouse, in addition to performing in the design role for the Ft. Hood STES project, is providing Project Integration service to Georgia Power Company in a DOE funded STES for a knitwear factory in Shenandoah, Georgia. This system is generally similar to the Ft. Hood unit except that a process steam load of about 1000 kg/hr is required to supply the fabric presses.

Westinghouse, as further evidence of the corporate committment to solar electric power systems, is presently engaged in the design, fabrication, and testing of a unique, low cost heliostat concept using in-house funds. Westinghouse is closely coordinating this program with the DOE heliostat program managed by Sandia in order that the resulting heliostat configuration can be of the maximum benefit in satisfying the requirements of present and future DOE solar power systems. Westinghouse plans to test the heliostat in cooperation with Sandia Livermore in September 1978.

Westinghouse has also performed, in cooperation with Colorado State University, design parameter research to develop systems for thermal-mechanical conversion of solar energy that will minimize cost per kWh generated.

Again in conjunction with Colorado State University, Westinghouse has studied solar energy conversion under contract to ERDA. Diversified power plant concepts entail consideration of the possible replacement of steam turbines by organic and non-aqueous rankine turbines in three to 300 MW plant configurations.

Under contract to the National Science Foundation, Westinghouse Special Systems Division and Research Laboratories have conducted investigations of the technical, economic, institutional, social and environmental feasibility of solar heating and cooling.

Moving beyond conceptual studies, Westinghouse Special Systems Division managed the design, construction and operation startup of the large-scale solar system that serves the George A. Town Elementary School of Atlanta, Georgia, which is currently the largest solar heating and cooling system in the world.

Under contract to ERDA, Westinghouse has completed conceptual design studies and systems analysis of photovoltaic power systems in three basis types: 1) one to ten kW residential; 2) 100 kW to ten MW intermediate, and 3) 50 to 1,000 MW central station. In addition, Westinghouse was recently awarded a contract from DOE to continue the systems analysis of photovoltaic power systems.

Wind Power Systems - Cooperative efforts by Westinghouse Research Laboratories and an eastern utility have formulated system performance and cost studies for the application of a wind energy conversion system (WECS) in a fuel displacement operational mode.

A large system study contract for offshore windmill power plants has recently been initiated by Westinghouse under DOE sponsorship. This contract will evaluate the technical problems and limitation of offshore wind power plant siting as well as the economics of such plants operating in competition with other forms of generation in typical utility systems. This study will include an economic and technical analysis of the various methods of transferring the energy to shore.

Solar Cell Research and Development - In 1960, a web solar cell program was initiated and in 1966 a pilot line installed at Westinghouse Semiconductor Division. A radiation-resistant drift-field solar cell, 30 cm long by one cm wide, was developed and capability for 1,000 cell-per-month production achieved.

Energy Storage Systems - Realizing potential obstacles to large-scale use of solar energy in power production, namely, those posed by the need for system reliability and competitive generation costs, Westinghouse has undertaken evaluation of various methods of energy storage as follows: batteries and other electro-chemical methods, chemical, mechanical, compressed air, pumped hydro, super-conducting magnets and thermal.

Westinghouse has recently initiated work on an NSF sponsored analysis of energy storage for solar photovoltaic power plants. The results of this study will have considerable potential application also to solar thermal power plants.

Turbine-Generator Control System Design and Analysis - The Steam Turbine Division of the Westinghouse Power System Company has performed numerous design and analysis projects. Their over 10,000 square feet of control laboratory area contains such equipment as the EAl Pacer 500 hybrid computer for simulation and dynamic analysis and the W-2500 computer systems laboratory for software development. They also have a well equipped microprocessor laboratory for development and testing and a hydraulic control development facility for low and high pressure systems using both petroleum and synthetic fluids.

Among their many accomplishments are the following which are the first and only in their field:

> Digital electro hydraulic (DEH) steam turbine control system. This is of particular relevance to this program as it involves changing the control system design of existing turbines.
>
> Standard automatic steam turbine startup and loading control.

Standard steam turbine control with cathode ray tube (CRT) display.

Microprocessor based electronic control for retrofit to mechanical hydraulically controlled steam turbines.

Supplier with standard microprocessor based boiler feed pump steam turbine control system.

Master Control System Design, Procurement, and Installation - The Industry Systems Division of Westinghouse has been producing control systems for utility power plants for more than fifty years, tracing its origins to the Hagan Controls Company. The Division produces analog and digital boiler controls, and steam turbine controls as well as plant data acquisition systems. In addition to generation, ISD also manufactures energy management systems for control of electrical grids.

ISD hardware spans the full spectrum from electronic analog controls, 7300 Series, to mini-computers, W2500, to state-of-the-art microprocessor based control systems. ISD engineers are experienced in analog control techniques as well as computer software and have developed the PROTEUS process control software system.

ISD manages many control projects for fossil, nuclear and combined cycle plants each year, designing, building, and starting up these control systems. In addition, ISD has been involved in many power plant control system developments. Among these are:

Analog and digital steam turbine controller

Combined cycle gas-turbine waste heat boiler plant control system

Direct digital control system for a once-through boiler (Missouri Public Service Co.)

Microprocessor based protection system for a nuclear power plant.

Multiprocessor based power plant data acquisition system
(Electricity Board of New South Wales, Australia, Wallerawang Unit)

ISD has the expertise, experience and ability gained from years of developing and building control systems for the power industry to develop new control concepts. In addition, the practical side of supplying actual cost efficient systems based upon proven available hardware and software is always foremost and not forgotten by ISD.

Utility Systems Analyses - The Advanced Systems Technology unit of Westinghouse Power System Company will be responsible for the satisfactory performance of this task. Its fundamental responsibility is to perform power system engineering and economic studies for electric utilities and for the manufacturing divisions of Westinghouse. The Advanced Systems Technology Department actively participates with the electric utility industry in solving technical problems ranging from electrical network studies to systems planning and economic analysis. It also conducts field and laboratory tests for the industry.

Among the utility systems for which generation planning and load analysis services have been recently provided are:

New York Power Pool	Omaha Public Power District
New England (Pool) Planning Committee	Columbus and Southern Ohio
Individual New England Companies	Texas Municipal Power Pool
Virginia Electric Power Company	Gulf States Utilities
Potomac Electric Power Company	City Public Service Board of San Antonio
Florida Power and Light	City of Fayetteville, N. C.
Nebraska Public Power District	

In the area of network planning services, (W) PSC-AST has modeled major transmission of the entire United States for the National Electric

Reliability Council and for a number of pools, regions and individual companies. Among recent customers for network modeling and analysis are:

National Electric Reliability Council	Manitoba Hydro
SOUCO-TVA-CARVA	Florida Power and Light Company
Florida Coordinating Group	Georgia Power Company
Mid-America Planning Pool	Potomac Electric Power Company
New England Planning Pool	Consolidated Edison of New York
Texas Interconnected Systems	Duquesne Light Company
Power Authority State of New York	

7.2.3 Bechtel

Bechtel intends to support the proposed PNM solar repowering project from its Los Angeles Power Division. From Bechtel's many years of experience with various types of fossil-fueled and nuclear projects, Bechtel has established documentation procedures and manuals which form the basis for engineering and construction activities. These include project procedures, design standards by discipline, standard specifications, standard plant arrangements, system descriptions, flow diagrams, etc. Their implementation on a project provides a consistency in approach, a guide for implementation, and a quality product.

Bechtel provides technical services for a great variety of special study needs for power stations. Examples are siting, environmental, seismology, soils and geology, and SO_2 removal. Bechtel has pioneered in the development of a standardized nuclear power plant (SNUPPS), and presently has standardized fossil-fueled plant design.

Bechtel also has a long-standing interest in all advance energy system concepts, including solar energy. They have been actively involved in all types including central receiver, parabolic mirror, photoelectric, and solar ponds and Ocean Thermal Energy Conversion. Bechtel has been using models for several years in the engineering of nuclear and fossil-fueled plants. The piping and electrical drawings are taken from the design model, instead of the model being made from the drawings. The process permits numerous rearrangements of the equipment model to be tried out within a limited plant volume until an easily-maintained, easily-constructed arrangement results.

Bechtel is placing emphasis on ways to minimize forced outages and power reductions. As an example of its effort in this area, Bechtel has conducted onsite reviews of the performance of control systems at 20 Bechtel-designed units.

Many of the findings of Bechtel's reliability investigations, such as the one just described, are incorporated in its standard specifications, design guides, and normal operating procedures. However, Bechtel can also provide a special program for the client in which it will identify alternatives, supported by cost/benefit evaluations, where the expenditure of additional funds in selected areas to produce higher-than-normal operating reliability should be cost-effective.

During the early stages of a project, the construction department provides the planning necessary for proper execution of construction activities. This planning includes, but is not limited to construction input to design, construction scheduling, layout of construction facilities and utilities, cost program, safety program, security program, and labor relations program.

The startup engineering department also participates in the design evolution of mechanical and electrical systems. The startup input provides for systems checkout, preoperational testing, and plant startup.

The following table summarizes Bechtel's power experience.

BECHTEL POWER EXPERIENCE

Type of Facility	Number of Plants or Units	Capacity
Fossil Fuel Generating Units	190	50,000 MWe
Nuclear Units	82	66,874 MWe
Hydroelectric Generating Units	82	10,000 MWe
Gas Turbine Generating Units	15	560 MWe
HV and EHV Transmission Lines	Over 1,500 miles	Up to 750 kV
Distribution and Transmission Substations	Over 1,000	

Since 1972 Bechtel has closely followed the major solar programs in the United States and has been actively engaged in many solar research and development programs. Representative activities are briefly described below.

Bechtel is currently providing engineering services to Sandia Laboratories to define the requirements and to provide a preliminary design for a photovoltaic central power station experimental test facility. This one year effort will define the test facility's requirements to secure information needed by photovoltaic equipment manufacturers and the utility industry before a commercial-sized demonstration power plant is built. The study will establish the critical parameters and proposed criteria for site selection. It will include reviews with the utility industry to obtain end user comments and expressions of interest in further participation in the facility program with DOE.

Under subcontract to Spectrolab, Inc., Bechtel is at present participating in a DOE/Sandia funded feasibility study of hybrid photovoltaic/solar thermal power plants. Bechtel responsibilities in this study involve the selection and evaluation of appropriate thermal power cycles and economic analysis.

Bechtel is presently engaged in two projects concerning Ocean Thermal Energy Conversion (OTEC) power plant design as a subcontractor to Lockheed Missiles and Space Company (LMSC). These projects will re-examine earlier designs and will result in updated commercial plant conceptual and preliminary designs. Two prior OTEC studies by Bechtel as subcontractor to LMSC address the definition of an OTEC test facility and the technical and economic feasibility of a commercial size (160 MWe) OTEC power plant. Bechtel's responsibilities in these studies include the development of flow diagrams, equipment lists, equipment specifications, main and auxiliary system descriptions, plant layout drawings and cost estimates. Some of the special features of the resulting design are very large, low-temperature-difference evaporators and condensers, as well as a binary cycle employing ammonia as a working fluid.

Bechtel is conducting a study for the project analysis and integration area of the Jet Propulsion Laboratory (JPL) Low-Cost Silicon Solar Array (LSSA) Project. The objective of the study is to provide support to JPL in assessing the life-cycle costs of solar arrays for electric utility central station power plants. The emphasis of the study is on fixed, flat-plate arrays, with seasonally adjusted and tracking arrays addressed for purposes of comparison. Conceptual designs for the balance of plant are to determine their impact on array design and to assess the impact of array design on the balance of plant. Factors to be evaluated include the costs of equipment, site preparation, installation, and operation of maintenance. Cost interdependencies among these factors and electric utility industry practices are also being evaluated.

In addition to the above study, Bechtel is currently conducting another study for the engineering area of the JPL-LSSA Project. The objective of this study is to develop, evaluate and provide life cycle cost data on the interface between solar photovoltaic panels and the array framework. Various panel styles array sizes and power and voltage levels are being considered parametrically in order to aid JPL in determining cost-effective array configuration, and in developing solar panel/array specifications.

Bechtel is currently conducting a study for Sandia Laboratories directed at the design of low-cost structures and installation techniques for photovoltaic arrays. This effort will consider flat plate and low concentration ratio (non-tracking) collectors of both photovoltaic only and combined photovoltaic/thermal designs. Bechtel will provide assistance in analysis and design of structures which lead to a lowering of photovoltaic system cost through the use of new materials, novel configurations and innovative construction and installation techniques. Included in this study will be a survey of photovoltaic cell researchers and developers, potential commercial manufacturers for the cells and other array components, firms that may be involved in the engineering and construction of commercial terrestrial solar cell facilities, and potential users of commercial photovoltaic power.

A technical and economic assessment of solar distillation concepts was conducted for Sandia Laboratories under ERDA sponsorship in 1977. This study provides a baseline comparison between costs for solar distillation and non-solar distillation plants based on the current technology. It also evaluates future potential of solar distillation based on development of concepts beyond the existing technology.

In another 1977 study for Sandia Laboratories under ERDA sponsorship Bechtel reviewed the available technology and the economics of using solar energy for water pumping in remote areas. The study covered the market potential for solar pumping and the potential energy conversion technology available in the near term. The economics of solar pumping estimated for a representative system was compared with a conventional water pumping system.

Bechtel conducted a study during 1976-77 for Argonne National Laboratory to determine the requirements imposed on batteries when they are used for energy storage in solar photovoltaic power systems. Advanced batteries currently being developed, as well as commercially available batteries, were evaluated in applications that ranged from fractional watt remote power supplies up to 1000 MWe central station power plants.

As a subcontractor to Acurex Corporation, Bechtel completed work in 1977 on an ERDA-funded project to develop a preliminary design of a 150 kWe solar powered deep well water pumping and irrigation facility. Bechtel had the responsibility for the design of the power generation subsystem and its auxiliary systems, the water storage and delivery subsystem, civil-structural buildings and general site development. In parallel with these prime efforts, Bechtel provided consultation, analyses, and designs on the thermal storage the collector, and the receiver subsystems. As part of the study, Bechtel also developed overall plant costs, and has assessed potential environmental impacts of the complete facility.

In 1976, Bechtel performed an in-house technical research and development program to assess the technical and economic feasibility of solar space heating and cooling of buildings. In order to identify the major trends in the industry for building space conditioning and domestic water heating, major concepts and evolving system designs were studied to assess their potential vailability, feasibility and economics. While technical and economic feasibility is the key to the success of this technology, non-technical problems were also addressed.

In 1976 Bechtel participated with Spectrolab, Inc., in an ERDA-funded conceptual design and analysis of three photovoltaic solar power systems by compiling data and specifying the energy storage, power conditioning, and converter aspects of all three systesm: a 2.5 kWe residential system, a 1 MWe commercial system, and a central station plant in the 50 to 1,000 MWe range. In this project, Bechtel had prime responsibility for a conceptual design of a 200 MWe photovoltaic central power plant.

In 1975, as a subcontractor to Lockheed Missiles and Space Company, Bechtel completed work in a design study to determine the technical and economic feasibility of a commercial size (160 MWe) Ocean Thermal Energy Conversion (OTEC) power plant. This study was conducted for the National Science Foundation Research Applied to National Need (NSF/RANN) Program. Bechtel's responsibilities included the development of flow diagrams, equipment lists, equipment specifications, main and auxiliary system descriptions, plant layout drawings, and cost estimates. Some of the special features of the resulting design are very large, low-temperature-difference evaporators and condensers, as well as a binary cycle employing ammonia as the working fluid. Further work was performed in 1976 to design and plan an OTEC test facility, to develop a design for dependable low cost heat exchangers to operate efficiently over the small temperature differences in OTEC facilities and to provide Lockheed with support in evaluating thermal and structural engineering and manufacturing feasibility.

In 1975 Bechtel conducted a technical and economic evaluation of the compound parabolic concentrator (CPC) solar collector for Argonne National Laboratory. The purposes of this effort was to compare the CPC with other types of collectors and to recommend relative priorities for the development of the CPC for commercial applications.

In 1975 Bechtel conducted a design study for ERDA to assess the general technical and economic feasibility of using nonconvecting solar ponds as a means of generating electric power. As part of the study, a baseline design of a power plant was conceptualized and its capital cost estimated. In addition, the potential environmental impact was assessed and the applicability of this basic power concept in developing countries was also evaluated.

In 1974 Bechtel conducted a design study for Sandia Laboratories, Livermore, on a central receiver solar and coal fired hybrid thermal power concept. The main purpose of the study was to provide the client with technical and cost aspects of the engineering and construction of major parts of the concept system.

7.3 KEY PERSONNEL RESUMES

This section contains resumes of key project management personnel arranged alphabetically.

JOHN T. ACKERMAN

Education: BS, Electrical Engineering, University of New Mexico
MS, Power Engineering and Utility Management, New Mexico State University

Experience: Mr. Ackerman has been with the Public Service Company of New Mexico for a period of 7 years, serving in management and Project Management positions. Prior to that, he served with the General Electric Company as a Design and Development Engineer for a period of 3 years.

Mr. Ackerman was in the U.S. Navy, as a technician, for 4 years.

Professional Affiliations:

Registered Professional Engineer, State of New Mexico
Institute of Electrical and Electronic Engineers National Society of Professional Engineers.

Proposed Assignment:

Operating Committee

GLEN BRATZLER

Education: BS, Civil Engineering, University of Wyoming
Certificate in Business Administration, University of California

Experience: Mr. Bratzler is presently assistant Project Manager on the construction of the Cholla Generating Station Units 2, 3 and 4. He was Project Manager responsible for the engineering, procurement, construction, startup and testing of the horizontal scrubber Demonstration Test Module at Four Corners Generating Station. He served in the same capacity in the development of the Emission Abatement System for Units 4 and 5 at the Four Corners Generating Station.

Prior to the above, his assignment was in project engineering for the Navajo Generating Station. He was Project Engineer for study, design and development of the precise power plants for the Nike-X and safeguard Intercontinental Ballistic Missile Defense Systems. During the missile crisis Mr. Bratzler was project engineer on the Mobile Medium Range Ballistic Missile and the Atlas ICBM. On the latter program he directed design engineering functions for eight Atlas bases comprising 75 missile sites. He was personally cited by the Commanding General of the U. S. Air Force Ballistic Systems Division for his meritorious service and many contributions to the Ballistic Missile Program.

His early assignments with Bechtel have included engineering responsibilities of Southern California Edison's, Alamitos Units 1 and 2, Huntington Beach Units 1 and 2 and Mandalay Steam Generating Stations, and nickel mining and smelting facility. He also was assigned as Assistance Project Engineer on a grass roots cement plant for the Hawaiian Cement Company. One of his initial assignments was a field engineer on the construction of a dam for the Southern California Edison Company.

Professional Affiliations:

Member, Structural Engineers Association of Southern California
Member, American Concrete Institute

Proposed Assignment:

Bechtel Project Manager

DONALD J. GROVES, JR. (JACK)

Education: BS, Mechanical Engineering, New Mexico State University
Graduate studies toward MBA, New Mexico State University
Certified BASIC and FORTRAN programmer, RI 1972, MDAC 1974
PUR Guide

Experience: Mr. Groves' current assignment, since April of 1975, is that of Energy Conversion Engineer for the Public Service Company of New Mexico. He also is Supervisor of the Resource Appraisal Group, which assesses the future availability of resources for PNM, and is responsible for all research and development programs concerning solar power generation. He was proposal co-author and Project Coordinator for Solar Hybrid Repowering Assessment Studies and served as Utility Council Member for Advanced Central Receiver Study.

Before his association with PNM, Mr. Groves was Engineer Scientist for the McDonnell Douglas Corporation, Energy Systems Division, 1972-1976. He performed conceptual and development engineering design analysis and test work in the energy systems department. His experience was in the thermal systems group with responsibility for developing engineering models of liquified natural gas storage and transfer systems, solar collector configuration, thermodynamic and heat transfer processes associated with solar system operation during varying environments, etc.

Prior to that, Mr. Groves was Engineering Analyst for Rockwell International, Inc., 1970-1972. He was a member of the Advanced Fluids and Heat Transfer group, performing thermal and fluid flow analysis on high and low pressure storage and distribution systems. Much of the work was in the field of cryogenics, developing both active and passive thermal control systems for long-term storage. Certain projects led to the development of large simulation computer programs.

Professional Affiliations:

National Mechanical Engineering Honor Society
American Society of Mechanical Engineers
New Mexico Solar Energy Association
Committee WEST Associates Energy Task Force
EPRI Solar Electric Working Group
Advisory Board, New Mexico Solar Resource Assessment Project
Utility Liaison, EPRI RP 475
New Mexico EIT No. 2190

Proposed Assignment:

Project Manager

JACK D. MADDOX

Education: MS, Nuclear Engineering, University of New Mexico
BS, Chemical Engineering, Washington University

Experience: Mr. Maddox currently is serving as Project Manager, since September of 1977, of the Solar Hybrid Repowering Study. This is a project funded by the Department of Energy, EPRI, West Associates, and Individual Utilities for the purpose of conducting a technical and economic assessment of solar hybrid repowering from a utility perspective.

Mr. Maddox also is assigned to the position of Supervisor of Resource Analysis, since March of 1976, of the same company. The objectives of this section are to define the nature, extent, and cost of energy resources along with technical and economic assessments of the necessary energy conversion technology. Recent project investigations have involved geothermal energy, solar energy, coal, nuclear power, pumped storage, and natural gas and oil availability and cost. The section has also been concerned with topics such as the optimum generation mix of peak versus base loaded plants and advanced peaking concepts.

Prior service with the Public Service Company of New Mexico was as a Nuclear Systems Engineer, 1974-1976, responsible for nuclear power system analysis and project reviews for ANPP. As such, he performed engineering and economic sensitivity studies for PNM nuclear base load plant feasibility analysis.

As Chemonuclear Consulting Engineer for Babcock and Wilcox, 1973-1974, Mr. Maddox was responsible for monitoring and evaluating the performance of PWR fluid systems at Three Mile Island Nuclear Station. He also served as Research Engineer for Babcock and Wilcox, 1972-1973.

Prior assignments included:

Weapons Controller, 1969-1972
Research Engineer, Monsanto Company, 1965-1968.

Professional Affiliations:

Registered Professional Engineer in the State of New Mexico, No. 6065
National Society of Professional Engineers
American Nuclear Society
Executive Committee, Institute Advisory Board, New Mexico State Energy Institute
EPRI Solar Program Committee

Proposed Assignment:

Operating Committee

THEODORE H.P. MORSE

Education: BS, Electrical Engineering, New Mexico State University

Experience: Mr. Morse currently is serving as Manager, gas and oil-fired plants, for all plants of the Public Service Company of New Mexico.

Mr. Morse became affiliated with PNM in 1962 as Electrical Distribution Engineer for the Albuquerque Division. Succeeding positions, prior to his current assignment, included Senior Engineer--Projects, Albuquerque Division Engineer, Albuquerque Line Superintendent, Operations and Construction Superintendent, and Materials Manager.

Professional Affiliations:

Registered Professional Engineer, State of New Mexico
Institute of Electrical and Electronics Engineers

Proposed Assignment:

Operating Committee

ROSS MULLINS

Education: BS, Electrical Engineering, State University of Iowa

Experience: Mr. Mullins presently is serving as Vice President, Engineering and Construction, for the Public Service Company of New Mexico.

Prior to his current assignment, beginning in 1974, Mr. Mullins filled positions as: Vice President, Engineering and Operations, 1971; Vice President, Albuquerque Division, 1970; Division Manager, Albuquerque Division, 1968; Division Manager, Deming Division, 1960; Division Engineer, Albuquerque Division, 1955; Field Engineer, 1953.

Before joining PNM, Mr. Mullins was affiliated with the Commonwealth Edison Company of Chicago, 1948-1953. Prior to that, he served in the U. S. Army, 1942-1946, experience that included participation in the Army Specialized Training Program at the State University of Iowa.

Professional Affiliations:

Registered Professional Engineer, States of Illinois and New Mexico.
Area Director, Emergency Electric Power Administration, Washington, D.C.
Institute of Electrical and Electronics Engineers, Past member of Transmission and Distribution Committee
National Society of Professional Engineers
New Mexico Society of Professional Engineers
Prime Movers, Committee, Edison Electric Institute

Proposed Assignment:

Operating Committee

WALTER G. PARKER

Education: BS, Engineering Mechanics, Pennsylvania State University
MS, Mechanical Engineering, University of Pittsburgh
Graduate Studies, Carnegie-Mellon University
PhD Studies, University of Pittsburgh (all requirements complete except dissertation)

Experience: Mr. Parker is presently a Project Manager in the Solar Energy Programs branch of the Programs Department at the Advanced Energy Systems Division. In this capacity, Mr. Parker is currently Manager of Project Integration for the current Phase I Technical and Economic Assessment Study of Solar Hybrid Repowering being performed in conjunction with the Public Service Company of New Mexico. Mr. Parker is technically and financially responsible for the performance of all Westinghouse tasks for this study, which includes, in addition to activities at the Advanced Energy Systems Division, the activities of the Steam Turbine Division, Industry Systems Division, Advanced Systems Technology Division, and the Research Laboratories. In addition, Mr. Parker is responsible for the performance of two subcontractors, Energy Impact Associates and Watt Engineering, Ltd.

Mr. Parker's recent responsibilities include definition of plant system requirements and operating characteristics in support of the Requirements Definition and Impact Analysis of Solar Thermal Power Plants Study as well as other solar related activities. He previously managed the Economic Radioisotope Thermoelectric Generator Study. He has been engaged in Project Management aspects of the Advanced Energy Systems Division's programs since 1967 when he was the responsible Project Engineer for the design, fabrication, and testing of a Cascaded Thermoelectric Test Generator for JPL.

As supervisor, Thermal Design and Analysis, from 1969 to 1971, Mr. Parker was responsible for all thermal design and analysis projects in Power and Propulsion Systems.

Honors: Recipient, Westinghouse Astronuclear Laboratory Graduate Student Scholarship
Recipient, NASA Tech Brief (No. B72-10634) Award

Proposed Assignment:

Westinghouse Project Manager

7.4 SUPPORTING PERSONNEL RESUMES

7.4.1 Public Service Company of New Mexico

LAWRIE C. CHISHOLM

Education: BA, Biology, Wells College
MS, Forestry/Resource Management, State University of New York

Experience: Ms. Chisholm's present assignment, since 1976, is that of Environmental Coordinator for the Public Service Company of New Nexico. She is responsible for reviewing all applicable environmental regulations and guidelines and for interfacing with pertinent PNM departments and various Federal, State, and local government agencies to ensure compliance. Recent projects included development of environmental analysis for two 345 kV transmission lines, a site selection study for a solar hybrid repowering project, and a site selection and environmental analysis for a pumped storage hydroelectric project.

Prior to her current assignment, Ms. Chisholm served as Staff Biologist for Arthur D. Little, Inc., 1973 to 1976. In this capacity she was responsible for Environmental Impact Statement assessment, preparation of environmental methodology and planning, and biological/ecological analysis. She also was involved in report prepartion, case management, and client presentations.

Professional Affliations:

American Society of Planning Officials

CARL LANG

Experience: Mr. Lang is responsible for the startup and operation of gas and oil fired plants for the Public Service Company of New Mexico. He also is responsible for results engineering, maintenance, and water management. His experience encompasses 27 years of progressively responsible assignments with PNM.

DALEEN S. OLSON

Education: BS, Mathematics, Hillsdale College
MA, Mathematics, Unversity of Michigan
Corporate Economics, Northern States Power Company
Mark IV User Program, Northern States Power Company
Honeywell Time-Sharing Workshop, Public Service Company of New Mexico
Management of Capital Investments - Session 1
PUR Guide, Public Service Company of New Mexico
Engineering Economics, General Electric (Public Service Company of New Mexico)
Management of Capital Investments - Session 2, Iowa State University

Experience: Ms. Olson is currently serving as Economic Analyst for the Public Service Company of New Mexico. In this capacity she developed the company's economic research function to provide economic analysis of investment decisions on a uniform basis. She also is responsible for the preparation of economic studies dealing with bulk generation, transmission, and other major capital investments as well as for special studies pertaining to company financing and the analysis of the economic impact of various FERC, SEC, and IRS orders.

Prior to that, she was Rate Analyst, July 1973 to May 1975, responsible for the preparation of exhibits and testimony for electric and water rate cases before the New Mexico Public Service Commission(NMPSC) and for the preparation of electric cases before the Federal Power Commission (FPC).

Ms. Olson filled the assignment of Operation Analyst for the Northern States Power Company, Minnesota, from October 1970 to June 1973. She was responsible for the preparation of economic studies in the engineering, financing, ratemaking, and plant investment areas. These analyses consisted of capital investment decisions, leasing versus owning alternatives, financing alternatives, bond redepmtion studies, profitability and cost of service studies, and numerous engineering studies.

LAWRENCE D. RATLIFF

Education: BS, Mechanical Engineering, University of New Mexico

Experience: Mr. Ratliff presently is serving as Betterment Engineer Supervisor for gas and oil fired plants of the Public Service Comapny of New Mexico. He is responsible for maintaining and up rating plant efficiencies; assuring compliance of plant emissions, plant revision and new construction; coordination of G&O plant engineering activities, plant equipment revision, and up rating.

Prior to his current assignment, Mr. Ratliff served as Plant Mechanical Engineer, 1974 to 1976. As such, he was responsible for coordination of gas and oil fired plant maintenance activities, including justification and cost analyses related to the modification, revison of installation of mechanical systems in existing power plants.

As Design Engineer for the Edison Metal Corporation, 1973 to 1974, Mr. Ratliff was responsible for the design and construction of large liquid storage reservoirs and pressure vessels. Prior to that he was involved in the design of commercial HVAC systems for The Trane Company, 1971 to 1973, and in the mechanical design of environmental sensors for the Thunder Scientific Corporation, 1970 to 1971.

Professional Affiliations:

American Society of Mechanical Engineers
Registered Professional Engineer, State of New Mexico No. 6569

JAMES C. STEWART

Education: BS, Mechanical Engineering, University of New Mexico

Experience: Mr. Stewart currently is a Plant Design Engineer for the Public Service Company of New Mexico, 1976 to the present.

He has performed economic and technical studies to determine the feasibility of new plants and modifications to existing plants. He also developed and implemented a computerized Reliability and Productivity Improvement System for all PNM power plants.

Prior to his present assignment, Mr. Stewart served as a Production Test Engineer, from 1972 to 1976, for the Public Service Company of New Mexico. This included service as a Production Results Test Engineer for gas and oil fired plants and as a Technical Evaluator for subcontractor bids and as Technical Liaison between PNM and other firms.

Professional Affiliations:

American Society of Mechanical Engineers
State of New Mexico EIT

TERRY L. YARYAN

Education: BS, Electrical Engineering, New Mexico State University
MS, Electrical Engineering, New Mexico State University

Experience: As supervisor of Generation Planning for the Public Service Company of New Mexico since February of 1977, Mr. Yaryan is responsible for the recommendation of a generation expansion plan based on alternative analyses which reflect the impact on power production, inter-utility activites, and corporate finances.

Mr. Yaryan served as Senior Planning Engineer, Generation Planning, from May of 1976 to February 1977. He was responsible for analysis of generation alternatives and for the effects that generation expansion plans have on the exising generation and transmission system.

Prior to that, Mr. Yaryan was Assistant to the Vice President, Electric Power Supply Division, San Diego Gas and Electric Company, 19751976. In this position he was responsible for varied assignments in the areas of generation alternatives analysis, power plant efficiency studies, fuel management, bulk power transactions, economic studies, and preparation of regulatory and financial institution required information.

His experience with the San Diego Gas and Electric Company, in position of a System Planning Engineer, 19731975, included responsibility for analysis and engineering for portions of the transmission and distribution system. Economic, environmental, reliability, and power system parametric studies also were performed in the development and recommendation of solutions to transmission and distribution problems.

Mr. Yaryan served with U.S. Army AIr Defense Branch as a Captain.

Professional Affiliations:

Institute of Electrical and Electronics Engineers, Inc.
Registered Professional Engineer in States of New Mexico

DAVID L. ARMSTRONG

Education: BS, Mechanical Engineering, Carnegie-Mellon University
Advanced Studies at CMU in areas of Programming and Numerical Methods

Summary:

	Present:	Manager, Generation Systems
	9 years:	Project Management
	13 years:	Electrical Power Systems

Experience: Mr. Armstrong is currently Manager, Generation Systems Department. In this position he is responsible for the management and technical direction of 200 concurrent analog and digital control and data acquisition systems projects for the utility market. Systems currently being managed include digital coordinated control systems for optimizing boiler/turbine control; microprocessor based integrated protection and control systems for nuclear plants; microprocessor based control packages for feed pump turbine, moisture separator reheater, and generator temperature monitor; direct digital boiler control; large multiprocessor based data acquisition systems for nuclear and fossil power plants; and a digital turbine controller.

Mr. Armstrong has specific design background in the area of control systems for supercritical, subcritical, and variable pressure boiler control. He has system integration experience in the area of combined cycle plant control and turbine control. He has been responsible for the functional design specification of large multiprocessor data acquisition systems for nuclear and fossil power plants.

Professional Affiliations:

Numerous technical publications concerning power plant control systems.

Professional Affiliations:

Senior Member, IEEE
IEEE Load Forecasting Working Group
IEEE Weather/Load Correlation Task Force
IEEE Current Load Forecasting Practices Task Force
Member, Operations Research Society of America
Registered Professional Engineer

ANDREW R. JONES

Education: BS, Electrical Engineering, Clemson University
MS, Electrical Engineering, University of Pittsburgh
Undergraduate Study, Physics and Math, Western Illinois State University
Reactor Engineering School, Bettis Atomic Power Laboratory
Westinghouse Business Management Courses
Modern Engineering for Engineering Executives, UCLA
Problem Analysis and Decision Making, Kepner-Tregoe

Experience: Mr. Jones is currently Manager, Engineering, Advanced Energy Systems Division, with responsibility for materials, design & integration, analysis, and drafting.

Previously, he was Manager, Special Projects, with responsibility for direction of corporate activities devoted to a very high temperature reactor.

Earlier, Mr. Jones held various management assignments at the Advanced Energy Systems Division with two relevant responsibilities: continuing responsibility for design, development and safety activities in gas and lithium cooled nuclear systems for 1600° to 2000°F exit temperature operations, and direction of a number of Project Managers for a variety of design, development, and manufacture programs. These included a wide range of applications of the ultra-high temperature technology produced in the Nuclear Rocket Program.

In an earlier assignment as Manager, Advanced Development and Planning Department, his responsibilities included preliminary plant engineering, pre-proposal engineering, and utility technical coordination. He was also responsible for the study of energizing plant concepts, planning and executing programs, and chemical development, including spent fuel analysis, metallographic analyses, loop testing, and health phsysics.

His earlier engineering and management assignments were in the design and development of nuclear power plants including extensive assessments of the state-of-the-technology of all identified reactor concepts for electric utility, process heat and mobile applications.

Professional Affiliations:
Member, Institute of Electrical and Electronics Engineers, Inc. (IEEE)
Member, American Nuclear Society (ANS)
Member, American Institute of Aeronautics and Astronautics (AIAA)
Member, Sciety of Naval Architects and Marine Engineers (SNAME)

DONALD J. JONES

Education: BS, Electrical Engineering, University of Pittsburgh
Graduate Studies, Electrical Engineering, University of Pittsburgh
Graduate Studies toward MBA, University of Pittsburgh

Experience: Mr. Jones is currently Manager, Direct Digital Control Systems, responsible for design and program management of digital control systems in fossil power plants.

Previously, he was EngineerinCharge of steam turbine control projects. In this position, he worked on design of analog and digital electro-hydraulic governors for steam turbines and designed automatic turbine control program.

In an earlier position as Project Engineer, he was responsible for the engineering and design of an automated hybrid control system for a combined cycle plant at Louisiana Power and Light's Sterlington Unit 7.

In earlier assignments, he was responsible for the design of several analog boiler control systems for utility power plants.

Professional Affiliations:

Mr. Jones holds three U.S. Patents in the area of turbine controls and power plant automation.

RICHARD E. LOWDER

Education: BS, Matural Science, University of Pittsburgh
Mechanical Engineering Program, University of Virginia
Statistical Quality Assurance, Temple University
Business Law Courses, University of California, Riverside
MBA Program, University of Pittsburgh
Additional industrial sponsored courses include Reliability, Business and Matrix Management, Electronics, Communications, Radiography, Statistics, and Analysis of Experiments.

Experience: Mr. Lowder is responsible to the General Manager for the Quality Assurance and Reliability efforts of the Advanced Energy Systems Division. His responsibilities encompass all policies and procedures pertinent to the top level DOE, ASME, NASA, DOD and commercial quality and reliability specifications currently applied for energy systems and comparable projects. Program controls include design, procurement, fabrication, construction and testing of safety-related components, structures and systems.

Previously, during the NERVA program, Mr. Lowder held a variety of Westinghouse Astronuclear Laboratory quality and product control engineering and management positions. His last NERVA assignment was that of Manager, Nuclear Core Operations Quality Assurance, with responsibilities for all phases of the quality program supporting the design, development, qualification, production, and reliability of fuel elements and associated hardware for NERVA reactors. Additional assignments included the development and implementation of reactor assembly inspection and test plans, NDE systems designs, defects analyses, and computerized data collection and certification systems.

Earlier, Mr. Lowder was a quality representative for the Martin-Marietta Corporation, Orlando, Florida. In this position he was responsible for the performance of a wide variety of subcontractors whose products included electromechanical subsystems, telemetry units, guidance valves, and explosives for the Pershing, Lacross, and Bullpup Missile programs.

Professional Affiliations:

Member, American Society for Quality Control (Publication: QA of NERVA Fuel, May 1971)
Member, American Society for Nondestructive Testing

R. W. POWELL

Education: BS, Electrical Engineering, University of Nevada
MS, Electrical Engineering, University of Pittsburgh

Experience: Mr. Powell is currently Manager of the Systems Analysis Department, Advanced Systems Technology Division with responsibility for the program development and the performance of systems studies with the Westinghouse programs for power systems analysis.

Previously, he was Engineering Manager for the Generation Systems Division, Lester, Pa., responsible for the design of Econopac, Combined Cycle, Repowering, Desalination and Mechanical Drive plants including all periphery systems.

Prior to that he was Manager of Systems Design, Gas Turbine System Division with responsibility for the design of Econopac Power Plants. Earlier he was Manager of Business Development and Substation Marketing responsible for transmission forecasting, business acquisition analysis and packages substation application and sales.

Mr. Powell began his career at the General Electric Company in Hanford, Washington as a Nuclear Instrument Design Engineer working on electronic measurements. He later joined the Electric Utility Engineering Department of Westinghouse Electric Corporation in East Pittsburgh, Pa. For the next several years he worked on a wide variety of power systems problems including powercasting, transmission and distribution planning, surge protection, secondary network systems and radio interference while advancing from Assistant Sponsor Engineer to Distribution Consultant.

Professional Affiliations:

Senior Member, IEEE
Professional Engineer in Pennsylvania

Mr. Powell has authored several technical papers and served as a lecturer at the Northeastern University Electric Utility Engineering School.

WALTER SINTON

Education: BS, Mechanical Engineering, University of Nebraska

Experience: Mr. Sinton presently is the Manager of Design and Modernization activities in the Service Engineering area of the Westinghouse Electric Corporation, Steam Turbine Department. His 37-year career with Westinghouse began as a Design Engineer in 1941.

Intermediate positions and responsibilities with Westinghouse included the design of main propulsion and auxiliary steam turbines for U.S. naval vessels. This was followed by a 9-year responsibility for the design of a line of AIEE-ASME Preferred Standard steam turbines ranging from 11.5 MW to 100 MW.

Mr. Sinton became Manager of Medium Turbine Apparatus Engineering in 1956. As such he was responsible for customer order engineering on generator drive steam turbines ranging from 15 to 100 MW.

In 1961 Mr. Sinton became Manager of Large and Medium Turbine Apparatus Engineering. Immediately prior to his present assignment in 1973, he served as Manager of a special turbine design project.

Professional Affiliations:

Registered Professional Engineer, State of Pennsylvania

American Society of Mechanical Engineers

Member of the American National Standards Institute Mechanical Technical Advisory Board

Recipient of Prime Movers Committee award for best technical paper in 1963.

M. SMITH

Education: BS, Electrical Engineering, Drexel
MS, Business Administration, Drexel
MS, Electrical Engineering, Drexel

Experience: Mr. Smith's career with the Westinghouse Electric Corporation, Steam Turbine Department, includes 6 years as a Section Manager of Control Systems and 2 years as Section Manager of Control Systems and Operations. In the latter position he was responsible for various functions including: working with customers on the development of plant operation modes; development of operating instructions such as startup and loading times, restrictions, etc.; interfacing with design disciplines in the coordination of operational requirements.

During his preceding assignment, Mr. Smith was responsible for the application of mechanical-hydraulic controls to steam turbines; standardization of electrical control devices; the application of electro-hydraulic control systems to meet customer requirements; development work in the initial phases of electro-hydraulic control systems.

Prior to that, Mr. Smith served as Design Engineer in the area of control systems. This was preceded by 2 years as a second lieutenant in the U. S. Army, including 1 year in post engineering.

PETER P. ZEMANICK

Education: BS, Aerospace Engineering, St. Louis University
MS, Nuclear Engineering, Iowa State University
PhD, Mechanical Engineering, University of Pittsburgh
Extensive supplemental training in reliability analysis techniques.
Corporate training courses in management skills.

Experience: Mr. Zemanick is presently Manager, Engineering Analysis, Westinghouse Advanced Energy Systems Division, responsible for all engineering analysis activities for the division. His responsibility includes thermal, structural, performance, and controls analysis groups, providing analysis services for all current projects, primarily advanced energy production facilities.

Previously, as Technical Assistant to Manager, Solar Programs, he was Assistant to the Project Manager, Solar Total Energy - Large Scale Experiment at Fort Hood, responsible for project engineering support and direct responsibility for solar collector trade studies, collector system design, and reliability assessment. Earlier, as Manager, Structural Reliability and Safety Analysis, he was responsible for probabilistic structural reliability and safety analyses of Clinch River Breeder Reactor Plant and later generation liquid metal fast breeder reactor design. The scope included equipment reliability assessment, nuclear licensing activities, and methods development. As Manager, Valve Engineering, he was responsible for design, analysis, testing, and procurement of large sodium valves for fast breeder test bed reactor (Fast Flux Test Facility) to ASME B&PV Code Section III and High Temperature Code Case 1331.

In a previous assignment, as Manager, Structural Design he was responsible for stress analysis of NERVA nuclear rocket engine reactor components. The methods applied within the group included basic stress analysis, advanced finite element methods in static and dynamic analysis, fracture mechanics, and probabilistic analytic methods. Prior to this he was a thermal-hydraulic analyst (at increasing levels of responsibility), involved in heat transfer, fluid mechanics, and hydrocarbon therm-chemical problems related to NERVA nuclear rocket engine.

JOHN BOUMA

Education: BS, Mechanical Engineering, Leeuwarden Technical College, Netherlands

Experience: Mr. Bouma recently completed an assignment as Project Engineer for a 50 MW geothermal power project study for Public Service Company of New Mexico.

Mr. Bouma is presently assigned as Project Engineer to a 250 MW oil-fired unit for the Marsden Power Station being constructed near Whangarei, New Zealand. Engineering is nearly complete.

Prior to the above, Mr. Bouma has been Project Engineer for the design of a 580 MW supercritical, oil-fired unit at Willow Glen near Baton Rouge for the Gulf States Utilities Company. During the course of the design the EPA requirements came into effect, causing redesign of systems such as cooling water, waste water disposal and flue gas dispersion. Also during the start-up of this unit Mr. Bouma's power plant experience became useful in resolving numerous equipment problems. (1972-1976)

Mr. Bouma was assigned to supervise the preparation of two preliminary designs for 580 MW, oil/gas-fired units for Gulf States Utilities Company in various locations. (1969-1972)

Mr. Bouma was Project Mechanical Engineer on the preliminary design of two 400 MW supercritical, gas-fired units for the city of Leiden in the Netherlands as well as for the preliminary design of the Bolsa Island Nuclear Power Plant. (1967-1969)

Mr. Bouma was also responsible for the mechanical design of the first two units at Marsden Power Station in New Zealand, which involved two 120 MW subcritical, oil-fired units. Mr. Bouma also conducted a study of diesel engines and gas turbines as prime movers for the Nike-X Power Plants. (1964-1967)

He was responsible for the selection of all mechanical equipment of the 500 MW supercritical units at Alamitos 5 & 6 and for Units 3 & 4 of the Huntington Beach, Alamitos and the Etiwanda Steam Stations. (1960-1967)

He was Project Mechanical Engineer on the Cochrane, Swift 1 & 2, and Mammoth Pool Hydroelectric Projects and spent four years planning maintenance and design for seven power plants in Canada. (1952-1960)

(September 1977)

R. H. CUTLER

Education: Pasadena City College (1 year)
Civil/Structural Engineering, ICS

Experience: Mr. Cutler is presently Project Field Engineer on the San Onofre Nuclear Project. In this capacity, he is responsible for all electrical and mechanical field engineering work in addition to civil/structural. Prior to this, Mr. Cutler was Project Field Engineer on the Sacramento Municipal Utility District's Rancho Seco Nuclear Project, where Bechtel was the Construction Manager. In that capacity, he was responsible for all electrical and mechanical work in addition to civil/structural. He also performed liaison between the E&I Office and with the customer.

Previously, Mr. Cutler was Bechtel Senior Field Engineer on the Ormond Beach Steam Generating Plant. He was also Senior Field Engineer responsible for estimating and civil/structural work on the 5,225 MW Churchill Falls Hydro Project. He served in a similar capacity as civil/structural shift supervisor on the Muddy Run pumped storage project including dam and powerhouse work.

As Field Engineer, Mr. Cutler was responsible for civil/structural work on the Robbs Peak powerhouse and several dam and tunnel projects associated with the Upper American River Project. His responsibilities included contract coordination and inspection, and liaison.

Also as Field Engineer, Mr. Cutler worked on the Swift Creek project and the Nacimiento Dam.

E. H. HAMMOND

Education: BS Mechanical Engineering, University of California

Experience: Currently, as Engineering Specialist on the staff of the Chief Mechanical Engineer, Mr. Hammond is developing design concepts and estimates for a combined power generation and sea water desalination plant for installation in Kuwait which will consist of six 300 MW fossil fueled units. His earlier staff engineering responsibilities have included representation on the corporate standards committee where he was responsible for preparing and developing standard design guidance and instructions on various power plant mechanical systems and equipment, the preparation of standard equipment specifications and design review and field troubleshooting of large rotating mechanical equipment.

Prior to his current staff assignment, he was responsible for the design of various balance-of-plant systems on the Vogtle and Palo Verde projects such as cooling water system, circulating water, chemical treatment systems, makeup demineralizer system and other raw water treatment facilities.

Earlier, he supervised an equipment design group on the Navajo project which consists of three 750 MW coal-fired units. He was directly responsible for developing the design and implementing the procurement including bid evaluation of all major mechanical equipment.

As a senior field engineer on Redondo Beach Units 7 and 8, Mr. Hammond supervised a team of mechanical engineers in the design of various piping systems. In addition, he coordinated the design and on-site work of numerous equipment suppliers and subcontractors and supported the various field superintendents with details of layout, welding, drawing interpretation and related matters.

Professional Affiliations:

Registered Professional Mechanical Engineer (No. M10677), State of California.

Member American Society of Mechanical Engineers.

CHARLES LACUGNA

Education: BSME Illinois Institute of Technology (IIT)
Graduate Courses in Power Plant Design & Advanced Thermodynamics, IIT
Control Systems Course at Bechtel
Completed Bechtel Management Certification Program

Experience: Mr. Lacugna has experience in the design and application of instrumentation, control and automation systems for Bechtel Power Corporation. This includes the Mohave Station and San Onofre Nuclear Generating Station Unit 1 for Southern California Edison and Willow Glen Unit 5 for Gulf States Utilities Company.

At present Mr. Lacugna is the Control Systems supervisor on the San Onofre Nuclear Generating Station Unit 1. This project provides modifications and improvements to the plant's normal and emergency control systems. An additional project is concerned with the seismic reevaluation of the balance of the plant. He is responsible for the supervision of the Control Systems personnel, maintaining budgets and schedules, and the finished quality of the engineering.

On the Willow Glen Unit 5 Project, Mr. Lacugna was responsible initially for the boiler turbine and balance of plant P&I diagrams. He was responsible for the boiler - turbine control system specification, engineering and system checkout and he performed the same function for the unit data acquisition system. Later he became the Controls Group Supervisor for this project. During this period he was responsible for supervision of the Control Systems personnel, maintaining budgets and schedules, specifications, procurement and installation of control equipment, plant control logic design and implementation and engineering support during unit checkout and startup.

On the Mohave Project, as a senior engineer, Mr. Lacugna was responsible for the instrumentation, control, control logic and automation of the two units during the final design phase and subsequent start-up of the first unit. Mr. Lacugna worked directly for the Mechanical Group Supervisor as a group leader and coordinated the controls effort with the Electrical Group.

Professional Affiliations:

Member Instrument Society of America
Member American Society of Mechanical Engineers
Registered Professional Engineer, California (Mechanical)
Registered Professional Engineer, California (Control Systems)
Registered Professional Engineer, Illinois

JOHN W. LARROWE

Education: High school graduate, Frank Wiggins Trade School; mechanical drafting and ICS fundamentals of electrical engineering.

Experience: Mr. Larrowe presently is acting group supervisor of San Onofre Unit 1 Balance of Plant Seismic Reevaluation responsible for Plant Design organization, supervision, work schedules and manhour budgets.

On his previous assignments Mr. Larrowe was supervising designer on the Marsden B fossil power plant. He was responsible for the plant layout of the boiler and turbine generator building and production of finished piping drawings. He prepared and was responsible for the oil-fired burner front design on the Willow Glen fossil plant.

Prior to joinging Bechtel, Mr. Larrowe was a senior piping designer preparing complex piping layouts and detail piping drawings.

EVERETT L. SPECTOR

Education: BE, Civil Engineering, University of Southern California
Certificate of Business Administration, University of California.

Experience: Mr. Spector is currently Civil/Structural Engineering Group Supervisor for the preliminary engineering phase of the Korean Nuclear Project, Units 5 and 6. Prior to this, he was responsible for structural design of a portion of the Fuerzas Electricas de Cataluna, S.A. Nuclear Project, now under construction in Spain. He also participated in the domestic support of other foreign projects.

He served for six years as the Civil Engineering Group Supervisor on the Gulf States Utilities Blue Hills Nuclear Generating Station project and the General Public Utilities - Atomics International fast breeder study. His responsibilities included major site investigations, site layout, and preliminary engineering studies.

Mr. Spector was Project Civil/Structural Engineer on studies related to the Southern California Edison Company portion of the Bolsa Island Nuclear Power and Desalting Project. Prior to that, he was Project Test Engineer on the wave defense model study for the same project, conducted in collaboration with the California Institute of Technology. He also served as Assistant Civil/Structural Group Supervisor on Southern California Edison Company's San Onofre Nuclear Generating Station, Unit 1. His assignments included responsibility for the 140-foot diameter steel containment vessel. At the conclusion of construction, he was the responsible Test Engineer for pneumatic and leak rate testing of the vessel.

He has had civil/structural design experience on a number of Southern California Edison Company fossil fuel power plants, including Alamitos Generating Station, Units 1, 2, 3 and 4; Huntington Beach Generating Station, Units 3 and 4; and the Redondo and Mandalay Beach Stations. Mr. Spector's assignments included responsible charge of structural steel design and alterations involving all of the civil/structural engineering disciplines.

Professional Affiliations:

Member, Chi Epsilon, Civil Engineering Honorary Fraternity
Registered Professional Engineer, Civil, California

WILLIAM A. STEVENS

Education	BS, Mechanical Engineering Purdue University, 1968
Professional Data	Professional Mechanical Engineer; California.
Present Bechtel Activity	Since 1975, as a senior engineer Mr. Stevens was responsible for preparation of studies on advanced energy conversion systems and energy storage applications. Presently he is lead mechanical engineer on preliminary design study of a 150 kWe solar powered deep well irrigation pumping facility. He recently authored the preliminary design report on initial startup and testing of a 10 MWe central receiver solar thermal power plant. Earlier he was lead mechanical engineer for the conceptual design study of ocean thermal energy coversion (OTEC) test facility including the pilot plant.
Prior Bechtel Experience	Prior to that, Mr. Stevens was a senior mechanical engineer, Design Group Leader for six years with Bechtel Power Corporation, supervising the design of boiler plant systems for large fossil-fuel power plants. This work included the development of flow, heat balance, and control logic diagrams; sizing and specification of piping, valves, pumps, and a wide variety of other power plant equipment; review and approval of vendor designs; and preparation of plant operating manuals. Mr. Stevens also served as a senior startup engineer with Bechtel Power on jobsite assignments for the checkout, initial operation, and testing of equipment, systems, and controls at four large fossil-fueled power plants.

WALTER J. STOLTE

Education	BS, Electrical Engineering, University of California, Berkeley, 1962
	MS, Electrical Engineering, University of Santa Clara, 1969
Professional Data	Member: IEEE. Author of numerous reports on power technology and other fields.
Present Bechtel Activity	Currently Supervisor of the Advanced Electrical System Section. Project Manager on two JPL sponsored studies of terrestrial photovoltaic arrays and on a Sandia sponsored study to conceptualize a national facility to test photovoltaic arrays under conditions simulating central station applications.
Prior Bechtel Experience	He was Project Engineer on an ANL sponsored study to determine the performance requirements for batteries in photovoltaic power systems and on an ERDA sponsored conceptual design of a photovoltaic central plant and a study of energy storage and power conditioning aspects of solar power systems ranging from 1 kW to 1000 MW. Served as the Project Manager of an EPRI sponsored study of zinc/chlorine batteries in electric utility load leveling service and as Project Engineer on two studies of a lead-acid battery energy storage load leveling plant. Was the Project Engineer on Bechtel's conceptual design of the Battery Energy Storage Test (BEST) facility for testing advanced batteries under electric utility load leveling conditions.
	He was Project Engineer in charge of developing a commercial agricultural device to kill weeds with microwaves. The prototype of this device was given an IR 100 award.
Other Prior Experience	As a Senior Development Engineer at Eimac/Varian Associates, he worked on the design and development of medium, high and power microwave tubes and associated systems.

PHIROZE K. WADIA

Education	BE, Civil Engineering University of Bombay MS, Civil Engineering University of Illinois
Professional Data	Registered Civil and Structural Engineer in California. Member of American Society of Civil Engineers, the American Concrete Institute, Structural Engineers Association of California, Seismological Society of America, Earthquake Engineering Research Institute. Member of the Seismology, Research and Building Code Committees.
Present Bechtel Activity	Mr. Wadia is the Project Civil and Structural Engineer for solar energy related projects including the 10 MW Central Receiver Solar Pilot Plant at Barstow, California, conceptual design of 150 MW Central Receiver Solar Power Plant, the 150 kWe Solar-Powered Deep-Well Irrigation Facility in Arizona and the structural optimization of solar cell supporting systems.
Prior Bechtel Experience	Mr. Wadia was the Supervising Structural Engineer for a Military Airport in Saudi Arabia with Bechtel's Hydro Division. on which he had major responsibilities include the nuclear waste reprocessing plant for Allied Gulf Nuclear Services, the Badak LNG Project in Indonesia, the Nuclear Waste Reprocessing Plant for the Exxon Nuclear Co., Inc. and the low sulfur fuel oil refinery for SOCAL in Richmond, California.
Other Prior Experience	With Earthquake Engineering Systems, San Francisco, Mr. Wadia's primary responsibilities included marketing of engineering services, managing a consulting practice. While working with other engineering firms, his assignments included preliminary design, and computerization of structural engineering work. With Shah Construction Company, Bombay, India, Mr. Wadia supervised construction at the Atomic Energy Establishment, Trombay, India.

JOSEPH H. WESTSIK

EDUCATION	BS, Mechanical Engineering, University of Buffalo, 1959 Courses in Project Engineering, Procurement, Environmental Engineering
Professional Data	Member: ASME, ANS, NSPE. Registered Nuclear Engineer, California. Author and co-author of papers in the fast breeder area and on technology related to the High Flux Isotope Reactor. Co-holder of patent for a Fast Burst Neutronic Reactor.
Present Bechtel Activity	Engineering specialist, responsible for conceptual and engineering studies in advanced power technology, including solar energy applications.
Prior Bechtel Experience	On the Alabama Enrichment Plant Project, coordinated licensing activities, including Environmental Report preparation. Previous responsibilities on that project included Mechanical Group Leader, in charge of system and equipment studies and Assistant Project Engineer on the Centrifuge Enrichment Plant team during the Evaluation Phase.
Other Prior Experience	Seven years as a Principal Engineer with Westinghouse Hanford Corporation and its predecessor company on the Fast Flux Test Facility. Work included management of the Configuration Engineering Group, responsible for establishing drawing, document and interface control systems for the project. Earlier he was program manager for the Reactor Design Contractor and manager of the Systems Section, responsibile for design of the coolant and test systems. At Oak Ridge National Laboratory he was leader of the cooling system and reactor design group of the Molten Salt Reactor Experiment, and later, of the Reactor Internals Design Group on the High Flux Isotope Reactor. Six years as Senior Technician with the Linde Company he worked on design and development of industrial gas plants.

ERNEST Y. LAM

Education	BS, Chemistry and Physics, 1959 BS Sp., (Honors) Chemistry, 1960 University of Hong Kong Ph.D., Chemistry California Institute of Technology, 1968 Postdoctoral studies, Cornell University and Brookhaven National Laboratory
Professional Data	Member, International Solar Energy Society Author of numerous study reports and papers on solar energy, waste heat utilization, fuel cells, hydrogen technology and chemistry.
Present Bechtel Activity	Program Supervisor for Solar Technology, two years, responsible for engineering development and support in the areas of solar energy. Project manager on solar studies that include solar powered water pumping, solar distillation, photovoltaic power generation, and solar photovoltaic/thermal hybrid systems. Task manager on agricultural, aquacultural and other beneficial uses of waste heat.
Prior Bechtel Experience	Four years, Project Engineer, Research and Engineering, responsible for conceptual designs of several solar thermal power plants, analysis of beneficial utilization of power plant waste heat, and feasibility study of utility fuel cell applications.
Other Prior Experience	Two years, Assistant Professor, University of Petroleum and Minerals, Saudi Arabia, conducting solar energy research. Three years, postdoctoral chemistry research at Cornell University and Brookhaven National Laboratory. Two years, heading the Chemistry Department of the United College, Chinese University of Hong Kong.

8.0 APPENDICES

APPENDIX A

UTILITY AND NEW MEXICO STATE SUPPORT LETTERS

APR 1 9 1978

STATE OF NEW MEXICO

OFFICE OF THE GOVERNOR
SANTA FE
87503

JERRY APODACA
GOVERNOR

April 17, 1978

Mr. Jerry Geist, President
Public Service Company of New Mexico
P. O. Box 2267
Albuquerque, New Mexico 87103

Dear Jerry:

Representatives from my office and cabinet have informed me of the proceedings of two briefing sessions held by Public Service Company of New Mexico in Santa Fe and Washington on solar hybrid projects. I would like to commend you and your staff for the advanced planning program developed to address the area of alternative energy resources.

Here in the State of New Mexico, we realize the importance of looking ahead to alternative methods of utilizing the ample sunlight falling on our state. Your proposal for solar assistance to the generation of electricity also addresses the needs expressed in the President's National Energy Plan. If successful, the pilot program proposed will do much to provide useful information for future development of solar hybrid systems.

I want, at this time, to pledge my help and support to your continuing efforts to develop new and progressive systems that may alleviate our nation's energy shortages. If further assistance is needed in your endeavors, Secretary Nick Franklin of the Energy and Minerals Department will be the cabinet secretary designated by me to remain in contact with your office.

Sincerely,

JERRY APODACA
Governor

JA:nf

STATE OF NEW MEXICO
ENERGY AND MINERALS DEPARTMENT
OFFICE OF THE SECRETARY

JERRY APODACA
GOVERNOR

NICK FRANKLIN
SECRETARY

POST OFFICE BOX 2770
113 WASHINGTON AVENUE
SANTA FE, NEW MEXICO 87501
(505) 827-2471

April 24, 1978

Mr. Jerry Geist
Public Service Company
of New Mexico
P.O. Box 2267
Albuquerque, New Mexico 87103

Dear Mr. Geist:

I would like to take this opportunity to compliment you and your staff for the outstanding presentation on the solar hybrid project being proposed by your company.

I am pleased to learn that the Public Service Company of New Mexico, on its own initiative, has been engaging in innovative research that may be of practical benefit to the energy consumers of this state. New Mexico has been a leader nationally in research and development programs and your pilot program is another indication of New Mexico's forward-looking energy plans.

I want, at this time, to pledge my support and that of my staff in your solar hybrid pilot program research and funding efforts. Please feel free to call on me or my staff if further assistance is needed.

Sincerely,

Nick Franklin

NICK FRANKLIN
Secretary

NF:rj

APR 13 1978

NEW MEXICO

Public Service Commission

BATAAN MEMORIAL BUILDING

Santa Fe, New Mexico

87503

RICHARD P. MONTOYA
CHAIRMAN
EILEEN GREVEY
COMMISSIONER
GARY BLAKELEY
COMMISSIONER

April 12, 1978

JERRY APODACA
GOVERNOR

Mr. Jerry Geist, President
Public Service Company of New Mexico
Post Office Box 2267
Albuquerque, New Mexico 87103

Dear Mr. Geist:

The New Mexico Public Service Commission supports Public Service Company of New Mexico's (PNM) proposal seeking funding from the United States Department of Energy to institute a Solar Hybrid Repowering Demonstration Project.

It is our understanding that operation of a solar thermal repowering plant has not yet been commercially proven and that the proposed demonstration project is a necessary first step in the development of the Department of Energy's Solar Thermal Electric program. Additionally, it is our understanding that the Department of Energy has not yet determined the amount of funds that it will commit to the project and the amount of funds, if any, the utility will have to commit to the project.

PNM's participation in this demonstration project can play an integral role in reducing the country's reliance upon non-renewable energy sources.

We appreciate your attention to our comments and concerns.

Sincerely,

Richard P. Montoya, Chairman

Eileen Grevey, Commissioner

Gary Blakeley, Commissioner

APR 27 1978

TEXAS UTILITIES COMPANY

2001 BRYAN TOWER · DALLAS, TEXAS 75201

T. L. AUSTIN, JR.
CHAIRMAN OF THE BOARD
AND CHIEF EXECUTIVE

April 25, 1978

Mr. J. D. Geist, President
Public Service Company of New Mexico
P. O. Box 2267
Albuquerque, New Mexico 87103

Dear Jerry:

We are aware of your interest in solar hybrid repowering. It is my understanding that our operating companies have previously indicated to you their desire to be kept informed and their willingness to participate as members of your advisory committee.

However, we do not presently have any plans to apply solar hybrids to our system and we would encourage your working out an arrangement with DOE for the installation of a unit at one of your plants in the Southwest region.

Should this technology eventually prove to be feasible, we would certainly want to evaluate it for possible use on the Texas Utilities Company System in accordance with our policy of research and investigation of all potential energy sources.

Sincerely,

Lu

APR 24 1978

ARIZONA PUBLIC SERVICE COMPANY

P. O. BOX 21666 · PHOENIX, ARIZONA 85036

KEITH TURLEY
PRESIDENT AND
CHIEF EXECUTIVE OFFICER

April 19, 1978

Mr. J. D. Geist, President
Public Service Company of New Mexico
P. O. Box 2267
Albuquerque, New Mexico 87103

Dear Jerry:

As you know, APS has been active and, in fact, taken the lead role in developing solar energy since 1954. We have followed your activities in the solar hybrid repowering project with much interest, and with the view toward the ultimate possibility that we could apply a similar technology to one of our oil fired generating plants.

We believe the work you have done and the plans you have for constructing the first demonstration project on the Public Service of New Mexico system will be a significant stride toward reaching the 1985 guidelines set by the federal government.

We will be pleased to join and take part in the Advisory Council and believe it will assist us in our progress toward the solar repowering of a unit on our system in the very near future.

Yours very truly,

Keith Turley

KT/1f

APR 2 4 1978

TUCSON GAS & ELECTRIC COMPANY

220 WEST SIXTH STREET
P. O. BOX 711
TUCSON, ARIZONA 85702

THEODORE M. WELP
PRESIDENT

AREA CODE 602
TELEPHONE 622-6661

April 21, 1978

Mr. J. D. Geist, President
Public Service Company of New Mexico
P. O. Box 2267
Albuquerque, NM 87103

Dear ~~Mr. Geist~~: Jerry

Tucson Gas & Electric Company has been interested in solar developments for many years. We have followed the plans for Solar repowering which you have been working on, and we have appreciated the opportunity to participate and thereby accelerate the commercialization of solar energy by way of your ongoing study for the Department of Energy.

Knowing the significant groundwork PNM has laid and the extreme time constraints required, the placement of the first demonstration site within the PNM system seems not only logical but necessary if the 1985 guidelines are to be met.

TGE does not have any existing facilities conducive for the conversion to a solar repowering operation. Therefore, we would again wish to take part in an advisory council with respect to the conversion of your existing gas- and oil-fired generating unit in order to further the technology and our knowledge of it.

As you have pointed out, the urgency of the situation is significant. Solar Hybrid Repowering appears to be a viable near-term solution.

Sincerely,

Ted

TMW:jk

Central and South West Corporation
2700 One Main Place • Dallas, Texas 75250 • 214-748-8481

S. B. PHILLIPS, JR.
Chairman and Chief Executive Officer

APR 26 1978

April 21, 1978

Mr. Jerry D. Geist
President
Public Service Company of New Mexico
Post Office Box 2267
Albuquerque, NM 87103

Dear Jerry:

Central and South West Corporation is interested in your company's initiative in Solar Hybrid Repowering and appreciate the opportunity to consider participation. We are desirous of forwarding the cause of commercial solar energy however we can.

I suggest that we do, indeed, have possible sites for such a pilot or demonstration project in one of our subsidiary operating companies, most likely in the West Texas Utilities Company area.

Kindest regards,

SBPJr:jc

cc: Durwood Chalker
B. J. Harris
R. W. Hardy
R. O. Newman
J. L. Stall
P. I. McConnell
J. E. Taulbee

SALT RIVER PROJECT
P. O. BOX 1980
PHOENIX, ARIZONA 85001
(602) 273-5900

APR 24 1978

April 21, 1978

KARL F. ABEL, PRESIDENT
JOHN R. LASSEN, VICE PRESIDENT
A. J. PFISTER, GENERAL MANAGER

Mr. J. D. Geist
President
Public Service Company
of New Mexico
P. O. Box 2267
Albuquerque, New Mexico 87103

Dear Jerry:

The Salt River Project has for many years been actively interested in the development of solar thermal power conversion technology. This interest has been evidenced by, among other things, our participation in the Arizona Solar Power Project proposal for the siting of the 10 MW Central Receiver Demonstration Project near Gila Bend, Arizona. We have also agreed in principle to participate with Atomics International in the DOE sponsored "Advanced Central Receiver Design Program."

With regard to your Solar Hybrid Repowering Program, we continue our interest as expressed to you in previous correspondence. Additionally, we have been supportive of your program through WEST associates and EPRI, both of whom are providing funds for your efforts.

In view of the significant groundwork PNM has laid in the development of the Solar Hybrid Repowering concept, we are quite confident that PNM is well qualified to carry out the initial demonstration project.

A preliminary assessment of Salt River Project facilities indicates that we do have generating units which could be considered candidates for solar hybrid repowering based on unit size and steam condition parameters. Each of these units, however, appears to have significant land use conflicts in the adjacent areas which could preclude the installation of the requisite solar collection equipment. Until such time as we could confidently predict the resolution of these conflicts, we would be hesitant to suggest that they be seriously considered as candidate sites.

If we may be of further assistance in your Solar Hybrid Repowering Program, do not hesitate to call.

Very truly yours,

A. J. Pfister
General Manager

AJP:mw

Central and South West Corporation
2700 One Main Place • Dallas, Texas 75250 • 214-748-8481

S. B. PHILLIPS, JR.
Chairman and Chief Executive Officer

APR 26 1978

April 21, 1978

Mr. Jerry D. Geist
President
Public Service Company of New Mexico
Post Office Box 2267
Albuquerque, NM 87103

Dear Jerry:

Central and South West Corporation is interested in your company's initiative in Solar Hybrid Repowering and appreciate the opportunity to consider participation. We are desirous of forwarding the cause of commercial solar energy however we can.

I suggest that we do, indeed, have possible sites for such a pilot or demonstration project in one of our subsidiary operating companies, most likely in the West Texas Utilities Company area.

Kindest regards,

SBPJr:jc

cc: Durwood Chalker
B. J. Harris
R. W. Hardy
R. O. Newman
J. L. Stall
P. I. McConnell
J. E. Taulbee

APPENDIX B

Solar Repower Potential in Southwestern United States

- Market Survey
- Reference Plant Selection
- Cost/Benefit Analysis

1.0 INTRODUCTION

This Appendix contains the detailed results of an assessment of the potential for Solar Repowering in the Southwestern United States.

The primary basis for these results is an extensive utility survey of nine states including Arizona, California, Colorado, Louisiana, Nevada, New Mexico, Oklahoma, Texas and Utah. In addition, a literature survey of the area was conducted using the following sources:

- Federal Power Commission Form 12 files.
- Westinghouse Electric Corp. market information.
- DOE/RA-0001 "Inventory of Power Plants in the United States."
- Federal Power Commission Regional Reliability Council Reports for the Southwest.

The literature survey was utilized to supplement the results of the specific utility survey where necessary.

2.0 OVERVIEW OF SOLAR REPOWERING POTENTIAL

Sixty (60) utilities in the southwest responded to the utility survey conducted by Public Service Co. of New Mexico. In these responses, a total of 379 units $\leq$ 200 MWe were identified. Considering land availability, 263 of these 379 units were reported as potentially solar repowerable. Thus, the PNM Utility Survey responses for repowering covered approximately 35 percent of all the units in a data base established by the Literature Survey. These 263 units represent 47 percent of the total rated generating capacity in the literature survey.

The results of the Literature survey and the PNM Utility Survey are shown in Table B-1. These results, coupled with the fact that approximately 77 percent of the utilities elected to respond to the survey (60 of

Table B-1

MARKET EVALUATION SUMMARY

Category	Number of Units	Total MWe
Potential Market Size (rated MWe)		
Literature Survey	755	40954
Utility Survey	263	19273
Solar Repowering Potential (effective MWe)		
Based on land availability	263	10699
and <2500 ft. from plant	197	6879
and >50% repowering	72	4799
and utility interest	72	4799

78 utilities), indicate a strong potential for, and definite interest in, solar hybrid repowering in the Southwestern United States.

The 263 units reported in the utility survey represent 19,273 MWe of rated generating capacity. After the reported repowering levels, based on land availability, were applied to the rated sizes of the units, 10,699 MWe of effective solar repowering potential resulted (see Table B-1). In some cases, the utilities responded with a specific repowering percentage, based on a land availability criteria of $\sim$6 acres per MWe. In most cases, the utilities reported their repowering levels in brackets of: 0 percent, 1-25 percent, 26-50 percent, 51-75 percent, and 76-100 percent. In the latter case, the upper bound of the bracketed repowering level was applied to the rated size to arrive at an effective solar repowering level in MWe.

By restricting the distance of the available land to <2500 feet from the existing unit, the number of units is reduced to 197 representing an effective solar repowering potential of 6879 MWe. If a further restriction on repowering percentage (>50 percent) is applied to the above units, the total potential is reduced to 72 units at 4799 MWe of effective solar repowering. It should be stressed that the latter numbers represent a very realistic and practical potential in terms of solar repowering because they include: a) only those units the utilities chose to report as being candidates for solar repowering, and b) only those units that also meet the land distance (<2500 ft.) and repowering percentage (>50 percent) restrictions.

An evaluation of the size distribution of the units from the literature and utility surveys is given in Figure B-1. The light shaded bars in Figure B-1 represent the number of units derived from the literature survey. The concentration of the units at the low plant rating levels, particularly in the 0-50 MWe categories, is obvious from the chart. The darker shaded bars in Figure B-1 represent the number of repowerable units reported in the utility survey. A similar concentration of units in the 0-50 MWe categories (107 units total) exists. However, it is not as obvious from the figure because the size categories at the upper end of the plant rating scale cover a wider band (50 MWe) than the bands for those categories at the smaller end of the scale (10 MWe, 20 MWe and 30 MWe). For equal size

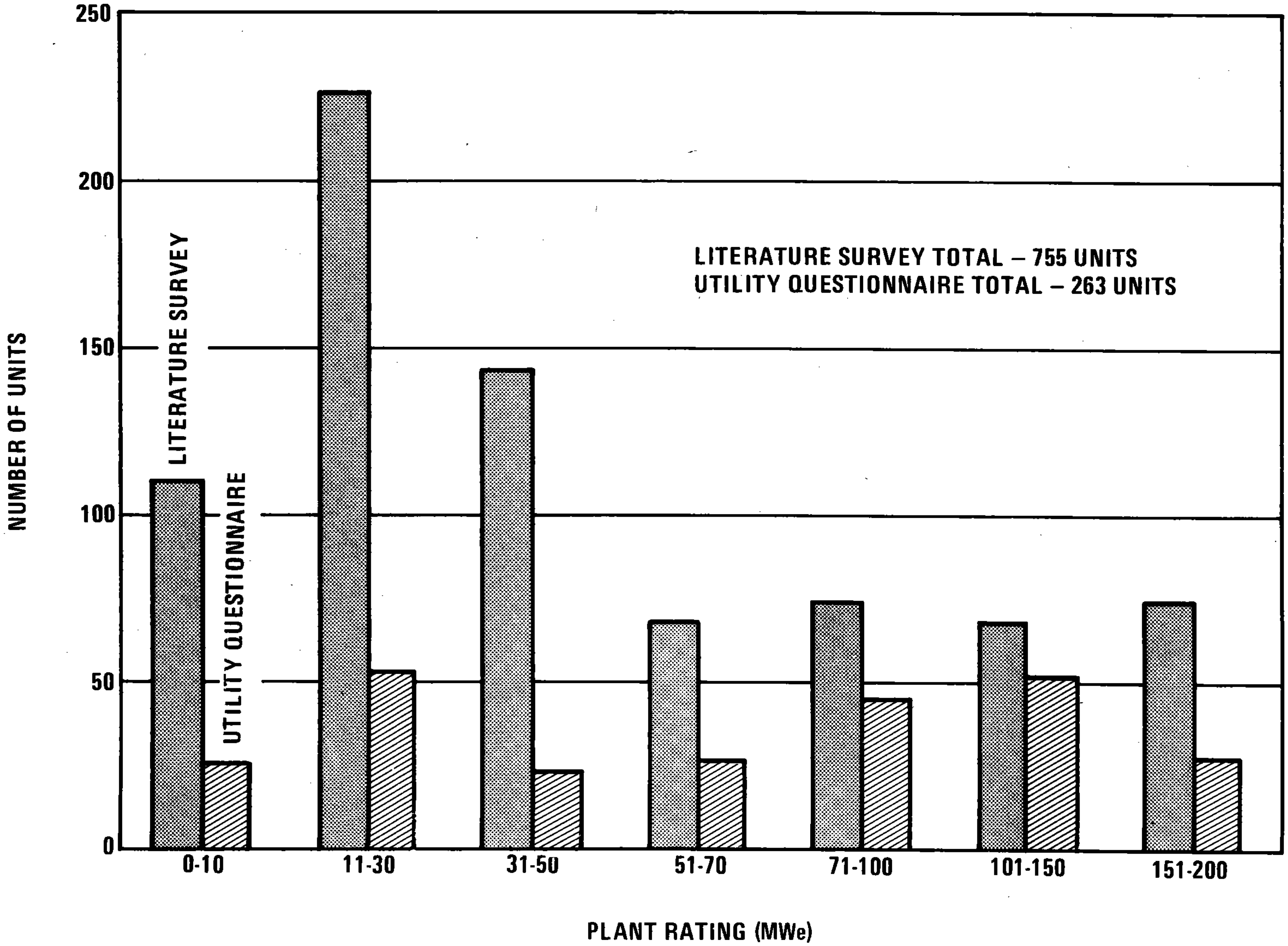


Figure B-1
CANDIDATE UNITS FOR SOLAR HYBRID REPOWERING
(SOUTHWESTERN UNITED STATES)

band categories, corresponding to the 107 units in the 0-50 MWe range, the following numbers of units were identified: for a plant rating range from 51 to 100 MWe, there are 71 units; for a range from 101 to 150 MWe, there are 59 units; and for a range from 151 to 200 MWe, there are 26 units which are repowerable.

Table B-2 is a listing of the top twenty utilities ranked by effective solar repowering in MWe. These utilities have a total effective solar repowering potential of 8,941 MWe, the equivalent of 83 percent of the total effective solar repowering potential defined in the survey. Note also that the average percentage of repowering for each of these top twenty utilities has been shown in Table B-2. These results demonstrate that most of the utilities in the southwest have sufficient land available to consider solar hybrid repowering (on the average) at a level greater than 50 percent. Conversely, one Texas, one Louisiana and the three California utilities in the top twenty, because of the lack of available land, could not be repowered (on the average) at greater than 50 percent.

3.0 DETAILED SURVEY RESULTS ON REPOWERABLE POTENTIAL

Table B-3 gives the breakdown by state for the total number of repowerable units and the total rated MWe reported in the survey. From the utility survey, there are 263 repowerable units with a total rated capacity of 19,273 MWe. Especially noteworthy is Texas with 8004 MWe total rated capacity and 91 repowerable units.

Table B-4 shows the same breakdown by state, including the effective solar MWe and the repowering percentages for each state. The effective solar repowering potential (MWe) for each unit was derived by applying the reported repowering percentage, based on a land availability of approximately 6 acres per MWe, to the individual rating of the unit. When explicitly reported by the utility, specific repowering percentages were applied to the MWe ratings of the units. In most cases, however, the effective solar repowering potentials were determined by applying the upper bound of the appropriate notation to the following repowering levels: 0 percent, 1-25 percent, 26-50 percent, 51-75 percent and 76-100 percent. The effective solar repowering potential

Table B-2

RANKING OF UTILITIES BY TOTAL EFFECTIVE SOLAR REPOWERING (MW_E)

Ranking	State	Utility	Effective Solar MW_E	Percentage of Repowering (Ave)
1	TX	Houston Lighting & Power	1231.MW_E	83%
2	TX	West Texas Utilities	922.	90.
3	TX	San Antonio Public Service Service Board	660	87.
4	AZ	Tuscon Gas & Electric	580.	100.
5	CA	Pacific Gas & Electric	575.	28.
6	CA	Southern California Edison	509.	32.
7	TX	Gulf States Utilities	446.	100.
8	OK	Western Farmers Electric Cooperative	421.	56.
9	NE	Sierra Pacific Power	388.	84.
10	TX	Texas Power & Light	372.	100.
11	CA	San Diego Gas & Electric	364.	34.
12	TX	Garland Municipal Power & Light	342.	100.
13	OK	Public Service of Oklahoma	334.	59.
14	TX	El Paso Electric	304.	59.
15	NM	Public Service of New Mexico	297.	93.
16	NE	Nevada Power	278.	100.
17	AZ	Arizona Public Service	278.	89.
18	LA	Cajun Electric Power Cooperative	230.	100.
19	LA	Southwestern Electric Power	208.	43.
20	TX	Central Power & Light	202.	31.
		TOTAL:	8941.	

Table B-3

UTILITY DATA QUESTIONNAIRE

- Questionnaire Submitted to 78 Utilities
- 60 Utilities Responded to Questionnaire

State	Number of Utilities	Number of Candidate Units	Total Rated Power (MWe)
Arizona	5	22	1217
California	7	61	5301
Colorado	8	9	166
Louisiana	8	25	1664
Nevada	2	9	739
New Mexico	6	22	423
Oklahoma	5	21	1493
Texas	16	91	8004
Utah	2	1	66
OTHERS	1	2	200
TOTALS	60	263	19273

Table B-4

UTILITY MARKET SURVEY SUMMARY

State	Number of Candidate Units	Rated MWe	Effective Solar MWe	Percent Repower	Percent of Effective Solar
Arizona	22	1217	974	80.0	9.1
California	61	5301	1601	30.2	15.0
Colorado	9	166	35	21.1	0.3
Louisiana	25	1664	758	45.6	7.1
Nevada	9	739	666	90.1	6.2
New Mexico	22	423	371	87.7	3.5
Oklahoma	21	1493	887	59.4	8.3
Texas	91	8004	5141	64.2	48.0
Utah	1	66	66	100.0	0.6
OTHERS	2	200	200	100.0	1.9
TOTAL	263	19273	10699	55.6 (Avg.)	100.0

for each individual unit was totaled for each utility and each utility was likewise included in the overall state total. The percent repowering for each state is the total effective solar MWe divided by the total rated capacity of the repowerable units. The percent repowering is an indication of the general repowering potential of units ≤200 MWe in that state.

From Table B-4, it becomes apparent that some states have a large power generating capability of units ≤200 MWe and therefore a high number of rated MWe and effective solar MWe. California, for example, has 5301 MWe of rated capacity of units that are repowerable. California's effective solar repowering potential is 1601 MWe. Thus, the overall state repowering percentages indicate that the availability of land is a major factor in considering solar repowering. This can be seen from the fact that California's effective solar MWe potential is only 30 percent of its reported MWe capacity.

The above results become important when one interprets the repowering percentages as a function of rated size of the candidate repowerable units, as presented in Table B-5. As shown in this table, two high repowering percentage categories are indicated: the 1-25 percent and the 76-100 percent categories. The 1-25 percent category is large because many of these units are located in or near more densely populated areas where sufficient land is not generally available for significant solar repowering. There are 100 units that can be repowered in the 76-100 percent category. The units in this higher percentage of repowering category are clustered around the 11-50 MWe size (34 units) and the 70-100 MWe size (30 units). The latter size category, however, usually represents a reheat steam turbine cycle unit which will be more complex to repower with solar energy.

Shown in Table B-6 is an evaluation of land availability and the distance from the unit to this available land. Of significance is the fact that 197 repowerable units, having an effective solar repowering total of 6879 MWe have land within 2500 feet.

When the restriction of >50 percent repowering potential is applied to the above evaluation of land availability and land distance (Table B-6), as

Table B-5

REPOWERING PERCENTAGE EVALUATION OF CANDIDATE UNITS
(TOTAL NUMBER OF UNITS)

Rated Size (MWe)	Repowering Percentage				
	1 - 25	26 - 50	51 - 75	76 - 100	Total
0 - 10	12	7	0	6	25
11 - 30	31	2	0	22	55
31 - 50	14	0	1	12	27
51 - 70	13	4	1	8	26
71 - 100	8	6	1	30	45
101 - 150	31	10	5	13	59
151 - 200	15	0	2	9	26
TOTAL	124	29	10	100	263

Table B-6

UTILITY MARKET SURVEY RESULTS
EVALUATION OF LAND AVAILABILITY

State	Land Distance (Ft.)							
	<1000		1000 - 2500		2500 - 5000		>5000	
	No. of Units	Effective Solar MWe	No. of Units	Effective Solar MWe	No. of Units	Effective Solar MWe	No. of Units	Effective Solar MWe
Arizona	2	198	12	221	7	480	1	75
California	32	671	16	533	4	124	9	274
Colorado	7	5	2	30	-	-	-	-
Louisiana	12	427	7	172	6	158	-	-
Nevada	4	278	3	225	2	163	-	-
New Mexico	17	243	5	128	-	-	-	-
Oklahoma	2	212	8	212	5	298	6	165
Texas	44	1948	22	1176	18	1022	7	995
Utah	-	-	-	-	-	-	1	66
OTHERS	-	-	2	200	-	-	-	-
TOTALS	120	3982	77	2897	42	2245	24	1575

shown in Table B-7, the total number of repowerable units at a distance of <2500 feet is reduced to 72 and the total effective solar repowering potential is reduced to 4799 MWe. With the exception of Texas, the ranking of the states by total effective solar MWe changes dramatically. With the restrictions of >50 percent repowering and <2500 feet applied to the repowerable units, the ranking of states by effective solar MWe becomes:

Texas	2614 MWe
Nevada	503 MWe
Arizona	378 MWe
New Mexico	348 MWe
Oklahoma	286 MWe
Louisiana	274 MWe
Others	200 MWe
California	166 MWe
Colorado	30 MWe
Utah	-
Total	4799 MWe

In the above ranking of states, the restrictions of Table B-7 (greater than 50 percent repowering and <2500 feet), have shown that Texas, Nevada, Arizona, and New Mexico are the major contributors to the total practical repowering potential in the Southwest. This ranking is reflective, to a large extent, of the fact that the repowerable units of medium size (10-70 MWe) are located in rural areas which generally have enough available land to repower to a relatively high percentage; frequently to 100 percent. The "others" listed above is actually one utility who specifically requested to be involved in the Solar Hybrid Repowering Program.

The above 4799 MWe represent the practical solar repowering potential because this total power level includes: a) only those units that the utilities chose to report as repowerable candidates, b) only those units that are within a distance of <2500 feet of the available land, and c) only those units that can be repowered to >50 percent.

Table B-7

MARKET EVALUATION SUMMARY

Category	Number of Units	Total MWe
Potential Market Size (rated MWe)		
Literature Survey	755	40954
Utility Survey	263	19273
Solar Repowering Potential (effective MWe)		
Based on land availability	263	10699
and <2500 ft. from plant	197	6879
and >50% repowering	72	4799
and utility interest	72	4799

Of the 263 repowerable units from the survey, there were only 29 repowerable combustion turbines rated at 1112 MWe total. The effective solar repowering potential of these 29 units was reported as 443 MWe. If the available land distance (<2500 feet) and repowering percentage (>50 percent) restrictions are applied to these combustion turbine units, their effective solar repowering potential falls to 138 MWe.

Finally, it is worthy to note that of the 10,699 MWe of total effective solar repowering potential, approximately 9,502 MWe (~89 percent) is representative of units located at plants which have multiple units. The concept of multiple units located at a given solar hybrid repowered plant lends itself well to the possibilities of steam sharing by the solar and fossil boilers and steam borrowing from other existing units to assist in providing a more economic and a more operationally flexible solar repowered plant.

4.0 CANDIDATE REPOWERING UNIT

4.1 SUMMARY

An objective of the market survey was to establish the characteristics of a typical candidate unit for Solar Hybrid Repowering.

This typical unit is a non-reheat steam turbine with a rating of 10-50 MWe. The steam turbine inlet conditions include a throttle pressure range of 850 to 1250 psig and a turbine inlet temperature range of 900 to 950^{o}F.

For the general unit data, the typical candidate repowering unit is currently in good condition and was built (or went into service) between the years 1950 and 1960. The unit is currently used for intermediate or peak load service and has an estimated 20-25 years of useful service before it's planned retirement. The typical unit is located in a rural area.

4.2 SURVEY RESULTS FOR CANDIDATE UNIT DESCRIPTION

The selection of the appropriate characteristics and general data for the repowering candidate unit was based on a detailed assessment of the utility survey results and the parallel literature survey information. As shown previously, 263 repowerable units representing 19,273 MWe of total rated capacity were identified by the utility survey. Table B-8 shows a breakdown of this potential by state and repowering unit type; i.e., steam turbine and combustion turbine. Note that there were a total of 234 steam Rankine cycle units identified by the survey which represents 18,161 MWe of rated capacity. Table B-8 also shows that a total of 29 combustion turbine units representing 1112 MWe of rated capacity were identified by the survey.

As mentioned previously, when one applies the restrictions of available land at a distance <2500 feet from the candidate unit and >50 percent repowering based on land availability (see Table B-7) the number of repowerable candidates (both steam and combustion turbines) was reduced to 72 units representing 4,799 MWe of effective solar repowerable potential. Included in the 72 units are 6 combustion turbines with a total of 138 MWe of effective solar repowerable potential. Considering the results, the conclusion was drawn that steam turbines are typical candidate unit types for solar hybrid repowering.

Table B-9 gives a breakdown by state of the repowerable steam turbines (234 units total) into reheat and non-reheat categories. As shown, the number of non-reheat units greatly exceed the number of reheat units (by almost a factor of 2). Therefore a non-reheat steam turbine was selected for the typical candidate unit.

Table B-10 shows a breakdown of the repowerable steam turbine units by plant rating (MWe) categories and typical operating conditions. The figure maintains the reheat, non-reheat units type distinction shown in the previous figure; 55 units of the total 151 non-reheat units (more than one-third) have inlet conditions of 850 psig and 900°F. Shown on Table B-10, 53 units of the total 83 reheat units (more than one-half) have inlet conditions of 1800 psig and 1000°F with a 1000°F reheat cycle.

Table B-8

EVALUATION OF REPOWERING UNIT TYPE

State	Steam Turbine		Combustion Turbine	
	Number of Units	Rated MWe	Number of Units	Rated MWe
Arizona	15	1042	7	175
California	44	4569	17	732
Colorado	9	166	0	0
Louisiana	24	1645	1	19
Nevada	9	739	0	0
New Mexico	21	405	1	18
Oklahoma	18	1325	3	168
Texas	91	8004	0	0
Utah	1	66	0	0
OTHERS	2	200	0	0
TOTALS	234	18161	29	1112

Table B-9

EVALUATION OF REPOWERABLE STEAM TURBINE UNITS

State	Non Reheat Number of Units	Reheat Number of Units	State Totals
Arizona	9	6	15
California	22	22	44
Colorado	9	0	9
Louisiana	19	5	24
Nevada	4	5	9
New Mexico	21	0	21
Oklahoma	13	5	18
Texas	53	38	91
Utah	1	0	1
OTHERS	0	2	2
TOTALS	151	83	234

Table B-10

STEAM TURBINE UNITS
OPERATING CONDITIONS (PRESSURE/TEMPERATURE)

	Non-Reheat Units					Reheat Units			
Pressure Temperature Plant Rating MW_E	350 psi 625°F	600 psi 825°F	850 psi 900°F	1250 psi 950°F	1450 psi 950°F	1450 psi 1000°F 1000°F	1800 psi 1000°F 1000°F	2000 psi 1000°F 1000°F	Totals
0 - 10	8	17							25
11 - 25	3	5	13						22
26 - 50	4	1	23	8		3	1		40
51 - 75			13	12	1	5	5		36
76 - 100			5	5	5	10	4	1	30
101 - 125				7	20	5	13		45
126 - 150			1				6	3	10
151 - 200							24	2	26
TOTALS	15	23	55	32	26 151	24	53	6 83	234

The non-reheat steam turbine type was chosen as the typical candidate unit. This decision was based on the fact that a reheat cycle unit would require: a) a more complex solar receiver at the top of the tower, b) additional extensive lengths of steam piping between the receiver at the top of the tower and the existing turbine generator (possibly including significant horizontal runs), c) a more elaborate interface with the existing fossil boiler (intermediate as well as high pressure sections), and d) a more complex control system.

The general unit data tabulated on Table B-11 indicates the additional features that are typical of the candidate unit. Table B-11 shows that most of the non-reheat units (80) were built between 1951 and 1960, are generally (91 units) in good condition, and have an estimated retirement date before the year 2000. Most of these units are currently used for intermediate (42 units) and peak (52 units) load service. Inspection of the data on general plant location reveals the fact that the typical candidate unit is located in a rural area.

Most of the utilities (49 out of the 53 reporting such data) established the time of their system peak load demand as occurring between 8:00 AM and 6:00 PM in the summer. In the winter, 34 utilities (out of 53 reporting such data) established that their peak load demand occurred between 8:00 AM and 6:00 PM. Since this time period corresponds to the time frame of good solar insolation, a favorable solar power available versus electric power demand match is achieved.

5.0 COST BENEFIT ANALYSIS

A cost benefit analysis is being performed for selected utilities in the southwest. These include Public Service Co. of New Mexico, Arizona Public Service Co., EPRI Synthetic Utility System E (Texas, Oklahoma, Louisiana), and Nevada Power Co. The emphasis to date has been placed on the first three of these.

The analysis methodology assumptions and results to date are presented below.

Table B-11

EVALUATION OF UNIT DATA
(NUMBER OF UNITS)

Category	Steam Turbine Non-Reheat	Steam Turbine Reheat	Combustion Turbine
Year Built			
Before - 1941	8	0	0
1941 - 1950	30	0	1
1951 - 1960	80	48	0
1961 - 1970	16	27	16
1971+	13	12	12
General Unit Condition			
New	26	10	3
Good	91	74	26
Fair	25	3	0
Poor	5	0	0
Current Use			
Base	27	26	0
Intermediate	42	55	1
Peak	52	4	22
Standby	22	0	5
Estimated Retirement			
1978 - 1980	4	0	0
1981 - 1990	51	22	1
1990 - 2000	48	24	12
2000+	44	41	16
General Plant Location			
Industrial	30	18	4
Suburban	34	20	2
Urban	22	7	12
Rural	55	41	10

5.1 METHODOLOGY

For the proper assessment of the prospective value and impact of solar hybrid repowered plants upon a electric utility system, detailed modeling of the operation of such a plant is required. This modeling must involve the interactive dispatch of the solar plant with other generating units on the utility system. Through this procedure proper sizing of the solar plant and its subsystems , such as solar collector area, can be ascertained. Also, solar plant operational strategies involving the use of the fossil boiler can be evaluated.

The methodology developed for analyzing the solar hybrid repowered plant consists of the coordinated use of several computer models and procedures for economic evaluation. The basis of the evaluation models is a set of Westinghouse utility planning computer programs and a specially developed solar plant model. The utility models include a production costing model which 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 which is capable of accepting a probability distribution for the availability of the solar plant. (Figure B-2)

The methodology implemented for economic and reliability system impact assessment relies heavily upon system simulation. The Load Projection, Load Statistical Analysis, Reliability Analysis and Detailed Production Cost blocks shown in Figure B-2 are separate existing Westinghouse models (computer programs) which are routinely used to analyze utility systems. These models have had minor modifications to allow them to interface with the Solar Thermal Plant 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 load is input to the solar plant model which simulates the operation of the solar plant and outputs the remaining load to be served, for further analysis. The solar plant model uses incremental operating cost data for the balance of the utility system to guide its dispatch. This is particularly important to the proper conservation of fossil fuel.

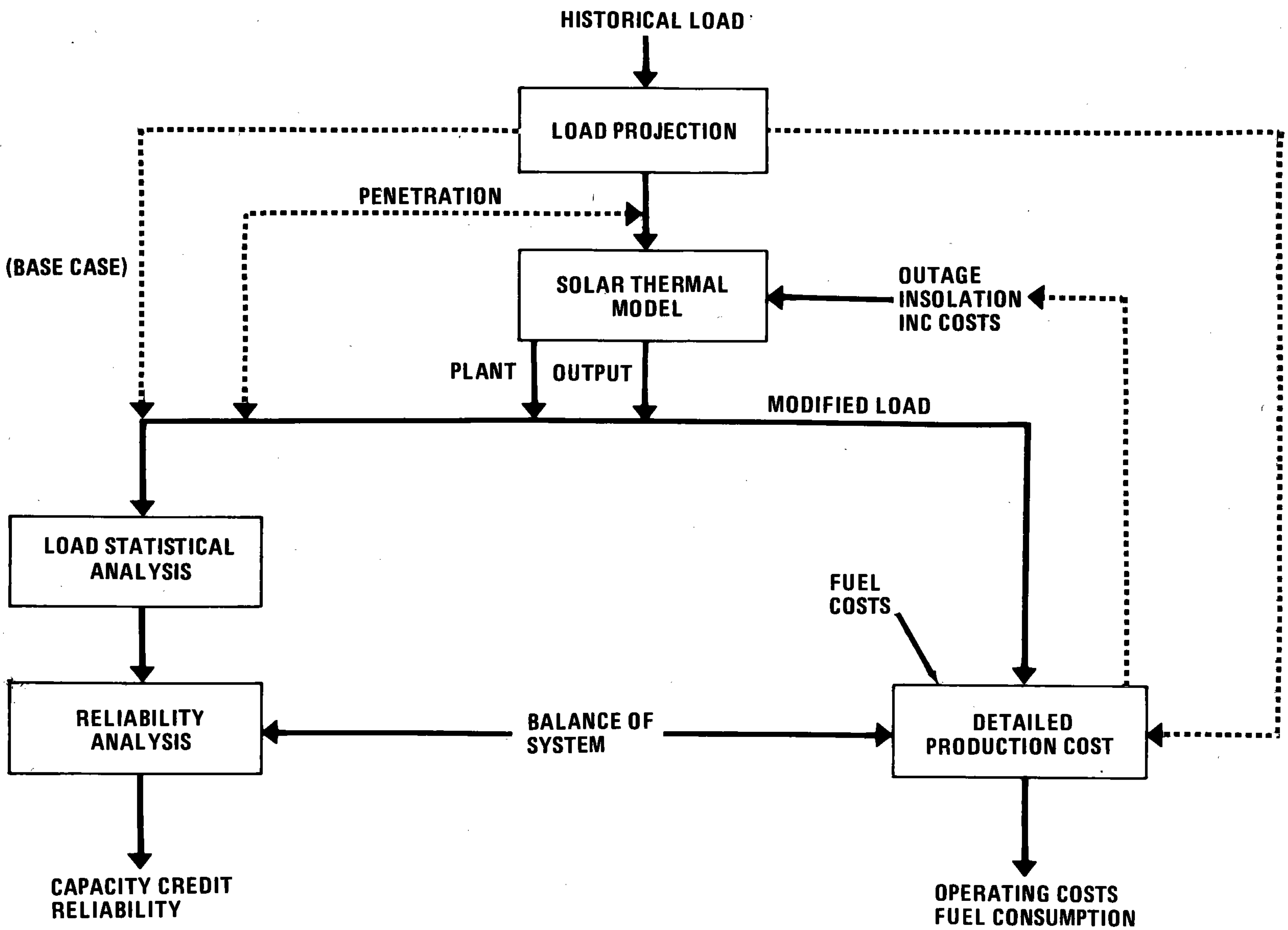


Figure B-2
MODEL USAGE FLOW

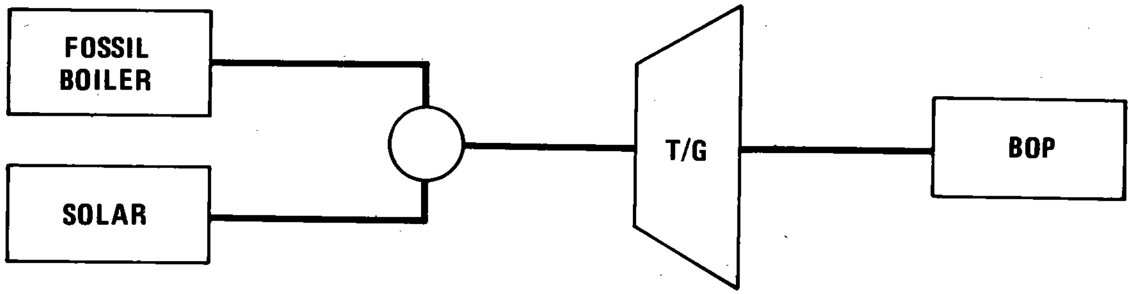
Figure B-3 shows the basic solar hybrid repowering plant model used for the cost/benefit analysis. Also indicated in the figure are the assumptions used to develop the model. Included in the model is a dispatch routine which recognizes balance of utility system incremental costs, turbine efficiency modifications, a plant availability table, and residual system load format changes. The dispatch rule that has been implemented is shown in Table B-12.

The dispatch rule is a daily iterative procedure which relies upon a simple preliminary dispatch which is iteratively improved. This rule utilizes an assumption of 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, along with the various solar plant efficiencies. During periods of rapid insolation transients, the solar plant output is augmented by steam from the fossil boiler. This is simulated by hourly testing the skycover conditions on the insolation tape. Wind conditions are also tested such that when the design limits are exceeded the simulation assumes the heliostats are stowed.

There are several reasonable criteria of economic merit to use in the evaluation of solar electric plants (Table B-13). However, they are not always consistent in their selection of the most economic alternative.

The inclusion of plant value (to a specific utility system) as well as plant cost is considered important in determining the economic choice; therefore, the cost/benefit ratio was selected as the primary evaluation criteria. Plant value is calculated independent of plant cost such that a number of cost assumptions can be applied.

The operating value of solar repowered plants results from a reduction in energy production by the balance of the electric utility system. The reduction in conventional plant operation saves fuel and variable O&M costs on the most costly (operating cost) units that would have been operating at the time the solar repowered plant is producing power. Since the solar repowered plant operates during different times of the day and throughout the year, the highest cost conventional unit being displaced changes. Thus



GENERAL ASSUMPTIONS

- THE SOLAR PLANT MODEL DEVELOPED AS PART OF EPRI RP-648 WILL BE USED IN THE COST/BENEFIT ANALYSIS
- PLANTS WILL BE OPERATED TO MAXIMIZE THE BENEFIT OF THE SOLAR REPOWERING
- PLANT CAN OPERATE FROM EITHER SOLAR, FOSSIL, OR A COMBINATION OF SOLAR AND FOSSIL
- AEROSPACE INSOLATION TAPES WILL BE USED FOR THE ANALYSIS
- THE REPOWERING MODEL WILL BE BASED ON STEAM TURBINE PLANTS
- WET COOLING TOWERS WILL BE USED FOR THE HEAT REJECTION SYSTEM
- THE DAYS INSOLATION PROFILE AND LOAD DEMAND ARE KNOWN

Figure B-3
SOLAR HYBRID REPOWERING MODEL FOR COST/BENEFIT ANALYSIS

Table B-12

SOLAR HYBRID REPOWERING MODEL DISPATCH

- Oil Startup Logic
- Oil Buffer for Insolation Transients
- Close Up 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/Benefit 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 B-13

SOLAR PLANT 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/Benefit Ratio

- Solar Plant Lifetime Costs
- Solar Plant Lifetime Value

the operating credit varies with the utility 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 plant are shown in Table B-14.

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 only be taken for those years of operation of the repowered plant beyond the normal retirement date. Calculationally one can think in terms of megawatt savings being obtained first and then being converted to dollars. In general for a solar hybrid plant, 100% capacity credit can be considered for those years of operation beyond the normal retirement date due to the presence of the fossil boiler. This is not true for solar plants having thermal storage.

5.2 REFERENCE PLANT DESCRIPTION

A reference solar hybrid repowered plant concept has been established for the purpose of performing the cost/benefit analysis. The reference concept consists of repowering existing gas-and-oil-fueled electric power generating units to operate on solar energy whenever it is available. The concept will displace a large portion or all of the fossil fuel normally used during daylight hours. The ability to operate on fossil fuel however is retained, thus providing full backup capability and maximum operational flexibility during periods of inclement weather as well as the potential for conventional electric power generation at night. The basic concept utilizes the solar hardware and technology being developed for the 10 MWe solar central receiver pilot plant to be built near Barstow, California.

The reference solar hybrid repowered plant has been defined utilizing, to the maximum extent possible, the characteristics of the typical candidate unit resulting from the survey.

Table B-14

OPERATING VALUE FACTORS

- Insolation Characteristics
- Utility System Load Shape
- Utility Mix of Generating Units
- Fuel Cost and Escalation Projections
- Conventional Unit Heat Rates
- Variable O&M Cost and Projections
- Plant Collector Area
- Penetration of Solar Hybrid Repowered Plants
- Present Worth Discount Rate

Table B-15 summarizes the characteristics of the reference plant. The reference plant is a 50 MW(e) steam plant having a non reheat steam turbine. The solar subsystem has been sized to provide 100% repowering based on an insolation level of 950 Watts/m^2.

The solar system design is characterized by an external receiver mounted on a tower, and located in a 360^o array of sun-tracking heliostats which comprise the collector subsystem. Feedwater from the electrical power generation subsystem is pumped through a riser to the receiver, where the feedwater is converted to superheated steam in a single pass through the tubes of the receiver panels. The steam from the receiver is routed through a downcomer to the ground and thence to the turbine.

The collector field has been sized to provide for 100% repowering of the 50 MW(e) fossil plant; 8160 heliostats having a total mirror area of $310,000^2$ are required to produce 50 MW(e) at an insolation level of 950 Watts/m^2. The 950 Watts/m^2 insolation level assumed for sizing the collector fields is representative of 2 PM winter solstice conditions; the design point for the solar repowering program established by DOE/PNM. Since the insolation level varies throughout the year (peak value to about 1100 Watts/m^2) there will be periods when the thermal power producing capability of the heliostat field will exceed the turbine generator 50 MW(e) rating. During those time periods, a portion of the heliostat field will have to be defocused in order not to exceed the turbine generator rating.

The 310,000 m^2 reference collector field may not represent the most cost effective size. One of the sensitivities being considered in the cost/benefit analysis is therefore collector field size. Two collector field sizes - 163,000 m^2 and 233,000 m^2 - in addition to the reference field have been established for the cost/benefit analysis. These latter two collector fields represent, on the basis of the design insolation level of 950 Watts/m^2, a repowering percentage of 50 and 75% respectively.

Table B-15

SOLAR HYBRID REPOWERED PLANT
REFERENCE PARAMETER SUMMARY

• Plant Type	Steam Turbine
• Plant Rating	50 MWe
• Plant Repowering Percentage*	100%
• Plant Operating Scenario	Maximize solar benefit Fossil operation only on cloudy days Economic dispatch fossil energy
• Collector Subsystem	
- Field Configuration	360^o
- Field Area	300 Acres
- Heliostat Area	310,000 M^2
- Number of Heliostats	8160
• Receiver/Tower Subsystem	
- Receiver Type	External (single pass to superheat)
- Receiver Size	15 M dia by 27 M Long
- Tower Height	175 M
• Electric Power Generation Subsystem	
- Cycle	Steam Rankine
- Net Plant Efficiency	33%
- Turbine Inlet	950^oF/1250 psi
- Heat Rejection	Wet Cooling Tower
• Fossil Boiler	
- Type	Oil
- Rated Load Efficiency	82%
- Start Up	Cold

*Based on an insolation level of 950 Watts/M^2

The ability to operate on fossil fuel has been maintained in the repowered plant concept. The plant can therefore operate and produce 50 MW(e) using steam generated from the solar subsystem, the fossil boiler, or a combination of both fossil and solar. It is assumed that the plant will always operate on a combination of solar and fossil produced steam during cloudy days - a cloudy day for the purpose of the cost/benefit analyses is defined as a day during which the sky cover exceeds 0.5 for two consecutive hours.

The operation scenario assumed for the fossil boiler is important in determining the economic benefit of solar hybrid repowering. In order for the fossil boiler to be capable of responding to insolation variations during periods of intermittent cloud cover, the boiler must be operating at a minimum of 25% of rated thermal output. The boiler response time to achieve 100% rated output from an operating level of 25% of rated output is approximately 10 to 15 minutes. The cost of the fossil fuel required to maintain the boiler at 25% of rated output is high and substracts directly from the economic benefit derived from operating the plant on solar energy. An incentive therefore exists to minimize the amount of fossil fuel consumed for purposes other than the economic operation of the plant.

Three operating scenarios have therefore been established for the fossil boiler for the purpose of performing the cost/benefit analysis. These scenarios are:

- <u>the fossil boiler operates only on cloudy days</u> - The fossil boiler is assummed to be started from a cold condition for each cloudy day. A ten hour startup period is assummed for the boiler in order to reach 25% of rate load; the fossil fuel consummed during startup is approximately 750 M BTU's. The fossil boiler is maintained in the hot standby condition (25% of rate load) throughout the cloudy day. The boiler firing 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 system) or if it is required in order to overcome severe insolation transients in order to maintain steam conditions at the turbine inlet. The boiler is shut down at the end of each cloudy day.

- <u>the fossil boiler is operated every day</u> - this scenario assumes that the fossil boiler is operated on both clear and cloudy days and is only shut down for routine or forced maintenance. During those periods of the day when the plant is operating from solar generated steam, the fossil boiler is maintained in the hot standby condition similar to the above scenario. At the end of the day, however, the boiler is "banked" and maintained in a warm standby condition overnight. The boiler is also "banked" during days when it is not economical to operate the plant from either solar or fossil energy. The amount of energy required to maintain the boiler in a warm standby condition is approximately 7.5 M BTU for 12 hours. The boiler can achieve 25% of rated output from the warm standby condition in approximately 1-2 hours. In order to account for scheduled and forced plant outages throughout the year, three "cold" starts of the boiler have been included in the cost/benefit analysis for this option.

- <u>steam sharing</u> - this scenario assumes that the repowered unit is part of a multiple unit station. The results of the market survey indicated that approximately 90% of the candidate units were part of a multiple unit station. A dedicated boiler, in this option, would not be proposed for the repowered unit; rather, the repowered unit would use steam produced from a boiler dedicated to an adjacent unit at the plant (even if the power produced by the adjacent unit had to be reduced to provide steam to the repowered unit). The amount of fossil fuel required for starting the boiler and maintaining the boiler in a "banked" or hot standby condition as required for the options discussed above would not be required for the steam sharing option. Steam would be supplied to the repowered unit from an adjacent unit only when required to maintain the operation of the repowered plant during cloudy days. The cost of the fossil fuel to provide the steam must be accounted for in establishing the overall economic benefit of solar repowering. The steam sharing option, however, is attractive from the standpoint of minimizing the fossil fuel required to operate the repowered plant.

Each of the above options for the operation of the fossil boiler are analyzed as part of the cost/benefit analysis.

Table B-16 defines the capital cost of the reference solar hybrid repowered plant. The estimates for the solar subsystem cost for the first and Nth commercial plants are based on Sandia's evaluation of the results of the Phase 1 Central Receiver Program Preliminary Designs. The heliostat cost estimate for these plants are approximately $\$160/m^2$ and $\$100/m^2$ respectively. The DOE heliostat cost goal estimate is based on achieving a heliostat cost of $\$65/m^2$. The cost estimates for the other plant components are based on the results of the conceptual design to date obtained in the present Phase 1 Assessment Study.

5.3 ECONOMIC ANALYSIS BASIS

The economics used in the following analysis are an attempt to represent the costs and value as viewed directly by the utility. That is, it is somewhat of a microeconomic approach in that it does not consider any potential gains in national Balance of Payments conditions, environmental or employment gain benefits, or any other socioeconomic factors. These additional factors might be reflected by Federal incentive programs which are not treated here.

The basic economic assumptions used are shown in Table B-17. For the solar repowering, an 18% Fixed Charge Rate was used on the new investment. The operating and maintenance costs were assumed to be 3% of the capitalization the first year with an escalation rate of 8% annually. A present worth discount rate of 11% was used for all analysis shown.

The economic methodology used is based upon Minimum Revenue analysis frequently used by electric utilities. As used, this incorporates the present worth of the lifetime costs and value of the repowered plant. A thirty-year life from repowering was assumed with repowered operation beginning in 1985.

Table B-16

REFERENCE SOLAR HYBRID REPOWERING PLANT (50 MWe)
COST ASSUMPTIONS (1977 M $)

	First Commercial	NTH Commercial	DOE Heliostat Goal
Land	0.3	0.3	0.3
Structures and Facilities	0.5	0.5	0.5
Heliostats	48.5	31.0	20.2
Receiver/Tower	14.5	13.0	13.0
Turbine Plant Equipment	3.0	3.0	3.0
Electric Plant Equipment	2.2	2.0	2.0
Miscellaneous	1.0	1.0	1.0
TOTAL DIRECT	70.0	50.8	40.0
Contingency and Spares (15%)	10.5	7.6	6.0
Indirect Costs (10%)	7.0	5.1	4.0
Total Capital Investment	87.5	63.5	50.0
IDC (15%)	13.1	9.5	7.5
Total Capitalization	100.6	73.0	57.5
Escalated to 1985 (@7%)	172.8	125.4	98.8
Annual O & M 1985 (3%)	5.2	3.7	3.0

Table B-17
REFERENCE ECONOMIC ASSUMPTIONS
(1985 $, PRESENT WORTH DISCOUNT RATE 11%)

	Combustion Turbine	Combined Cycle	Coal Plants	Nuclear Plants
Capital Cost ($/KWe)	300	600	1400	1500
Capital Escalation Rate (%/yr)	10%	10%	10%	10%
Carrying Charge Rate (%)	20%	18%	18%	18%
Fixed O&M ($/kw-yr)	1.0	2.5	10.0	10.0
Variable O&M (mills/kwhr)	8.0	1.85	3.16	0.76
O&M Escalation Rate (%/yr)	8%	8%	8%	8%
Fuel Cost ($/MBTU)	5.5	5.5	2.0	1.25
Fuel Escalation Rate (%/yr)	12%	12%	10%	9.13%
Heat Rate (BTU/kwhr)	12,000	8,400	9,500	10,400
Scheduled Maintenance (weeks/hr)	2	2	5	6
Forced Outage Rate (%)	10%	10%	13%	11%

For capacity credit calculations it was assumed the plant to be repowered had a life expectancy to 1995 if not repowered. Thus, capacity credit was calculated to begin in 1995 and last for twenty years.

The methods used in the analysis involved hourly modelling of the operation of the repowered plant as well as the balance of the utility system.

Three utility systems were analyzed, all basically in the Southwest. Actual load and generating unit data were used for Public Service Company of New Mexico and Arizona Public Service Company. A synthetic utility system developed by EPRI, which is characteristic of the Texas-Oklahoma region, was used as the third system. As will be noted, PNM has a moderate amount of oil/gas-based generation, with APS having more, and the Texas system the most. Number two oil prices were used for plants currently burning gas.

The insolation data used was for Albuquerque, Phoenix, Midland, Texas, and El Paso.

5.4 UTILITY SYSTEM ASSUMPTIONS

Past load data was obtained from PNM and APS and adjusted by Westinghouse in accordance with the utilities' expected peak loads in 1985. Hourly loads created by Westinghouse for Texas Utility based on the information obtained in EPRI report EM-285.

Figures B-4 and B-5 show a relative mix of generating capacity by fuel type for PNM and APS. These figures do not reflect the total reserve assumed but rather an approximation to the capacity that would likely be operating during a high load day.

It should be pointed out that for PNM the peak load and the generating mix shown in the figure have been altered slightly for our study, but that the general shape of the curve is the same. A tabulation of the 1985 assumed generating mix assumed for the three utilities is shown in Table B-18 with their expected annual peak load.

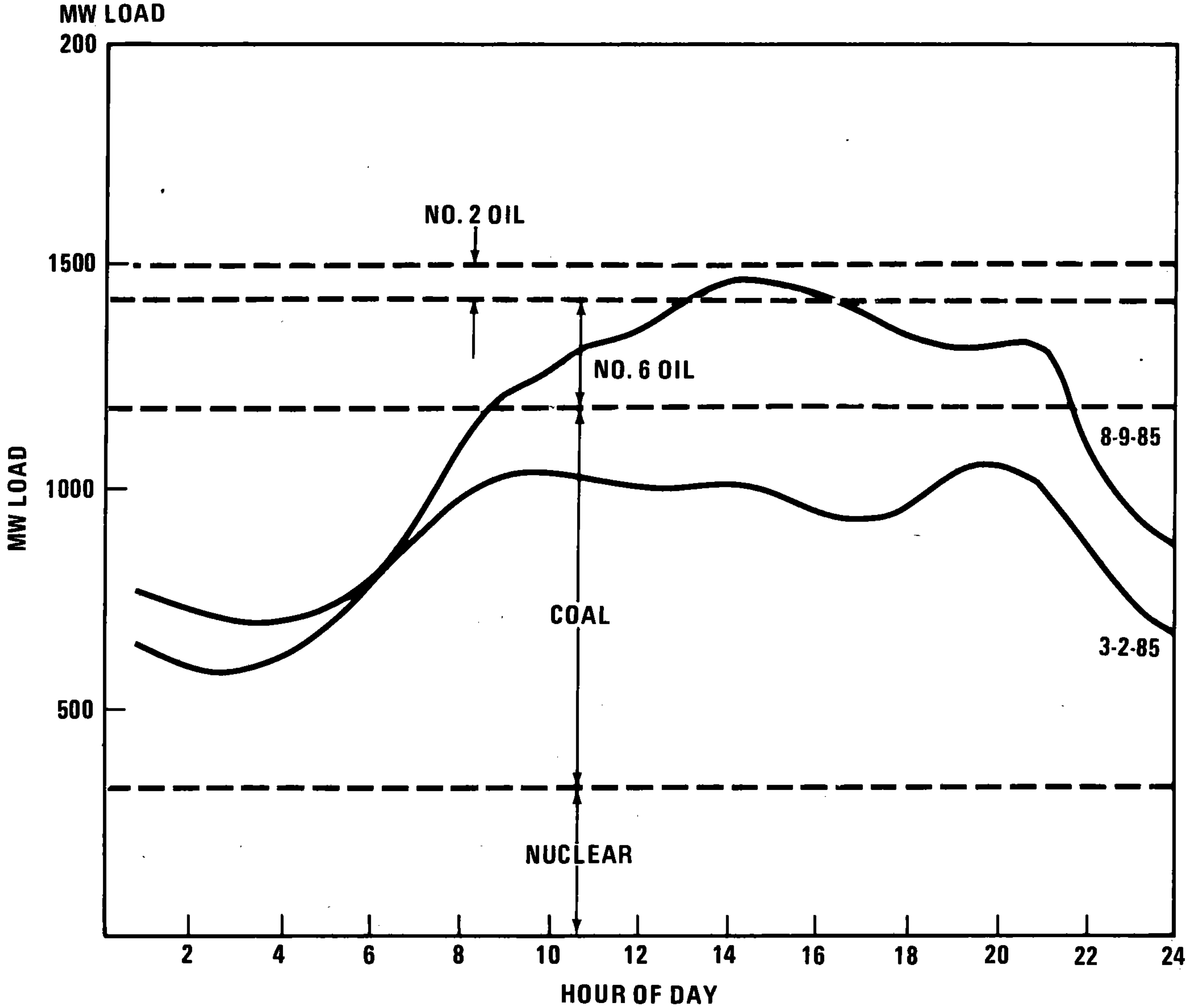


Figure B–4
PSNM GENERATION MIX AND TYPICAL DAILY LOAD CURVES

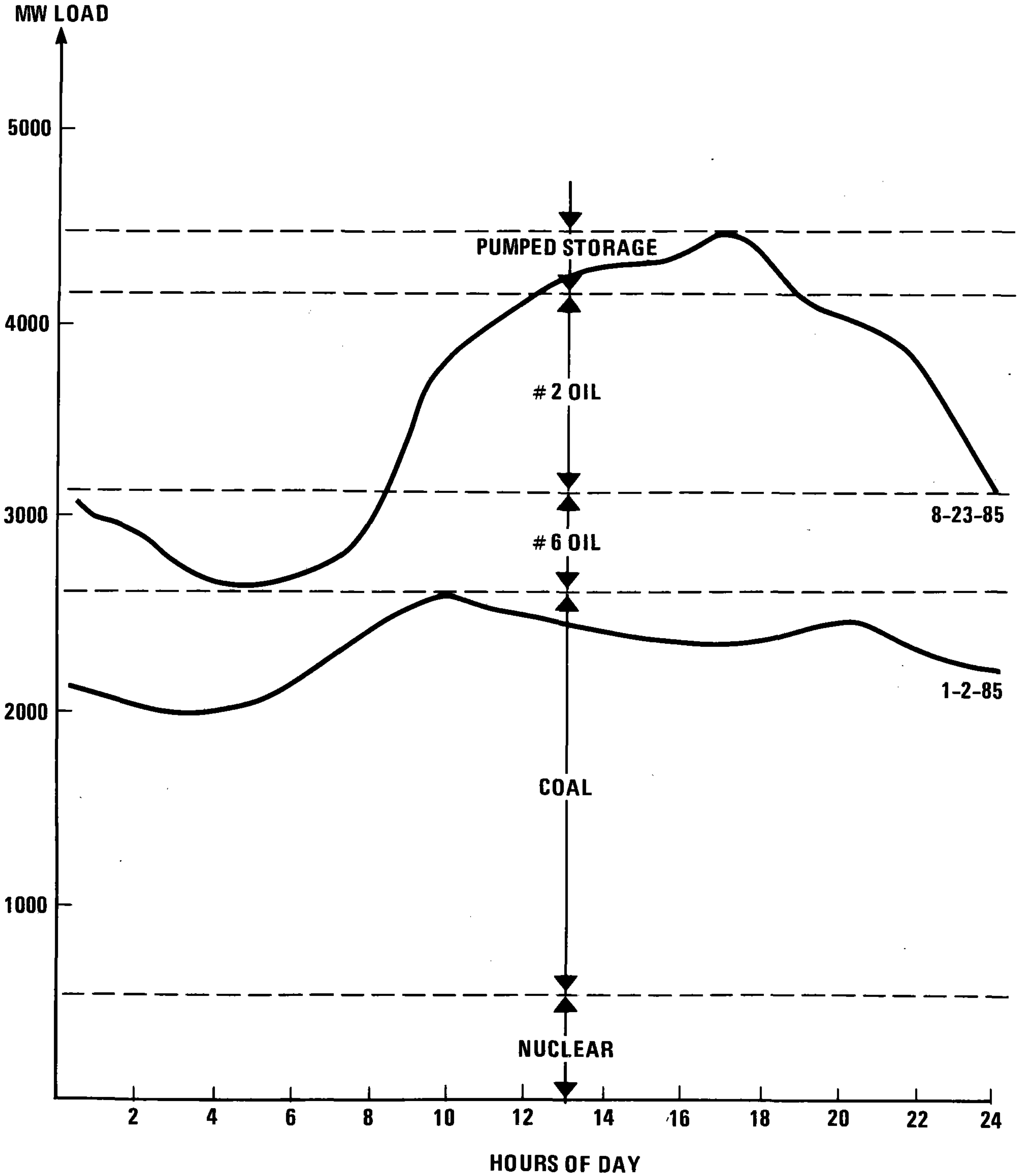


Figure B-5

APS GENERATION MIX
AND TYPICAL DAILY LOAD CURVES

Table B-18

UTILITY GENERATING MIX
1985

	PNM		APS		TEXAS	
	MWe	%	MWe	%	MWe	%
Comb. Turbine	20	1.0	652	12.8	500	4.9
Oil-Steam	282	13.5	836	16.4	5,600	54.4
Combined Cycle	-	-	225	4.4	-	-
Coal	1,222	58.6	2,443	48.0	2,600	25.2
Nuclear	260	12.5	714	14.0	1,600	15.5
Hydro-Electric						
Pumped Storage	300	14.4	225	4.4	-	-
Conv. Hydro.	-	-	4	-	-	-
Total	2,084	100	5,099	100	10,300	100
Annual Peak Load	1545 MWe		4432 MWe		8078 MWe	

As can be seen, for PNM a good percentage of the capacity is base load capacity, and during low load periods the hybrid plants must compete with coal. This is also true to a lesser degree with APS, but APS is more dependent on oil fueled plants than is PNM. However, with Texas Utility the majority of the system capacity is made up of oil fueled plants. Therefore one would expect that the value of the hybrid plant would be highest on this system, as will be shown.

It should be noted that no natural gas is shown in the mixture of fuels. It was assumed that combustion turbines or any other gas-burning plant will be using number two oil or an equivalent surrogate fuel during the period of operation of the hybrid plant.

5.5 PNM SYSTEM ANALYSIS RESULTS

Repowering Cost Assumptions

There were three different cost assumptions used in the reference plant design as was discussed in the reference plant section. The effect of these plant costs on the cost/benefit ratio is shown in Table B-19 for the reference plant.

Table B-19

PRELIMINARY ANALYSIS
PUBLIC SERVICE COMPANY OF NEW MEXICO
50 MWe SOLAR HYBRID REPOWERED PLANT*
1985 INSTALLATION

	DOE Heliostat Goal	Nth Commercial Plant	First Commercial Plant
Direct Plant Cost (1977 M$)	32.8	40.9	55.6
($/KWe)	(656)	(818)	(1112)
Plant Cost (PWRR, 1985 M$)**			
Capital	126.8	158.1	214.9
Operating	45.4	56.6	76.9
Total	172.2	214.7	291.8
Value (PWRR, 1985 M$)			
Fuel Savings	119.7	119.7	119.7
Fuel Cost	(33.5)	(33.5)	(33.5)
Variable O&M	5.9	5.9	5.9
Capacity Credit	22.3	22.3	22.3
Total	114.4	114.4	114.4
Energy (GWH/yr)	121.1	121.1	121.1
Cost (mills/KWH, 1985)	163.6	203.9	277.2
Direct Plant Breakeven ($/KWe, 1977)	435.9	435.9	435.9
Cost/Benefit Ratio	1.50	1.88	2.55

*Collector Area - 233,000 M^2
Fossil Boiler Startup Mode - Cold
**PWRR - Present worth of revenue requirements

Since the plant value is independent of the plant cost, the value of the reference plant remains the same. Therefore, as can be seen, the lowest cost assumption will produce the best cost/benefit ratio. From the results shown, the DOE Heliostat Goal cost assumption will be used as the reference plant cost in the remainder of the analysis.

Also of interest is the type of energy that the hybrid repowered plant displaces. Because the plant operates during all load conditions, it displaces energy normally supplied by base, intermediate, as well as peaking units as shown in Table B-20.

Table B-20

PNM OPERATING ENERGY DISPLACED BY REFERENCE PLANT
(50 MWe, 233,000 M^2)

	GWHRS DISPLACED	% ENERGY DISPLACEMENT	1985 M$ VALUE	% $ VALUE
Coal	87.7	66.6	1.8	43.9
Oil	44.0	33.4	2.3	56.1
Total	131.7	100.0	4.1	100.0

Alternate Economic Scenario

The value of the reference plant was also determined using an alternative economic scenario. This alternate economic scenario differs from the reference scenario only in the carrying charge rate (fixed charge rate). The carrying charge rate is changed from 18.0 to 14.6% for the hybrid repowered plant and from 20.0 to 16.0% for the conventional peaking units on the rest of the system. The differences in cost benefit are shown in Table B-21.

Table B-21

PRELIMINARY ANALYSIS
PUBLIC SERVICE COMPANY OF NEW MEXICO
50 MWe SOLAR HYBRID REPOWERED PLANT*
1985 INSTALLATION

	Reference Economic Scenario	Alternate Economic Scenario
Direct Plant Cost (1977 M$)	32.8	32.8
($/KWe)	(656)	(656)
Plant Cost (PWRR, 1985 M$)**		
Capital	126.8	102.8
Operating	45.4	45.4
Total	172.2	148.2
Value (PWRR, 1985 M$)		
Fuel Savings	119.7	119.7
Fuel Cost	(33.5)	(33.5)
Variable O&M	5.9	5.9
Capacity Credit	22.3	17.8
Total	114.4	109.9
Energy (GWH/yr)	121.1	121.1
Cost (mills/KWH, 1985)	163.6	140.8
Direct Plant Breakeven ($/KWe, 1977)	435.9	418.7
Cost/Benefit Ratio	1.50	1.35

*Collector Area - 233,000 M^2
Plant Cost - DOE Heliostat Goal
Fossil Boiler Startup Mode - Cold
**PWRR - Present worth of revenue requirements

Collector Area Impact

Variations in the size of the repowering collector area were examined to determine what effect the collector area has on the cost benefit ratio. In addition to the reference plant collector area, two other collector areas were analyzed, one larger and one smaller. The results are shown in Table B-22.

Table B-22

COST/VALUE DETAILS VS COLLECTOR AREA
(50 MWe, Hybrid Plant, PWRR - 1985 M$)

	COLLECTOR AREA		
	163,000 M^2	233,000 M^2	310,000 M^2
Total Plant Cost	136	172	210
Total Plant Value	83	114	128
Cost Benefit	1.65	1.51	1.64

As can be seen, the collector area which resulted in the best cost/benefit was the reference plant collector area of 233,000 M^2. This area was used as the collector area for the remaining cases shown.

OPERATING MODES

Three different operating modes of the solar hybrid repowered plant were investigated. These are cold start, warm start, and steam sharing.

The cold start operating mode assumes that everytime the plant is brought on line it is started from a cold boiler condition.

Under the warm start operating mode, oil is burned to keep the boiler warm when the plant is not being used. As a result, less energy is needed to start the plant when it is brought on line. For our analysis it was assumed that the plant would require three cold starts over the year to allow for maintenance.

With the steam sharing operating mode it was assumed that an auxiliary steam supply is available for the hybrid plant to use for startup and standby conditions. Therefore, the cost to the hybrid plant of startup and maintaining the plant in standby condition is very small if not zero. In the steam sharing results shown, these were assumed to be zero.

Based on these assumptions, Table B-23 indicates that the best operating mode is steam sharing using cost/benefit as a criterion. The operating credit of the steam sharing mode is not as high as the other two modes, but the fuel cost is approximately 50% less than the others, resulting in a greater net plant value.

When the plant is operating under the warm startup mode, the energy output of the hybrid plant is greater than that of the cold startup mode because the plant is run more often due to economic reasons. The reason behind this is the difference in startup cost between the warm and cold startup modes. The fuel cost associated with the warm startup scenario is greater than that of the cold startup because of the fuel needed to keep the boiler warm. However, the increased energy output of the hybrid plant outweighs the additional fuel cost, giving a cost/benefit of the warm startup plant better than that of the cold startup plant.

Table B-23

PRELIMINARY ANALYSIS
PUBLIC SERVICE COMPANY OF NEW MEXICO
50 MWe SOLAR HYBRID REPOWERED PLANT*
1985 INSTALLATION*

	Fossil Boiler Startup Mode		Steam Sharing
	Cold	Warm	
Direct Plant Cost (1977 M$) ($/KWe)	32.8 (656)	32.8 (656)	32.8 (656)
Plant Cost (PWRR, 1985 M$)**			
Capital	126.8	126.8	126.8
Operating	45.4	45.4	45.4
Total	172.2	172.2	172.2
Value (PWRR, 1985 M$)*			
Fuel Savings	119.7	123.9	114.1
Fuel Cost	(33.5)	(34.9)	(16.2)
Variable O&M	5.9	6.2	5.8
Capacity Credit	22.3	22.3	22.3
Total	114.4	117.5	126.0
Energy (GWH/yr)	121.1	127.0	117.7
Cost (mills/KWH, 1985)	163.6	156.0	168.3
Direct Plant Breakeven ($/KWe, 1977)	435.9	447.7	480.1
Cost/Benefit Ratio	1.50	1.47	1.37

*Collector Area - 233,000 M^2
Plant Cost - DOE Heliostat Goal
**PWRR - Present worth of revenue requirements

5.6 OTHER UTILITY SYSTEMS IMPACT

APS System Analysis

The value of the reference plant using both cold and warm startup operating modes was analyzed on the APS system. The results are shown in Table B-24. This table shows the cost/benefit ratios of the two operating modes are very close with a slightly better cost/benefit using warm startup. The difference is not greater due to the fact that the solar hybrid plant does not rely to a great extent on the use of oil to start the boiler, as can be seen by the relatively small fuel cost. This is due to a relatively good weather year being used for Phoenix.

The total value of the hybrid plant is quite high due to the fact that there is a good percentage of oil generation on the system which the hybrid plant can displace.

Based on the results of the PNM analysis, it can be expected that the cost/benefit can be reduced even further by using the steam sharing operating mode.

Texas Utility System Analysis

In like manner the Texas Utility System was analyzed for both cold and warm startup modes using Midland, Texas insolation data. In addition El Paso, Texas, which has better insolation, was analyzed for the cold startup mode. The results are shown in Tables B-25 and B-26 respectively.

Although the energy output of the hybrid plant on this system differs only slightly from that of APS and PNM, the total value of the plant is greatly increased, producing a cost/benefit of less than one. This is due to the large percentage of oil based generation on the system.

Similar to previous results, a warm startup operating mode has a better cost/benefit than that of the cold startup mode, but unlike previous results

Table B-24

PRELIMINARY ANALYSIS
ARIZONA PUBLIC SERVICE
50 MWe SOLAR HYBRID REPOWERED PLANT*
1985 INSTALLATION

	Fossil Boiler Startup Mode	
	Cold	Warm
Direct Plant Cost (1977 M$) ($/KWe)	32.8 (656)	32.8 (565)
Plant Cost (PWRR, 1985 M$)**		
Capital	126.8	126.8
Operating	45.4	45.4
Total	172.2	172.2
Value (PWRR, 1985 M$)		
Fuel Savings	125.9	132.3
Fuel Cost	(12.7)	(18.0)
Variable O&M	6.8	7.2
Capacity Credit	22.3	22.3
Total	142.3	143.8
Energy (GWH/yr)	105.5	112.8
Cost (mills/KWH, 1985)	187.7	175.6
Direct Plant Breakeven ($/KWe, 1977)	542.2	547.9
Cost/Benefit Ratio	1.21	1.20

*Collector Area - 233,000 M^2
Plant Cost - DOE Heliostat Goal
**PWRR - Present Worth of Revenue Requirements

Table B-25

PRELIMINARY ANALYSIS
EPRI SYNTHETIC UTILITY E
(TEXAS, LOUISIANA, OKLAHOMA)
INSOLATION - MIDLAND, TEXAS
50 MWe SOLAR HYBRID REPOWERED PLANT*
1985 INSTALLATION

	Fossil Boiler Startup Mode	
	Cold	Warm
Direct Plant Cost (1977 M$)	32.8	32.8
($/KWe)	(656)	(656)
Plant Cost (PWRR, 1985 M$)**		
Capital	126.8	126.8
Operating	45.4	45.4
Total	172.2	172.2
Value (PWRR, 1985 M$)		
Fuel Savings	197.5	198.5
Fuel Cost	(53.7)	(40.3)
Variable O & M	3.6	3.6
Capacity Credit	22.3	22.3
Total	169.7	184.1
Energy (GWH/yr)	115.4	116.1
Cost (mills/KWH, 1985)	171.6	170.6
Direct Plant Breakeven ($/KWe, 1977)	646.6	701.4
Cost/Benefit Ratio	1.02	0.94

*Collector Area - 233,000 M^2
Plant Cost - DOE Heliostat Goal
**PWRR - Present worth of revenue requirements

Table B-26

EPRI SYNTHETIC UTILITY E
(TEXAS, LOUISIANA, OKLAHOMA)
50 MWe SOLAR HYBRID REPOWERED PLANT*
1985 INSTALLATION

	Insolation Base	
	Midland Texas	El Paso Texas
Direct Plant Cost (1977 M$)	32.8	32.8
($/KWe)	(656)	(656)
Plant Cost (PWRR, 1985 M$)**		
Capital	126.8	126.8
Operating	45.4	45.4
Total	172.2	172.2
VALUE (PWRR, 1885 M$)		
Fuel Savings	197.5	208.2
Fuel Cost	(53.7)	(44.1)
Variable O & M	3.6	3.2
Capacity Credit	22.3	22.3
Total	169.7	189.6
Energy (GWH/yr)	115.4	128.0
Cost (mills/KWH, 1985)	171.6	154.7
Direct Plant Breakeven ($/KWe, 1977)	646.4	722.4
Cost/Benefit Ratio	1.02	0.91

*Collector Area - 233,000 M^2
Plant Cost - DOE Heliostat Goal
Fossil Boiler Startup Mode - Cold
**PWRR - Present worth of revenue requirements

the fuel cost of the hybrid plant using the warm startup mode is less than that using the cold startup mode. This again goes back to the fact that the hybrid plant is displacing high incremental cost conventional plants, i.e., oil plants. As a result the hybrid plant is almost never shut down for economic reasons. Since the plant is almost always used, it would be more economic for it to start up using the warm rather than the cold mode.

Although it wasn't investigated, it can be expected that a warm startup using the El Paso insolation tape would produce an even better cost/benefit ratio. Again, based upon the PNM analysis a steam sharing operating mode, assuming zero startup and standby costs, would have an even better cost/benefit ratio.

5.7 COMPARISON WITH SOLAR STAND-ALONE PLANTS

Although it is difficult to normalize the solar plant cost assumptions, the repowering of existing plants appears to be economically superior to building a solar stand-alone plant. This conclusion is reached by comparing preliminary repowering cost numbers with preliminary numbers from EPRI study RP 648-1, performed by Westinghouse.

Using the repowering cost numbers based upon the DOE heliostat cost goals (65 $\$/M^2$, 1977), and the low cost assumptions from the EPRI solar thermal stand-alone study (60 $\$/M^2$, 1976), we find the following, assuming 1985 operation.

PNM

Repowering Cost/Benefit -	1.37-1.50
Stand-Alone Cost/Benefit -	1.53

APS

Repowering Cost/Benefit -	1.21 or less
Stand-Alone Cost/Benefit -	1.28

As would be expected, the repowering cost/benefit improves when applied to utilities with more oil/gas in their generating mix. Also, an improvement occurs in going from a cold-start to a warm-start to a steam-sharing scenario. Steam sharing for APS or Texas was not investigated but should be superior.

The solar/fossil hybrid concept offers certain advantages not included in the economic comparison. One is operating flexibility leading to better operating acceptance by the utility and potential spinning reserve benefits not available from stand-alone plants. Another is that the cost/benefit numbers for stand-alone plants relied upon a technically viable and economic thermal storage system. This system has not yet been demonstrated. The repowering concept does not depend upon this technology.

Many questions involving repowering options and more definitive economics can only be achieved through a detailed design phase, and some of the confirmation as to operating flexibility may require the operational experience of the pre-commercial unit.

Analysis such as that shown can be used to evaluate different design options which affect operating flexibility and system efficiency, as well as alternate operating strategies. This can be applied to individual utilities using their specific system parameters and local insolation.

It is the intent of the work proposed to perform such analysis using the modeling and economic techniques demonstrated here as part of the Phase I effort.