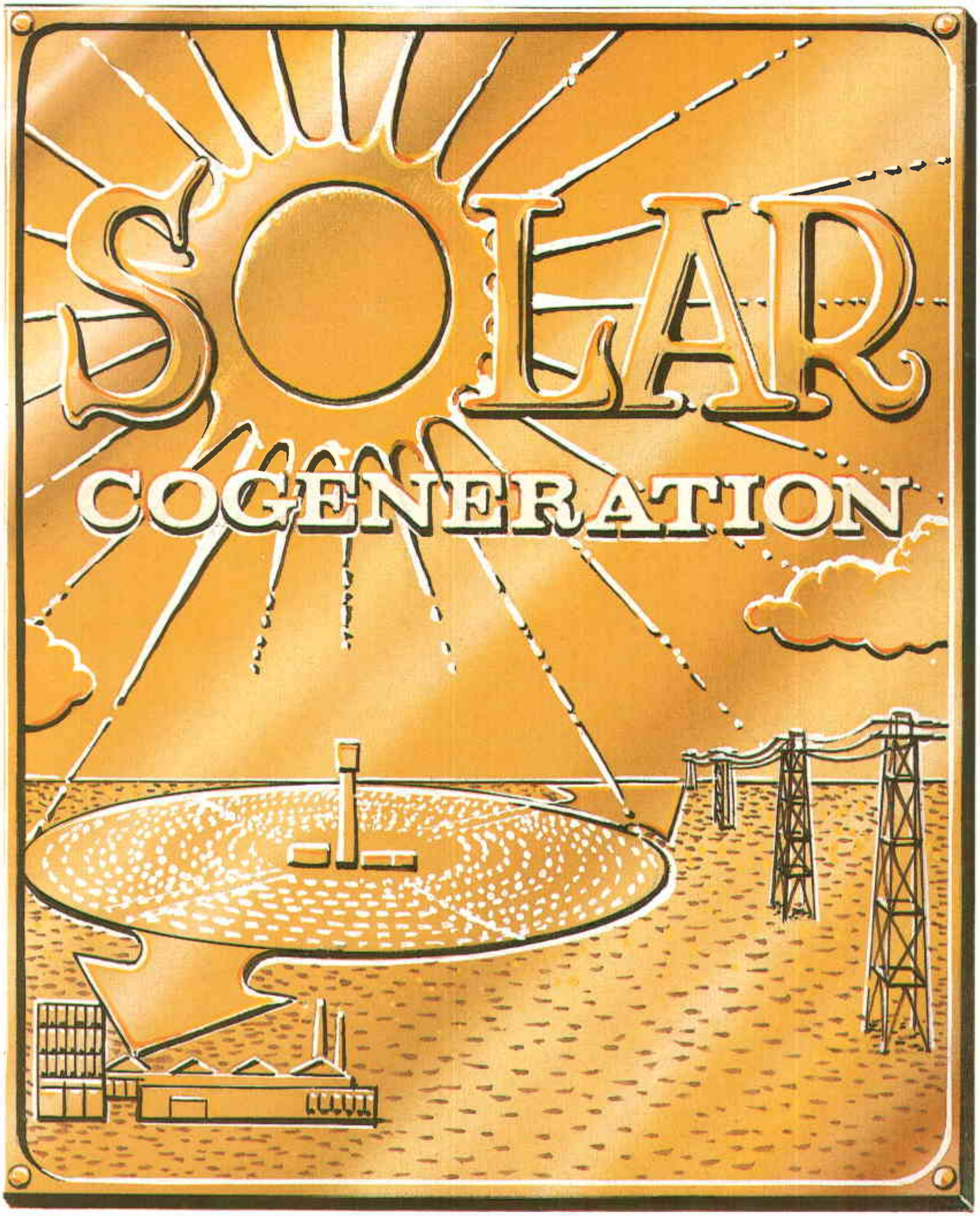
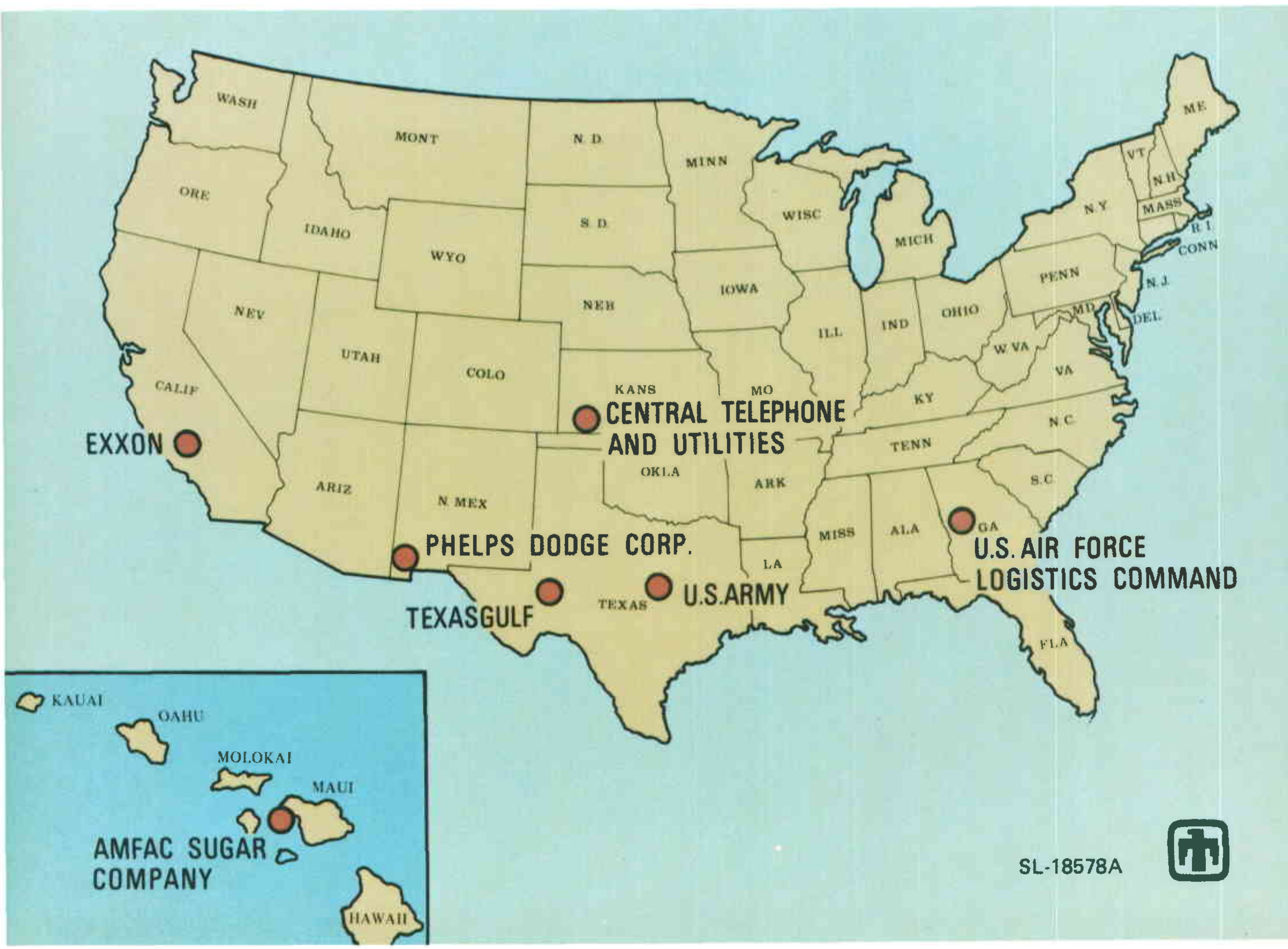



Sandia National Laboratories | Livermore

## Solar Cogeneration Facility Sites




Sandia National Laboratories

San Francisco Operations Office

April 1982

# INTRODUCTION

The United States currently faces an uncertain energy future as supplies of fossil fuels continue to decline. Solar energy, a renewable fuel source, has the potential for providing a significant amount of the nation's future energy needs. The Department of Energy (DOE) has undertaken the Solar Central Receiver Systems Program as a key part of its effort to accelerate the development of solar technology. Several concepts are being studied that would supply thermal energy to plants for generating electricity, operating industrial processes, or a combination of both. The Federal government's role in this program is to provide research and development funds, guide the development of systems toward demonstrating reliable operation, and provide test facilities, applications experiments, and information dissemination. Much of the central receiver component (heliostat, receiver, storage) testing is being conducted at the Central Receiver Test Facility at Sandia National Laboratories in Albuquerque, New Mexico.

Solar system development and testing activities encompass a wide range of potential applications. A solar central receiver pilot plant near Barstow, California, will begin operation beginning in 1982 and will provide 10 MWe to the Southern California Edison power company grid network. Fourteen utility and industrial process heat (IPH) repowering system conceptual design studies employing solar central receivers at specific site locations have been completed, and seven repowering conceptual design studies for the cogeneration of electricity and heat from solar energy are now underway. The seven cogeneration proposals, which would provide electrical power and thermal heat at the same site, include a wide range of geographic areas and address new potential applications. They include sulfur mining, copper smelting, enhanced oil recovery, natural gas processing, sugar mill operations, and space heating and cooling. Summaries of the seven cogeneration studies are presented later in this brochure.

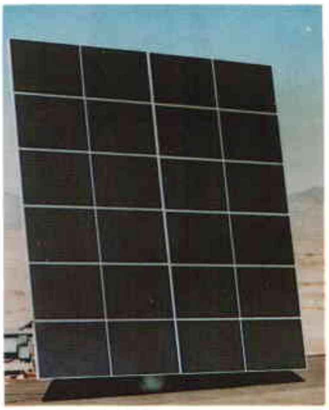
## PROJECT OBJECTIVES

The objectives of the solar cogeneration projects are to obtain site specific engineering designs, system specifications, economic analysis, and individual operating experience with central receiver technology. The projects will also illustrate the potential reduction of fossil fuels normally consumed at the project sites and possibly provide a market for the large-scale production of heliostats, the most expensive component of the central receiver system. The solar cogeneration conceptual design studies will provide technical data to guide potential users in selecting the optimal system configuration for a given application.

A solar cogeneration system consists of a solar central receiver integrated into a new or existing cogeneration facility. A solar cogeneration facility has an advantage over other types of electric power plants or fuel-burning installations because cogeneration is currently not classified as either an electric power plant or a major fuel-burning installation and is therefore exempt from the requirements of the Fuel Use Act. Cogeneration is also promising because it requires lower capital cost per energy unit produced since the conversion of thermal energy to energy for useful work (electrical, mechanical, thermal) can be almost 100 percent.

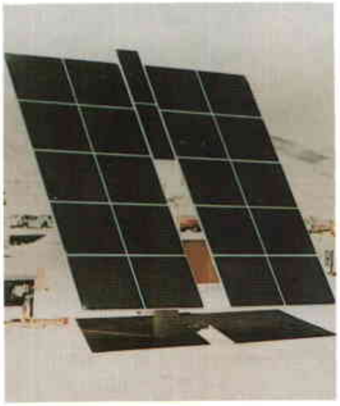
Solar cogeneration has the potential for lower capital cost per unit energy consumed due to the efficient utilization of the solar energy collected. The potential market for solar cogeneration is significant. However, much less is currently known about specific potential applications of solar cogeneration than about utility or IPH repowering. Therefore, the information gained from these solar cogeneration studies is very useful.

## Second Generation Heliostats

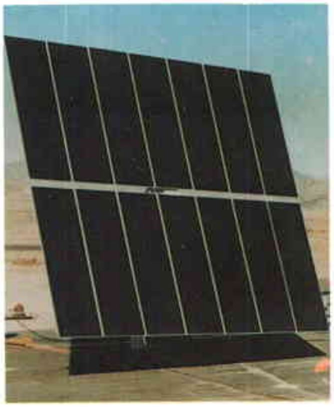


**ARCO Power Systems**

**Boeing Eng. & Const. Co.**



**Martin Marietta Corp.**



**McDonnell Douglas Corp.**

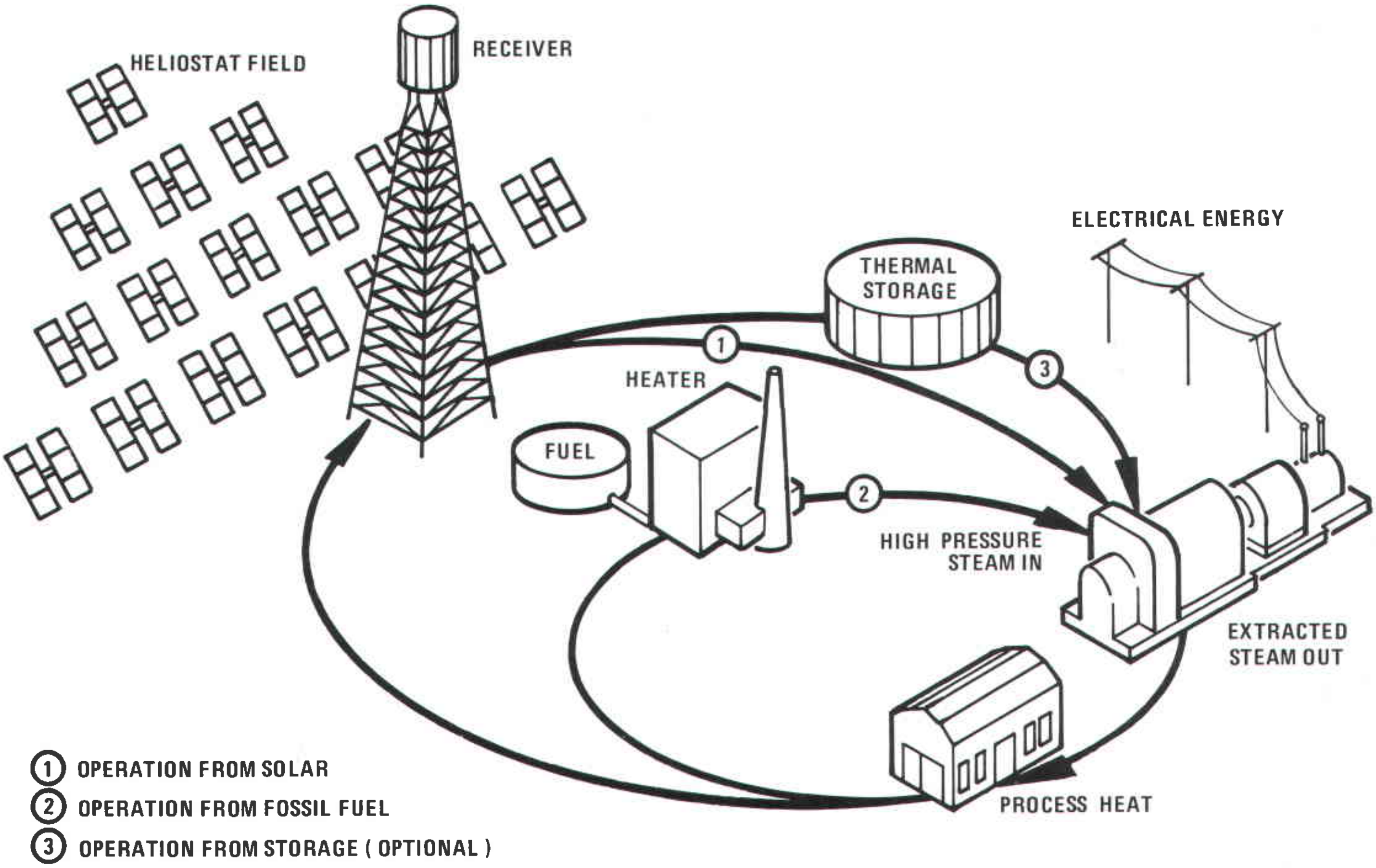
## U.S. D.O.E. Central Receiver Test Facility

**Receiver, heliostat, and storage system performance data from this and other test facilities are being used to design solar plants**

**Second generation heliostats are being tested in the foreground**

## 10 MWe Solar Central Receiver Pilot Plant (inset Martin Marietta Heliostat)

**Water/steam external receiver (40 MWt)**
**Oil/rock thermal storage**
**1818 Heliostats**




Cogeneration can deliver electrical energy and process heat more efficiently than systems that deliver this energy separately. Adding solar energy to a fossil cogeneration facility (as shown above) reduces the required amount of fossil fuel even further.

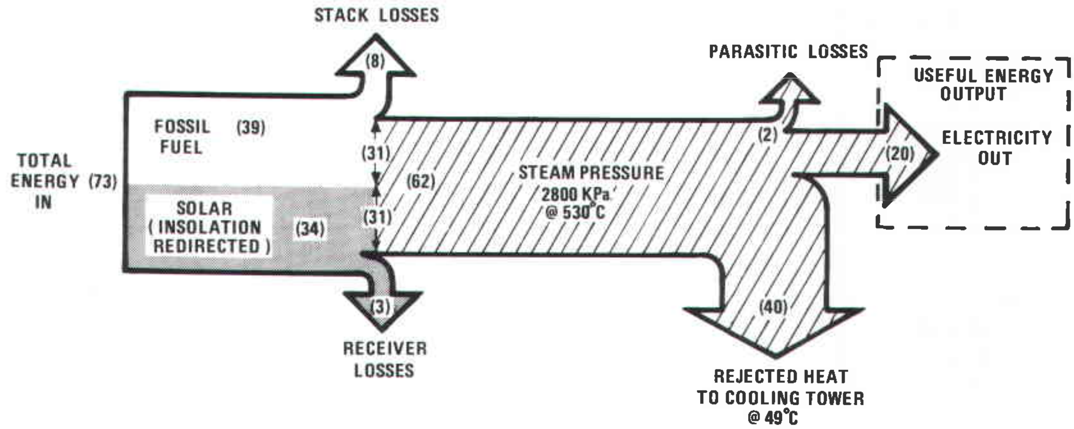
The energy flow diagrams shown to the right were developed for comparison of a cogeneration facility that has the same output as a conventional electrical generating plant and IPH plant. The steam conditions are typical. The hybrid configuration selected is 50 percent solar. The numbers shown are equivalent energy units.

These diagrams illustrate the advantages of cogenerating systems. The total energy input for the cogeneration facility is 121 energy units as compared with 170 for the two conventional plants. The heat to electrical energy ratio for the cogeneration facility is 4:1, which is typical of many cogenerating systems. For these examples:

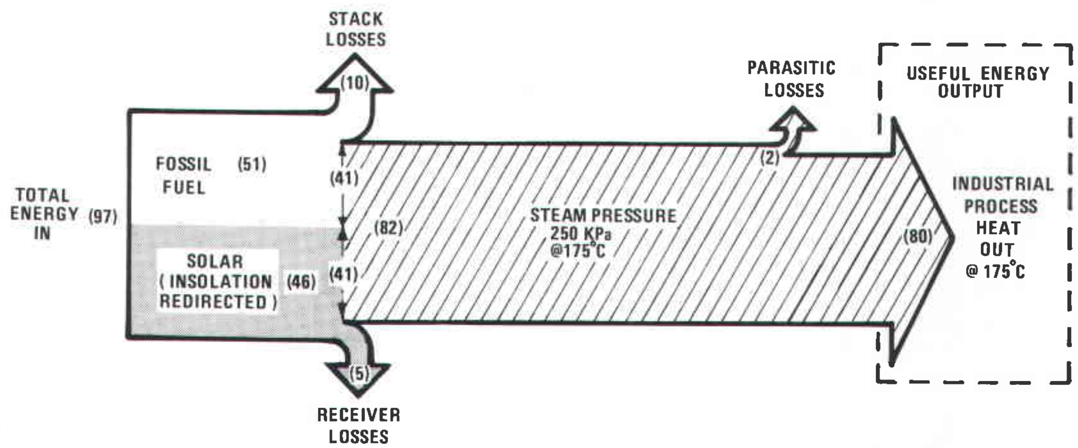
- Efficiency of the conventional electrical system is 27 percent, of the conventional IPH system 82 percent, and of the cogeneration system 83 percent.
- Cogeneration advantage is 71 percent net.
- Cogeneration net electric heat rate is 3,754 Btu/kWhe, while the conventional net electric heat rate is 10,580 Btu/kWhe, thus it takes 2.8 times as much energy into the conventional electrical system to produce the same amount of electrical energy as in the cogeneration system.

Hybrid Solar Energy Flow Diagrams (50 Percent Solar) for Comparison of Conventional Electrical and IPH Systems with a Cogeneration System

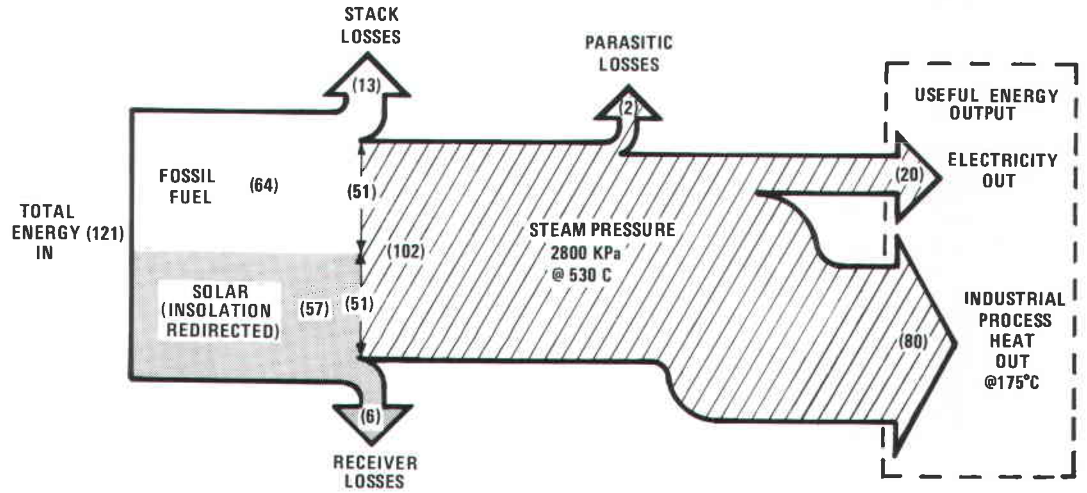
Conventional Electrical Energy Flow




Conventional Industrial Process Heat Flow




Cogeneration Energy Flow




- Numbers in parenthesis are equivalent energy units.
- Energy output is normalized.
- It takes 1.4 times more input energy total to the two conventional systems to produce the same output as the cogeneration system.

## PIONEER MILL COMPANY, LTD.—Lahaina, Maui, Hawaii

**PRIME CONTRACTOR**

**Bechtel Group, Inc.**

**SUBCONTRACTORS**

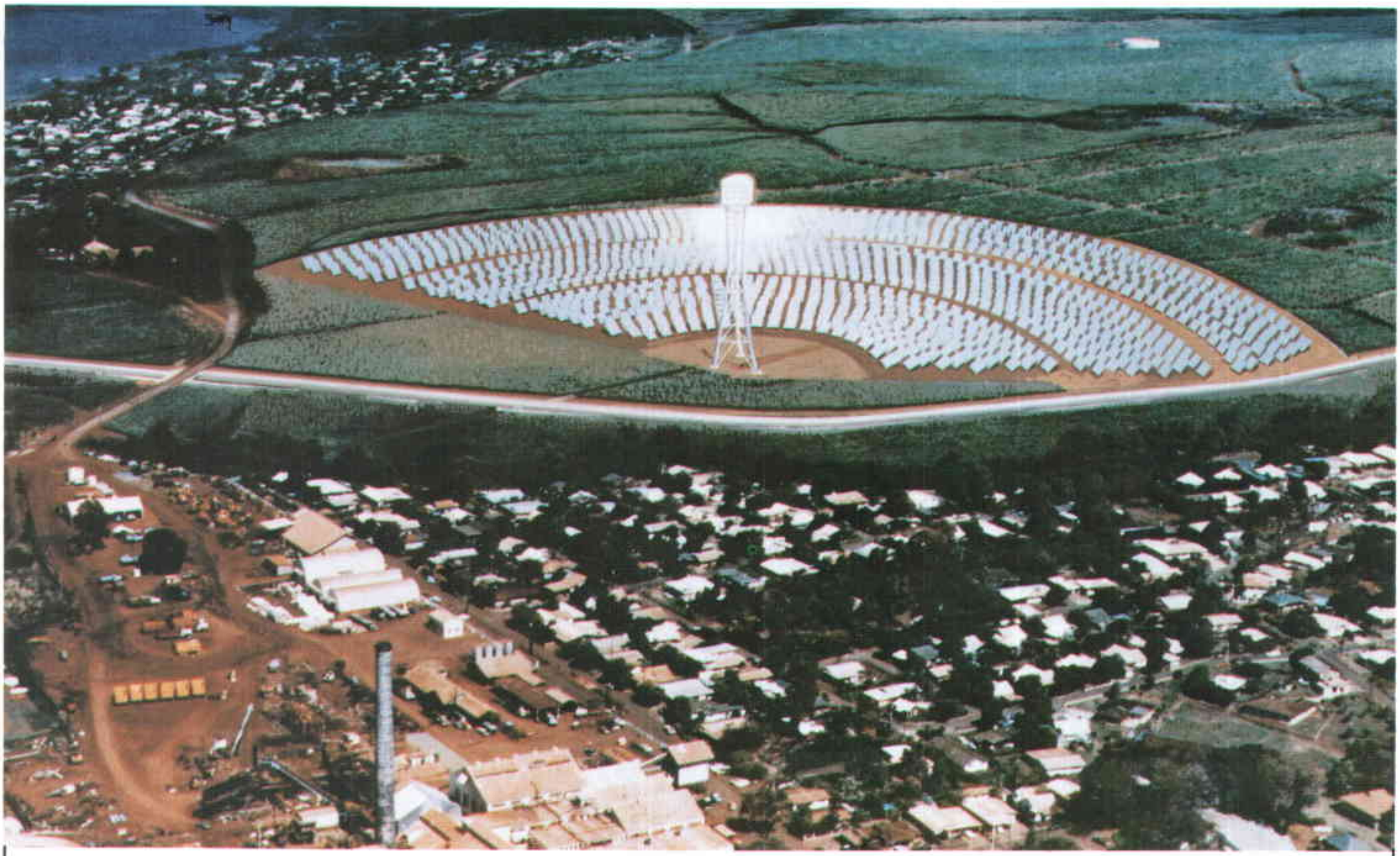
**Amfac Sugar**
**Foster Wheeler**
**Northrup**

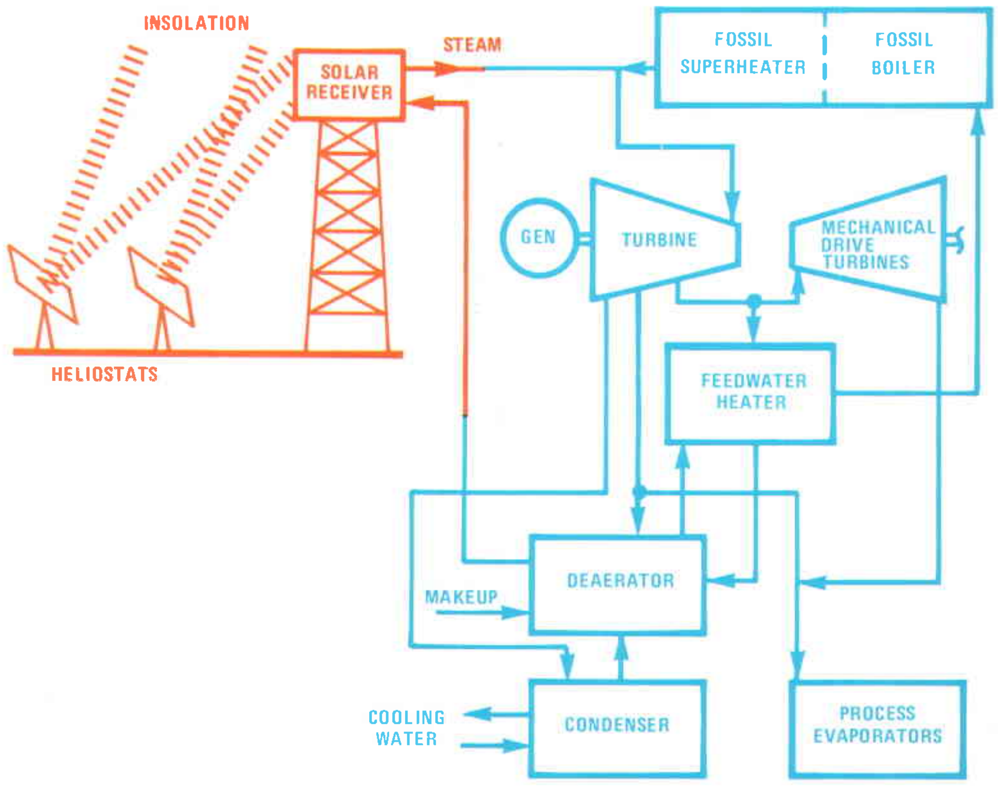
SITE DESCRIPTION—Pioneer Mill Company, Ltd., a subsidiary of Amfac Sugar Company, operates a sugarcane plantation and sugar factory near Lahaina on the island of Maui. The plantation occupies 35,500,000 $m^2$ (8,776 acres) on the west coast of the island on gently sloping ground between the coast and the foothills of the West Maui mountains. The climate is tropical but the site is dry with average annual rainfall of 0.36 m (14 in.) because it is sheltered from the tradewinds by the mountains. Average direct normal insolation at the site is estimated to be 7.4 $kWh/m^2$ per day. The sugar factory processes sugarcane at an average rate of 93,000 kg (102 tons) per hour into raw sugar and molasses during a nine-month harvest season. The mill has an existing cogeneration facility, supplying intermediate and low-pressure steam for mechanical drive turbines and process evaporators, and electric power for irrigation pumps. Excess electric power is supplied to the Maui Electric Company grid. The mill consumes #6 oil to supplement the use of bagasse, the cellulose residue of the processed sugarcane, in the existing dual-fuel boilers to produce steam at 5.86 MPa (850 psia) and 400°C (750°F).

PROJECT SUMMARY—The objective of the project is to retrofit a solar central receiver system to the existing cogeneration facility. The use of bagasse in lieu of thermal storage will allow the maximum utilization of solar energy while accommodating the weekly and annual variation of the factory operating cycle. The retrofit is expected to save 40,000 barrels of #6 oil per year. It is estimated that the project can be designed and built in about three years.

CONCEPTUAL DESIGN—The solar retrofit consists of the addition of a collector field, tower-mounted receiver, and a pipeline connecting the receiver with the existing plant and controls. Approximately 815 heliostats, each with 52.8 $m^2$ reflective area, are arranged in a 150° north field covering about 171,000 $m^2$ (42 acres) of land. The two-cavity, natural circulation water/steam receiver is supported upon a 72-m (236-ft) steel tower. The receiver output is approximately 26 MWt, supplying about 50 percent of the total steam demand for the factory at the design point. Steam and condensate pipelines about 1130 m (3700 ft) long connect the receiver with the plant. An expanded control room and additional bagasse storage capacity are also needed to accommodate the retrofit.

FUNCTIONAL DESCRIPTION—A water/steam solar receiver will operate in parallel with the existing boilers. Bagasse will be diverted from the boiler to the storage house where it can be reclaimed when solar-produced steam is not available. This use of bagasse eliminates the need for thermal energy storage and allows the displacement of about 53 percent of all the oil currently consumed during the harvest season. During the three-month off-season, when the factory does not produce bagasse, solar-produced steam will displace a portion of the oil currently burned to meet the year-round irrigation requirements.





INSOLATION
STEAM
SOLAR RECEIVER
FOSSIL SUPERHEATER
FOSSIL BOILER
HELIOSTATS
GEN
TURBINE
MECHANICAL DRIVE TURBINES
FEEDWATER HEATER
DEAERATOR
MAKEUP
COOLING WATER
CONDENSER
PROCESS EVAPORATORS

## CENTRAL TELEPHONE AND UTILITIES—WESTERN POWER, Cimarron River Station

**PRIME CONTRACTOR**

**Black & Veatch**

**SUBCONTRACTORS**

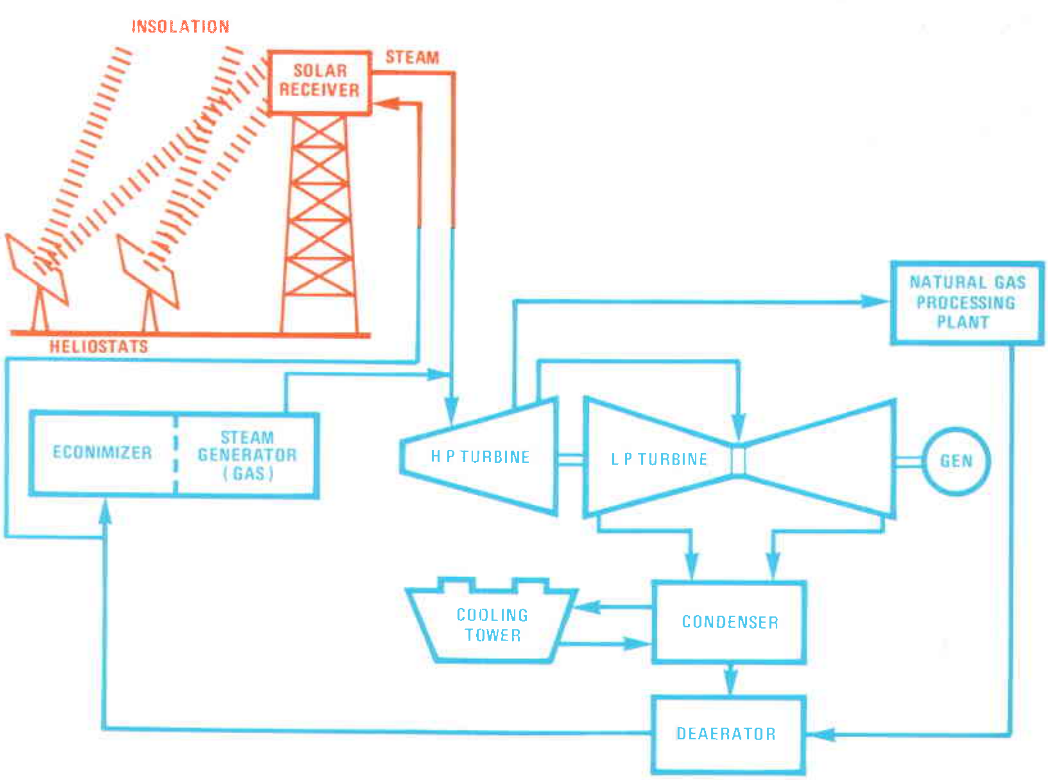
**Central Telephone & Utilities—
Western Power
Babcock & Wilcox Company
Foxboro Company**

SITE DESCRIPTION—The Central Telephone & Utilities-Western Power (CTU-WP) Cimarron River Station (CRS) cogeneration facility provides electrical energy to customers on the CTU-WP grid and electrical and thermal energy to the natural gas processing plant of National Helium Corporation (NHC). The plants are contiguous and located 11 miles northeast of Liberal in southwestern Kansas. CRS has a net output of 55 MWe and 16 MWt of process heat; normally, 20 MWe and 15.1 MWt of process heat are provided to NHC. The CRS gas-fueled steam generator provides 230,000 kg/h (500,000 lb/h) of steam to the nonreheat turbine generator at throttle conditions of 9.59 MPa (1390 psia) and 510°C (950°F). The station also includes a 14-MWe combustion gas turbine and a package auxiliary boiler. The site is located in an arid climate with annual average insolation of 6.1 kWh/$m^2$ per day and 70 percent possible sunshine.

PROJECT SUMMARY—A site-specific conceptual design has been selected to demonstrate the technical viability and identify the economic potential of a solar cogeneration facility. The solar receiver has a peak output of about 37 MWt (15 MWe equivalent); this is the most cost-effective capacity that will provide a meaningful cogeneration demonstration. The conceptual design does not include energy storage. A site test program is monitoring direct normal insolation and contamination of heliostat mirror surfaces.

CONCEPTUAL DESIGN—The solar cogeneration facility is comprised of eight integrated systems. The collector system consists of 1,057 second-generation heliostats covering approximately 222,000 $m^2$ (55 acres). The receiver is an external, water/steam type, mounted on a 74-m (244-ft) tower. The receiver piping system transports feedwater and steam between the receiver and the existing CRS turbine cycle. The fossil energy delivery system, electric power generating system, and process heat system comprise the existing CRS cogeneration facility. The solar auxiliary electric system supplies electric power to solar facility components. Finally, a computer-based master control system monitors and controls all system parameters necessary to ensure safe and reliable operation.

FUNCTIONAL DESCRIPTION—The collector system redirects and concentrates solar energy onto the solar receiver. The thermal energy absorbed by the receiver is transferred to the feedwater and steam, producing superheated steam at a pressure and temperature compatible with turbine inlet conditions. Steam from the gas-fueled boiler is mixed with steam from the solar receiver and delivered to the turbine. The turbine generator converts thermal energy in the steam to electrical energy. A portion of the steam flowing through the turbine is extracted as process steam for NHC.


INSOLATION
SOLAR RECEIVER
STEAM
HELIOSTATS
NATURAL GAS PROCESSING PLANT
ECONIMIZER
STEAM GENERATOR (GAS)
H P TURBINE
L P TURBINE
GEN
COOLING TOWER
CONDENSER
DEAERATOR

## EXXON CORPORATION—Edison Field Enhanced Oil Recovery

### PRIME CONTRACTOR

**Exxon Research and Engineering**
**Contract Research Office**

### SUBCONTRACTORS

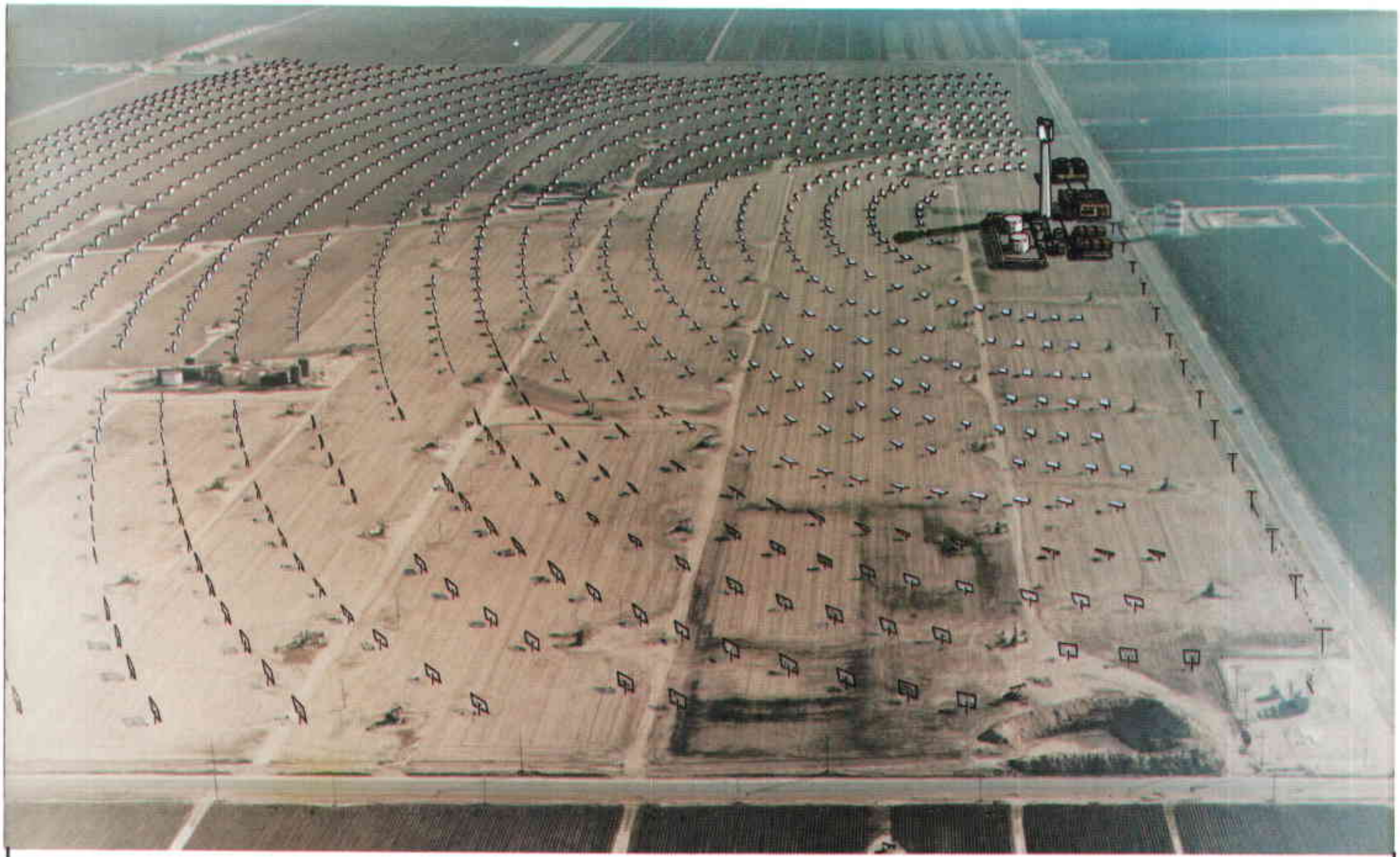
**Martin Marietta Aerospace**
**Pacific Gas and Electric Company**
**Badger Energy Inc.**

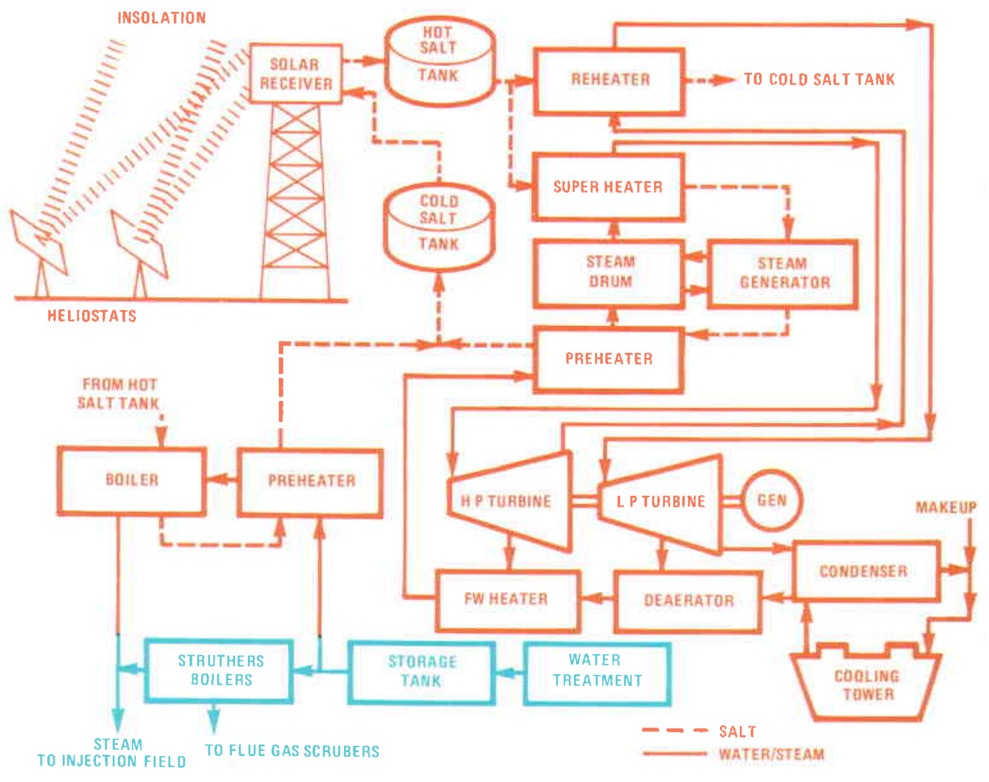
SITE DESCRIPTION—The site selected for the Solar Cogeneration Conceptual Design is Exxon's Edison Field, located approximately seven miles southeast of Bakersfield, California. Steam injection for Enhanced Oil Recovery (EOR) has been in use at the field for many years and the field is typical of those in Kern County, California. The terrain is flat alluvial plain at an average elevation of 180 m (590 ft). The climate is warm and semi-arid. Summers are normally cloudless, hot, and dry. Annual average direct normal insolation is 6.2 $kWh/m^2$ per day. Total field area available for the heliostat field is 1,300,000 $m^2$ (321 acres). The local utility is Pacific Gas and Electric Company (PG&E).

PROJECT SUMMARY—The concept being studied uses a solar central receiver system to generate steam for EOR and for the generation of electricity. The electricity produced is sold to PG&E. The oil field steam produced replaces steam that would be generated by burning oil.

CONCEPTUAL DESIGN—About 3295 second-generation heliostats reflect energy into a dual-cavity molten salt receiver mounted on a 137-m (450-ft) concrete tower. The hot molten salt at 566°C (1050°F) is stored in the hot tank of a two-tank storage system. The hot salt is pumped from the hot tank to unfired boilers that produce 13 MWt of steam at 293°C (560°F), 80 percent quality, for injection into the oil field 24 hours a day. Extra hot salt is used to make steam to generate electricity during PG&E's peak demand period at a rate of 20 MWe. The spent salt is returned to the cold tank.

FUNCTION DESCRIPTION—Steam is injected into a pattern of wells interspersed between producing oil wells. The steam increases the field pressure and heats the oil, lowering its viscosity. This permits the oil to be pumped out of the ground at a faster and more economical rate. It also permits oil to be recovered that cannot be produced by conventional pumping.





INSOLATION
SOLAR RECEIVER
HOT SALT TANK
REHEATER
TO COLD SALT TANK
SUPER HEATER
COLD SALT TANK
STEAM DRUM
STEAM GENERATOR
HELIOSTATS
PREHEATER
FROM HOT SALT TANK
BOILER
PREHEATER
H P TURBINE
L P TURBINE
GEN
MAKEUP
CONDENSER
FW HEATER
DEAERATOR
STRUTHERS BOILERS
STORAGE TANK
WATER TREATMENT
COOLING TOWER
STEAM TO INJECTION FIELD
TO FLUE GAS SCRUBERS
SALT
WATER/STEAM

## TEXASGULF SOLAR COGENERATION PROGRAM

**PRIME CONTRACTOR**

**General Electric Company**
**Energy Systems Programs Department**

**SUBCONTRACTORS**

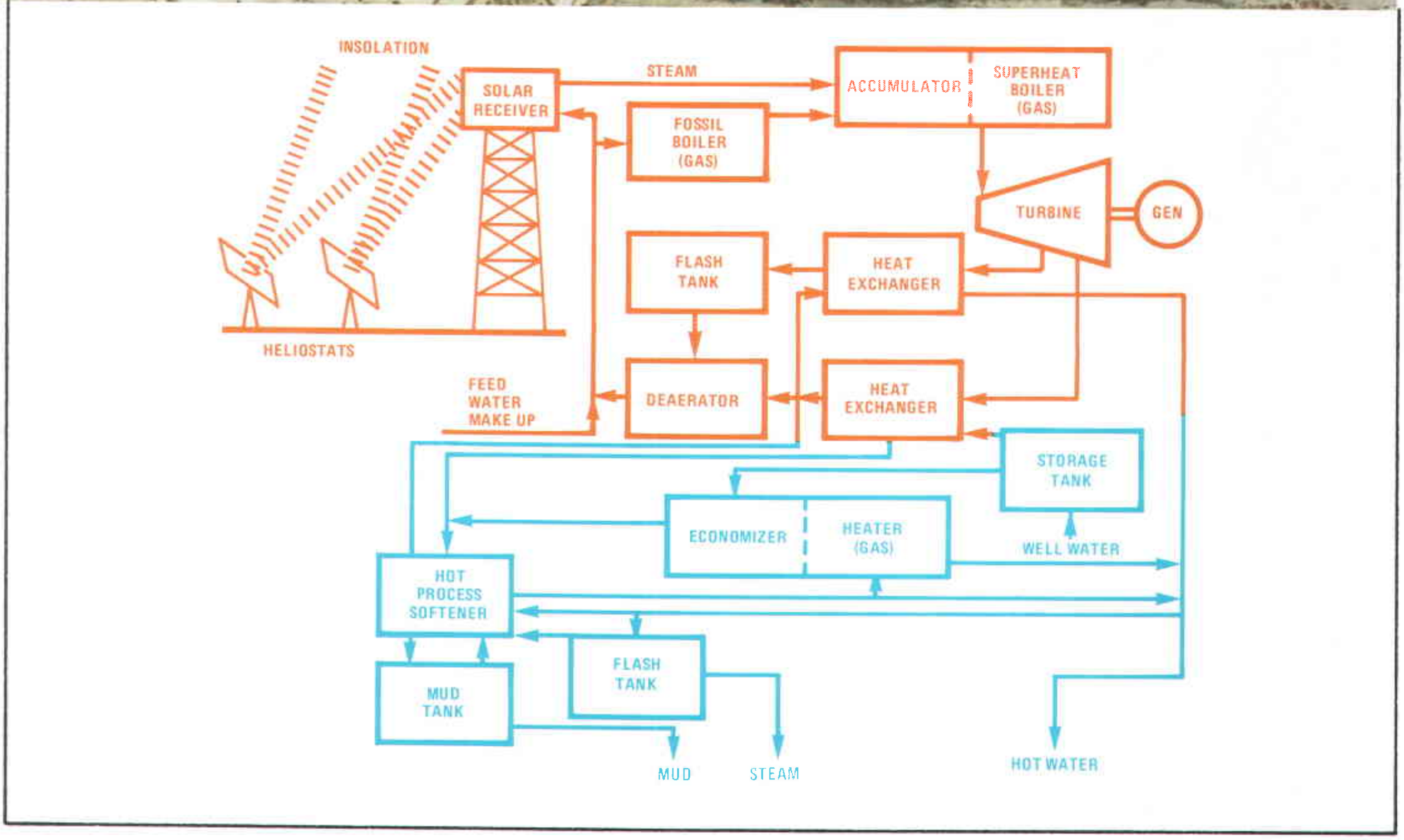
**Texasgulf, Inc.**
**Brown and Root Development, Inc.**

SITE DESCRIPTION—The site selected for the Texasgulf Solar Cogeneration Program is the Comanche Creek Sulfur Mine located near Fort Stockton, Texas, approximately 328 km (240 miles) east of El Paso. The site is located at 30° 52′N latitude, 102° 55′W longitude and its elevation is 913 m (2995 ft). The solar facility will occupy approximately 166,000 $m^2$ (41 acres) of the more than 28,300,000 $m^2$ (7000 acres) available. The climate is arid, subtropical with an estimated average direct normal insolation of 7.1 kWh/$m^2$ per day. The Comanche Creek Sulfur Mine has eight gas-fired water heaters that generate the required process heat. Electricity is purchased from West Texas Utilities. The mine is in continuous operation, 24 hours per day, 365 days per year.

PROJECT SUMMARY—The solar cogeneration facility will be operated in parallel with a gas-fired package boiler to provide 100 percent of the mining operation's electrical requirements (3.0 MW) and 19.9 percent of the process heat requirement (21.6 MW) to yield a power-to-heat ratio of 0.14. This will permit a 16.5 percent turndown of the existing heaters while still providing reliable continuous operation.

CONCEPTUAL DESIGN—The baseline conceptual design consists of a north field arrangement of 588 heliostats that reflect the solar insolation onto a flat, external receiver mounted atop a 69-m (226-ft) tower. The receiver is a natural convection, saturated water/steam boiler. The output of the receiver and the gas-fired boiler (minimum turndown of five percent) are fed in parallel to the accumulator. The accumulator is sized to supply only two minutes of buffer storage since the gas-fired boiler will respond very rapidly to maintain constant accumulator output conditions. The accumulator output is directed into a separate gas-fired superheater that will raise the saturated steam to superheat conditions for entry into the turbine. A master control system will be provided to integrate the instrumentation and control elements of the solar and fossil energy components.

FUNCTIONAL DESCRIPTION—The natural circulation receiver generates 5.65 MPa (820 psia) saturated steam. The superheat boiler generates 5.17 MPa (750 psia), 482°C (900°F) superheated steam for the uncontrolled extraction, condensing superheat steam turbine. Steam exhausted from the turbine will be routed through the low-pressure heat exchanger where cold water from the existing water supply will be preheated to 46°C (115°F). An extraction port on the steam turbine feeds a high-pressure heat exchanger that raises the process water temperature to 177°C (350°F) for transport to the sulfur wells. The solar steam cycle will be a closed-loop operation, since the process water is of poor quality and is not recycled after it is pumped into the sulfur wells. The impact on the existing sulfur mine is limited to piping tie-ins and controls modifications.



INSOLATION
HELIOSTATS
SOLAR RECEIVER
STEAM
ACCUMULATOR
SUPERHEAT BOILER (GAS)
FOSSIL BOILER (GAS)
TURBINE
GEN
FLASH TANK
HEAT EXCHANGER
DEAERATOR
HEAT EXCHANGER
FEED WATER MAKE UP
STORAGE TANK
WELL WATER
ECONOMIZER
HEATER (GAS)
HOT PROCESS SOFTENER
MUD TANK
FLASH TANK
MUD
STEAM
HOT WATER

**PHELPS DODGE CORPORATION—Hidalgo Copper Smelter**

**PRIME CONTRACTOR**

**Gibbs & Hill, Inc.**

**SUBCONTRACTORS**

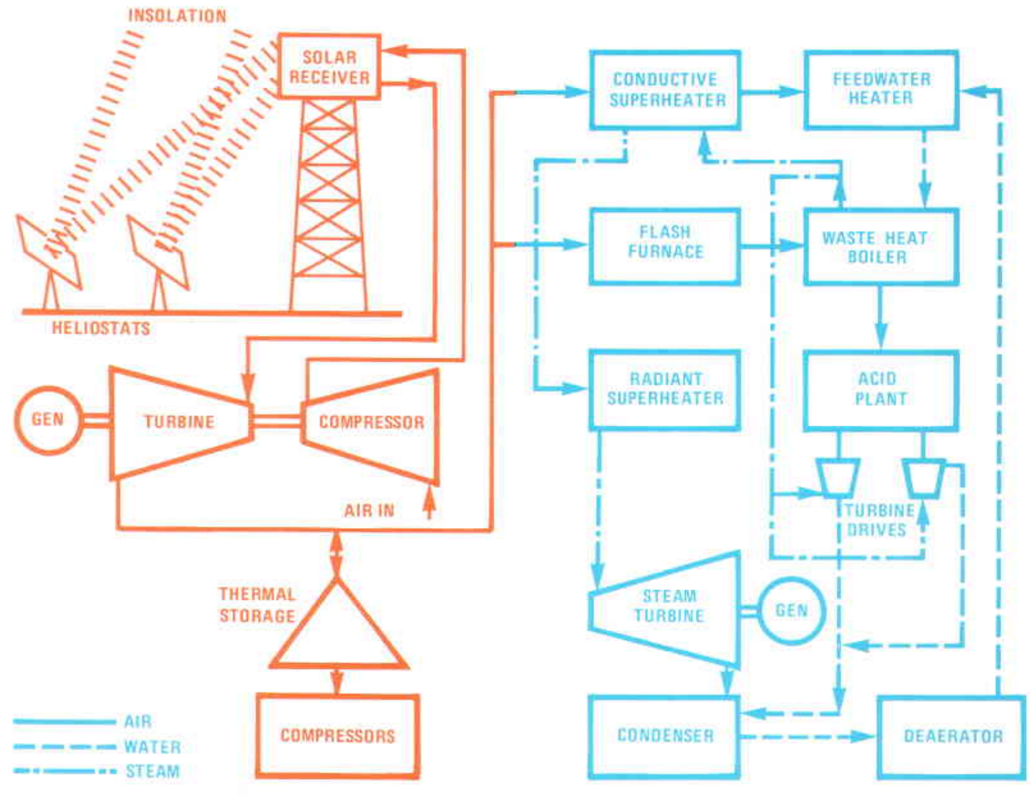
**Phelps Dodge Corporation**
**Boeing Engineering & Construction**

SITE DESCRIPTION—The Hidalgo copper smelter of Phelps Dodge Corporation is located on a 6,470,000 $m^2$ (1600 acres) site in southwest New Mexico about 48 km (30 miles) north of the Mexican border and 48 km (30 miles) east of the Arizona border. The smelter occupies about 2,160,000 $m^2$ (530 acres) of the site. The terrain is relatively flat, with an east-to-west slope of about one percent, at an elevation of about 1310 m (4300 ft) above sea level. The facility processes 2880 tons of dried and fluxed ore concentrate per day, producing about 635,000 kg (700 tons) of copper per day. The smelting process uses air at temperatures from 232 to 482°C (450 to 900°F) and generates steam in waste heat boilers to produce 22 MWe in conventional turbine generators. It consumes about 1500 barrels of oil and 650 MWh of electricity per day. The estimated annual average direct normal insolation is about 6.6 kWh/$m^2$ per day.

PROJECT SUMMARY—A solar central receiver will provide up to 270 MWt of heated air for use in the smelting process, displacing about 95 percent of the present oil consumption. It will also provide the input to gas turbines cogenerating 312 MW of electricity. Waste heat from the smelter is used to produce steam for generating an additional 22 MW of electricity. This permits the net annual sale of 13,000 MWhe compared to the present purchase of 82,000 MWhe/yr.

CONCEPTUAL DESIGN—In the baseline design, compressed air from cogeneration gas turbines is heated to 816°C (1500°F) in a cavity receiver by a surrounding field of 10,500 heliostats. The heated air is expanded to about 546°C (1014°F) in the gas turbines and then ducted to a thermal storage reservoir consisting of a mound of waste slag (iron oxide-silicate) from the smelter. The slag is covered with a layer of soil for insulation and operates in the same manner as a rockbed storage system. Heat is extracted from the storage reservoir by circulating ambient air through the slag where it is heated to 538°C (1000°F) and is then ducted to the flash furnace of the smelter and to the superheaters. Waste heat is recovered from both operations by use of waste heat boilers and ore concentrate dryers.

FUNCTIONAL DESCRIPTION—Ambient air is drawn into the compressors of gas turbines where it is compressed to 0.31 MPa (45 psia), 220°C (428°F). The compressed air ascends through the riser and enters the cavity receiver. The heliostats focus solar energy to the receiver where it heats the compressed air passing through tubes that line the walls of the receiver cavity to 816°C (1500°F). The air passes from the receiver via downcomer piping to the power-generating gas turbines that expand the air to near ambient pressure and a temperature of about 546°C (1014°F). The air exhausting from the turbines is ducted to a thermal storage reservoir consisting of a soil-covered mound of smelter slag (iron oxide-silicate). The thermal energy is recovered by passing ambient air through the storage reservoir where it is heated to about 538°C (1000°F). The heated air is used in the smelter flash furnace and in the superheater of the waste heat boiler system. Waste heat is recovered by the waste heat boilers and the ore concentrate dryers.



INSOLATION
SOLAR RECEIVER
HELIOSTATS
GEN
TURBINE
COMPRESSOR
AIR IN
THERMAL STORAGE
COMPRESSORS
AIR
WATER
STEAM
CONDUCTIVE SUPERHEATER
FEEDWATER HEATER
FLASH FURNACE
WASTE HEAT BOILER
RADIANT SUPERHEATER
ACID PLANT
TURBINE DRIVES
STEAM TURBINE
GEN
CONDENSER
DEAERATOR

## FORT HOOD SOLAR COGENERATION FACILITY STUDY

**PRIME CONTRACTOR**

**McDonnell Douglas Astronautics Co.**

**SUBCONTRACTORS**

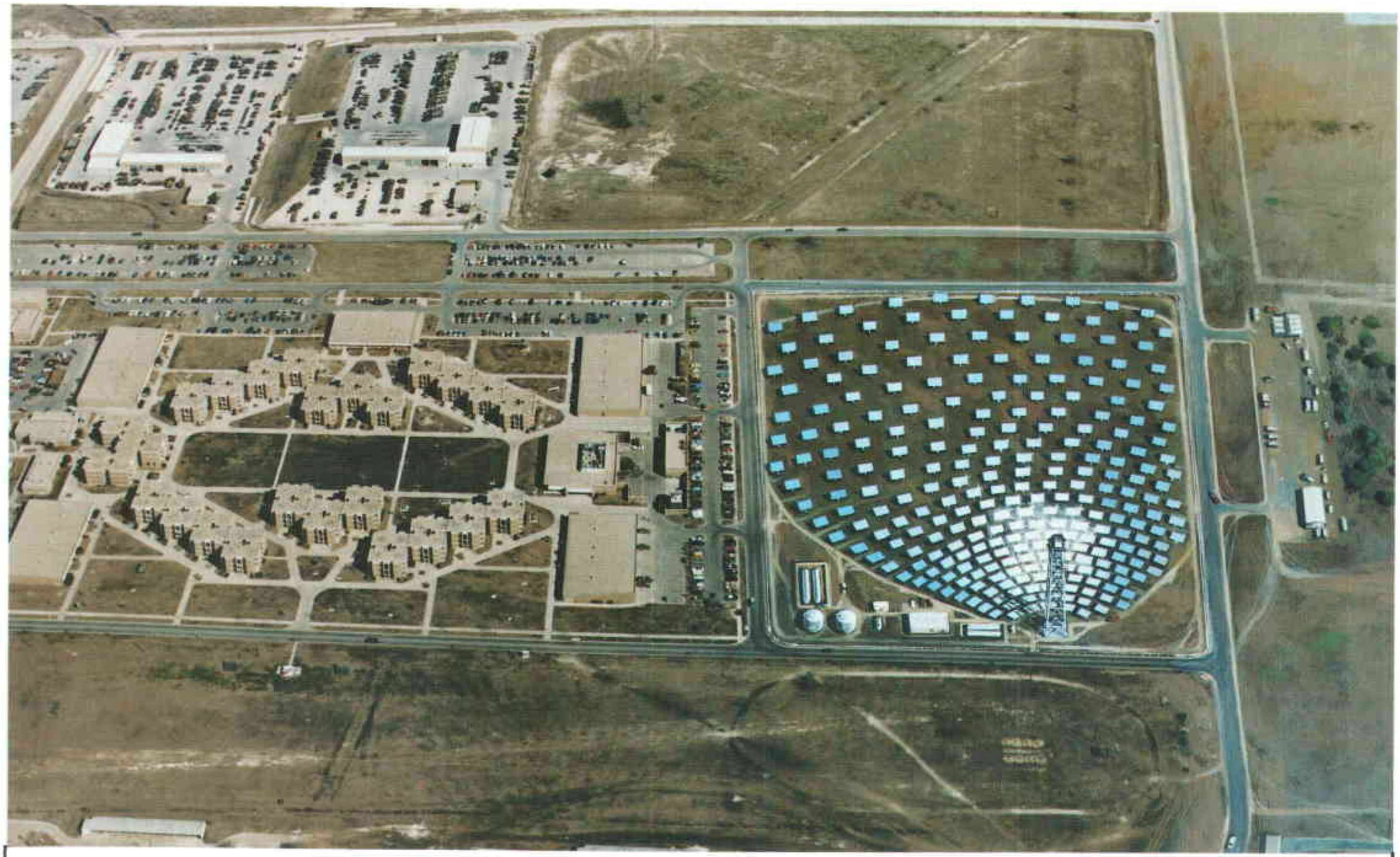
**Stearns-Roger**
**University of Houston**

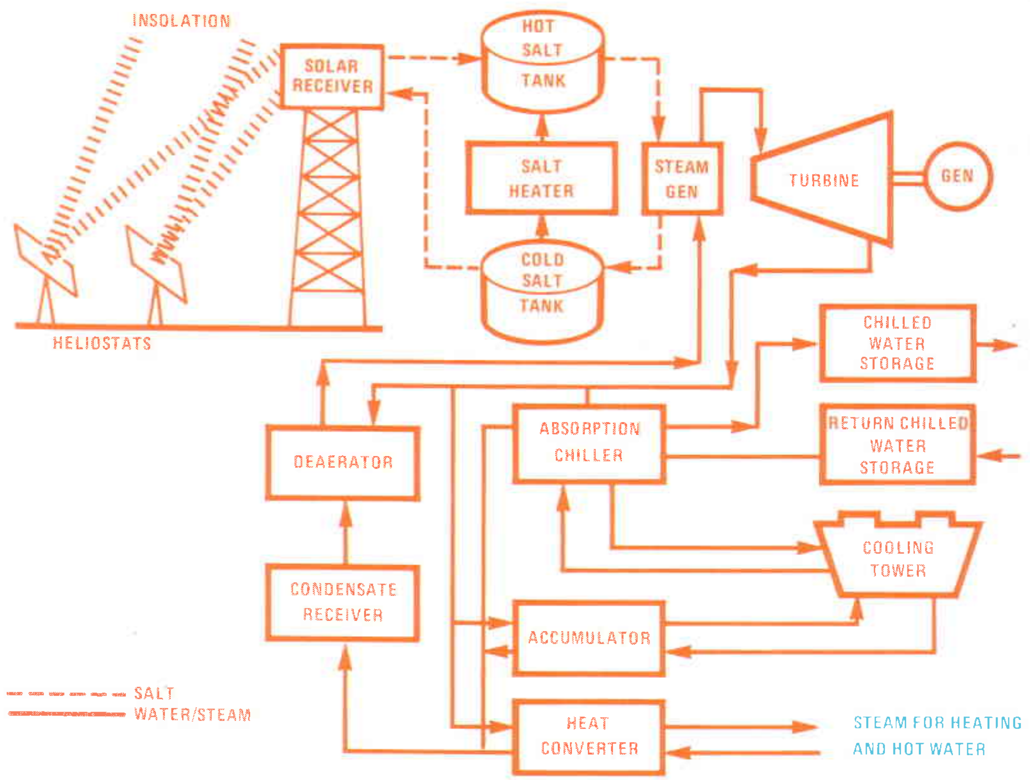
SITE DESCRIPTION—The site being studied for solar cogeneration is the Ft. Hood Army Base located at Killeen, Texas, approximately midway between Ft. Worth and San Antonio. The cogeneration system will service Complex 87000 which consists of a group of 20 buildings providing the housing, food services, and other facilities for approximately 1,650 troops. The proposed solar collector equipment will be located in a 60,700 $m^2$ (15 acres) undeveloped area located immediately to the east of the complex, adjacent to the central plant building. Electrical energy for the complex is presently supplied by the Texas Power and Light Co. Thermal energy for room heating and domestic hot water is supplied by two gas-fired steam boilers located in the central plant building. Chilled water for air conditioning is supplied from two electrically driven centrifugal compressors, also located in the central plant building. Gas is provided by the Lone Star Gas Company.

PROJECT SUMMARY—The proposed solar cogeneration facility will supply more than 60 percent of the thermal energy needs of the complex on an annual basis, and the electrical energy generated will exceed the annual requirements of the complex, with the excess distributed through the electrical grid for other Ft. Hood uses. Energy spillage is minimized with approximately 85-90 percent utilization of the solar energy collected. The solar cogeneration facility will displace the equivalent of approximately 9,700 barrels of oil per year.

CONCEPTUAL DESIGN—The solar cogeneration facility will utilize approximately 242 second-generation heliostats in a north field configuration to deliver up to 8.7 MWt of solar energy to a single-aperture partial-cavity receiver. The absorbed heat will be transferred by molten salt (HITEC) to a two-tank high-temperature storage system (20 MWht). A gas-fired HITEC heater will also generate heat for the system during prolonged periods of low or no insolation. Hot HITEC at 454°C (850°F) will be subsequently pumped through a natural circulation type steam generator to produce steam at 399°C, 4.9 MPa (750°F, 715 psia) for the operation of a 570 kWe rated turbine/generator unit.

FUNCTIONAL DESCRIPTION—Solar energy directed to the receiver from the heliostat field is absorbed by the HITEC and then transferred to a steam generator. The steam is sent to an extracting-type steam turbine/generator unit that produces electricity and low-pressure steam. The low-pressure steam is sent to an absorption water chiller for space cooling. Turbine exhaust steam is used for space and water heating. Water for peak demands is available from chilled water and hot water storage tanks.




INSOLATION
SOLAR RECEIVER
HOT SALT TANK
SALT HEATER
COLD SALT TANK
STEAM GEN
TURBINE
GEN
HELIOSTATS
CHILLED WATER STORAGE
CHILLED WATER
RETURN CHILLED WATER STORAGE
CHILLED WATER
ABSORPTION CHILLER
DEAERATOR
COOLING TOWER
CONDENSATE RECEIVER
ACCUMULATOR
HEAT CONVERTER
STEAM FOR HEATING AND HOT WATER
SALT
WATER/STEAM

## ROBINS AIR FORCE BASE—Warner Robins, Georgia

### PRIME CONTRACTOR

**Westinghouse Electric Corp.**

### SUBCONTRACTORS

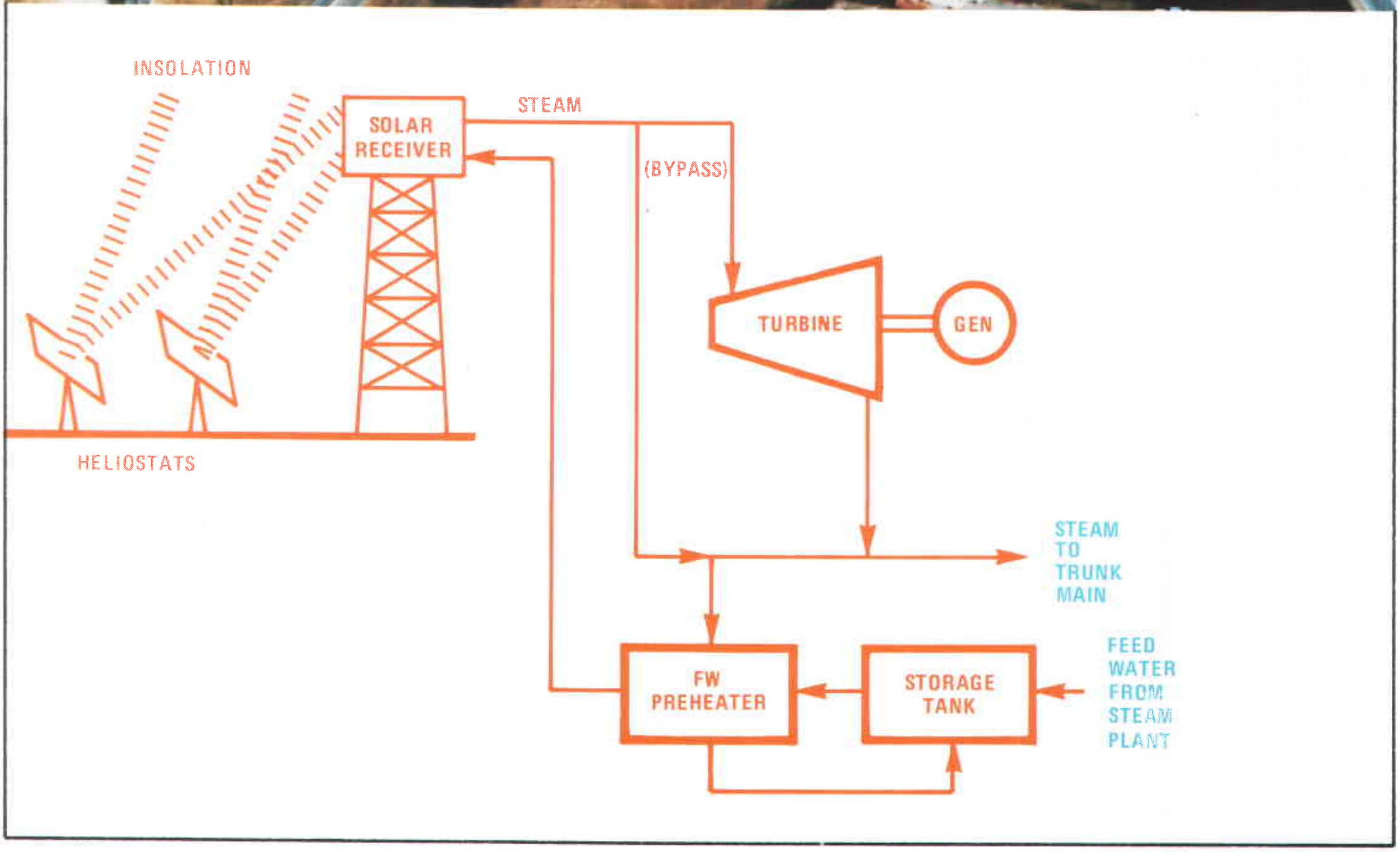
**Heery & Heery, Inc.**
**Foster Wheeler Solar Development Corp.**
**Mechanical Technical Technologies, Inc.**

SITE DESCRIPTION—Robins Air Force Base is located east of Warner Robins, Georgia. The base encompasses 31,000,000 $m^2$ (7,625 acres) and employs some 34,000 military and civilian personnel. The site is on land committed to the solar cogeneration facility. The average direct normal insolation is estimated to be 4.3 $kW/m^2$ per day. The section of Robins AFB where the facility will be located is supplied with central steam for space conditioning and water heating by four boiler-plants with a total rated steam production of 42,700 kg/h (94,000 lb/h). Steam is used for space heating in the winter, absorption cooling in the summer, and some industrial process loads. The boilers are normally fired with natural gas and use fuel oil when natural gas use is curtailed by the Atlanta Gas Light Company. Underground trunk steam and condensate lines are nearby and of sufficient size to convey the thermal output of the solar plant to the entire complex served by the steam plant. A 10-MW, 12,000-volt electrical distribution system is supplied by a Georgia Power Company substation nearby.

PROJECT SUMMARY—The baseline design utilizes water/steam central receiver technology to provide main steam to the turbine generator. The electrical output is fed to the existing base electrical distribution system and the turbine exhaust steam is directed into the existing base steam distribution system. The cogeneration facility is sized to permit direct use of the solar-generated electricity and steam to displace electricity and gas normally purchased. The Air Force Logistics Command at Wright-Patterson Air Force Base and the Robins Air Force Base personnel are contributing to this study to ensure user suitability of the resultant design. Georgia Power Company is collaborating with Robins Air Force Base in both technical interface and fiscal matters relative to the facility operation.

CONCEPTUAL DESIGN—The external flat plate receiver concept is based upon natural circulation receiver boiler technology developed by Foster Wheeler Development Corporation in both private and DOE-sponsored experience. The receiver panel is estimated to be about 8.5 m (27.5 ft) high by 9.5 m (29 ft) wide. This technology was selected on the basis of utilizing commercial/user design and operating experience. No thermal storage is used in the conceptual design. The baseline heliostat field consists of 251 heliostats of the typical second-generation heliostat design on 15.5 acres of land north of the receiver tower. This field provides about 10 MWt at the receiver which is located 60 m (197 ft) above the ground.

FUNCTIONAL DESCRIPTION—Feedwater from the boiler plant is pumped up to the natural circulation receiver where it is heated to 410°C at 6.1 MPa (770°F, 890 psia). The steam is then sent to a turbine-generator producing about 725 kWe. Exhaust from the turbine is directed into the base steam trunk at 186°C and 1.07 MPa (366°F, 155 psia).



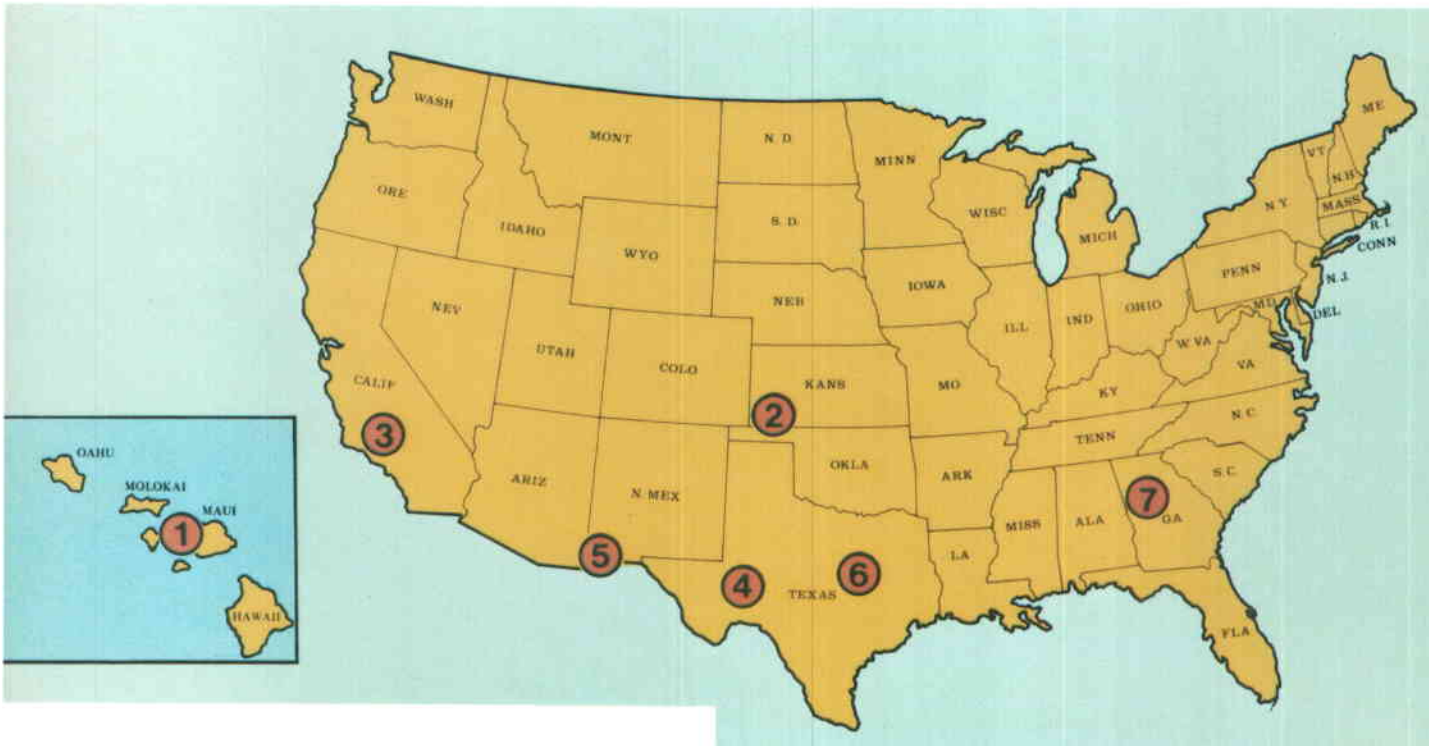
INSOLATION
SOLAR RECEIVER
STEAM
(BYPASS)
TURBINE
GEN
HELIOSTATS
STEAM TO TRUNK MAIN
FW PREHEATER
STORAGE TANK
FEED WATER FROM STEAM PLANT

## SOLAR COGENERATION CONCEPTUAL DESIGN SUMMARY

| User | Central Receiver: Power Output | Central Receiver: Temp (°C) Pres (MPa) | Central Receiver: Type | Tower Height (m) | Number of Heliostats (Mirror Area x $10^3$ $m^2$) | Solar Power* (Thermal Storage) | Annual BBL Oil (Equiv. Saved) |
|---|---|---|---|---|---|---|---|
| Amfac Sugar Co. | 26 MWt | 438<br>6.85 | cavity-water | 72<br>(43) | 815 | 17.1 MWt<br>3.4 MWe<br>0.3 MWm | 40,000 |
| Central Telephone & Utilities—Western Power | 37 MWt | 510<br>11.07 | external-water | 74 | 1,057<br>(55.8) | 3.7 MWt<br>15 MWe | 48,100 |
| Exxon Research & Engineering Co. | 115 MWt | 566<br>2.5 | cavity-salt | 137<br>(189.1) | 3,295 | 13.2 MWt<br>20.4 MWe<br>(380 MWhTS) | 140,000 |
| Texasgulf Chemical | 20 MWt | 272<br>5.65 | external-water | 69 | 588<br>(31.0) | 16.0 MWt<br>2.2 MWe | 40,100 |
| Phelps Dodge Co. | 270 MWt | 816<br>0.4 | cavity-air | 184 | 10,441<br>(521) | 54 MWt<br>46 MWe<br>(4080 MWhTS) | 436,000 |
| Fort Hood, U.S. Army | 8.7 MWt | 454<br>0.1 | cavity-salt | 53 | 242<br>(13.8) | 3.5 MWt<br>0.6 MWe<br>(20 MWhTS) | 9,700 |
| Robins AFB | 8.8 MWt | 410<br>6.1 | external-water | 60 | 251<br>(13.2) | 7.9 MWt<br>0.7 MWe | 8,300 |

*Proportion of net output from solar.

# Solar Cogeneration Projects




Listed below are addresses for obtaining additional information on the solar cogeneration projects:

1 Bechtel National, Inc.
Attn: Jack R. Darnell
P. O. Box 3965
San Francisco, CA 94119

2 Black & Veatch Consulting Engineers
Attn: John E. Harder
P. O. Box 8405
Kansas City, MO 64114

3 Exxon Enterprises, Inc.
Solar Thermal Systems
Attn: George Yenetchi
P. O. Box 592
Florham Park, NJ 07932

4 General Electric Company
Energy Systems Programs Department
Attn: Howard E. Jones
1 River Road
Schenectady, NY 12345

5 Gibbs & Hill, Inc.
Attn: Robert Prieto
393 Seventh Avenue
New York, NY 10001

6 McDonnell Douglas Astronautics Company
Attn: Robert P. Dawson
5301 Bolsa Avenue
Huntington Beach, CA 92647

7 Westinghouse Electric Corporation
Attn: Robert W. Devlin
P. O. Box 10864
Pittsburgh, PA 15236