Solar Thermal Repowering

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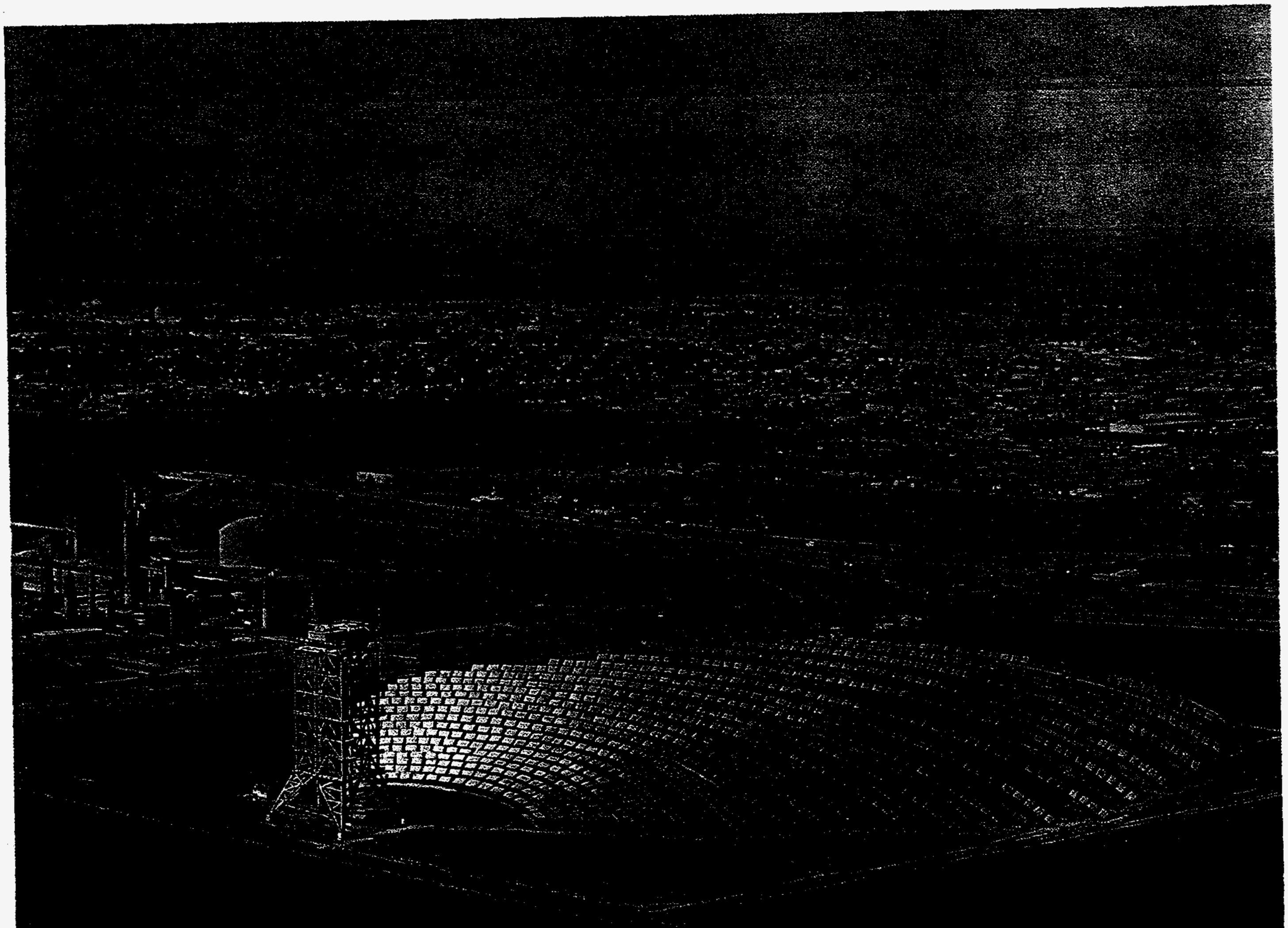

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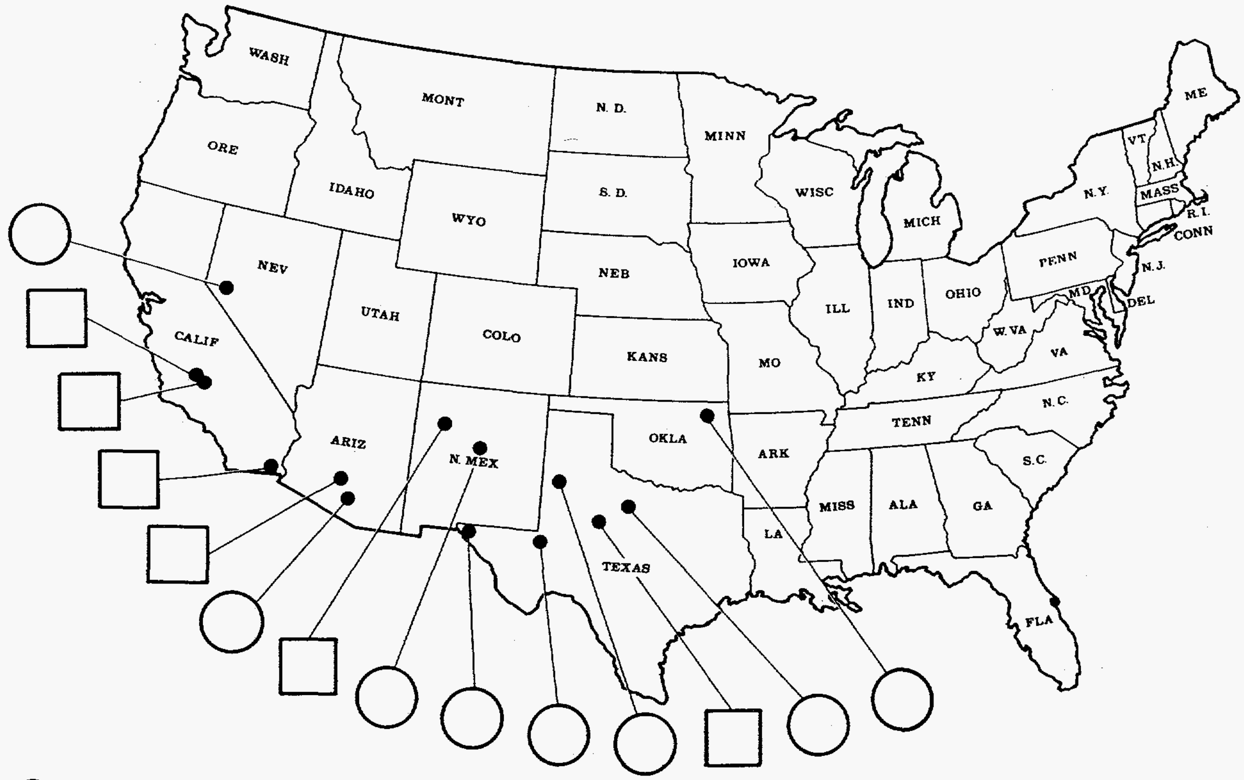
Site Locations



○ **Electrical Generation**

□ **Industrial Process Heat**

Sandia National Laboratories

San Francisco Operations Office

August 1980

COVER: Valley Nitrogen Producer's El Centro Ammonia Plant Solar Repowering Project

INTRODUCTION

Solar central receiver technology is developing steadily with promise of becoming a real commercial alternative for energy generation in the late 1980s. Significant potential markets have been identified,[1,2,3] research and development of important components is proceeding well, and the first full-system verification experiment at Barstow, California, is under construction. However, much work still lies ahead. A big step toward the realization of large-scale commercial use of solar energy was taken when the Department of Energy (DOE) issued a solicitation in March 1979 for utility repowering/industrial retrofit system conceptual design studies employing solar central receivers. Twenty-two responses were evaluated, and twelve were selected for funding. The results of the twelve studies, plus one study completed earlier[2] and one privately funded, are sufficiently encouraging to warrant proceeding to the next stage of the program: cost-shared projects chosen through open competition. Notice for this stage of the program will soon be released. Present plans call for construction to be completed by 1985.

Eight of the fourteen studies are for electric utility repowering of existing oil or natural gas generating plants. The other six are the first site-specific studies of the use of solar central receiver systems for industrial process heat. The industrial processes include gypsum board drying, oil refining, enhanced oil recovery, uranium ore processing, natural gas processing, and ammonia production. Two poster board displays of these conceptual design studies are in active use in public meetings around the country. A map showing the site locations for the design studies, including the earlier study at Albuquerque, New Mexico,[2] is shown on the preceding page.

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[1]"Solar Thermal Repowering, Utility/Industry Market Potential in the Southwest," Mitre Corporation, MTR-7919, December 1978.

[2]"Technical and Economic Assessment of Solar Hybrid Repowering," Public Service of New Mexico (PNM), SAN/1608-4-1, September 1978.

[3]"Survey of the Applications of Solar Thermal Energy Systems to Industrial Process Heat," Battelle Columbus Laboratories, TID-27348-1, January 1977.

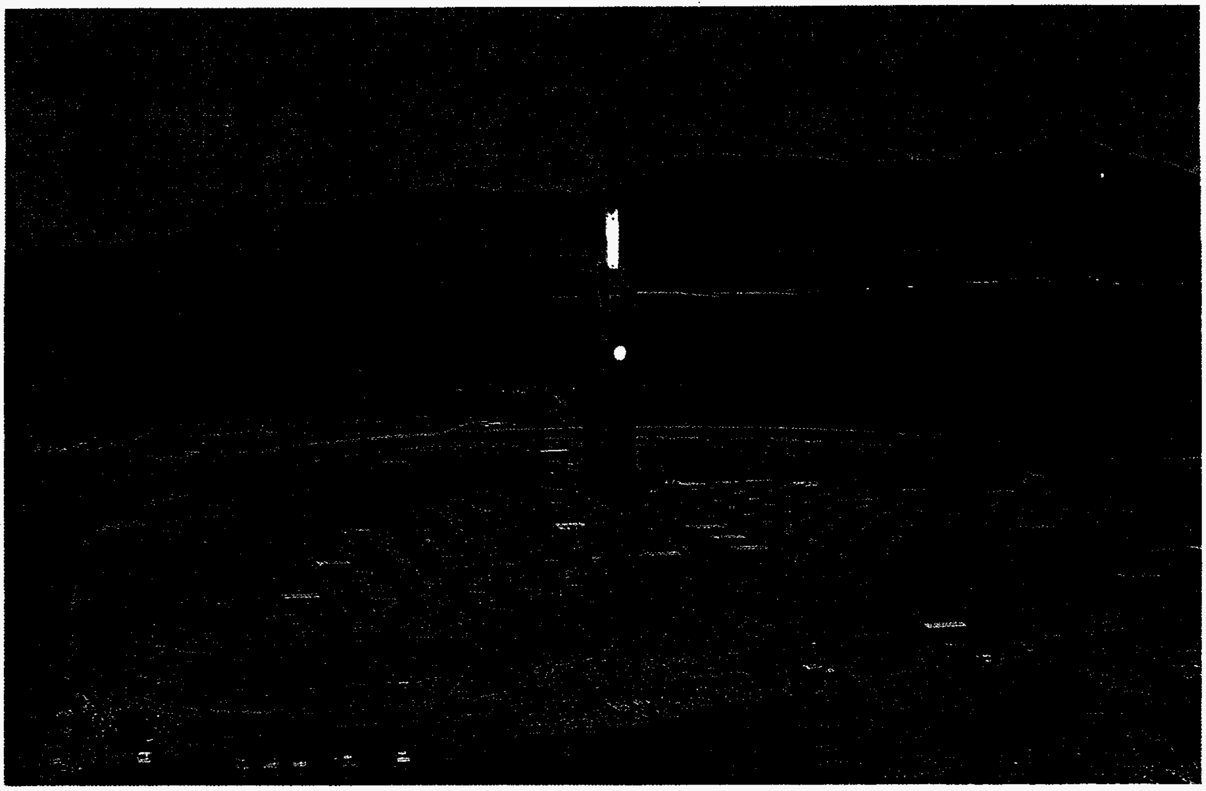
PROGRAM OBJECTIVE

The objective of the DOE Solar Thermal Central Receiver Repowering Program is to increase user confidence and experience with central receiver technology to the point that it becomes a practical future renewable energy system choice. The central receiver program has a goal of generating 1 QUAD of energy by the year 2000. The steps toward commercialization have progressed from design and testing of individual central receiver components at DOE test facilities, like the central receiver test facility (CRTF) at Sandia National Laboratories in Albuquerque, New Mexico, to design and construction of the cost-shared* central receiver system at Barstow, California. The next step toward commercialization is to provide valid demonstrations of central receiver technology in a variety of industrial settings under direct control of the users involved. The repowering program will provide the opportunities for these commercial demonstration projects.

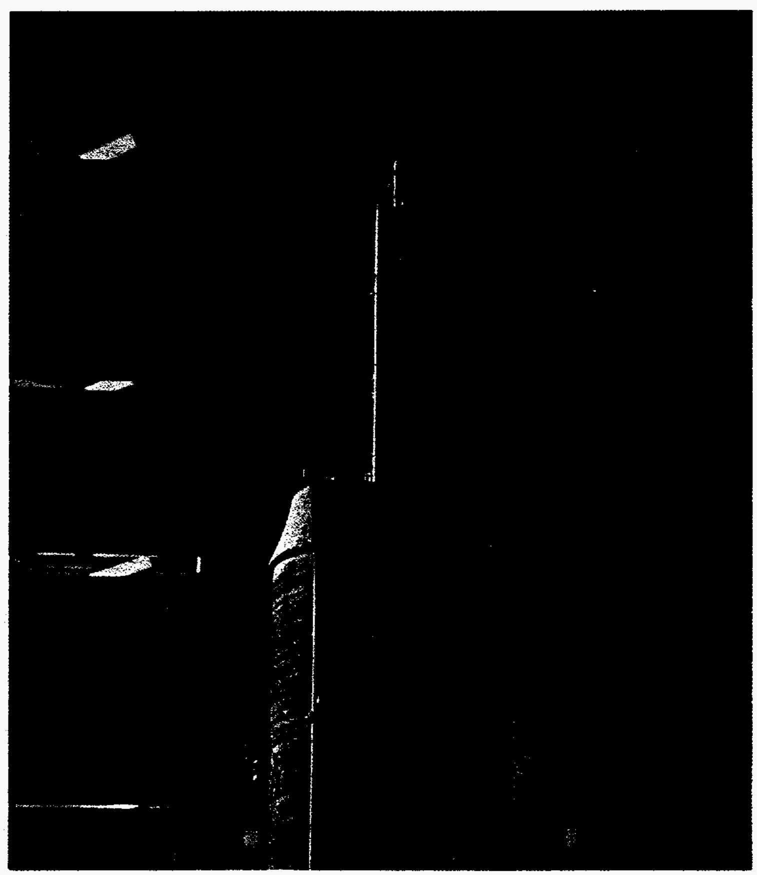
These projects will give industry practical hands-on experience in true industrial settings by interfacing with existing commercial plants, and will provide a continued demand for design and fabrication of central receiver components (e.g., receivers, heliostats, and storage). The projects will also supply cost, operating and maintenance, reliability, and economic data which could be the basis for some initial, privately-funded commercial applications of central receiver technology, as well as displacing significant amounts of oil and natural gas that would otherwise be consumed. These projects are essential steps toward commercialization.

A draft solar thermal central receiver repowering program element plan was released January 1980 and circulated within industry and government for comment. The comments received will be considered for any future revision of the plan. This plan focuses on the near-term opportunity of repowering existing oil and gas-fueled plants with solar energy and providing the commerical viability of solar central receivers. The benefits of displacing premium fuels creates a high value for solar repowering in the 1980s.

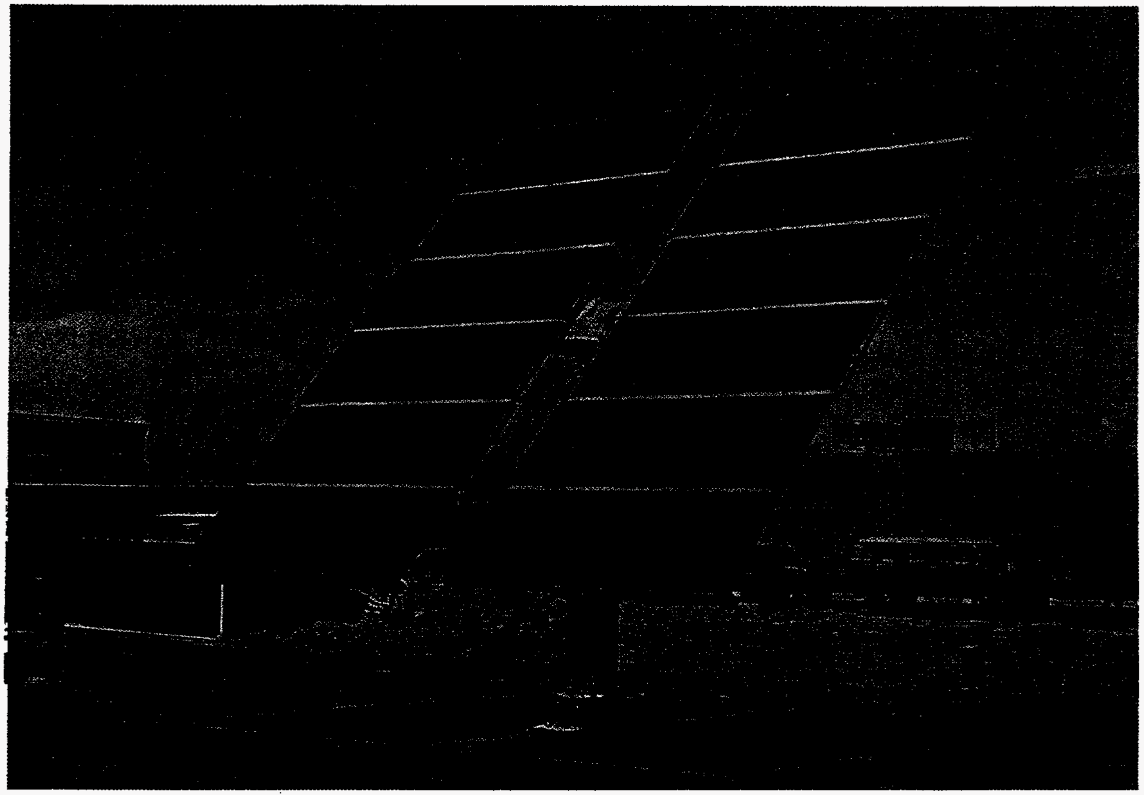
*The partners are Southern California Edison, Los Angeles Department of Water and Power, and the State of California Energy Commission.



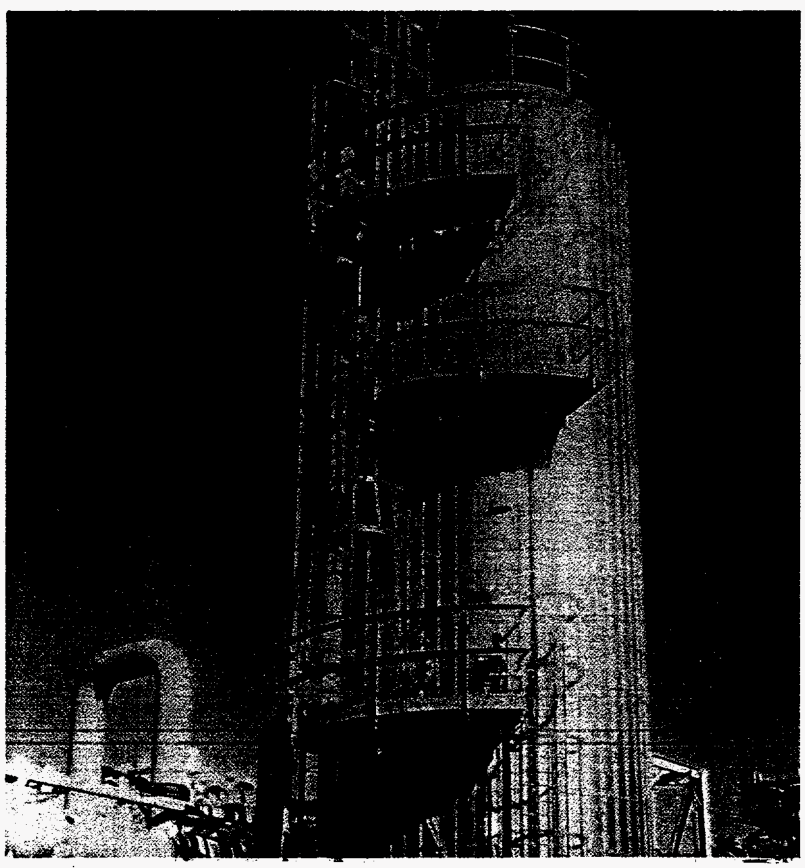
DOE Central Receiver Test Facility



Receiver Panel (Example)



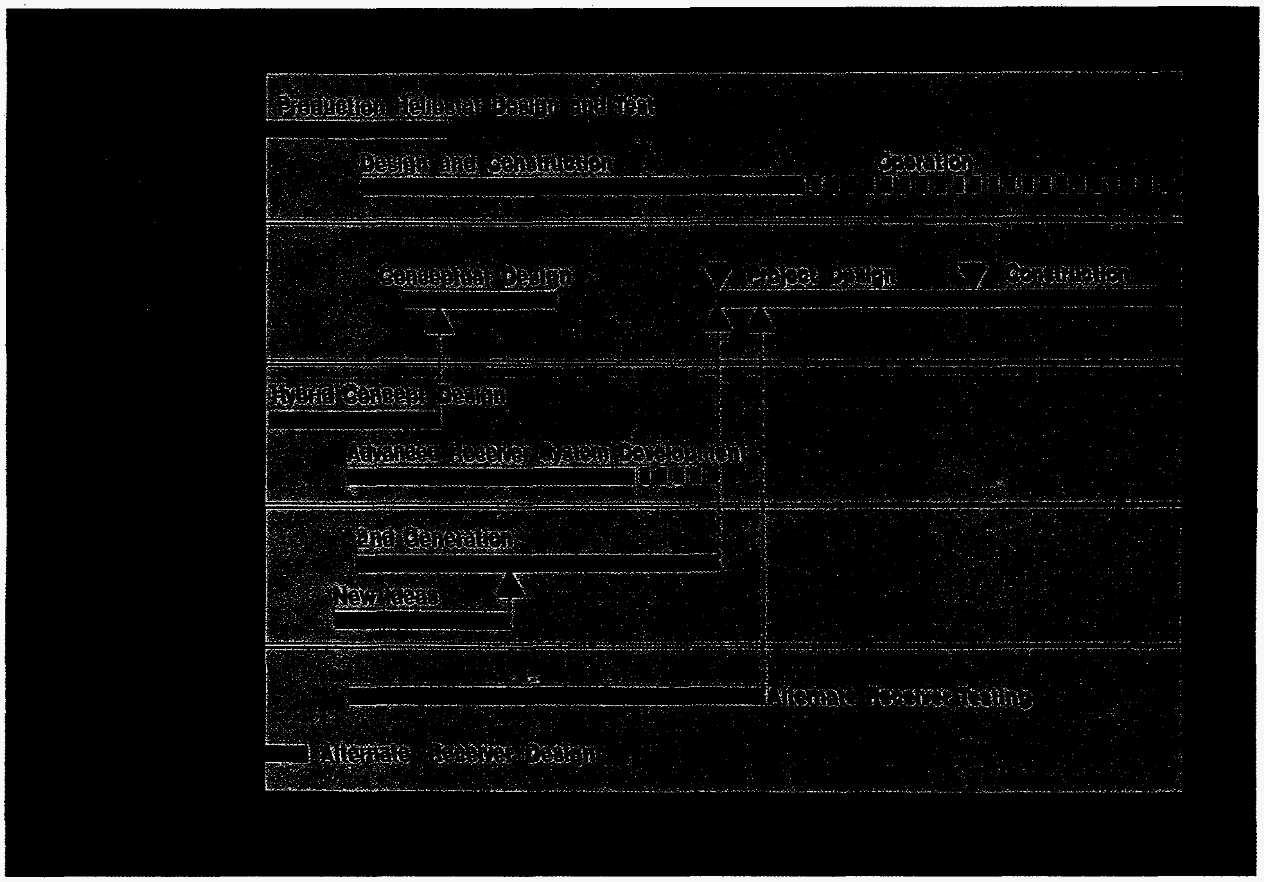
Heliostat (Example)



Solar Energy Storage Unit (Example)

The timing of these projects is critical. Utilities and industries are now forming their construction plans for the 1990s, taking into account the energy conversion mandate promoted by the 1978 Fuel Use Act. This situation makes the repowering commercial demonstration projects essential if solar central receivers are to be considered for the next round of industrial investment commitments. Missing this near-term window would prevent the acquisition of important operation and economic information needed for industrial decisions, and will effectively delay the commercialization of solar-powered plants well into the 1990s or beyond.

The following pages briefly summarize each of the 14 repowering conceptual design studies completed by or before July 1980. The conceptual designs are representative of actual plants that could be constructed if funding were approved.



Central Receiver Systems Program Schedule

ARIZONA PUBLIC SERVICE-Saguaro Power Plant, Unit 1

PRIME CONTRACTOR	SUBCONTRACTORS
Arizona Public Service Co.	Martin Marietta Corp. Badger Energy, Inc. Gibbs & Hill, Inc.

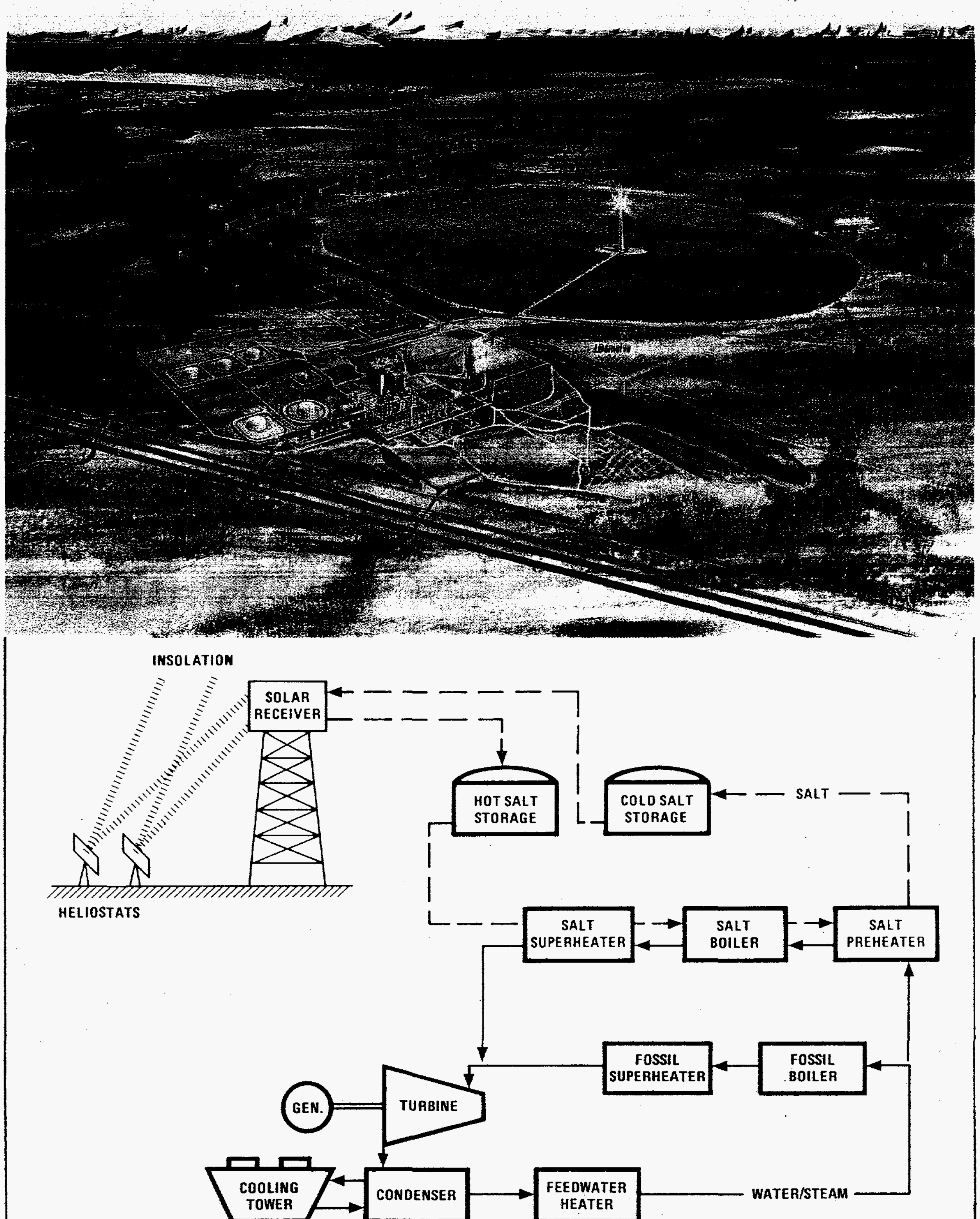
SITE DESCRIPTION--Arizona Public Service Company's Saguaro power station is situated on a triangular-shaped section of land east of Interstate Highway 10 and the Southern Pacific rail line, approximately 75 miles south of Phoenix. The area immediately surrounding the power station is state-owned, and has been reserved by the State of Arizona for the solar repowering project. The Saguaro Station consists of two oil/gas-fired steam units having electrical outputs of 115 and 99 MWe. The station also has two 55-MWe combustion turbines that serve as peaking units. The steam units are used for intermediate power production and were installed in 1954 and 1956. Based upon data from solar monitoring stations in Tucson and Gila Bend, the Saguaro Station site is estimated to have an average direct normal insolation of 6.90 kWh/m^2-day.

PROJECT SUMMARY--The portion of the Saguaro station selected for repowering is the 115-MWe oil/gas-fired steam plant designated as Unit 1. The concept being pursued involves repowering 112 MWe of the 115-MWe unit. Saguaro plant Unit 1 contains a single-admission, non-reheat turbine using 1000°F and 1475 psia steam supplied by an oil/gas-fired steam generator. The total project could be designed and built in about four years.

CONCEPTUAL DESIGN--Conceptual design for solar repowering is the central receiver power tower concept using molten salt (60 percent sodium nitrate, 40 percent potassium nitrate) as the receiver heat transport fluid. Tower height is 509 feet with a surrounding collector field of 10,500 heliostats. The receiver is a four-aperture cavity-type with dimensions of 85 x 85 x 98 feet high. Hot molten salt is pumped to the thermal storage subsystem. Four hours of thermal storage at 112 MWe is provided by a storage subsystem comprised of an internally-insulated hot salt tank and an externally-insulated cold salt tank. Hot molten salt, at 1050°F, is pumped from the hot tank to a salt/steam heat exchanger subsystem made up of a preheater, boiler, evaporator, and superheater supplying 1000°F, 1475 psia steam to the Saguaro Unit 1 steam turbine. The solar plant interfaces with the Saguaro Unit 1 main steam line to the turbine inlet and at the feedwater line to the fossil steam generator.

FUNCTIONAL DESCRIPTION--When solar energy is available, salt is pumped from the cold salt tank at 530°F to the solar receiver where it is heated to about 1100°F. The salt pressure in the receiver varies from about 275 psi at the inlet to about 20 psi at the outlet. The heated salt returns to the hot salt tank where it is pumped to the heat exchanger string to generate steam for the turbine operation at 1000°F, 1450 psia.

The turbine operates the same on solar-generated steam as it does on fossil-generated steam, with five steam extractions from the turbine for feedwater heating. Exhaust steam is condensed in a conventional water-cooled unit where the heat is removed and then disposed of in a cooling tower.



Arizona Pacific Service Company's Saguaro Power Station Solar Repowering Project

EL PASO ELECTRIC COMPANY-Newman Unit 1

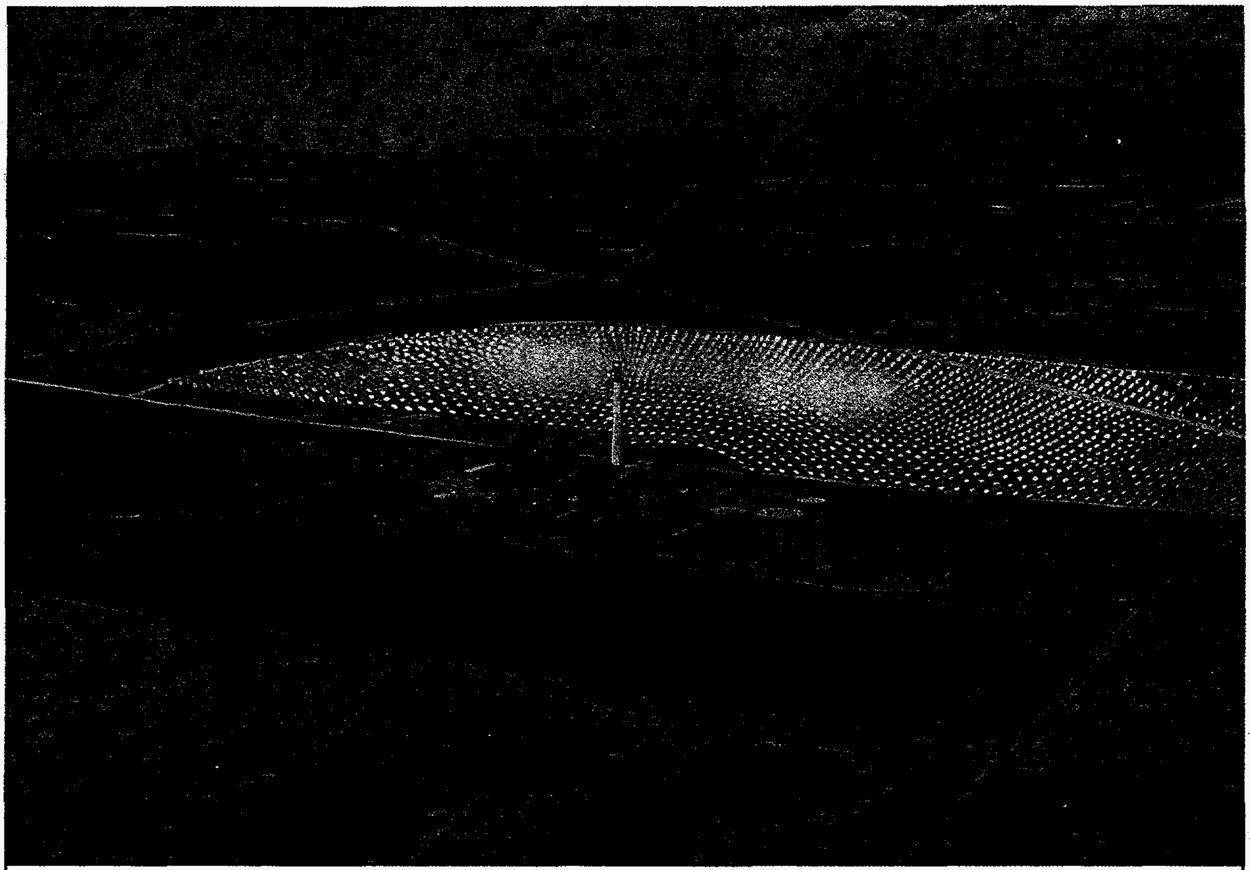
PRIME CONTRACTOR	SUBCONTRACTORS
El Paso Electric Company	Stone & Webster Westinghouse

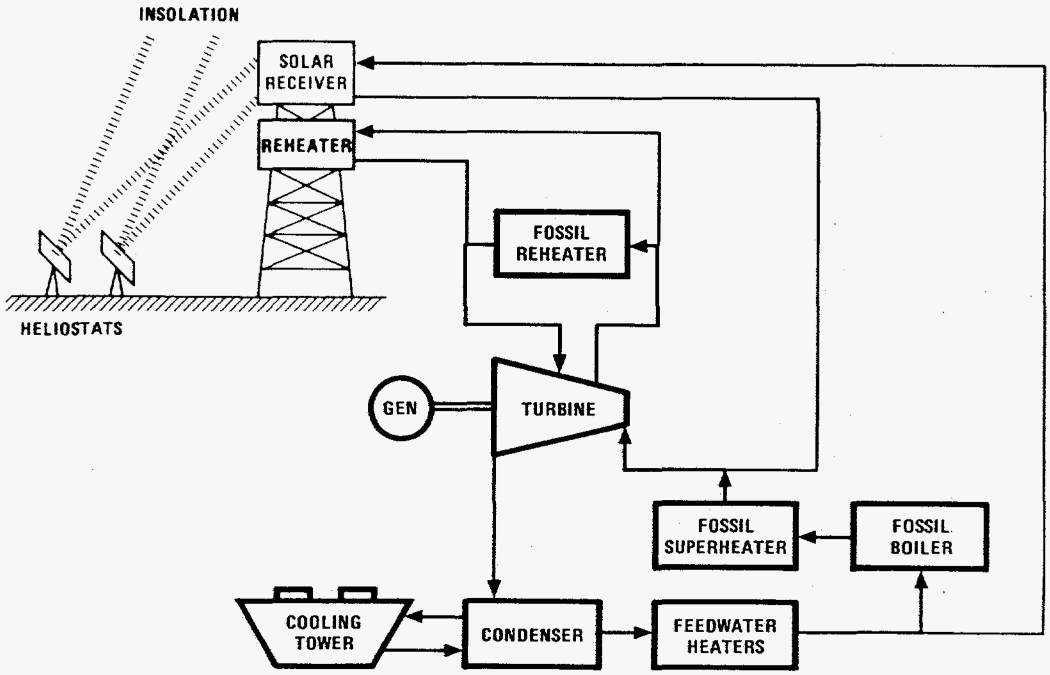
SITE DESCRIPTION--El Paso Electric Company's Newman Station is located in a rural area 15 miles northeast of downtown El Paso, and 12 miles from the El Paso SOLMET weather station. Newman Station consists of four electric power generating units rated at a combined total of 498 MWe. Newman Unit 1, selected for solar repowering, is an 82.3 MWe gas/oil-fired reheat steam turbine built in 1960. Newman Station is surrounded by 3,500 acres of flat land at an elevation of 4065 feet. It is owned by El Paso Water Utilities Public Service Board. The Board agreed in a public meeting held April 25, 1979, in El Paso, to make the land available for solar repowering. The average direct normal insolation is estimated to be 7.26 kWh/m^2-day.

PROJECT SUMMARY--The concept selected involves repowering approximately 40 MWe of Newman Unit 1. Fossil energy will supplement solar-generated steam for intermittent cloudy-day operation when solar energy is reduced, and for economic dispatch. Steam generated by the solar subsystem will be mixed with that from the existing fossil steam generator before entering the turbine. Considerable modifications to the existing mechanical/hydraulic turbine controls and pneumatic boiler controls will be necessary. The control system of the existing unit will be modified and interfaced with the solar system by means of a master control system. The total project could be designed and built in about four years.

CONCEPTUAL DESIGN--The preferred configuration for solar repowering Newman Unit 1 is an advanced external water/steam central receiver with pumped recirculation. This technology, under development by the DOE, can provide 1000°F main and reheat steam at 1450 psia to the turbine-generator. This technology, known throughout the utility industry, was selected on the basis of utilizing commercial/utility boiler design approaches using conventional boiler materials with known properties and demonstrated lifetimes. There are two solar receivers for this project, one for the main steam supply and the second for the reheat steam supply. Primary and reheat receivers each have a 54-foot length and subtend an arc of 210 degrees. Thermal energy storage systems are technically not required, and their absence lowers cost and increases concept reliability. The 160-degree north heliostat field consists of 2,776 Westinghouse heliostats (81.8 m^2) and provides 141 MWt at the receivers located on a 480-foot concrete tower. The Newman Unit 1 turbine building is located 140 feet from the base of the receiver tower, greatly reducing piping costs and enhancing performance.

FUNCTIONAL DESCRIPTION--The principal solar/fossil interface between the existing Newman Unit 1 and the solar subsystem consists of (1) steam supply interface from the solar (both primary and reheat receivers) and the fossil steam generators, (2) feedwater interface supply to the solar and fossil steam generators, (3) control interface between the fossil and solar subsystems, and (4) power supply interface to the heliostat field, primary and reheat receivers, valves, and pumps. Steam generated by solar will be mixed with the steam provided by the existing fossil steam generator prior to admission to the high-pressure and intermediate stages of the turbine.





El Paso Electric Company's Newman Power Station Solar Repowering Project

SIERRA PACIFIC POWER UTILITY-Ft. Churchill Plant, Unit No. 1

PRIME CONTRACTOR

McDonnell Douglas

SUBCONTRACTORS

Sierra Pacific Power Company
Stearns-Roger Services
Desert Research Inst.
Foster Wheeler Development Co.
University of Houston
Westinghouse Electric Co.

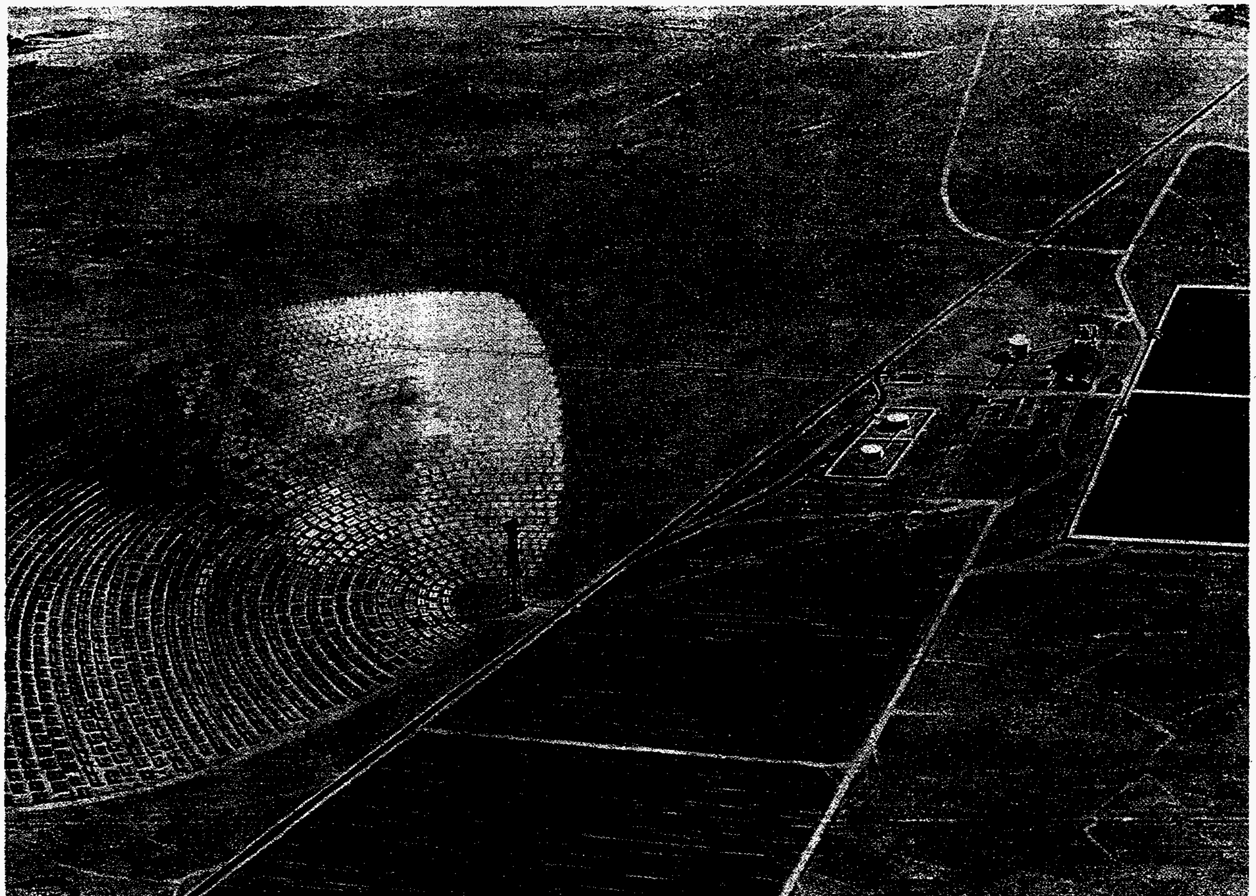
SITE DESCRIPTION--Sierra Pacific Power Company's (SPPCo) Ft. Churchill plant is located near the small town of Yerington, Nevada, 47 miles southeast of Reno. The plant has two identical oil/gas-fired reheat units each operated at 115 MWe. Turbine conditions are 1890 psia inlet pressure at 1000°F with 1000°F reheat at 422 psia. SPPCo owns approximately 10 square miles of land surrounding the plant. The land is typical high desert (4300 feet elevation) with a surface composition of silty sand. The terrain is relatively smooth and level with a slight slope east toward the Walker River. The average direct normal insolation is about 7.2 kWh/m^2-day.

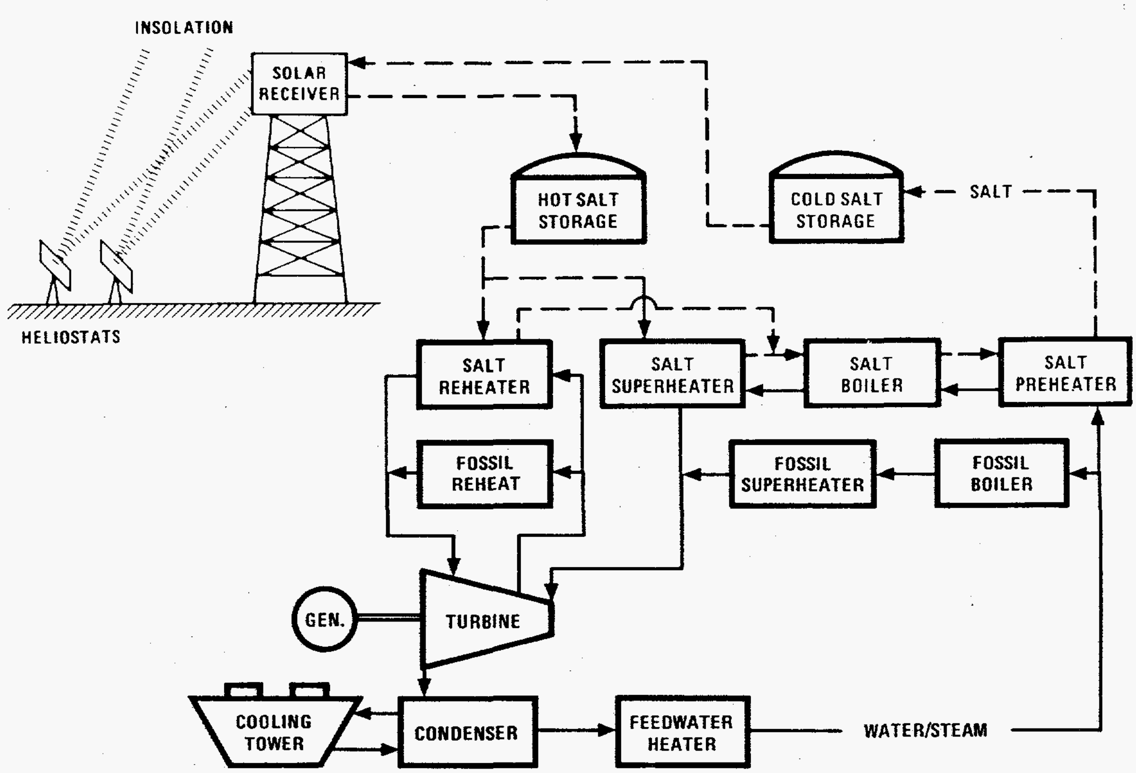
PROJECT SUMMARY--Unit No. 1, completed in 1962, was selected for repowering, and is expected to provide 77 MWe from solar. The solar energy operation will displace oil and gas estimated at 490,000 barrels oil-equivalent per year. The project would take about four years to design and build.

CONCEPTUAL DESIGN--The conceptual design is a molten salt, storage-buffered system. The fluid is heated in the partial cavity receiver to 1050 F. The hot molten salt flows to the thermal storage tanks where a storage capacity of approximately six hours is provided. Salt is withdrawn from storage to generate steam for the turbine. Eighty-four hundred and eleven MDAC second-generation heliostats will be required. The collector field will deliver approximately 330 MWth to the receiver fluid at the design point (equinox noon). A two-tank thermal storage unit with a storage capacity of 1150 MWh has been selected. Separate straight-tube, floating-heat exchangers provide water/steam evaporation, preheat, superheat, and reheat. Plant operation from solar energy can be initiated as soon as 100 MWh is accumulated in the thermal storage unit. Electric power from solar can continue to be generated as long as 100 MWh remains in sotrage. Transition to shutdown, or to fossil operation, will occur when thermal storage is depleted.

FUNCTIONAL DESCRIPTION--Thermal energy absorbed into the molten salt at the receiver is circulated to the storage subsystem and stored in the hot salt tank. Steam is generated in four heat exchangers (preheater, boiler, superheater, and reheater) by taking hot salt from the storage tank. Steam generated from the solar portion of the plant is mixed with steam generated in the fossil-fueled boiler and directed to the turbine. Solar-only and fossil-only operating modes are also possible.

Since the system is storage coupled, storage can be simultaneously charged and discharged. Steam can be sent to the turbine at rates from zero flow up to the maximum rate of the heat exchangers. The thermal storage system can accept heated molten salt from a zero flow rate up to the maximum output rate of the receiver.





Sierra Pacific Power Company's Ft. Churchill Power Station
Solar Repowering Project

SOUTHWESTERN PUBLIC SERVICE COMPANY-Plant X, Unit 3

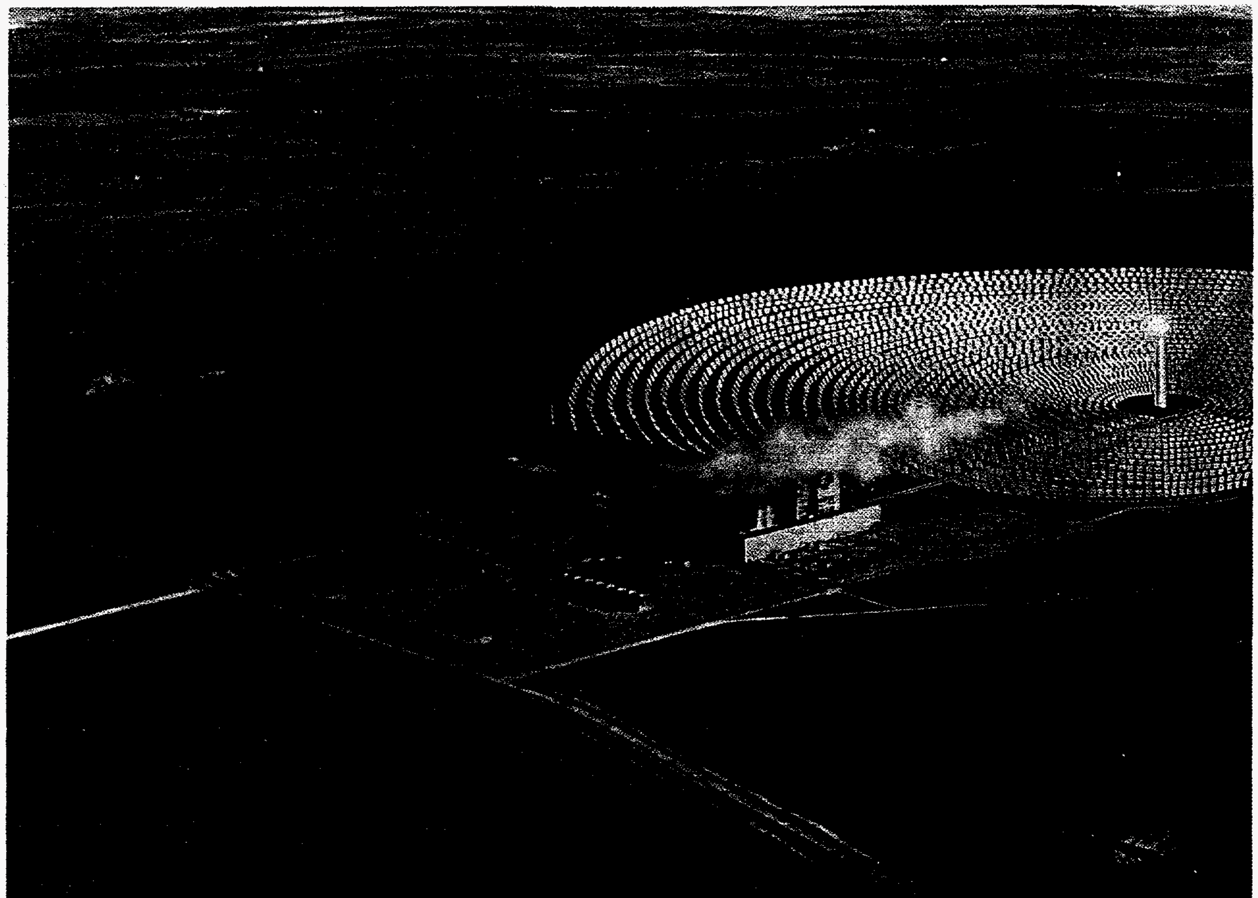
PRIME CONTRACTORS	SUBCONTRACTORS
General Electric Company Energy Systems Programs Department	Southwestern Public Service Kaiser Engineers

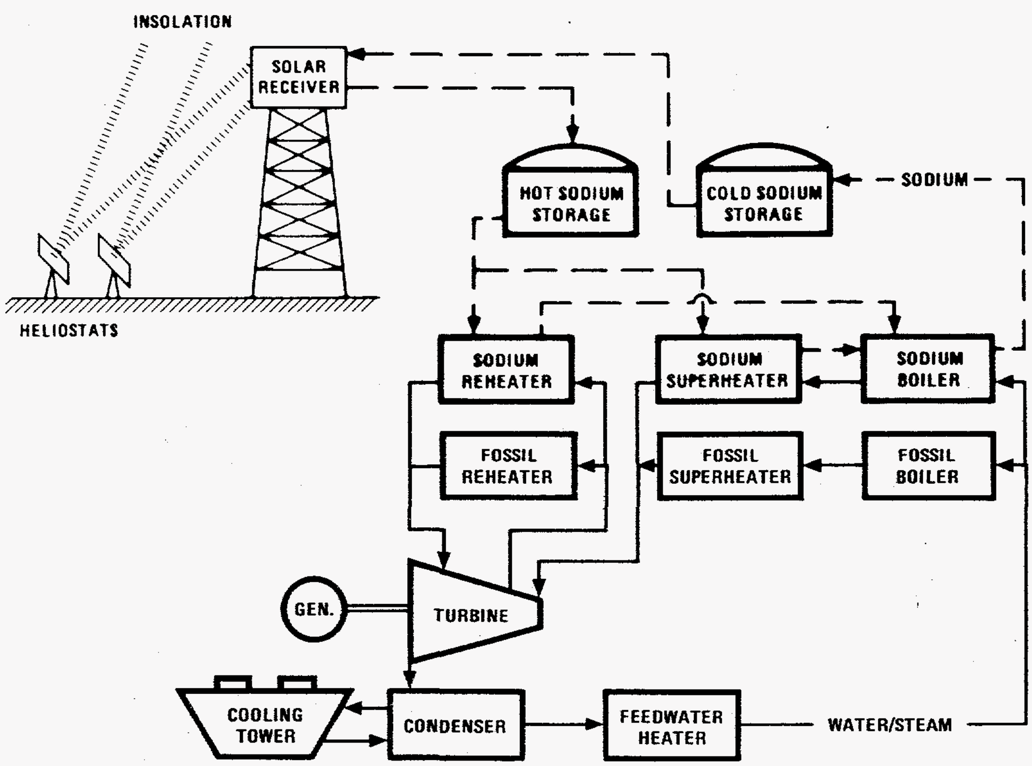
SITE DESCRIPTION--The site selected for the Southwestern Public Service Company (SPS) Solar Repowering Program study is Plant X, located near Earth, Texas, approximately 100 miles south of Amarillo. SPS owns approximately 1700 acres of unused land, generally flat and semi-arid, surrounding Plant X. The plant's elevation is 3660 feet. Solar repowering will utilize 220 of the 1700 acres available. The Plant X facility has four gas-fired generating units, although each can be fired by oil as a backup. Unit 3 is a 100-MWe reheat plant typical of other repowerable facilities in the Southwest. Direct normal insolation measurements have been recorded at a station eight miles from the site since August 1979. The estimated average direct normal insolation at the site is 6.5 kWh/m^2-day.

PROJECT SUMMARY--The SPS repowering system is to be operated in parallel with Unit 3 to provide 60 MWe of a total 100 MWe for the combined unit. The 40 MWe of fossil generation was chosen because it is the minimum boiler operating level under automatic control. The sodium-cooled receiver proposed for repowering will reflect General Electric's design and test experience gained from the Advanced Central Receiver Phase II program now being conducted for the DOE. The project has been tailored to ensure that reliable plant electrical output will be available at all times, with a significant amount of natural gas being displaced by solar whenever adequate insolation is available. This project would take about four years to design and build.

CONCEPTUAL DESIGN--The baseline conceptual design is a sodium-cooled solar central receiver heated by 4809 heliostats. The storage provided for the plant will be limited to approximately 10 minutes, a level sufficient to buffer the total plant output from solar transients. The 10-minute system will function identically to a larger storage system and thus will adequately demonstrate the storage concept for future plants.

FUNCTIONAL DESCRIPTION--The solar portion of the proposed system consists of a surrounding field of glass heliostats reflecting the solar energy to a tower-mounted cylindrical receiver. The receiver is cooled by liquid sodium with the flow rate through each receiver panel controlled by individual electromagnetic pumps to maintain a constant outlet temperature. The hot sodium flows to an in-line hot buffer storage system and then to the steam generator heat exchangers. Cold discharge sodium returns to the receiver through an in-line cold buffer storage tank. The steam lines of the superheater, reheater, and evaporator will parallel their respective fossil-fired components. The steam flows from the fossil and solar plants will be combined and routed to the steam turbines to produce the desired plant output. The impact on the existing plant is limited to piping tie-ins and controls modifications.





Southwestern Public Service Company's Plant X Solar Repowering Project

TEXAS ELECTRIC SERVICE COMPANY*-Permian Basin Unit 5

PRIME CONTRACTORS	SUBCONTRACTORS
Rockwell International Energy Systems Group	Stearns-Roger Services McDonnell Douglas University of Houston

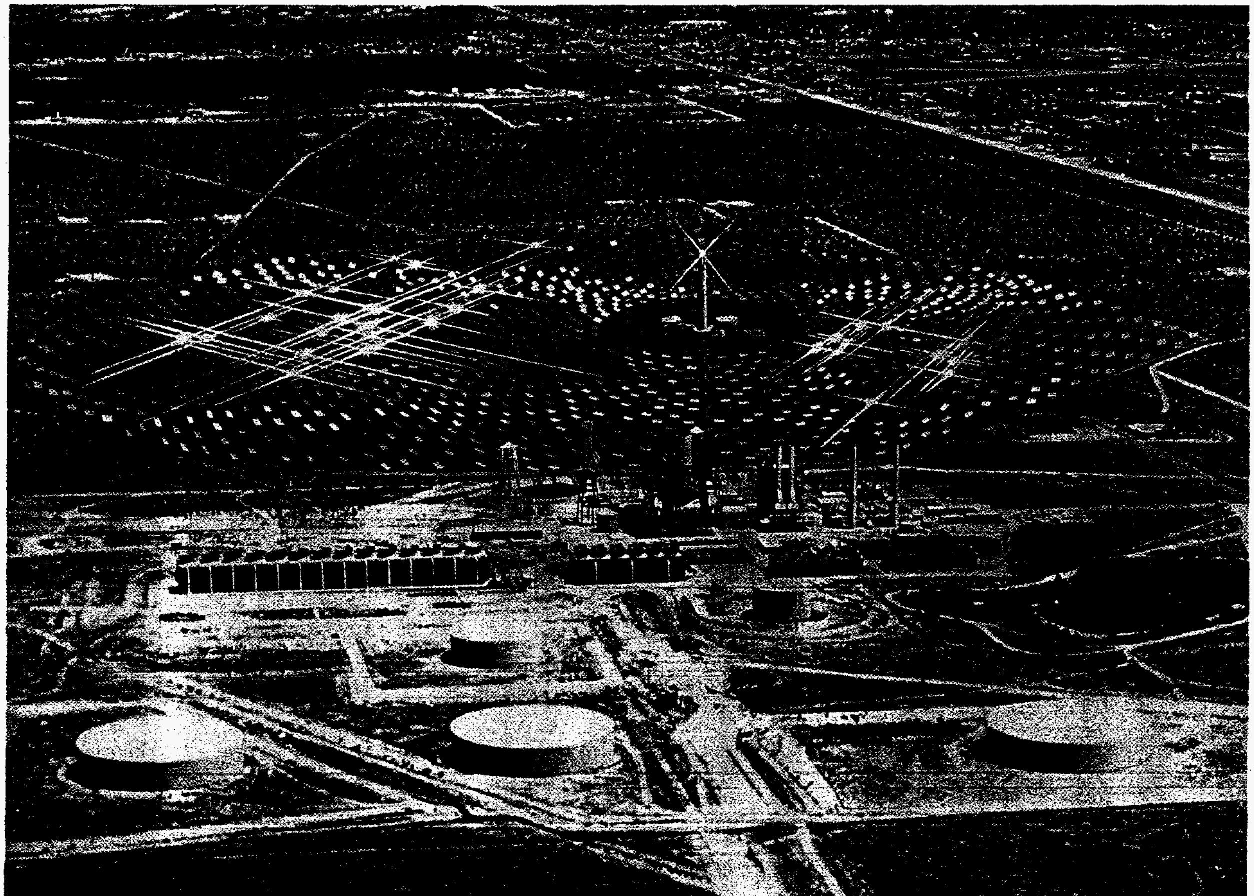
SITE DESCRIPTION--The Texas Electric Service Company's Permian Basin Steam Electric Station is located four miles west of Monahans, on 640 acres of land owned by Texas Electric Service Co. Approximately 160 acres are occupied by the current facility, and 400 acres are brush-covered and unused except for several oil wells. The property is at an elevation of 2650 feet with a gentle slope to the southeast. The station consists of six units. Unit 5, the candidate for repowering, is a 115-MWe gas/oil-fired intermediate-load reheat system. The fossil boiler supplies 1005°F superheat steam at 1516 psia, and 1005°F reheat steam. The turbine is a tandem compound, double-side exhaust, 3600-rpm, condensing type, and has a nominal gross heat rate of 8457 Btu/kWh. The condenser is cooled by water from a wet cooling tower. Average direct normal insolation is indicated to be 6.0 kWh/m^2-day.

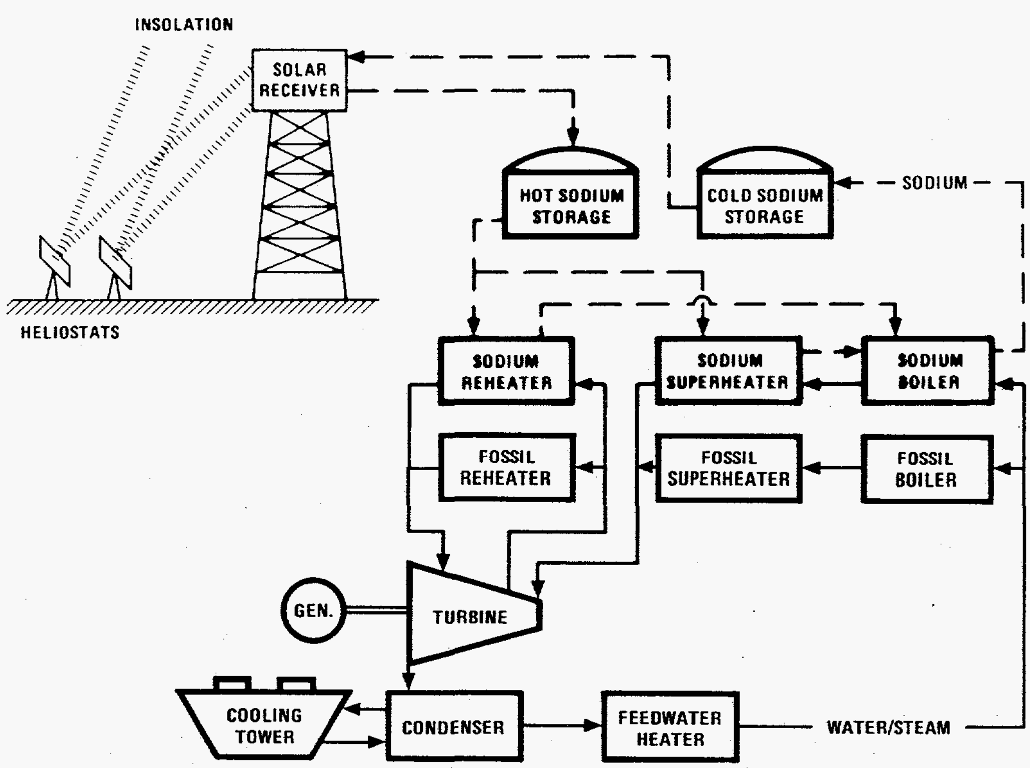
PROJECT SUMMARY--A liquid sodium-cooled central receiver was chosen to repower the existing fossil-fueled Permian Basin Unit 5. This type of receiver is small and light in weight, a single-phase fluid simplifies receiver operation, reheat is readily accomplished, and thermal storage is easily incorporated. The solar system has a thermal power input equivalent to 50 MWe, or about 42 percent of the gross rated power of 120.8 MWe of the existing steam boiler. A storage system is provided to permit operation of the plant from storage alone at 50 MWe for one hour. On an annual basis, the energy provided by solar, including the one-hour storage capability, will be about 28 percent of the total energy supply for Unit 5 in its current mode of operation. This project would take about four years to design and build.

CONCEPTUAL DESIGN--The receiver is the external type, approximately 35 feet in diameter by 44 feet high, located on top of a 360-foot tower. Solar energy in the form of heat is absorbed by the liquid sodium flowing through the receiver. Thermal storage acts as a buffer between the receiver and steam generator minimizing the effects of any receiver thermal transients. The solar portion of the plant is integrated into the existing plant by a tee in the feedwater line so the flow can be split between the boiler and the sodium-to-water evaporator unit, in accordance with the relative powers to be extracted from each. The existing feedwater pumps are expected to be adequate insofar as capacity and discharge pressure are concerned. The steam lines from the superheater and reheater are cut and mixing tees installed so the sodium-to-steam superheater and sodium-to-steam reheater are in parallel with the comparable units in the existing boiler. A master control system is provided to integrate the instrumentation and control elements of the solar and the fossil energy systems.

FUNCTIONAL DESCRIPTION--The hot sodium coming from the receiver flows into a hot storage tank. The sodium is then pumped by a second pump through a set of three steam generator units (an evaporator, a superheater, and a reheater) into a cold storage tank. From this tank the sodium is pumped to the top of the tower and back through the receiver. The central receiver system is integrated with the fossil plant by inserting a tee in the feedwater, superheater, and reheater lines. Feedwater is piped to the solar steam generators and steam, at the required conditions, is returned to the main steamline to be mixed with steam generatored by the fossil-fueled boiler.

*Texas Electric Service Company is a significant contributor to this study at its own expense.





Texas Electric Service Company's Permian Basin Steam Electric Station Solar Repowering Project

WEST TEXAS UTILITIES COMPANY-Paint Creek Power Station Unit 4

PARTICIPANTS (privately funded)

Energy Systems Group (ESG), Rockwell International
West Texas Utilities (WTU) Company
University of Houston

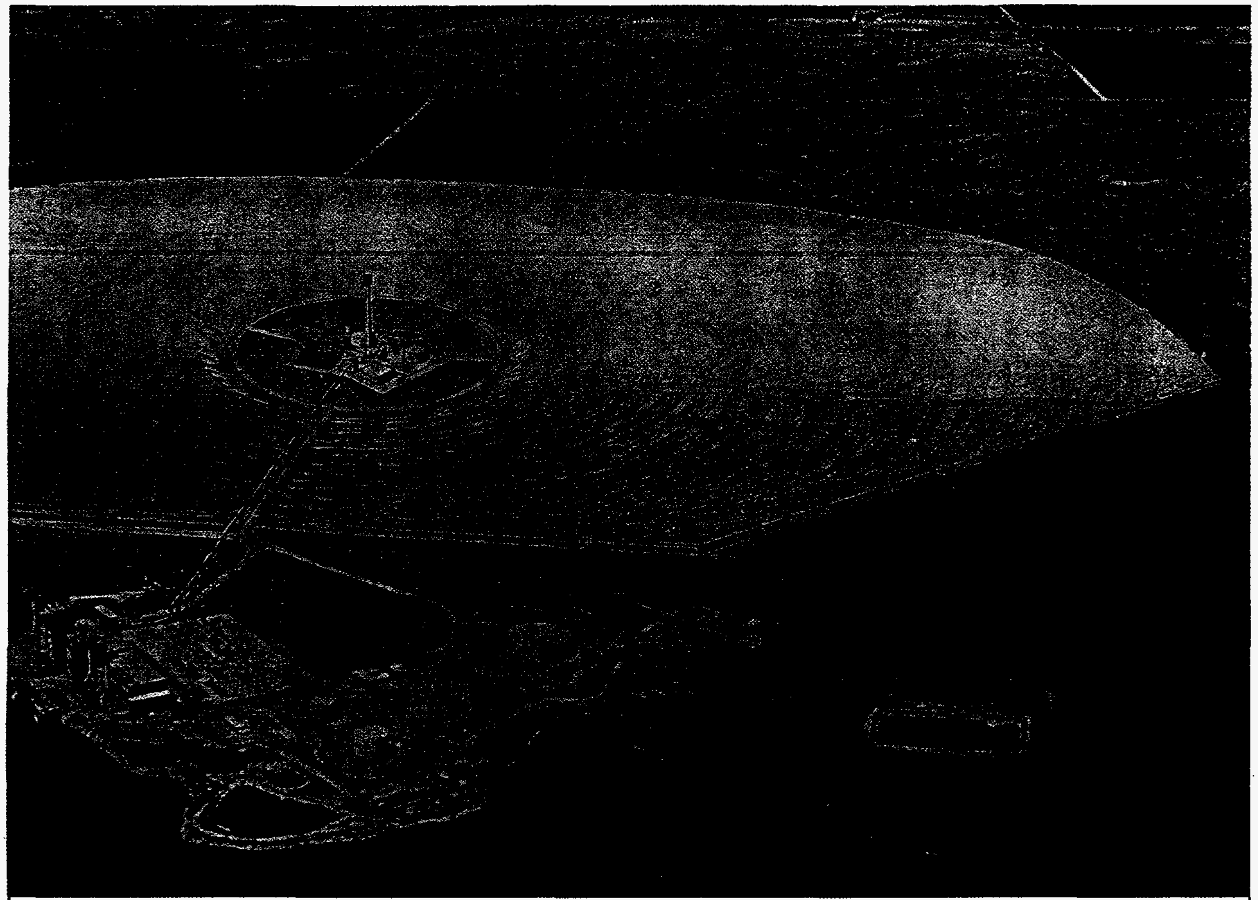
SITE DESCRIPTION--West Texas Utilities Company's Paint Creek Power Station is located about 48 miles north of Abilene. It is situated on 138 acres on a north shore peninsula of Lake Stanford in Haskell County, at an elevation of about 1425 feet. Haskell County has a subhumid, warm temperature, continental climate. Adequate land is available north of the site for a collector field. The Paint Creek Power Station Unit 4 has a net power output of 110 MWe. It is fired by natural gas under normal operation and uses No. 2 fuel oil for emergency backup. Unit 4 was placed in operation in 1972 and is operated as a base load plant. It employs a steam rankine cycle with main steam at 1000°F, 1450 psia, and reheat steam at 1000°F. The turbine is a GE tandem compound two-flow unit with a gross turbine heat rate of 8258 Btu/kWh. The plant heat rate is 10,200 Btu/kWh at full load. No direct insolation data was available for Paint Creek, but data is available at the Abilene weather station 60 miles south. The estimated average insolation at the site is about 6.43 kWh/m^2-day.

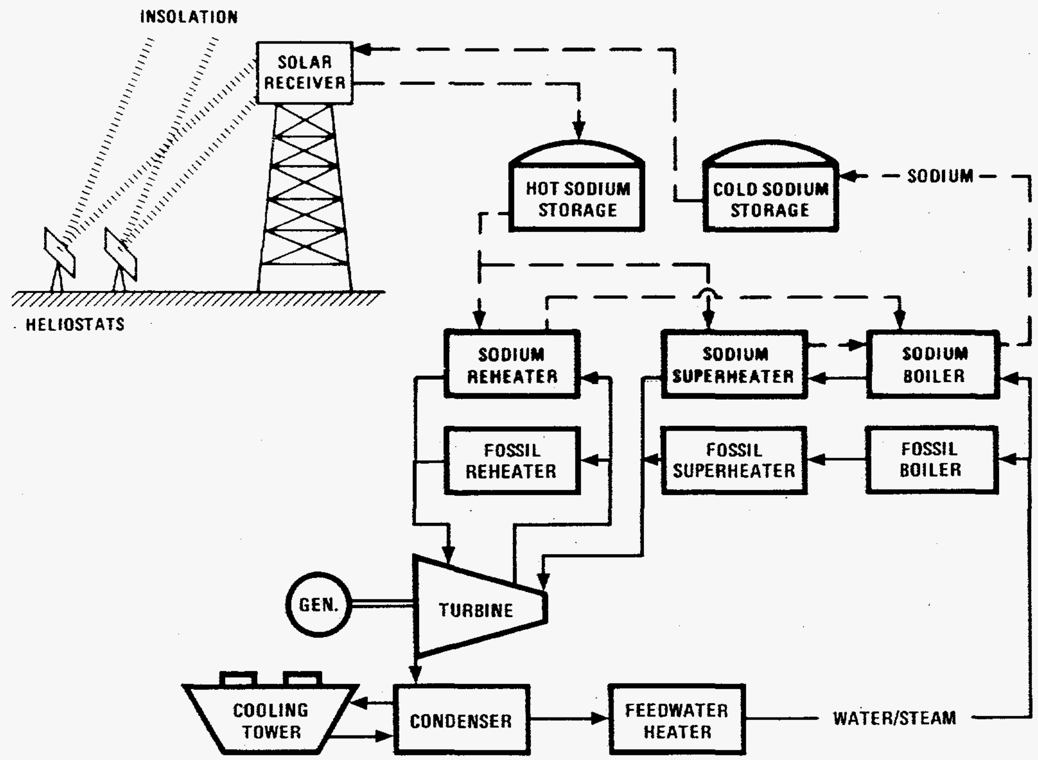
PROJECT SUMMARY--The collector field is sized for a solar multiple of 1.56 to provide about four hours storage at equinox. The storage level for winter solstice, 1.73 hours at 60 MWe, is necessary for all-night operations at 10 percent solar plant capacity, the lowest practical value for control system stability. The objective is to achieve limited continuous operation at winter solstice. This strategy is viewed as potentially increasing the solar system reliability by minimizing thermal cycling and providing many more hours of operating experience useful even at reduced power levels.

At a repowering level of 60 MWe, and with enough thermal energy storage to permit operation at full power for about four hours, it is estimated that approximately 53 billion cubic feet of natural gas (equivalent to 9 million barrels of oil) will be saved over the 30-year lifetime of the plant. There is a good match between peak power demand on the utility system and solar energy availability.

CONCEPTUAL DESIGN--The solar central receiver system consists of a sodium-cooled receiver mounted on top of a 505-foot concrete tower surrounded by a field of 7882 heliostats. Solar energy in the form of heat is absorbed by the liquid sodium flowing through the receiver. Thermal storage is buffered between the receiver and steam generator minimizing the effects of receiver thermal transients. The solar portion of the plant is integrated into the existing plant by a tee in the feedwater line so the flow can be split between the boiler and the sodium-to-water evaporator unit. The existing feedwater pumps are expected to be adequate. The steam lines from the superheater and reheater are cut and mixing tees installed so the sodium-to-steam superheater and sodium-to-steam reheater are in parallel with the existing boiler. A master control system is provided to integrate the instrumentation and control elements of the solar and the fossil energy systems.

FUNCTIONAL DESCRIPTION--Heat energy absorbed by the receiver is carried away by liquid sodium to a set of sodium-to-steam generators. The generators produce steam at the same temperatures and pressures as the fossil boiler in the existing plant. When solar energy is available, steam produced in the solar portion of the plant displaces that from the fossil boiler, reducing fossil fuel consumption and yet maintaining the original plant output. Storage of the solar energy is provided through separate hot and cold sodium storage tanks. This allows some of the energy obtained from the central receiver to be used instead of natural gas or oil fuels, even when the sun is not shining.





West Texas Company's Paint Creek Power Station Solar Repowering Project

PUBLIC SERVICE COMPANY OF NEW MEXICO-Reeves Station, Unit No. 2

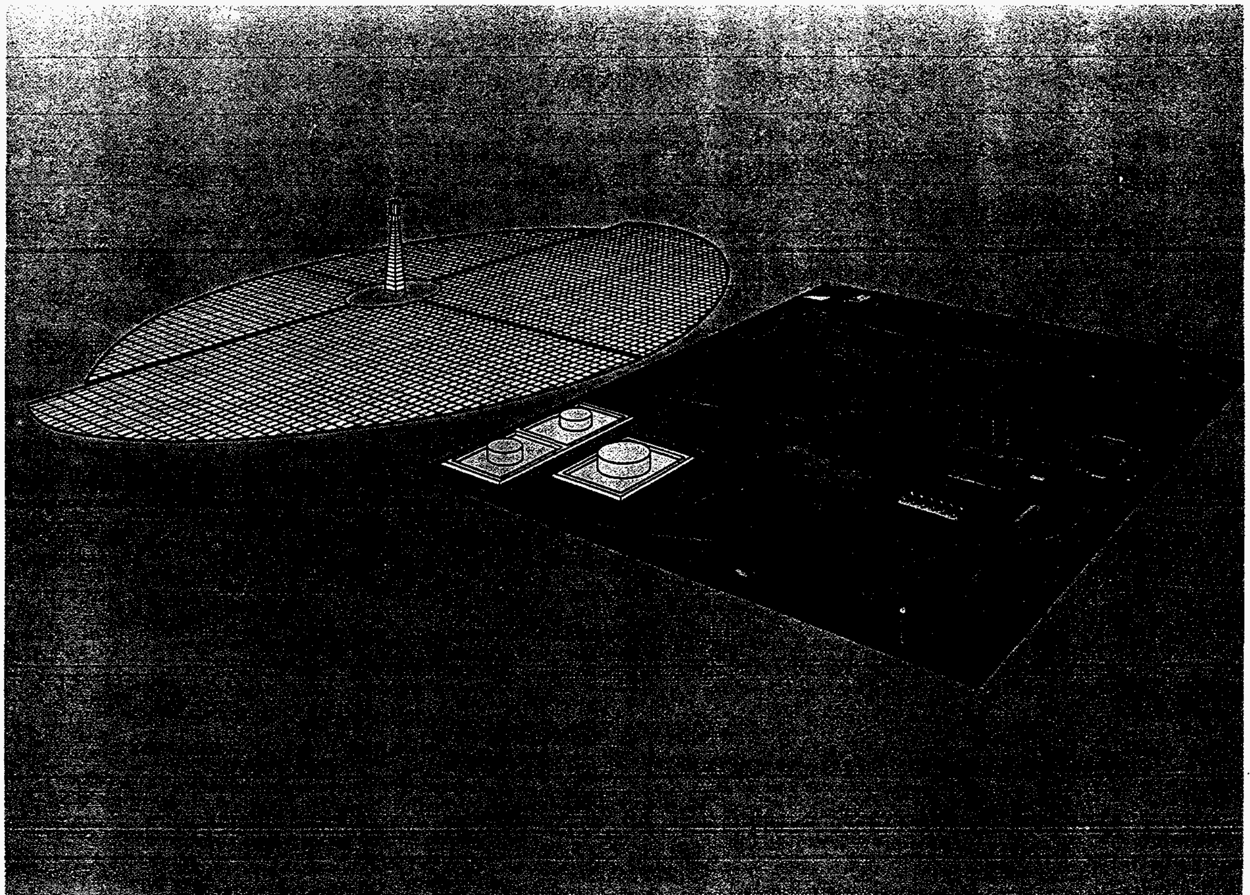
PRIME CONTRACTOR	SUBCONTRACTORS
Public Service Company of New Mexico	Stearns-Roger Services Westinghouse

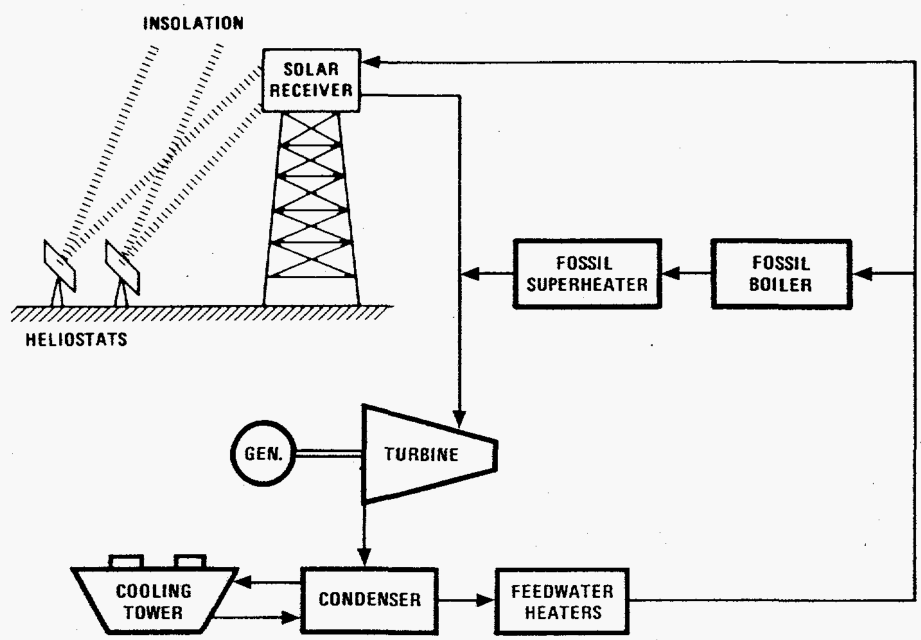
SITE DESCRIPTION--Public Service Company of New Mexico Reeves Station Unit No. 2 is located just north of Albuquerque, New Mexico. The Reeves Station site has approximately 30 acres available for the solar system, and an additional 125 acres of vacant land to the south of the present site boundary that can be made available through lease or purchase arrangement. The average direct normal insolation is approximately 6.6 kWh/m^2-day.

PROJECT SUMMARY--The Reeves Station has three oil/gas-fired steam electric units. Unit No. 2, a non-reheat steam turbine with a nameplate rating of 44 MWe, was selected for the repowering program for several reasons: the condition of the boiler and boiler auxiliaries is good; the boiler has minimal brick refractory and would be less affected by the expected temperature transients of hybrid operation; and the turbine generator is in good condition. It was recommended that additional water treatment be added for the solar repowering. The central receiver system will provide steam to generate 25 MWe at the design point insolation occurring at 2 p.m. winter solstice. The solar system nominally would provide 50 percent of full steam requirements, the remainder being supplied by the existing oil-fired boiler.

CONCEPTUAL DESIGN--The baseline central receiver design is a once-through type water/steam boiler located on top of a 423-foot concrete tower. Energy is optically transmitted to the receiver by 4100 mirrors (heliostats), each with a reflective area of 38 m^2. The tower is located in the center of this heliostat field. The design of the collectors and the solar receiver was based on the preliminary design of the 10-MWe pilot plant at Barstow, California. The conceptual design for this system was completed in September 1978, and is available through the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

FUNCTIONAL DESCRIPTION--Feedwater is pumped to the fossil boiler and solar receiver for heating. The superheated steam produced in parallel by the fossil and solar systems is piped to the turbine inlet, with waste steam piped through the condenser. The condensed water is then recirculated as feedwater back through the steam Rankine cycle.





Public Service Company of New Mexico's Reeves Station No. 2
Solar Repowering Project

ARCO OIL AND GAS COMPANY-North Coles Levee, Plant No. 8

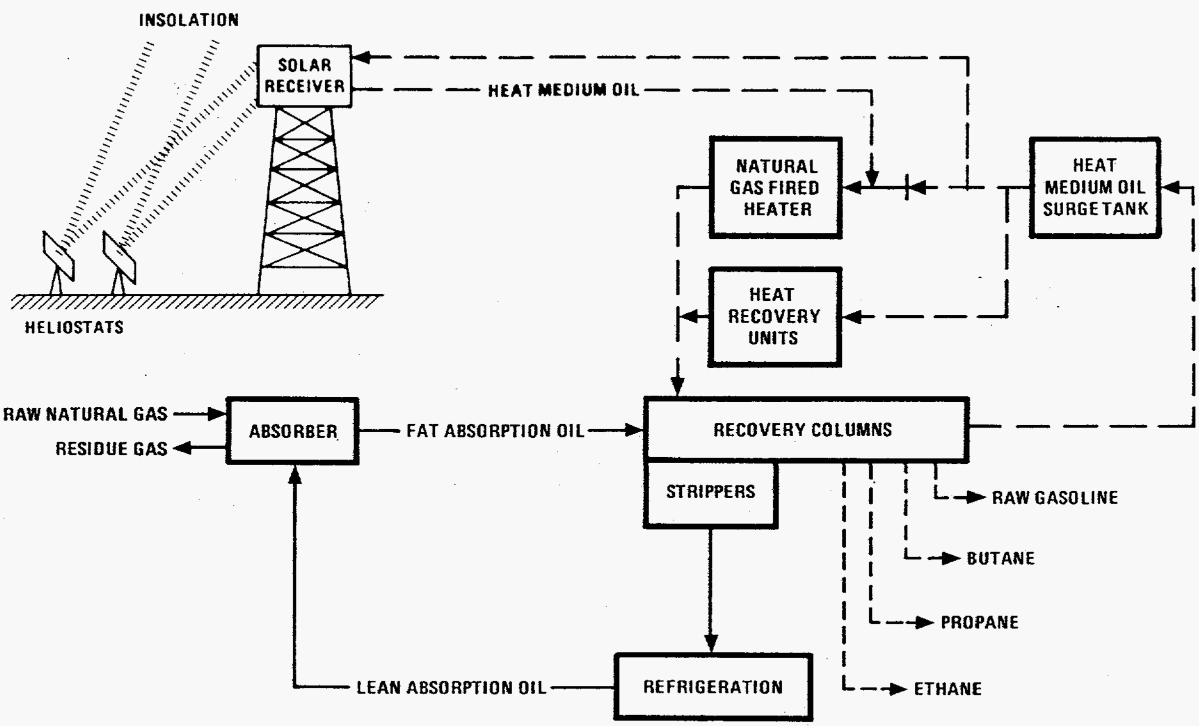
PRIME CONTRACTOR	SUBCONTRACTOR
Northrup, Inc.	ARCO Oil and Gas Co.

SITE DESCRIPTION--The ARCO Oil and Gas Company's North Coles Levee Natural Gas Processing Plant No. 8 is located 22 miles west of Bakersfield, California, at an average elevation of 300 feet above sea level. The plant is located within the North Coles Levee oil field which encompasses approximately 5000 acres. The oil field, including the plant site, is leased from Tenneco West Inc. The terrain is relatively flat. The area contains numerous operating gas wells, oil, gas and water lines, and electric power distribution facilities. The climate is warm and semi-arid. The plant is a refrigerated absorption oil plant that recovers propane, butane, and gasoline from raw natural gas. The process heat system consists of bubbling raw gas through an oil that absorbs hydrocarbons with molecular chains longer than methane's. The process oil is then heated to drive off the absorbed hydrocarbons which, in turn, are selectively heated to separate ethane, propane, butane, and gasoline. For safety reasons, the entire process avoids the direct use of flame and is powered instead by a remotely heated Heat Medium Oil (HMO). The system operates between 380-575°F. The process heat is supplied by a combination of two gas-fired heaters and a heat-recovery unit that makes use of the waste heat from a continuously-operated gas turbine. The average direct normal insolation is estimated between 6 and 7 kWh/m^2-day.

PROJECT SUMMARY--The solar retrofit system is being designed to directly heat a portion of the HMO (something like 10-40 motor oil). At design conditions (noon, summer solstice) the solar system will supply 9.5 MWt or approximately 90 percent of the heat normally supplied by the plant's existing gas-fired heaters. The project includes construction of a 19-heliostat, pilot module during the design phase. This towerless module will be interfaced with the existing plant, and will provide four months of operating experience prior to the start of the full project construction. The total project could be designed and built in about three years.

CONCEPTUAL DESIGN--The conceptual design includes 320 heliostats and a solar receiver mounted atop a 200-foot high steel tower. The receiver is made up of standard, commercially-available heat exchanger panels which transfer the solar energy collected to the HMO. During periods of sufficient insolation the entire HMO that normally flows to the heaters is diverted through the receiver and back to the heaters. The heaters then top-off the heat required to maintain an outlet temperature of 575°F. Fuel flow to the heaters is automatically controlled to ensure the correct heat input, or to carry the entire plant load during periods of insufficient insolation. This method of interfacing the solar and non-solar HMO system offers several advantages: all solar energy collected is used; all heat supplied by heat recovery units is used; direct heaters are maintained at operating temperature and can respond rapidly to transient conditions; system control is extremely simple; and there is minimum interruption of existing plant operation.

FUNCTIONAL DESCRIPTION--For solar retrofit, the flow of HMO from the surge tank to the fossil heaters is diverted through a solar central receiver and then back through the fossil heaters. The oil is heated from approximately 420 F out of the surge tank to about 560°F out of the solar receiver. The fossil-fired heaters, though turned down during solar operation, bring the oil to 570°F. The fossil heaters are left on to protect against cloud transients and during nighttime operation. This hot HMO then flows to the process recovery columns where selective heating of the absorption oil takes place. Cooled HMO returns in a closed cycle to the solar heater and continues back through the process.



ARCO Oil and Gas Company's North Coles Levee Natural Gas Processing Plant No. 8 Solar Repowering Project

EXXON CORPORATION-Edison Field

PRIME CONTRACTOR

Martin Marietta Corporation

SUBCONTRACTORS

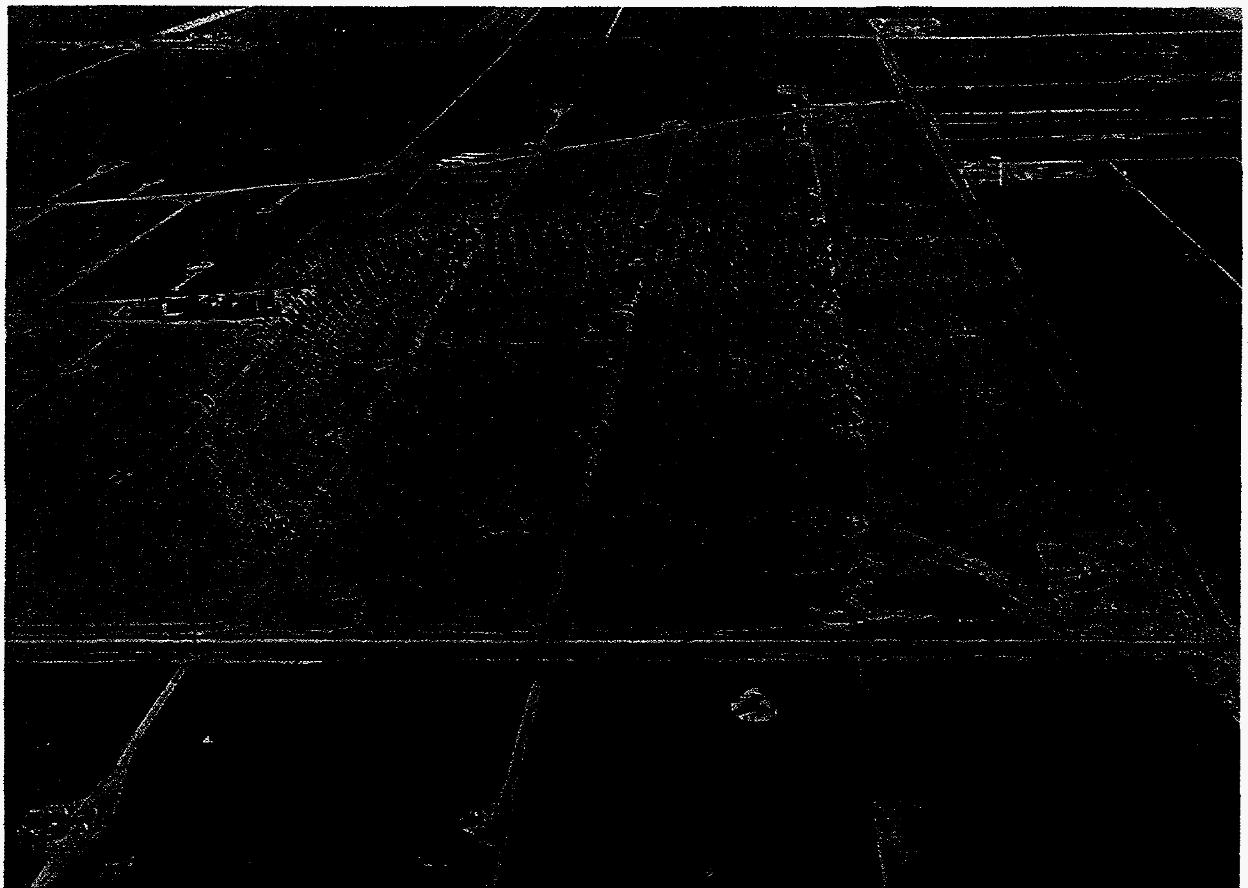
Exxon Corporation
Foster Wheeler
Black & Veatch

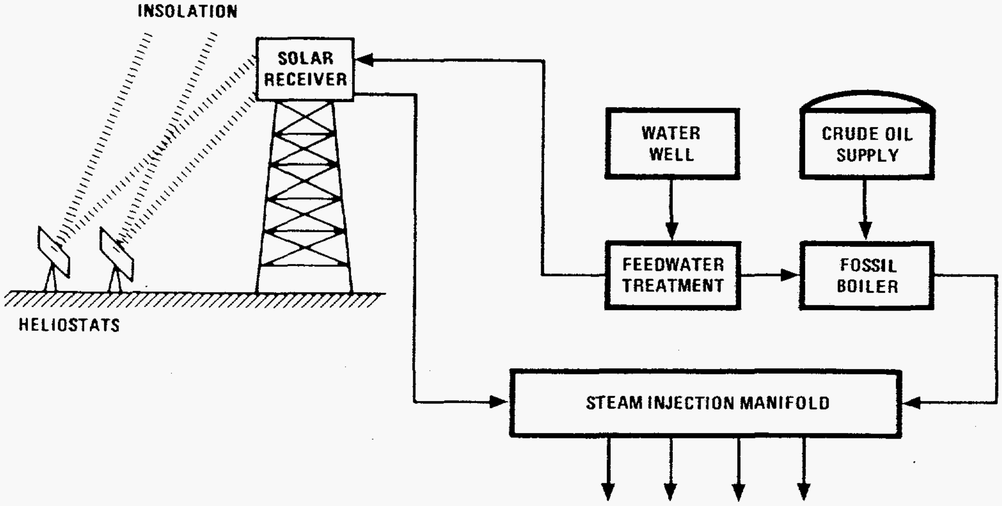
SITE DESCRIPTION--The site selected for the Solar Thermal Enhanced Oil Recovery (TEOR) project is Exxon's Edison Field, approximately seven miles southeast of Bakersfield, California. The use of steam injection has been well established at Edison Field since 1965, and the field is typical of TEOR operations. As such, it would provide a good demonstration of the potential benefits of solar TEOR in the oil production industry. The terrain is flat, alluvial plain at an average elevation of 600 feet. The climate is warm and semi-arid. Summers are normally cloudless, hot, and dry. Annual average direct normal solar insolation is 6-7 kWh/m^2-day. Total field size is over 1000 acres and, at the end of 1979, will have nearly 200 producing wells.

PROJECT SUMMARY--The particular concept being studied utilizes a central receiver solar thermal power system to replace the combustion of oil for generation of steam used for TEOR operation. Standard pumping techniques can produce only a small portion of the crude oil from underground reservoirs. The decrease in ground pressure, coupled with a high flow resistance in the oil-bearing formations, causes production rates to fall below economic levels while abundant amounts of oil remain. Furthermore, a larger portion of the world's known reserves consist of particularly heavy, viscous crude which cannot be pumped at all. As available crude oil reserves have been depleted and prices escalate, various methods of enhancing production capability have been developed. The most cost-effective process is the injection of steam into the reservoir, which heats and pressurizes the formation, allowing the oil to flow to recovery wells where it is pumped by normal means. Steam generators with output ratings of 22,000,000 Btu/hour and 25,000,000 Btu/hour are presently used at Edison Field. The baseline design solar system would produce 23,000,000 Btu/hour average over a typical year. Peak noon winter solstice output would be 29.3 MW (100,000,000 Btu/hour). This project could be designed and built in less than three years.

CONCEPTUAL DESIGN--Eight hundred and eighteen individually driven heliostats track the sun, aiming the concentrated reflected energy into the apertures of a dual-cavity, water/steam receiver mounted on a 295-foot steel tower. Interior surfaces of the cavity receiver consist of natural-circulation boiler panels that produce saturated steam at about 550°F. Steam exits the receiver into distribution piping to the point(s) of injection. Oil-bearing geological formations provide a high heat capacity and low-thermal-loss buffer thermal storage capability, so that intermittent shutdown at night and during cloudy periods can be tolerated.

FUNCTIONAL DESCRIPTION--Steam injection into oil wells is used extensively to recover thicker oil that will not flow unless heated. Steam is pumped directly into the ground to heat the surrounding rock. This increases the oil flow to existing producing wells where it is pumped out. The steam is produced by boiling water pumped from wells using crude oil as a fuel. For solar retrofit, treated feedwater is sent to a solar saturated steam receiver. The saturated steam is then piped to the injection well steam manifold. Water recovered from the oil/water mixture from the producing wells is separated and is disposed of by reinjection.





Exxon Corporation's Edison Field Oil Recovery Solar Repowering Project

GULF RESEARCH AND DEVELOPMENT COMPANY-Mt. Taylor Uranium Mill

PRIME CONTRACTOR

McDonnell Douglas

SUBCONTRACTORS

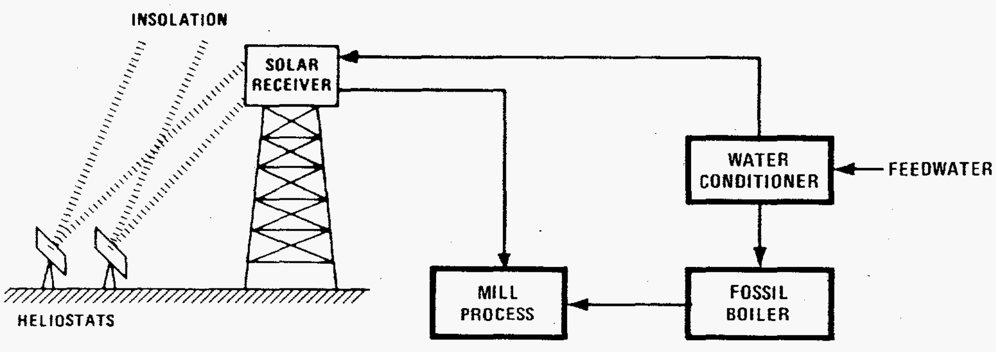
Gulf Research
Foster Wheeler
University of Houston

SITE DESCRIPTION--Gulf Mineral Resources Company, a division of Gulf Oil Corporation, proposes the construction of a retrofit solar steam generator at a uranium mill located northeast of San Mateo, New Mexico (60 miles northwest of Albuquerque). The uranium mill is scheduled for completion and operation in 1982. The mill site is in a relatively level valley where ample land is available for a heliostat field north of the mill. The mine supplying ore to the mill is three miles south of the mill. The Mt. Taylor Uranium Mill is designed to process 4200 tons of ore per day to yield 25,000 pounds/day of U_3O_8 as the finished yellow cake product, operating 24 hours/day, 340 days/year. The Mt. Taylor's 7200-foot elevation has a high-level of direct normal insolation for an estimated annual average of 6.8 kWh/m^2-day.

PROJECT SUMMARY--A solar central receiver will operate in parallel with two oil-fired boilers to provide steam to the uranium mill. Solar energy will be used to produce at least 20 percent of the plant's annual steam requirements. The solar energy will displace 22,600 barrels of No. 2 fuel oil annually. This project could be designed and built in about three years.

CONCEPTUAL DESIGN--In the baseline design a field of 383 heliostats concentrates solar energy onto an external planar water/steam receiver mounted on a 120-foot guyed steel tower. The receiver is a natural circulation boiler that will supply saturated steam at 150 psig to the mill processes. The fossil boilers, with a 13.5:1 turndown ratio, will be operated in parallel with the solar central receiver steam generator. Steam demand and available insolation will determine the ratio of use of solar versus fossil-generated steam. The solar receiver is designed to operate at a design point (noon summer soltice) power level of 13.9 MWt. No storage is necessary for this demonstration project.

FUNCTIONAL DESCRIPTION--The field of heliostats focuses solar energy on a water-cooled central receiver. The receiver, operating with a natural circulation drum separator, will generate saturated steam. This steam is used in parallel with steam from two oil-fired boilers providing steam to the various mill processes, leaching, solvant extraction, and yellow cake drying. Mill process temperatures vary from about 195°F to 365°F.



Gulf Mineral Resources Company's Mt. Taylor Uranium Mill Solar Repowering Project

PROVIDENT ENERGY COMPANY-Mobile Refinery

PRIME CONTRACTOR	SUBCONTRACTORS
Foster Wheeler Development Corp.	Provident Energy Company, Inc. McDonnell Douglas Foster Wheeler

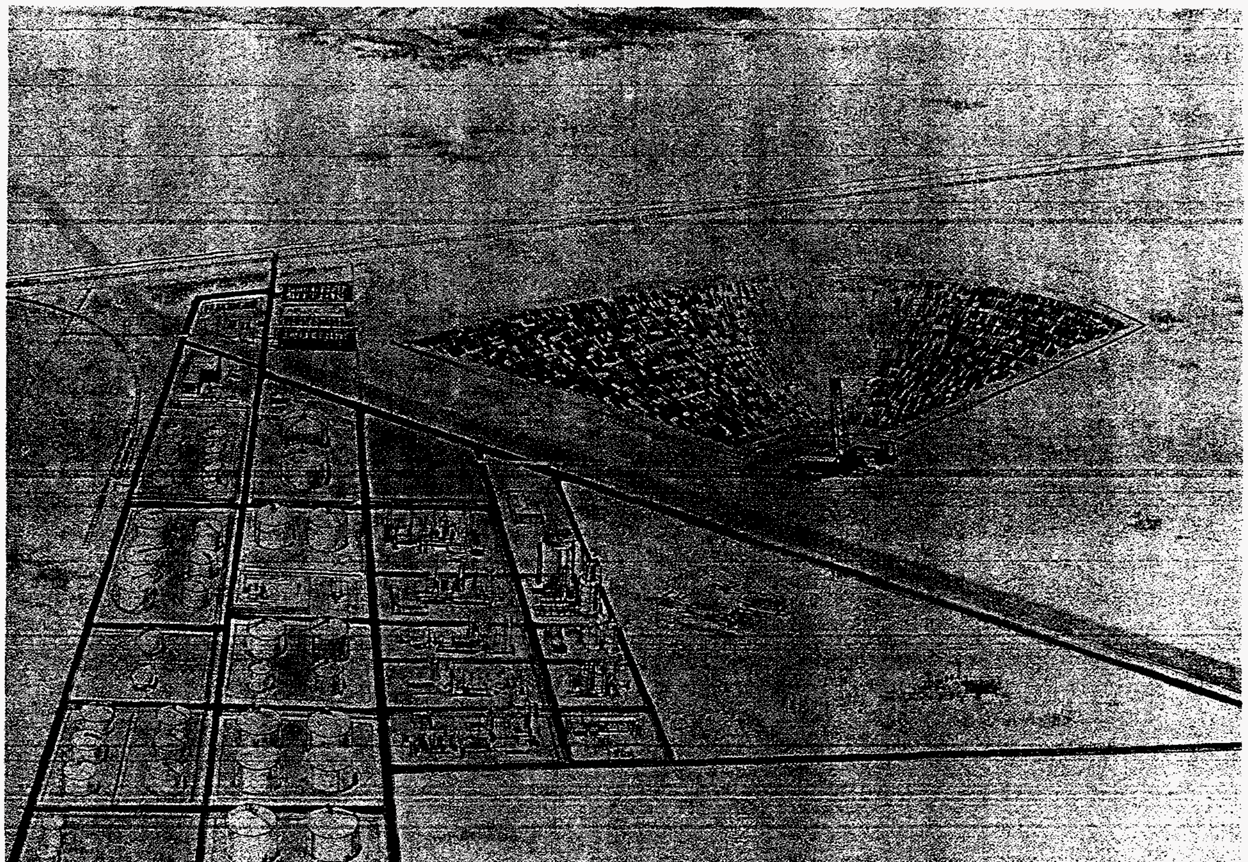
SITE DESCRIPTION--The Provident Energy Company (PEC) refinery will be located in Mobile, Arizona, 25 miles southwest of Phoenix, and is expected to be on-line by 1983. The site consists of 248 acres of relatively flat desert at an elevation of 1328 feet. The average direct normal insolation at the PEC site is about 7.5 kWh/m^2-day. The site is strategically located alongside an existing pipeline that will transport crude oil to the PEC refinery. The conventional side of the plant consists of three boilers, each designed for approximately 50 percent of the plant requirements. Energy is supplied to the boilers by burning a part of the fuel oil produced by the refinery.

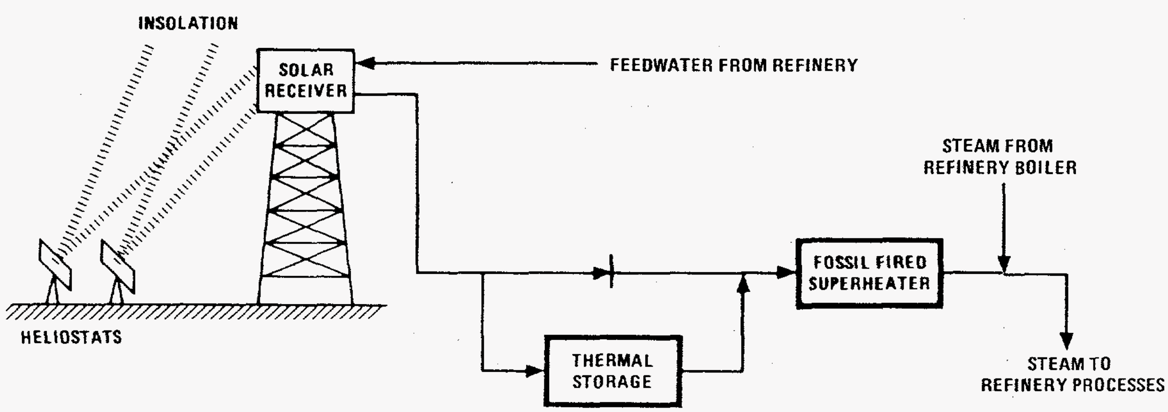
PROJECT SUMMARY--The objective of this program is to prepare a conceptual design for a central receiver system that will provide practical and effective use of solar energy in an oil refinery. The net annual input from the solar plant, 359×10^9 Btu's, will supply 20.8 percent of the annual refinery steam demand. The proposed solar plant would displace about 445×10^9 Btu's, or about 71,400 barrels per year of the fuel oil produced by the refinery that would otherwise be burned in the fossil boiler. This project could be designed and built in about three and a half years.

CONCEPTUAL DESIGN--The proposed baseline solar energy system consists of a tower-mounted, natural-circulation water/steam receiver with an exposed flat-panel absorber. The receiver generates saturated steam that is superheated to the desired temperature in a separate oil-fired superheater before it enters the main refinery superheated steam header. Solar energy is concentrated on the receiver by a 67-acre field of 1174 heliostats north of the tower. As currently planned, the refinery's fossil boilers will be operating during solar operation, but at a very low output. The control system's function is to modulate the fossil boiler output in response to the steam header pressure to vary steam flow to satisfy refinery demands. A three-minute pressurized water buffer storage is provided to protect the refinery from cloud transients.

FUNCTIONAL DESCRIPTION--The natural circulation boiler generates 800 psig saturated steam, that is conducted down the tower and fed into a fossil-fired superheater. Superheated steam at 625 psig 700°F is combined with steam from the refinery's own boilers to provide thermal energy for the refinery.

Saturated steam is also supplied to a pressurized water buffer storage vessel sized to provide three minutes of reserve steam capacity during short-term transients. The charging/discharging sequence is governed by a pressure controller in the main steam line. When the line pressure drops below a specified set-point, a valve located just downstream of the storage vessel opens and the steam is discharged. In a similar manner, when the storage vessel is being charged, this valve remains closed, allowing the pressure to build up to the maximum value. There is a sight gauge and a level transmitter to ensure that the water rises to an appropriate level during charging. Pressure and temperature readings are monitored in the storage vessel to serve as an additional check of the charging/discharging sequence.





Provident Energy Company's Mobile Refinery Solar Repowering Project

UNITED STATES GYPSUM COMPANY-Sweetwater, Texas, Plant

PRIME CONTRACTOR

Boeing Engineering

SUBCONTRACTORS

U.S. Gypsum Company
Institute for Gas Technology

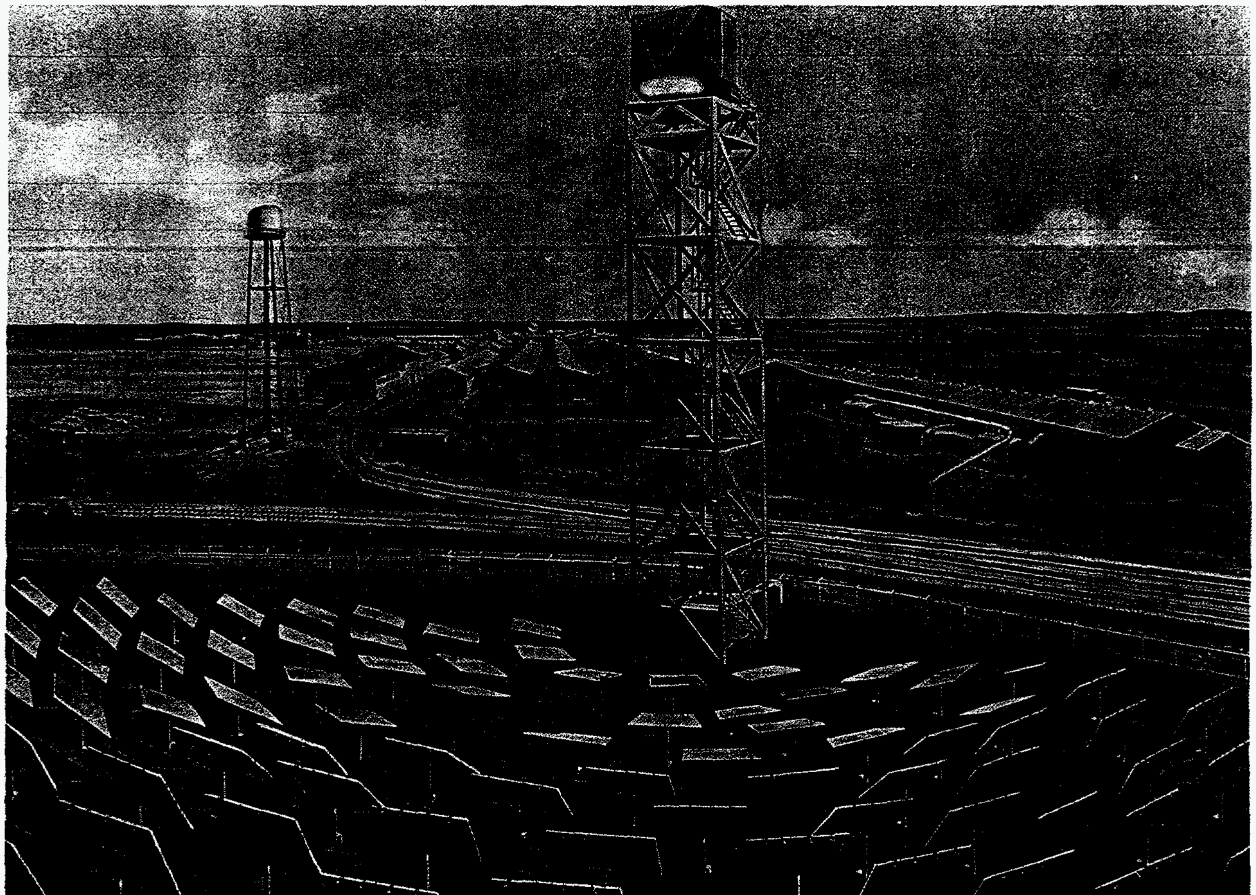
SITE DESCRIPTION--The U.S. Gypsum Sweetwater Plant is located on a 3800-acre tract east of Sweetwater, Texas, 45 miles west of Abilene. The plant currently produces 300,000 tons/year of calcined gypsum products, of which 90 percent is gypsum board. Major operations at the site include open-pit mining, crushing, and calcining of the gypsum; board manufacturing; and product warehousing and shipping. The immediate terrain around the manufacturing plant is clear and relatively level, approximately 2150 feet above sea level. Total plant energy consumption in the form of natural gas was 987×10^9 Btu's in 1978, with about one-third for calcining and two-thirds for board drying. The average direct normal insolation is estimated to be about 6 kWh/m^2-day.

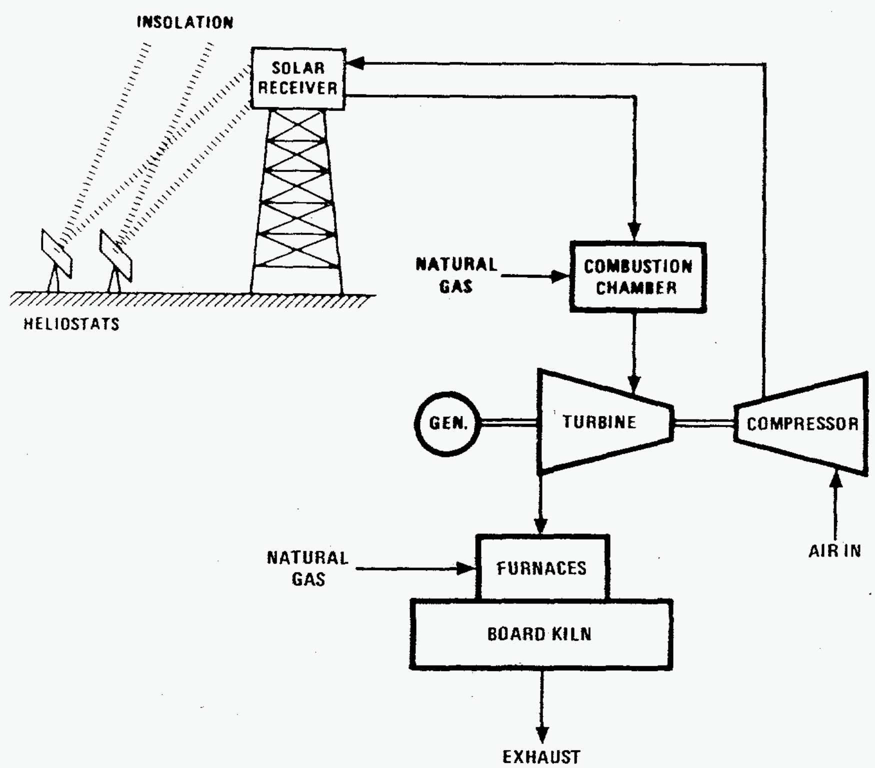
PROJECT SUMMARY--The solar retrofit system will supply solar-heated air during insolation hours to a wallboard-drying kiln at the USG Sweetwater plant in place of air heated by natural gas combustion. For the No. 2 kiln, this would represent a savings of about 25 percent of the yearly gas usage. The solar-heated air would be mixed with kiln recirculating air and passed over wallboard moving through the kiln in a 14-high deck arrangement. This hot air dries the board as it moves through the 200-foot-long kiln. This project could be designed and built in about two years.

CONCEPTUAL DESIGN--The solar plant would occupy approximately 16 acres of relatively level land north of the board plant. It would consist of approximately 469 heliostats (44 m^2), a cavity receiver, and a 200-foot steel tower on which the receiver would be mounted. Compressed air would be heated to a maximum of 1335°F in the receiver, expanded through a turbine which drives the compressor, and delivered to the two furnaces of the board kiln at temperatures up to 932°F.

Whenever adequate insolation was not available, the fossil-fired system would provide the energy requirements of the plant.

FUNCTIONAL DESCRIPTION--Ambient air at 90 F is drawn into the compressor where it is compressed to 48.5 psia. The air ascends through the tower riser and enters the receiver at 440 F. The collector field focuses reflected solar radiation through the aperture of the receiver. This energy, by direct and indirect impingement, heats the air passing through heat exchanger tubes in the receiver cavity to a maximum of 1335°F. The air passes from the receiver via downcomer piping to the gas turbine's combustor. If the entering air is greater than 1250°F, it passes directly to the turbine without firing the combustor. If it is less than 1250°F, the combustor is fired by natural gas to achieve a 1250°F entrance temperature to the turbine. The turbine expands the air to near ambient pressure levels and temperatures exceeding 900°F. The turbine expansion process drives the compressor to supply the necessary air, with additional energy available to generate up to 1300 kW of electrical power. The system provides 2945 lb/min of air through the air delivery pipe to the two-zone furnace area. Half the air enters each furnace area and the amount of natural gas used is reduced. The heated air, in combination with recirculated air, dries the wallboard traveling through the kiln. Moisture-laden air is exhausted from the kiln at 200°F.





U.S. Gypsum Company's Sweetwater Plant Solar Repowering Project

VALLEY NITROGEN PRODUCERS-El Centro Ammonia Plant

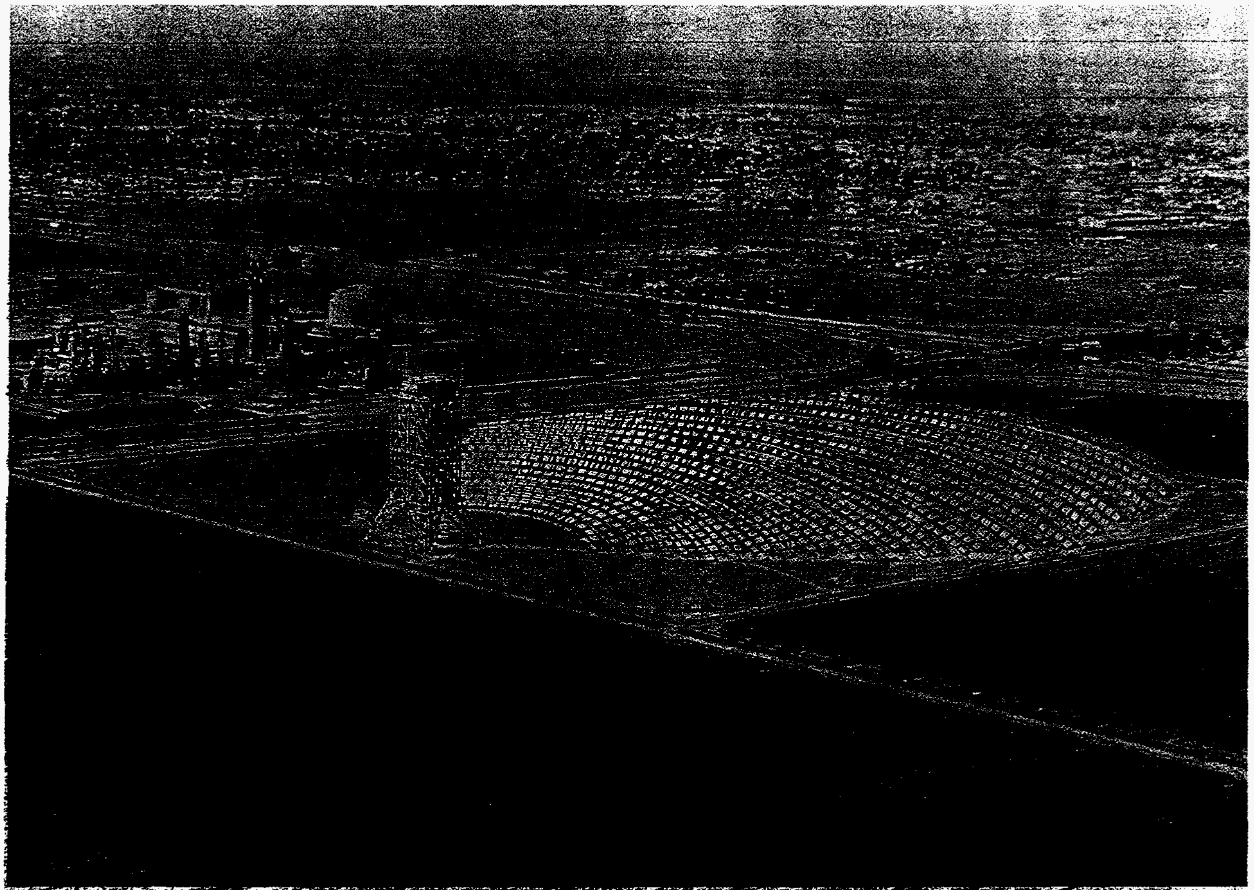
PRIME CONTRACTOR	SUBCONTRACTORS
PRF Engineering Systems, Inc.	Valley Nitrogen McDonnell Douglas

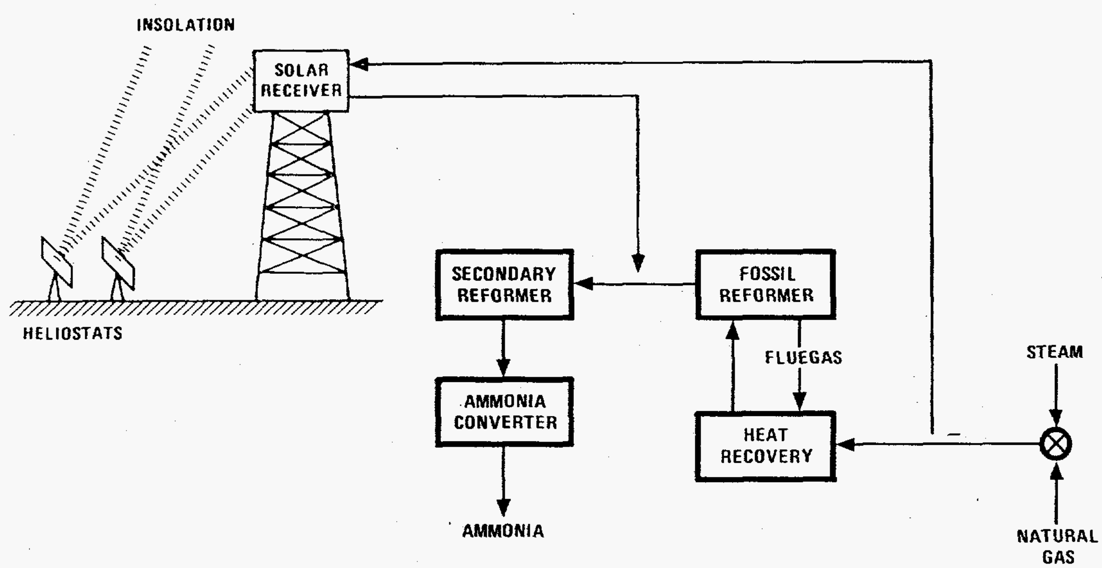
SITE DESCRIPTION--The Valley Nitrogen Producers, Inc., El Centro Ammonia Plant is part of a fertilizer-producing complex located in El Centro, California. It is spread over 70 acres, and consists of an integrated fertilizer facility that produces ammonia, urea, nitric acid, and ammonium nitrates. Most of the ammonia produced in the plant is processed into fertilizer. The plant location is very suitable for solar energy application. The climate is hot and dry with a high percentage of clear, cloudless skies; annual rainfall is only 2.83 inches and, on the average, only 30 cloudy days occur yearly. The average direct normal insolation is estimated to be 7 kWh/m^2-day.

PROJECT SUMMARY--The objective of this solar repowering project is to displace natural gas presently used in the combustion chamber of the primary methane-steam reformer. A solar central receiver is the baseline system. It will operate in parallel with the existing fossil-fired reformer. This configuration will provide a peak solar utilization of 34 MWt, or a total annual contribution of 23 percent. Other than the production of steam in a separate boiler, the reformer is the only major energy consumer in the fertilizer manufacturing plant. This project could be designed and built in about four years.

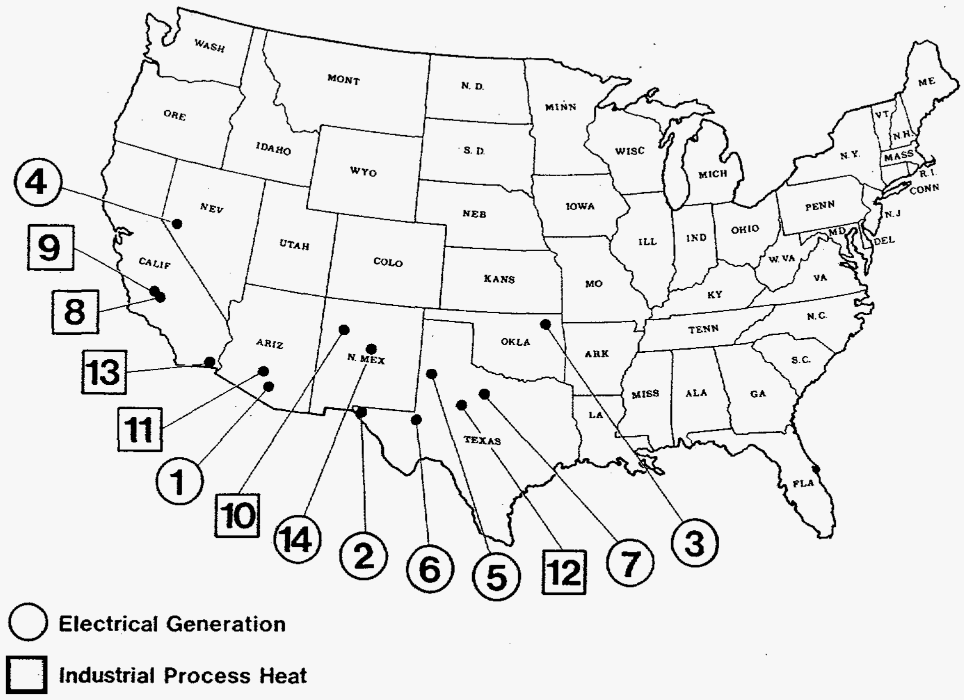
CONCEPTUAL DESIGN--The proposed baseline system employs a solar central cavity-type receiver operating in parallel with the existing fossil-fired reformer. A field of 1040 second-generation heliostats (56.4 m^2) focuses the solar energy through the receiver mounted on a 250-foot steel tower. Inside the receiver, internal reflection and reradiation heat the vertical primary reformer tubes to 1650°F maximum, and the process fluid exit temperature to 1455°F. Methane and steam flowing inside the tubes react catalytically to form a hydrogen-rich product gas ultimately used to prepare ammonia. The solar retrofit's characteristics and its interface with the existing plant are simple, incorporating state-of-the-art components with proven technology. The retrofit does not alter the normal plant operation. No storage system or complex control is required. The solar reformer will be directly connected to the fossil reformer by an insulated piping system. During the day, a fraction of the process flow will be routed to the solar reformer and the energy will be provided by the heliostat field. At night, all of the process flow is routed to the existing fossil reformer, with the solar reformer shut down. Full natural gas firing takes place in the fossil reformer, and plant operation is maintained at design capacity. The solar reformer is sealed during the night to maintain reformer tube, insulation, and cavity temperature; this minimizes thermal cycling of these components and simplifies restart in the morning.

FUNCTIONAL DESCRIPTION--The process flow, consisting of a mixture of steam and natural gas, splits into two parallel streams, one flowing to the solar reformer and the other continues to the existing fossil reformer. In the solar reformer, the process will undergo preheat and then the steam reforming reaction. The firing of fuel in the fossil reformer is reduced during daytime operation. Hydrogen-rich product gas from the solar reformer is combined with that from the fossil-fired reformer and introduced into the existing secondary reformer.





Valley Nitrogen Producer's El Centro Ammonia Plant Solar Repowering Project



Electrical Generation

Industrial Process Heat

Listed below are addresses for obtaining additional information on the solar thermal repowering projects.

(1) Arizona Public Service
Attn: Eric R. Weber
P.O. Box 21666
Phoenix, AZ 85036

(2) El Paso Electric Company
Attn: Jim E. Brown
P.O. Box 982
El Paso, TX 79960

(3) Black & Veatch Consulting Engineers
Attn: Sheldon Levy
P.O. Box 8405
Kansas City, MO 64114

(4) McDonnell Douglas
Attn: Robert Easton
5301 Bolsa Avenue
Huntington Beach, CA 92647

(5) General Electric Company
Attn: James A. Elsner
Energy Systems Programs Department
1 River Road
Schenectady, NY 12345

(6,7) Rockwell International
Attn: Tom H. Springer
Energy Systems Group
8900 De Soto Avenue
Canoga Park, CA 91304

(8) Northrup, Inc.
Attn: Roy L. Henry
302 Nichols Drive
Hutchins, TX 75141

(9) Martin Marietta
Attn: David N. Gorman
P.O. Box 170
Denver, CO 80201

(10) McDonnell Douglas
Attn: L. W. Glover
5301 Bolsa Avenue
Huntington Beach, CA 92647

(11) Foster Wheeler Development Corporation
Attn: D. R. Raghavan
12 Peach Tree Hill Road
Livingston, NJ 07039

(12) Boeing Engineering & Construction Company
Attn: Donald K. Zimmerman
P.O. Box 3707
Seattle, WA 98124

(13) PFR Engineering Systems, Inc.
Attn: Tzvi Roseman
4676 Admiralty Way, Suite 832
Marina Del Ray, CA 90291

(14) Public Service Company of New Mexico
Attn: J. P. Maddox
P.O. Box 2267
Albuquerque, NM 87103