VOLUME II
APPENDICES

DOE/SF/11437-2

FINAL REPORT
JUNE 1981

TEXASGULF SOLAR COGENERATION PROGRAM

PREPARED UNDER CONTRACT
NO. DE-AC03-80SF11437
FOR THE
U. S. DEPARTMENT OF ENERGY

GENERAL ELECTRIC COMPANY
ADVANCED ENERGY PROGRAMS DEPARTMENT
PHILADELPHIA, PENNSYLVANIA

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Appendix A
SYSTEM SPECIFICATION

ENERGY SYSTEMS PROGRAMS DEPARTMENT GENERAL ELECTRIC	ENGINEERING SPECIFICATION	SPECIFICATION NUMBER 295A4735
	TITLE SYSTEM SPECIFICATION FOR TEXASGULF SOLAR COGENERATION FACILITY	ORIGINAL ISSUE DATE October 15, 1980
	CLASSIFICATION "A"	

TEXASGULF SOLAR COGENERATION PROGRAM

COMANCHE CREEK SULFUR MINE

FORT STOCKTON, TEXAS

TEXASGULF INC.

TEXASGULF CHEMICALS CO.

U.S. SULFUR OPERATIONS

NEWGULF, TEXAS

APPROVALS

ENGR. Stuart Schwartz DATE 10/22/80	
MFG. DATE	PROGRAM MGR. Howard E. Jones DATE 10/22/80
	QA DATE
MAT'LS DATE	
PREPARED BY Denis J Bisantz DATE 10/22/80	ISSUED BY DATE

REVISION NUMBER	REVISION DATE	SUPERSEDES	PAGE
2	June 1, 1981	Revision 1 — dated 1/31/81	PAGE 1 OF 79

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1.0 GENERAL

1.1 SCOPE

This specification defines the system requirements, subsystem characteristics and required operating modes for a solar cogeneration facility to be located at the Texasgulf Comanche Creek sulfur mine in Fort Stockton, Pecos County, Texas. The requirements provided in this specification are consistent with the level of detail and accuracy of a conceptual design study.

1.2 SYSTEM DESCRIPTION

The solar cogeneration facility for the Texasgulf Comanche Creek sulfur mine will be accomplished with minimal modification of the existing Frasch process mining operation. The system consists of a saturated water/steam solar central receiver coupled to a condensing, uncontrolled extraction superheat steam turbine (thru a superheat boiler) that delivers electricity and thermal power in the form of heated water. The major elements of the system are:

- Site
- Site Facilities
- Collector Subsystem
- Receiver Subsystem
- Master Control Subsystem
- Fossil Energy Subsystem
- Electric Power Generation Subsystem
- Process Heat Subsystem
- Electrical Subsystem
- Fluid Circulation Subsystem

The primary interfaces of these subsystems are shown on Figure 1-1. A diagram of the cogeneration facility integrated with the existing plant is shown on Figure 1-2.

1.2.1 Site

The Texasgulf Solar Cogeneration Facility will be located 25.9 km (14 miles) northeast of Fort Stockton, Texas (about 245 miles east of El Paso), at an altitude of 913 m (2995 ft) above mean sea level. The site is located at 30° 52'N latitude, 102° 55'W longitude. The solar cogeneration facility at the Comanche Creek Plant will be laid out as illustrated in Figure 1-3.

1.2.2 Site Facilities

The addition of the solar cogeneration facility will require some modifications to the existing plant along with the new facilities in order to adapt the site to the solar system. These include:

- Storage and Maintenance Facilities
- Security Fencing
- Added Access Roads
- Combined Operations Center

1.2.3 Collector Subsystem

The collector subsystem provides the means of reflecting the incident solar radiation on to the receiver. It consists of a field of heliostats arranged in a north-field configuration located to the south of the sulfur mine. The heliostat layout is illustrated in Figure 1-4. Included in this subsystem are the following:

a. Heliostats, including reflective surface, structural support, drive units, control sensors, pedestals, foundations, cabling, and cable array installations.

b. Electromechanical and electrical controllers, including individual heliostat and heliostat field controllers, control system interface electronics, and power supplies.

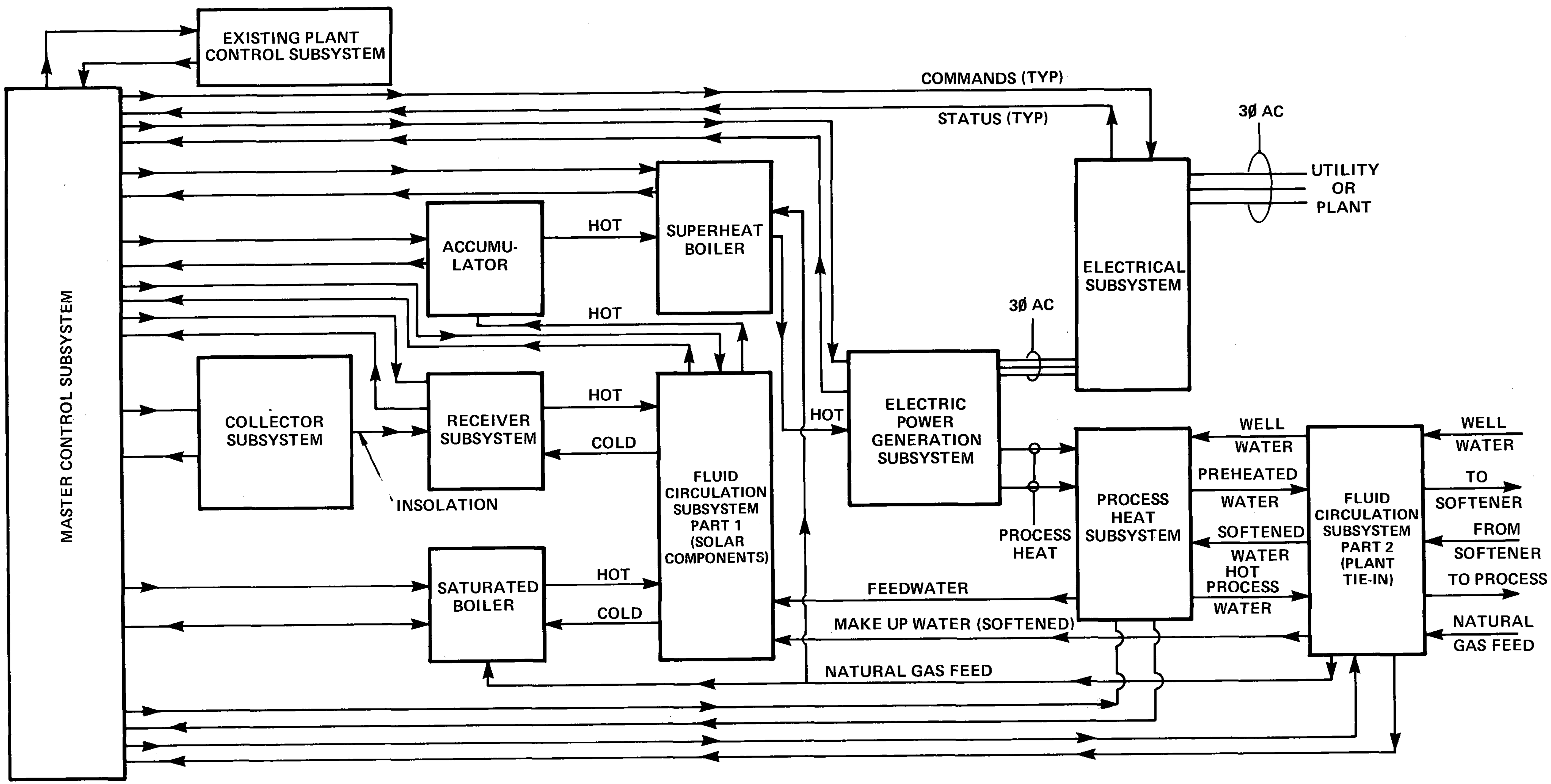


Figure 1-1. Subsystem Interface Schematic – Solar Cogeneration Facility

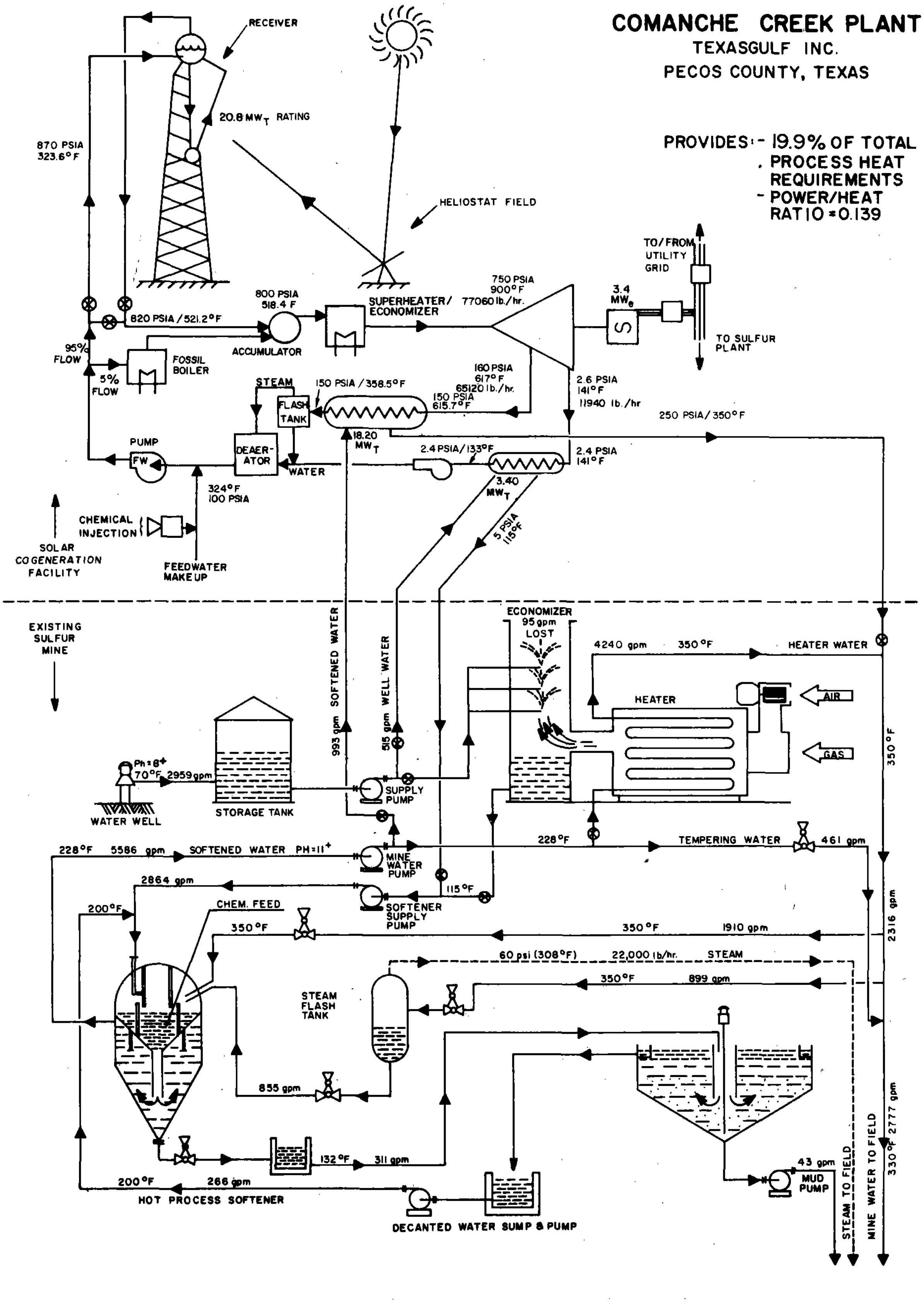
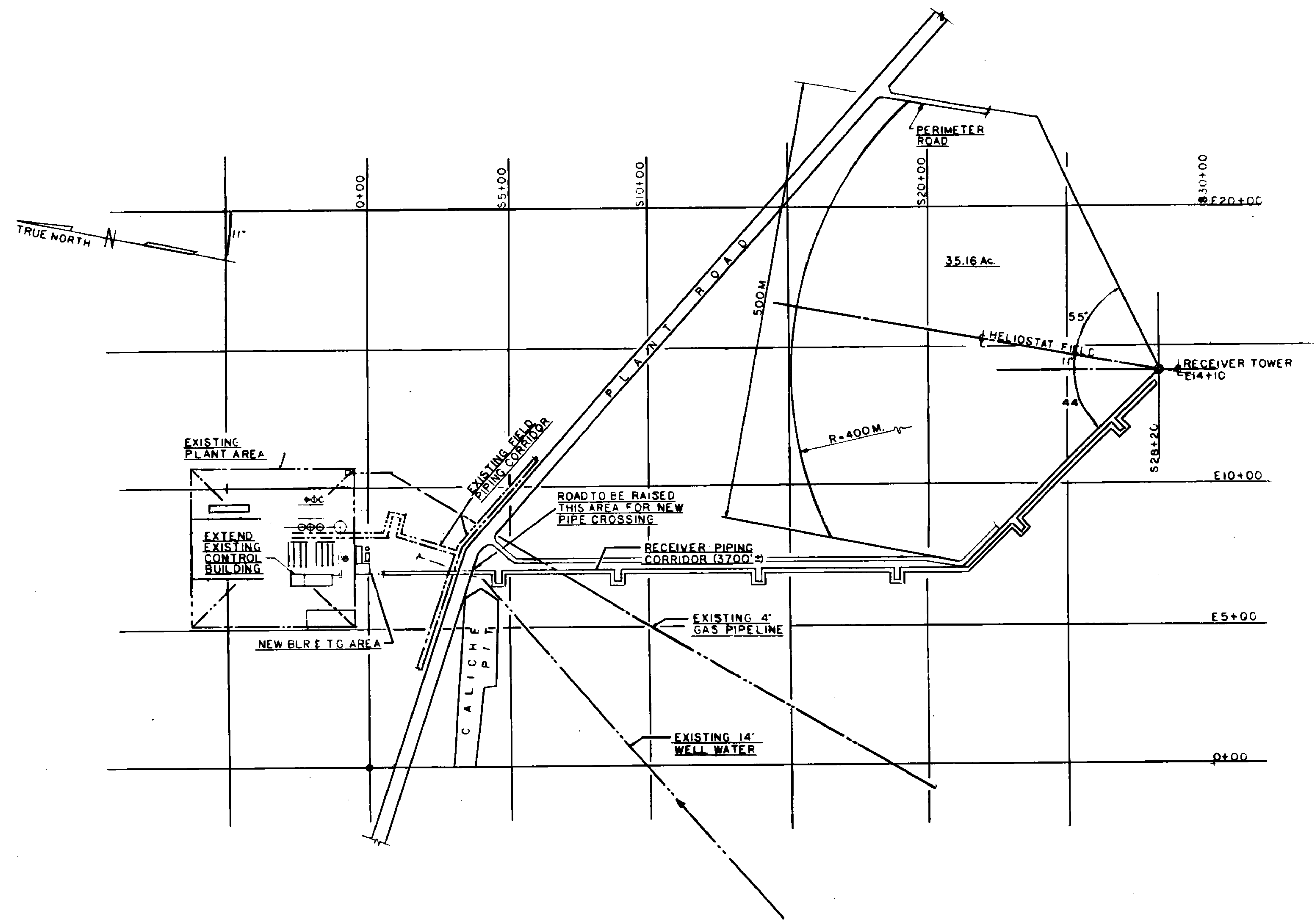


Figure 1-2. Schematic – Solar Cogeneration Facility Integrated with Existing Plant

GENERAL ELECTRIC



Brown & Root Development, Inc.
HOUSTON, TEXAS

DRAWN BY	WILLIAMS
DATE	1-2-81
SCALE	1"=200'
TITLE OF DRAWING	PLOT PLAN
	SOLAR COGENERATION STUDY
NAME OF OWNER	TEXASGULF, INC
LOCATION OF PROJECT	FT STOCKTON, TEXAS
CONTRACT NO.	ER-0798
DRAWING NO.	798-1
SHEET	1 OF 1

Figure 1-3. Solar Cogeneration Facility Plot Plan

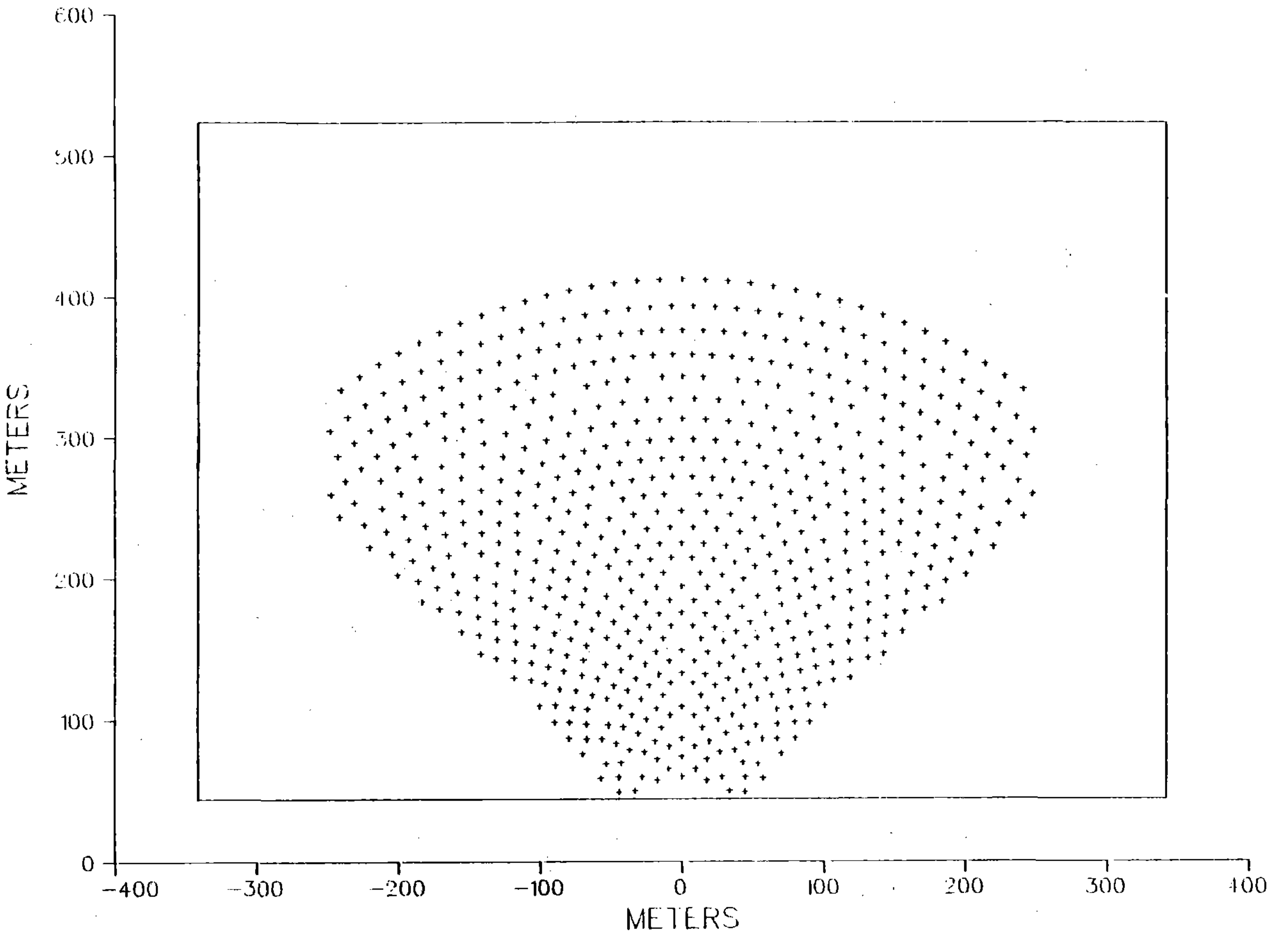


Figure 1-4. Heliostat Field Layout

1.2.4 Receiver Subsystem

The receiver subsystem provides the means of transferring the incident radiant flux energy from the collector subsystem into the receiver water/steam working fluid. It consists of an elevated, flat, tubular receiver, a steel tower to support the receiver, and the tower up/down piping to and from the receiver. This subsystem will also include a steam drum and control elements to regulate the flow and pressure for safe and efficient operation.

1.2.5 Master Control Subsystem

The master control subsystem shall be provided to sense, detect, monitor and control the solar portions of the cogeneration facility, and interfaces with all subsystems and the existing plant, in order to insure safe, reliable and efficient operation. The master control subsystem consists of controllers for each major subsystem, a central computer and control unit, control and display consoles, interface electronics and software.

1.2.6 Fossil Energy Subsystem

The fossil energy subsystem provides a nonsolar energy source which is used to maintain normal plant operation during periods of reduced or no insolation. It consists of a saturated boiler, a superheater and an accumulator, all selected to supply the steam requirements of the turbine.

1.2.6.1 Fossil Boiler

The boiler will be gas fired to a minimum firing rate of 5% and its output will parallel the solar steam supply and feed into the accumulator.

1.2.6.2 Accumulator
The accumulator provides a means of storing a portion of the thermal energy output of the receiver. Solar transients can be both large and virtually instantaneous. These severe transients can be smoothed by use of a buffer storage system which replaces the flow lost from the receiver and maintains a rate of change consistent with fossil boiler capabilities, thus keeping plant output constant.

Buffer storage is obtained from the accumulator. Both the receiver output and the saturated boiler output feed into the accumulator. The output from the accumulator goes into the superheater.

1.2.6.3 Fossil Superheater
The superheater receives its input from the accumulator in the form of slightly wet saturated steam. It heats this saturated steam to superheat conditions for the turbine inlet.

1.2.7 Electric Power Generating Subsystem
The electric power generating subsystem (EPGS) will be a superheat steam turbine. Steam is extracted at an intermediate turbine stage to heat the process softened water. The remaining steam is expanded thru the turbine and used to preheat the well water. The generator controls are designed to maintain 60 Hz operation independent of the utility grid.

1.2.8 Process Heat Subsystem
The process heat subsystem consists of two sets of condensing heat exchangers; one set located at the turbine extraction point to heat softened water for the sulfur mining process and the other set located at the turbine exhaust to heat the well water. To ensure system reliability, these heat exchangers will be arranged in multiples of 2, as described in 3.8.

Because of the sulfur mining process, the flow of water thru one set of heat exchangers must be proportional to the flow of water thru the other set. Consequently, the thermal requirements are proportional to each other.

1.2.9 Electrical Subsystem
The electrical subsystem consists of the necessary equipment to monitor and control the flow of power from the generator to either the utility grid or the sulfur mining operation, in addition to accommodating the existing power flow from the grid to the mine if required. It also disconnects the generator from the grid in cases of a grid or plant or generator fault. Automatic resequencing equipment is used to re-establish the grid connection.

1.2.10 Fluid Circulation Subsystem
This fluid circulation subsystem includes all the pumps, field piping, brackets and hardware that physically connect the other subsystems together. It allows all of the "off-the-shelf" hardware to be located in a specific category for ease of pricing and control.

1.3 MODES OF OPERATION
Operation of the Comanche Creek plant is well defined and Texasgulf works the sulfur mine on an around-the-clock, year-round basis. Therefore, to be compatible, the solar cogeneration facility will supply superheated steam to the turbine by operating in one of the following modes:

- Nonsolar - Normal Operation
- Solar - Normal Operation
- Solar - Intermittent Clouds Operation
- Solar - Startup
- Solar - Normal Shutdown
- Solar - Emergency Shutdown

1.4 DEFINITION OF TERMS

a. *Beam Pointing Error*—The angular difference between the aim point and the beam centroid of a mirror.

b. *Capacity Factor Annual,* Nonsolar—Annual nonsolar MWh divided by the product of 8760 hr and Thermal Power, Prime Mover (MW_t) (defined below).

c. *Capacity Factor Annual, Overall*—Annual solar MWh plus annual nonsolar MWh divided by the product of 8760 hr and Thermal Power, Prime Mover (MW_t) (defined below).

d. *Capacity Factor Annual, Solar*—Solar MWh divided by the product of 8760 hr and Thermal Power, Prime Mover (MW_t) (defined below).

e. *Cogeneration*—The combined production of electrical or mechanical energy and useful thermal energy.

f. *Conversion Efficiency, Gross*—Gross output provided by a conversion device divided by total input power at specified conditions.

g. *Conversion Efficiency, Net*—Actual net output (after deducting losses) provided by a conversion device divided by the required input power at specified conditions.

h. *Demand*—The power versus time profile of the energy required to satisfy the energy needs of the final consumer or end use consuming process.

i. *Design Point*—The time and day of the year at which the system is sized with reference insulation, wind speed, temperature, humidity, dewpoint, and sun angles.

j. *Direct Insolation*—Non-scattered solar flux falling on a surface of given orientation (watts per square meter).

k. *Discounted Cash Flow Rate of Return (DCRR)*—DCRR is the discount rate which makes the difference, in discounted after tax cash flows, of two alternate power plants over their economic life equal to their difference in capital costs. It is also analogous to the interest rate which would be obtained if the capital loaned as an investment.

l. *Field Receiver Power Ratio*—Maximum heliostat field power output divided by maximum receiver power absorption capability.

m. *Fluid, Working*—The fluid used in the turbine or other prime mover.

n. *Fluid, Receiver*—The fluid used to cool the solar receiver and distribute the absorbed solar energy to other parts of the system; heat transport fluid of the receiver.

o. *Geometric Concentration Ratio*—The ratio of the projected area of a reflector system (on a plane normal to the insolation) divided by absorber area.

p. *Levelized Annual Energy Cost (LAEC)*—LAEC is the constant cost required each year over the economic life of the power plant to cover the cost of capital and the recovery of the initial investment including all expenses, operation and maintenance, taxes and insurance, purchased or exported power, and purchased or displaced fuel. It is analogous to the utility method of calculating the cost of electricity in dollars per kwh except here it is in total cost per year for the power plant.

q. *Payback Period*—A traditional measure of economic viability to investment project. A payback period is defined in several ways-one of which is the number of years required to accumulate fuel savings which exactly equal initial capital cost of system. Payback often does not give an accurate representation of total life-cycle values.

r. *Power-to-Heat-Ratio*—The net electric power divided by the thermal power to the user.

s. *Process Heat*—Thermal energy which is used in industrial operations.

t. *Receiver Efficiency*—Ratio of thermal power output at receiver base to incident solar power upon receiver.

u. *Solar Cogeneration*—Utilizing solar central receiver technology for the combined production of electrical or mechanical energy and useful thermal energy.

v. *Solar Flux*—The rate of solar radiation per unit area (watt/m^2).

w. *Solar Fraction, Annual*—Ratio of solar energy to the process divided by the total energy consumption, annual average, measured at turbine inlet.

x. *Solar Fraction, Design Point*—As above at design point.

y. *Solar Multiple*—Defined at the design point as thermal power from receiver after downcomer and piping losses divided by Thermal Power, Prime Mover (definition below).

z. *Storage Capacity*—The amount of net energy which can be delivered from fully charged storage system.

aa. *Thermal Power, Fossil Heater Output*—Thermal power input to working or transport fluids from the fossil heater after stack and miscellaneous losses.

bb. *Thermal Power, Prime Mover*—Thermal power input to turbine or other prime mover at design point. For cogeneration, thermal power to operate the balance of the system is included.

cc. *Thermal Power, Receiver Output*—Thermal power derived from the receiver, does not include electrical parasitic or downcomer thermal losses.

2.0 REFERENCES

The design presented in this specification shall be prepared whenever possible, in accordance with the following standards. These standards govern the design and selection of vessels, heat-transfer equipment, mechanical equipment, structures, piping, instrumentation and electrical items that are used in process industries. These documents, of the issue in effect on the date of the contract award, form a part of this specification to the extent stated herein.

2.1 STANDARDS AND CODES

- Uniform Building Code - 1976 Edition by International Conference of Building Officials
- American National Standards Institute (ANSI)

- ANSI A58.1-1972	Minimum Design Loads in Buildings and Other Structures
- ANSI B31.1-1977	Power Piping
- ANSI C12.	Transformer
- ANSI C37.	Switchgear
- ANSI C50.	Generator

- Occupational Safety and Health Administration (OSHA) Regulations
  - OSHA Title 29, Part 1910 Occupational Safety and Health Standards
  - OSHA Title 29, Part 1926 Safety and Health Regulations for Construction
- ASME Boiler and Pressure Vessel Code:
  - Section I - Power Boilers
  - Section II - Materials Specifications
  - Section VIII - Unfired Pressure Vessels
- Institute of Electrical and Electronic Engineers (IEEE) Codes, as applicable
- National Fire Protection Association (NFPA) National Fires Codes - 1979
- Design, Construction, and Fabrication Standards
  - Standards of AISC (American Institute of Steel Construction)
  - Standards of ACI (American Concrete Institute)
  - Standards of TEMA (Tubular Exchanger Manufacturer's Association)
  - Standard 650 of API (American Petroleum Institute)
    - (Welded Steel Tanks for Oil Storage)
  - Sandia Livermore Laboratories
    Collector Subsystem Requirements Specification A10772
    (2nd Generation Heliostats, Issue D)
  - National Electric Safety Code
- International System Units, 2nd Revision, NASA SP-7012
- Human Engineering Design Criteria, MIL-STD-810C and MIL-STD-1472
- Environmental Test Requirements, MIL-STD-810B
- Nuclear Regulatory Commission (NRC) Regulatory Guides
  - NRC Guide 1.60
  - NRC Guide 1.61

2.2 OTHER PUBLICATIONS AND DOCUMENTS

- Rules and Regulations of the Texas Department of Water Resources
- West Texas Utilities Plant Grounding Practices:
  IEEE Std-80, 1976 and ANSI C2-1981.

2.3 PERMITS AND LICENSES REQUIRED

- FAA approval for tower construction

2.4 APPLICABLE LAWS AND REGULATIONS

- Regulations of the Federal Aviation Administration
- Regulations of the Civil Aeronautics Board
- National Energy Conservation Policy Act of 1978
- Power Plant and Industrial Fuel Use Act of 1978
- Public Utilities Regulatory Policy Act of 1978
- National Gas Policy Act of 1978
- Energy Tax Act of 1978
- National Environmental Policy Act (NEPA)

3.0 REQUIREMENTS

The solar cogeneration facility shall be designed to meet the performance requirements of this section. This specification is applicable as a design requirement only to the new or modified portions of the solar cogeneration facility. The solar cogeneration design specifications shall make maximum use of completed or ongoing DOE solar R&D activities.

3.1 SITE

The solar cogeneration facility will require $1.42 \times 10^5 m^2$ (35 acres) of land for the solar collector field. It will be located in close proximity to the sulfur mining operation with the collector field symmetric about the geographic North/South line. Minimal site grading will be required to provide a uniform nearly level slope in the direction of natural drainage. The collector field surface is to be treated following heliostat installation to minimize dust. Provisions are to be made to allow maintenance vehicle traffic between heliostat rows during all weather conditions.

The following are site characteristics which will be factored into the design of the new facilities to be installed:

- Soil stratigraphy and conditions are generally uniform across the site. The soils grade from sandy silts to silty sands and vary in relative density from loose to depths on the order of 0.6 m (two feet), medium dense to an average depth of 3 m (10 ft) and very dense below this zone. The soils will permit support of major and auxiliary structures at a depth of 0.6 m (2 ft) below ground surface. The natural slope of the heliostat field land area is from south to north, approximately 3.5 m (12 ft) drop in 610 m (2000 ft) run.
- Fort Stockton has an arid subtropical climate with hot summers. Typical climatological data is best represented by the thirty year period from 1938 to 1967 for which the mean annual total precipitation was 31.1 cm (12.23 inches). More than 70% of the total precipitation normally falls in the six month period from May through October. 1941 was the wettest year with a total rainfall of 74.4 cm (29.3 inches). June, 1941 recorded both the maximum monthly rainfall of 15.3 cm (6.0 inches) and the maximum daily rainfall of 9.8 cm (3.9 inches). Precipitation in the form of snow is very rare with the greatest depth recorded as 5.0 cm (2.0 inches) in February, 1961.
- For this same 30 year period the mean annual temperature was 18.4 °C (65.2 °F). The warmest month was July with an average temperature of 27.7 °C (81.9 °F) and the coolest month was January with an average temperature of 7.8 °C (46.1 °F). The highest temperature recorded during the period was 44.4 °C (112 °F) in June 1939; and the lowest temperature was - 15.6 °C (4 °F) in December 1953.

3.2 SITE FACILITIES

The following requirements apply to these facilities.

3.2.1 General

In providing the required facilities maximum use is to be made of existing structures and facilities to accomplish the required functions. New facilities are to be located so as to minimize the need for relocation or modification of existing facilities.

3.2.2 Specific Facilities

- Storage and Maintenance
  Sufficient space will be provided for storage of solar plant spare parts and components. It should be a roofed building for environmental protection of the stored parts. It will be supplied with electricity and lighted. Adequate space and equipment is to be provided to allow

maintenance to be performed on the largest plant item which can be removed from the system for local maintenance. Cleaning equipment is to be provided for the largest removable, repairable steam component. Lifting and handling equipment is to be provided in all storage and maintenance areas as required. Heating, ventilation and air conditioning equipment will be provided as required.

- Security Fencing
  A security fence will be required around the perimeter of the collector field. It will be of chain link design and 2.4 m (8 ft) high with 3 strand barb wire on top. The fence will have one personnel gate and other gates capable of admitting maintenance vehicles. Provisions will be made for piping and transmissions lines running to and from the sulfur mine.

- Operations Center
  The existing Comanche Creek control room will be expanded to accommodate the needs of the solar cogeneration facility.

3.3 COLLECTOR SUBSYSTEM

The collector subsystem shall reflect solar radiation onto the receiver subsystem in a manner which satisfies the receiver incident heat flux requirement. In addition, the collector subsystem shall respond to commands from the master control subsystem for emergency defocusing of the reflected energy or to protect the heliostat array against environmental extremes. The heliostats shall be properly positioned for repair or maintenance in response to either master control or manual commands. Heliostat design shall provide for stored or safe position for use at night, during periodic maintenance and during adverse weather conditions. The collector subsystem shall be designed to match the receiver design and provide energy to the receiver working fluid consistent with the end energy requirements of the Comanche Creek Plant.

3.3.1 Collector Field

The collector field design shall provide the optimum heliostat layout considering the following:

a. Heliostat capital cost
b. Operating and maintenance cost
c. Field wiring cost
d. Land availability and cost
e. Terrain contour
f. Heliostat performance
g. Receiver aperture size and cost
h. Receiver tower height and cost
i. Reliability
j. Shading and blocking
k. Atmospheric attenuation
l. Latitude
m. Receiver flux capability
n. Required design power

The optimization shall be by use of the DELSOL computer code developed by Sandia Laboratories.

The collector field shall be capable of supplying 22.4 MW_t (7.4×10^6 Btu/hr) incident power to the receiver at the noon, equinox design point at the Fort Stockton, Texas site.

3.3.2 Heliostat Performance

The heliostats shall meet the operational performance requirements of the Collector Subsystem Requirements Specification A10772, Issue D, Sandia Livermore Laboratories. The Heliostat Array controller (HAC) is not part of the collector subsystem, hence, any requirements for the HAC in the

Sandia specification are for reference only. The requirements of Section 4.0 of this specification shall take precedence over those of Appendix I in the Sandia specification.

3.3.3 Heliostat Field Data

The heliostat field will consist of typical, second generation heliostats having the following characteristics:

• Total mirror module area	53.51m^2 (576 ft^2)
• Heliostat dimensions	7.39 m wide × 7.44 m high (24 ft 3 in × 24 ft 5 in)
• Heliostat area	55.01 m^2 (592.1 ft^2)
• Total reflective area	52.77 m^2 (568.02 ft^2)
• % Reflective area $\left(\frac{\text{Total Reflective area}}{\text{Heliostat area}}\right)$	96%
• Mirror reflectivity (clean 92%) Nominally	90%
• Heliostat (1 - standard deviation) angular errors for pointing	.75 milliradians each axis
• Surface normal (1 - standard deviation) errors	1 milliradian each axis
• Minimum distance center to center (heliostat spacing)	10.79 m (35.4 ft)
• Height of elevation axis centerline	4.04 m (13 ft 3 in)

3.4 RECEIVER SUBSYSTEM

The receiver subsystem shall transfer the incident radiant flux energy from the collector subsystem into the water/steam working fluid that is circulated in the receiver. The subsystem consists of the receiver, the tower, the steam drum, and the riser and downcomer piping.

3.4.1 Structural Design

The receiver and tower shall be designed to provide access for maintenance and inspection of tower structure, receiver, working fluid, instruments and controls, utilities, etc. Consideration shall be given to ease of maintenance. Adequate provisions shall be made to ensure crew safety at all times for required operations, inspection, maintenance and repair. The receiver design shall be consistent with the intent of appropriate ASME Boiler Codes and meet the operational and survival requirements provided in Section 4.0.

3.4.2 Receiver

The receiver shall be of a natural circulation design in the form of an external, flat tubular panel that faces a north field of heliostats. The receiver shall be inclined downward at an angle of 20° from the vertical and have the following design and operating requirements:

• Active Surface Area	54.4 m^2 (585.6 ft.^{2})
• Design Point Peak Flux	0.685 MW/m^2
• Design Point Average Flux	0.38 MW/m^2
• Receiver Power Rating	20.8 MW_t
• Receiver Working Fluid	Water/Steam
• Steam Flow Rate	9.21 kg/s (73210 lb/hr)
• Receiver Fluid Inlet Temperature	162 °C (323.6 °F)
• Receiver Fluid Outlet Temperature	271.8 °C (521.2 °F)

• Receiver Outlet Pressure	5.65×10^6 Pa (820 psia)
• Total Receiver Dry Weight	34020 kg (75000 lb)
• Weight of Working Fluid	10603 kg (23375 lb)
• Overall Receiver Efficiency	93%

3.4.3 Receiver Fluid

The specifications for the receiver fluid shall be as follows:

Water purity requirements are

Total dissolved solids	0.10 ppm max
Suspended solids	zero
Hardness	zero
Free caustic	zero
Dissolved oxygen	zero
Carbon Dioxide	minimum, preferably zero
Total Silica (as SiO_2)	0.01 ppm max
Total Iron (as Fe)	0.01 ppm max
Total Copper (as Cu)	0.005 ppm max

pH value - Adjust to obtain 0.01 ppm iron maximum. This will normally require a pH value within the range of 8.5 to 9.5, measured at 77F.

3.4.4 Receiver Tower

The tower that supports the receiver, piping, and other elements of the receiver subsystem shall be designed to meet the operational survival requirements of Section 4.0. The design shall consider the geological characteristics of the site as indicated in Section 3.1. The tower shall also provide access for inspection and maintenance of all supported time.

The tower has the following characteristics:

• Tower Height	70 m (229.7 ft)
• Structural Type	Steel
• Base Dimensions	16 m × 16 m (52.5 ft × 52.5 ft)
• Top Dimensions	4.0 m × 9.2 m (13.1 ft × 30.2 ft)
• Deflection in 40 m/s wind	15 cm (5.9 in)

3.4.5 Tower Up/Down Piping

The tower up/down piping are to provide the means of transporting the cold and hot receiver fluid between the ground and the receiver. Provision is to be made for piping thermal expansion in reliable, cost effective manner. Materials are to be used which are compatible with pressurized water at a temperature/pressure of 162 °C/6.0×10^6 Pa (323.6 °F/870 psia) for the riser and saturated steam at a temperature/pressure of 271.8 °C/5.65×10^6 Pa (521.2 °F/820 psia) for the downcomer.

3.4.6 Receiver Steam Drum

The receiver steam drum is to be sized to obtain adequate system control over all types of solar transients. Materials are to be used that are compatible with saturated steam at a temperature of 271.8 °C (521.2 °F) and a pressure of 5.65×10^6 Pa (820 psia).

3.5 MASTER CONTROL SUBSYSTEM

A master control subsystem shall be provided to monitor and control all system and subsystem parameters to ensure safe and proper operation of the solar cogeneration facility.

3.5.1 General

The master control subsystem shall have sufficient data acquisition capability to completely characterize the operating status and efficiency of all major components of the cogeneration facility.

All changes, additions, or modifications to the existing control system shall result in a system which will allow the existing plant to operate *independently* whether the solar facility is operable or not.

3.5.2 Operating Modes

Operation of this cogeneration facility will be performed in one of the following modes:

- Nonsolar - Normal Operation
  The nonsolar mode is the predominant mode of operation since it occurs during all nondaylight hours and periods of extended cloud cover. In this mode, a gas fired boiler will supply the necessary saturated steam to the accumulator. The control system will sense turbine throttle conditions and adjust the boiler and superheater to maintain constant output. The solar central receiver is isolated from the loop during this mode.

- Solar-Normal Operation
  In this made the cogeneration facility primarily operates as a hybrid except at the design point when it operates as solar alone. During daylight hours, the heliostat array controller targets the heliostats on to the receiver. The receiver then delivers all the steam it can, for the available insolation, to the accumulator. The boiler and superheater will respond to resulting variations at the turbine throttle in the same manner as in the nonsolar mode.

- Solar-Intermittent Clouds Operation
  During periods of solar outage due to clouds, the receiver steam rate will decay with a resulting drop in flow and pressure at the accumulator output. The control system will sense this and signal the boiler to increase its steam rate. When the cloud cover passes, the receiver steam rate will increase and the boiler will turn down.

- Solar-Startup
  This traditional mode between nonsolar and solar operation begins by adjusting the fluid level in the receiver steam drum. The heliostat controller will steer the mirrors to a sun acquisition position for beam reflection onto the receiver. With increasing solar flux the receiver will start to produce steam. As drum pressure rises, the steam will be supplied to the accumulator. The change in flow and pressure will be sensed and the boiler will be turned down accordingly.

- Solar-Normal Shutdown
  This traditional mode between solar and nonsolar operation begins when the receiver drum pressure and steam flow fall toward a preset level and the outlet valve closes. Heliostats are steered to the stowage position and the water supply to the receiver is shutoff. The decrease in receiver flow and pressure will be sensed and cause a corresponding increase in boiler steam rate.

- Solar-Emergency Shutdown
  In the event of a receiver alarm, the receiver controller will automatically signal the heliostat controller to steer the mirrors off of the receiver. This reduces the incident radiant flux on the receiver and allows a normal shutdown procedure to occur while the cause for the alarm is diagnosed.

The master control subsystem shall provide three operator-selectable modes by which the solar cogeneration facility will be controlled in each of the operating modes described above. The three control modes are:

- Automatic - no operator interaction required (normal operating mode).
- Semiautomatic - operator interaction required at decision points.
- Manual - operator interaction required at each step or sequence of steps.

Under the non-solar normal operating scenario, both turbine follow and boiler follow mode options shall be furnished. When the system is operating under both fossil and solar, the control system shall provide a normal mode of fossil-follow (i.e., the fossil plant makes up the difference between the demand and the solar plant output).

3.5.3 Design Criteria

Reliability and availability shall be of paramount importance and shall be the overriding criteria for control system design. Of similar importance shall be the use of hardware and techniques that meet industry standards during the life of the cogeneration plant. The master control subsystem shall satisfy these criteria by the incorporation of the following:

a. Design Reliability: Single-point failures shall be eliminated through the use of redundant elements wherever criticality dictates. Control hardware and techniques shall be of a type which have proven its reliability in power plant control.

b. Operational Reliability: Plant operational controls shall be separated from data acquisition controls so that each may function independently. The control system shall be sufficiently thorough so that in-plant operating and maintenance personnel shall have all knowledge and skill necessary to perform reasonably expected maintenance and operational procedures. The operator will have manual hard-wired control of his final control drives, independent of the automatic control system. The operator shall also have hard-wired indication of major plant parameters independent of the control system. Redundant computer programmed units for overall plant control are to be provided.

c. Design Simplicity: The master control subsystem shall be sub-divided into control components, each to monitor and control a designated subsystem. The control strategy for each control component shall be of standard power plant practice. The interfaces between the individual control components shall be simple, functional, and well defined.

d. Cost-Effective Design: Generically similar equipment shall be employed in each master control system control component. Off-the-shelf equipment shall be selected wherever possible. All of the existing control units shall be utilized where applicable.

3.6 FOSSIL ENERGY SUBSYSTEM

The fossil energy subsystem shall be designed to enable startup and shutdown of the solar plant and to be capable of providing the difference between expected demand and the available solar output.

3.6.1 Fossil Boiler

The fossil boiler shall operate alone or in parallel with the receiver subsystem to supply steam to the superheater. The fossil boiler shall produce steam to match as close as necessary, (1) the steam conditions at the inlet of the superheater and (2) the load demand on the unit. The fossil boiler shall not be detrimentally affected by the presence of the solar components under any steady state or transient operating mode of the solar system.

The fossil boiler requirements are:

- Max. flow rate: 9.21 kg/s (73210 lbm/hr.)
- Inlet condition: 5.99 MPa/162 °C (870 psia/323.6 °F)
- Outlet condition: 5.51 MPa/270 °C (800 psia/518.4 °F)
- Max. Rating: 20.8 MW_t
- Minimum turn down: 5%
- Minimum efficiency: 84%
- Ramp rate: 5% to 100% power in 5 minutes

3.6.2 Accumulator

The accumulator is to provide sufficient energy to allow a ramp down of the solar output should solar insolation be interrupted. The storage ramp capability is to be consistent with the capability of the saturated boiler to ramp up to maintain steady overall plant output.

The design utilizes the output from the solar receiver and from the saturated boiler (minimum turn down of 5%) as inputs to the accumulator. Accumulator output goes into the superheat boiler.

The accumulator requirements are:

- Max. Flow Rate: 9.69 kg/s (77060 lbm/hr.)
- Pressure/Temperature: 5.51 MPa/270 °C (800 psia/518.4 °F) (outlet)
- Max. Rating: 0.89 MWh_t
- Allowable Heat Loss: ½% steam quality change, maximum per day
- Material - Low Alloy steel (per ASME Section VIII)

3.6.3 Fossil Superheater

The superheater receives its input from the accumulator in the form of slightly wet saturated steam. It heats this saturated steam to superheat conditions for the turbine inlet.

The fossil superheater subsystem requirements are:

- Max. Flow Rate: 9.69 kg/s (77060 lbm/hr)
- Inlet Conditions: 5.51 MPa/270 °C (800 psia/518.4 °F)
- Outlet Conditions: 5.17 MPa/482 °C (750 psia/900 °F)
- Max. Rating: 5.8 MW_t
- Minimum Efficiency: 84%
- Ramp Rate: 5% to 100% power in 5 minutes

3.7 ELECTRIC POWER GENERATING SUBSYSTEM (EPGS)

The EPGS shall be capable of accepting flow from the superheat boiler. The EPGS is also to provide the necessary steam dumping facility to allow startup or shutdown of either the solar or fossil portion of the facility while the other is operating.

The EPGS requirements are:

- Turbine Inlet: 5.17 MPa/482 °C (750 psia/900 °F) Superheat
  Flow = 9.69 kg/s (77060 lbm/hr.)

- Turbine Extraction: 1.10 MPa/325 °C (160 psia/617 °F) (Superheat)
  Flow = 8.19 kg/s (65120 lbm/hr.)
- Turbine Exhaust: 17.94 kPa/60.5 °C (2.6 psia/141 °F) (Slight Superheat)
  Flow = 1.50 kg/s (11940 lbm/hr.)
- Generator: 3.5 MW_e, 4160V, 3 phase, .8 pf, 40 °CAmb.
  Weather Protected II Enclosure (ambient breathing)

3.8 PROCESS HEAT SUBSYSTEM

The process heat subsystem slected for the extraction cycle turbine is made up of two sets of condensing heat exchangers:

Set #1 - Two (2) 50% capacity units located at the turbine extraction
Set #2 - Two (2) 100% capacity units located at the turbine exhaust

These condensers have the following design operating requirements:

HP Heat Exchangers: Rating 18.2 MW_t

Steam Side: Flow = 8.19 kg/s (65120 lbm/hr.)

1.03 MPa/324 °C (150 psia/615.7 °F) Inlet (Superheat)

1.03 MPa/181 °C (150 psia/358.5 °F) Outlet (Saturated liquid)

Water Side: Flow = 0.063 m^3/s (992 gal/min.)

2.07 MPa/109 °C (300 psia/228 °F) Inlet

1.72 MPa/177 °C (250 psia/350 °F) Outlet

LP Heat Exchangers: Rating 3.40 MW_t

Steam Side: Flow = 1.50 kg/s (11940 lbm/hr.)

16.55 kPa/61 °C (2.4 psia/141 °F) Inlet (Slight Superheat)

16.55 kPa/56 °C (2.4 psia/133 °F) Outlet (Saturated Liquid)

Water Side: Flow = 0.032 m^3/s (515 gal/min.)

0.38 MPa/21 °C (55 psia/70 °F) Inlet

34.5 kPa/46 °C (5 psia/115 °F) Outlet

3.9 ELECTRICAL SUBSYSTEM

The electrical subsystem shall provide for the selection of relays, potential transformers, current transformers, lightning arrestors, and breakers to be made after the determination of utility and solar facility interactive characteristics such as voltage dip, system stability, and fault currents which are sensitive to the specific utility system electrical characteristics.

All equipment will be constructed according to the applicable ANSI and IEEE standards and the electrical subsystem will be designed to the appropriate electric code, OSHA and state standards.

The major components of the electrical subsystem are:

- 13.8 KV class metalclad switchgear rated at 1200 amperes continuous and 18,000 amperes RMS. Switchgear shall have bus differential protection and four circuit breakers: incoming line, generator, 4375 KVA transformer and 1000 KVA transformer.
- Generator transformer — step-up 4160 V to 12.5 KV, 4375 KVA, 3 phase, 60 Hz with 2 — 2½% taps above and below 12.5 KV.
- Auxiliary transformer — step-down 12.5 KV to 480 volts, 1000 KVA, 3 phase, 60 Hz with 2 — 2½% taps above and below 12.5 KV.
- Distribution switchboard rated at 600 volts, 3000 amperes continuous, 50,000 amperes RMS.
- Motor control centers with combination starter units, rated at 600 volts, 6000 amperes continuous, 42,000 amperes RMS.

3.10 FLUID CIRCULATION SUBSYSTEM

This section lists all components that physically tie together the other subsystems.

- Piping and Valves

  Piping and valves added as part of modifications to the existing facility shall meet the same design temperature and pressure criteria as a portion of the system to which they are being added.

  Piping and valves added as part of new subsystems shall have temperature and pressure ratings as follows:

  Pressure: 10% over maximum transient steady state operating pressure

  Temperature: 10 °C (50 °F) over the maximum transient or steady state operating temperature

  The maximum flow velocity in piping is to be as follows:

  Water - 6.1 m/s (20 fps) | Saturated Steam - 38.1 m/s (125 fps)
  Steam/Water - 15.2 m/s (50 fps) | Superheated Steam - 61.0 m/s (200 fps)

The field piping connecting the receiver/tower with the main plant will consist of three standard wall thickness pipes made of ASTM A106 Gr. B carbon steel. The nominal sizes are given below:

Pipe	Diameter mm (in)
Main Steam	152 (6)
Feedwater	76 (3)
Warmup	76 (3)

- Pumps

  Feedwater pump - 9.69 kg/s (77060 lbm/hr): Inlet 162 °C/0.69 MPa (323.6 °F/100 psia)

  Outlet 162 °C/6.00 MPa (323.6 °F/870 psia)

- Deaerator - 9.69 kg/s (77060 lbm/hr.) at 165 °C/0.69 MPa (329.6 °F/100 psia)
- Chemical Injection — (Feedwater Treatment) See water purity requirements in Section 3.4.3.

3.11 SERVICE LIFE

The system shall be designed for a 20 year service life with no major component replacement required. All prime movers shall meet the 20 year service life requirement with other auxiliary and support equipment being replaced as required.

3.12 FACILITY AVAILABILITY AND RELIABILITY

The solar cogeneration facility (exclusive of insolation conditions) shall be designed for availability and reliability at least equal to that exhibited by the existing fossil fuel plant before the retrofit. Consideration shall be given in the design to achieving high reliability by providing design and operating margins and utilizing sound engineering design practices.

3.13 MAINTAINABILITY

The solar cogeneration facility shall be designed to be compatible with existing plant maintainability characteristics and practices. Potential maintenance locations shall be easily reached and components such as electronic units, motors, drivers, etc., readily replaced. Elements subject to wear ana aamage, such as supporting wheels, gears, etc. shall be easily serviced or replaced. The plant shall be capable of being services with a minimum of specialized equipment or tools.

3.14 SAFETY REQUIREMENTS

3.14.1 Plant Safety

The solar cogeneration facility will be designed to meet industry codes and standards, as well as OSHA requirements.

The main plant hazards are the effects of fire, explosion, lightning, wind storm, and equipment damage caused by unauthorized personnel and animal intrusion.

Fire probability will be minimized by inherent good design. Steam leaks can be minimized by good design and inspection practice. Fire detectors and other fire safety equipment will be located in fire hazard areas. A field grounding grid to protect heliostats and grounding of all equipment will be included as part of the plant design to minimize the risk of lightning strikes. Heliostats will be rotated to their stow position to provide protection of the reflective surfaces in wind storms. A security fence on the outer perimeter surrounding the cogeneration facility site will inhibit intrusion of unauthorized personnel.

3.14.2 Personnel Safety

Standard power plant safety precautions are to be observed and safety equipment/clothing used to prevent injuries caused by personnel contacting hot surfaces or electrical equipment.

3.15 ENVIRONMENTAL IMPACT REQUIREMENTS

The environmental impact of the cogeneration facility occurs mainly in the areas of ground water contamination, water usage, air pollution, and site aesthetics. These concerns are addressed in the following paragraphs:

- Ground Water

  The site will be contoured to channel the rainwater runoff from the heliostat field to a natural drainage. A nontoxic, biodegradable cleaning fluid will be used as a cleaning agent for the heliostat.

- Water Usage

  The General Electric design minimizes the impact of water use due to its closed loop solar system approach. See Section 4.2.2.

- Air Pollution

  The only source of air pollution is the release of CO, CO_2, and NO_X from the fossil energy subsystem and the superheat boiler subsystem. These substances are expected to be released in concentration levels permitted by the applicable codes. See Section 4.2.1

4.0 ENVIRONMENTAL CRITERIA

4.1 FACILITY ENVIRONMENTAL DESIGN REQUIREMENTS

4.1.1 Operating

The system shall be capable of operating in and surviving appropriate combinations of the following environments:

a. Temperature: The plant shall be able to operate in the ambient air temperature range from −18 °C to 48.9 °C (0 to +120 °F). Performance requirements shall be met throughout an ambient air temperature range selected to be consistent with efficient plant operation.

b. Wind: The plant shall be capable of operating given the following approximate wind profile as a function of height above ground level. (See Figure 4-1). Maximum operating wind speed shall be 16 m/s (35 mph) at a height of 10 m (30 ft). Performance requirements shall be met for the most adverse combination of wind and temperature conditions selected to be consistent with efficient plant operation. Wind analysis shall satisfy the requirements of ANSI A58.1-1972.

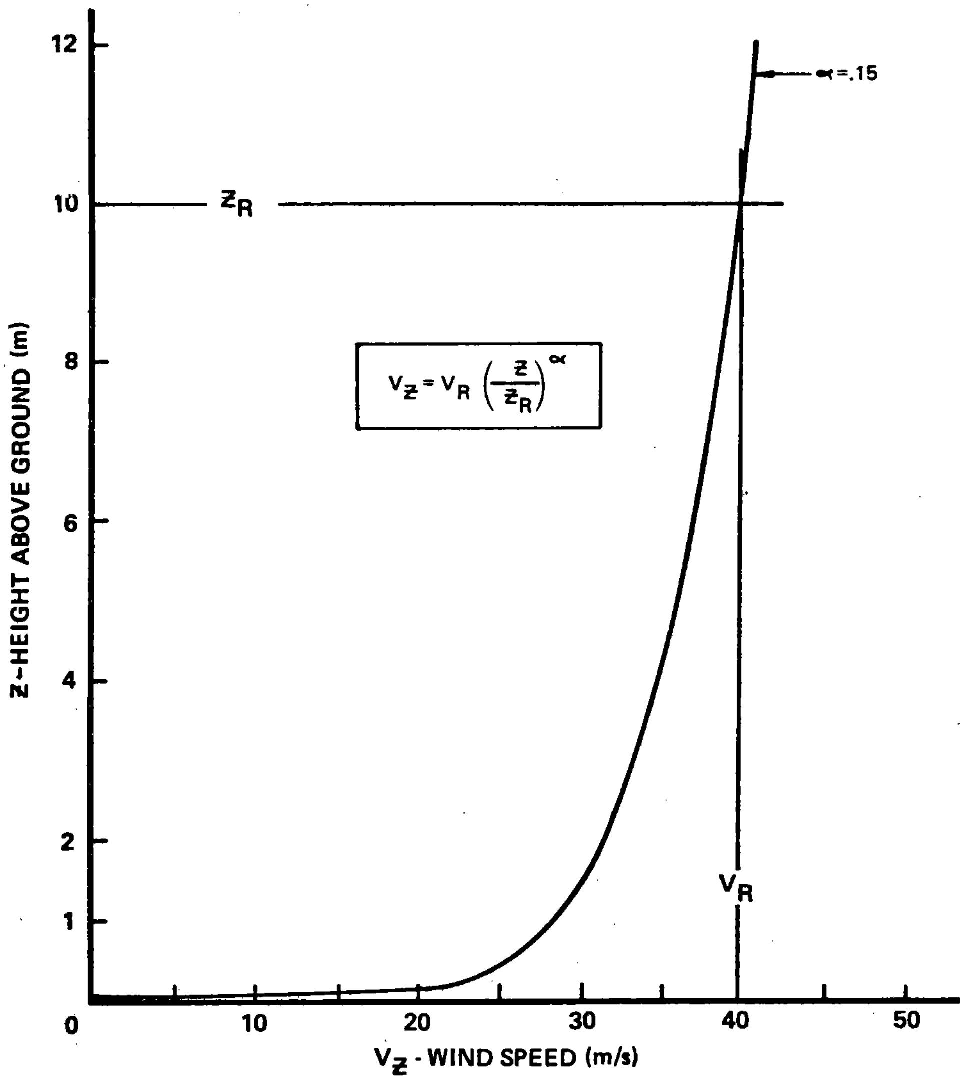


Figure 4-1. Site Wind Profile

c. Earthquake: Peak ground accelerations shall be presented below per applicable UBC Zone 2. This peak ground acceleration is combined with the response spectrum given by NRC Reg. Guide 1.60 and the damping values given for the operating bases earthquake in NRC Reg. Guide 1.61. ABS. Zone 2 values should be used for the baseline design.

4.1.2 Survival

The system shall be capable of surviving appropriate combinations of the environments specified below:

a. Wind: The plant shall survive winds with a maximum speed, including gusts of 40 m/s (90 mph), without damage. A local wind vector variation of ±10 degrees from the horizontal shall be assumed for the survival condition.

b. Wind Rise Rate: A maximum wind rise rate of .05 m/s^2 (6.7 mph/min) shall be used in calculating wind loads during stowage. However, the plant should withstand, without any catastrophic failure, a maximum wind of 40 m/s (90 mph) from any direction, for any heliostat orientation, such as might result from unusually rapid wind rise rates, e.g., severe thunderstorm gusts.

c. Dust Devils: Dust devils with wind speeds up to 40 m/s (90 mph) shall be survived without damage to the plant.

d. Snow: The plant shall survive a static snow load of 24.4 kg/m^2 (5 lb/ft^2) and a snow deposition rate of 12.7 cm (5 in.) in 24 hours.

e. Rain: The plant shall survive the following rainfall condition:

Average Annual	310 mm (12.2 in)
Maximum 24-hr. rate	98 mm (3.9 in)

f. Ice: The plant shall survive freezing rain and ice deposits in a layer 50.8 mm (2 in.) thick.

g. Earthquake: Peak ground accelerations shall be per UBC Zone 2. This peak ground acceleration is combined with the response spectrum given by NRC Reg. Guide 1.60 and the damping values given for the operating basis earthquake in NRC Reg. Guide 1.61.

h. Hail: The plant shall survive hail impact up to the following limits:

	Any Orientation	Stowed
Diameter	25.4 mm (1.0 in.)	50.8 mm (2.0 in.)
Specific Gravity	.8	.8
Terminal Velocity	20.6 m/s (40 mph)	38.6 m/s (75 mph)

i. Sandstorm Environment: The plant shall survive after being exposed to blowing dust comparable to the conditions described by Method 510 of MIL-STD-810C.

4.1.3 Lightning Considerations

a. Protection

The plant shall be provided with a lightning protection system. The system shall meet the West Texas Utilities Lightning Protection and Grounding Specification.

b. Direct Hit

Total destruction of a single heliostat and its controller when subjected to a direct lightning strike is acceptable.

c. Adjacent Strike

Damage to a heliostat adjacent to a direct lightning strike should be minimal. The central controller and the local controllers of heliostats adjacent to a direct lightning strike must be protected, or alternate control methods provided to minimize loss of collector subsystem control.

4.1.4 Special Environmental Considerations

Heliostats shall withstand sustained winds (See Section 4.1.2) at the periphery of the heliostat field. If it is determined that wind loading on interior heliostats is significantly altered by peripheral heliostats, this factor should be considered.

4.2 ENVIRONMENTAL STANDARDS

4.2.1 Air Quality Control Standards

The first move in a new plant permitting process is to determine if the site is located in an area designated as "attainment" or "non-attainment." If it is "non-attainment" that means that it has been shown by monitoring that one of the pollutants (O_3, O, NO_2, SO_2, particulates) has exceeded the National Ambient Air Quality Standards as shown in Table 4-1.

Table 4-1

NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Averaging Time	Primary Standard	Secondary Standard	General Objectives
Ozone	1 hr	240 $\mu g/m^3$ (0.12 ppm)	240 $\mu g/m^3$ (0.12 ppm)	To prevent eye irritation and possible impairment of lung functions in persons with chronic pulmonary disease, and to prevent damage to vegetation.
Carbon Monoxide	8 hr	10 mg/m^3 (9 ppm)	10 mg/m^3 (9 ppm)	To prevent interference with the capacity to transport oxygen to the blood.
	1 hr	40 mg/m^3 (35 ppm)	40 mg/m^3 (35 ppm)	
Nitrogen Dioxide	Annual average	100 $\mu g/m^3$ (0.05 ppm)	100 $\mu g/m^3$ (0.05 ppm)	To prevent possible risk to public health and atmospheric discoloration.
Sulfur Dioxide	Annual average	80 $\mu g/m^3$ (0.03 ppm)	–	To prevent pulmonary irritation.
	24 hr	365 $\mu g/m^3$ (0.14 ppm)	–	
	3 hr	–	1300 $\mu g/m^3$ (0.5 ppm)	To prevent odor.
Suspended Particle Matter	Annual geometric mean	75$\mu g/m^3$	60 $\mu g/m^3$	To prevent health effects attributable to long continued exposures.
	24 hr	260 $\mu g/m^3$	150 $\mu g/m^3$	
Hydrocarbons (corrected for methane)	3 hr	160 $\mu g/m^3$ (0.24 ppm)	160 $\mu g/m^3$ (0.24 ppm)	To reduce oxidant formation.

The United States Environmental Protection Agency has not been contacted concerning the Ft. Stockton area but it can logically be assumed that this is an almost pristine air condition and is certainly within attainment levels. In this case a new installation would come under PSD (Prevention of Significant Deterioration) regulations which largely call for application of BACT (Best Available Control Technology). The regulations require that BACT be demonstrated for each applicable pollutant if emissions of that pollutant are emitted in significant amounts. In the selection of equipment or processes to meet BACT, consideration is given to control efficiency, economics, energy consumption, and proven commercial success and reliability.

In the solar cogeneration facility, the only source of any of the above polutants is the fossil-fired boiler and superheater. These units, using natural gas as a fuel, will generate emissions at levels that are well within environmental limitations.

4.2.2 Water Quality Standards

The solar cogeneration facility shall not discharge any effluent that adversely affects water quality.

5.0 DESIGN DATA REQUIREMENTS

Note: Section 5 is not a specification but is included as data input for review and evaluation of the design for compliance with the specification. However, it is controlled by issue and included as part of the System Specification for purposes of the conceptual design study.

5.1 FACILITY CHARACTERISTICS AND PERFORMANCE DATA

This section describes the technical characteristics of the solar cogeneration facility design and perfomance. Characteristics are provided for each of the various subsystems and for the integrated plant.

5.1.1 Collector Subsystem

- Design

  Design Point - Vernal Equinox Noon
  Field Configuration - North
  Number of Heliostats - 588

  Collector Field Area - 1.42×10^5 m^2 (35 acres)
  Heliostat Characteristics - per Section 3.3.3

- Performance (Design Point)

  Design Insolation Level - 950 W/m^2

  Receiver Incident Power - 21.3 MW_t

  Peak Incident Flux - 0.685 MW/m^2
  Field Efficiency - 75.9%

  Field Losses - 7.1 MW_t

5.1.2 Receiver Subsystem

Receiver

- Design (See Table 5-1 for material list)

Receiver Configuration -	Natural Circulation, External Flat Plate, one layer parallel tubes, canted 20° to heliostat field
Receiver Width (Active Panel) -	8 m (26.25 ft.)
Receiver Height (Active Panel) -	6.8 m (22.25 ft.)
Number of Panels -	1
Panel Construction -	Welded (6.35 mm (.25 in) web between tubes)
Flow Control -	Natural Circulation
Water Inlet Temperature -	162 °C (323.6 °F)
Sat. Steam Outlet Temperature -	271.8 °C (521.2 °F)

- Performance

  Receiver Efficiency - 93.0%

  Absorbed Energy - 19.8 MW_t
  Flow Rate - 73210 lbs/hr.

Peak Flux - 0.685 MW/m^2
Peak Tube Temperature - 319 °C (606 °F)

Tower

- Design

Height - 70 m (229.7 ft.)
Construction - Steel girder structure
Safety - per FAA requirements

5.1.3 Master Control Subsystem (MCS)

Distributed control loops, redundant I/O busses with MCS supervision, integration and data acquisition.

Table 5-1

EXTERNAL RECEIVER MATERIAL LIST

Item	Quantity	Material	Outside Diameter dm	(in)	Thickness mm	(in)	Length m	(ft)
Tube	140	SA-210	0.51	(2.0)	3.5	(0.14)	6.8	(22.3)
Riser	17	SA-106B	1.14	(4.5)	6.0	(0.24)	5.7	(18.7)
Feeder	8	SA-106B	1.14	(4.5)	6.0	(0.24)	3.42	(11.2)
Header	1	SA-106B	1.55	(6.10)	12.7	(0.5)	8.4	(27.56)
Header	1	SA-106B	1.93	(7.60)	18.3	(0.72)	8.4	(27.56)
Drum	1	SA-515,70	9.73	(38.3)	78.7	(3.1)	4.25	(14.0)
Downcomer	4	SA-106B	1.19	(4.70)	7.1	(0.28)	6.55	(21.3)

5.1.4 Fossil Energy Subsystem

5.1.4.1 Fossil Boiler

It will be a package-type industrial boiler rated at approximately 605 kg/s (80,000 lb/hr) of 5.515 MPa (800 psia) saturated steam. The saturated boiler has a thermal rating of 20.4 MW, burns natural gas and has an operating efficiency of 84%.

5.1.4.2 Fossil Superheater

The natural gas fired superheater has radiant and convection heating sections. It can superheat 9.71 kg/s (77,060 lb/hr), 5.51 MPa (800 psia) saturated steam to 482 °C (900 °F), accompanied by a 0.345 MPa (50 psia) pressure drop. The superheater efficiency is 84%. Its thermal rating is 5.8 MW.

5.1.4.3 Accumulator

The saturated steam accumulator drum will be part of the superheater package and sized to provide 5 minutes of turbine design throttle flow or 0.89 MWh thermal energy.

5.1.5 Electric Power Generating Subsystem (EPGS)

The EPGS consists of a superheat, uncontrolled extraction, condensing type turbine coupled by a gear reducer to a synchronous generator. Its characteristics are listed in Table 5-2.

Table 5-2

EPGS CHARACTERISTICS

Maximum rating:	3500 kW
Generator rating:	4375 kVA at 0.80 p.f.
Generator voltage:	4160 V
Steam inlet:	5.175 MPa/482 °C (750 psia/900 °F)
Extraction:	1.104 MPa (160 psia) uncontrolled
Exhaust:	17940 Pa (2.6 psia)
Throttle flow:	9.69 kg/s (77,060 lbs/hr) at rating
Extraction flow:	8.19 kg/s (65,120 lb/hr) at rating
Extraction Enthalpy:	1318 Btu/lb at rating
Exhaust Enthalpy:	1097 Btu/lb at rating
Turbine Data:	8000 rpm 8 stages electrohydraulic control system solid forged rotor multi (5) inlet control valves trip/throttle emergency inlet valve baseplate mounted integral lubrication system
Reduction Gear Data:	double helical tooth solid forge pinion flexible couplings
Generator Data:	salient pole design rotating brushless exciter solid state voltage regulator

5.2 EXISTING PLANT DESCRIPTION

The Comanche Creed Mine utilized the Frasch Process for mining of sulfur. Well water is preheated, treated and superheater to 117 °C (350 °F) at 1.72 MPa (250 PSIA). This superheated water is tempered with hot treated water for close temperature control and distributed through insulated piping to a producing well. The tempered water flows into the well (700-900 foot depth) in the outer of three concentric pipes. Elemental sulfur is melted underground and collected in a pool into which the middle concentric pipe end is submerged. Compressed air is fed through the inner pipe to mix with the molten sulfur, aerating it in order to airlift it to the surface. The air is then removed from the liquid sulfur and the sulfur is piped to liquid or solid storage vats.

This sulfur mine was designed and built in 1975. Major pieces of equipment in the Comanche Creed Plant include pumps, tanks, hot process softener vessels, and natural gas fired water heaters. The plant has a once through flow of water (100% makeup) which is obtained from approximately 20 water wells located five miles from the site. In 1980, four tanks were added to allow use of Rustler water, a sulphide laden water with high hardness, which is more abundant than the original source of water.

Electrical energy for the Comanche Creek Plant currently is purchased from West Texas Utilities. This 2.87 MW average (3.0 MW peak) of electrical power drives the water well pumps, process water pumps, water heater blowers, and air compressors.

The Comanche Creek Plant is designed to produce 4.0 million gallons per day of superheated water. During 1980 it produced approximately 3.2 million gallons of superheated water and consumed 9.6×10^6 ft^3 of natural gas and 2.8 MW of electrical power daily. Variance off design were due mainly to limitations in the supply of raw water and to reduced needs for superheated water as dictated by the sulphur production area.

Figure 5-1 shows the process flow diagram for the Comanche Creek Sulfur mine at full load.

5.3 FACILITY COST DATA

5.3.1 Owner's Cost

The owner's costs include those Texasgulf expenses related to the construction project. For this cogeneration program the following costs have been estimated:

Environmental Permits	-	5,000
Managerial	-	3,500
Engineering Consultation	-	30,000
Construction Management	-	80,000
Accounting	-	4,000
Startup Costs	-	26,000
Total Owner's Cost	-	$148,500

Cost of money has not been shown here since it is included in the economic analysis.

5.3.2 Construction Cost Estimate

The capital cost of the solar cogeneration facility was estimated based on DOE guidelines as contained in Table 5-3, 5-4 and 5-5. Notes and qualifications are given in Table 5-6. On completion of the estimate, the data were placed in the format shown in Tables 5-7 and 5-8.

5.3.3 Operating and Maintenance Costs

The operating and maintenance cost estimate for the first year of operation at the Comanche Creek solar cogeneration facility is shown in Table 5-9. Table 5-10 gives the cost breakdown for each cost account.

Table 5-3

BASIS FOR CONSTRUCTION COST ESTIMATE

1. Structure of construction costs estimate will be:
   a. Construction cost codes (Table 5-4)
   b. Construction cost accounts, A through W (Table 5-7)
   c. Construction cost backup sheets (Table 5-8)
2. A/E performs as an engineer and constructor and is the Prime Contractor responsible for:
   - Plant Design
   - Quality Control
   - Construction
   - Subcontracting Construction
   - Major Equipment Procurement
   - Construction Management
3. Labor wages rates = base wage rate at job location (1980).
4. Labor man-hours according to U.S. Gulf Coast (Houston).
5. Adjustments for labor productivity from U.S. Gulf Coast to job location to be included in productivity (Acct. U).
6. Material priced to job location, 1980.
7. Field Indirects and Engineering will be according to Table 5-5.
8. The following two items are not to be included in construction costs:
   a. Sales Tax
   b. Cost of Money, AFDC (Allowance for Funds During Construction)
9. Design contingency not be be included in total for construction cost.
10. Any unique equipment not built at the construction site is to be treated as if it were for this cost estimate. Cost estimates are to follow the format outlined in this table as well as in Tables 5-4 through 5-8.

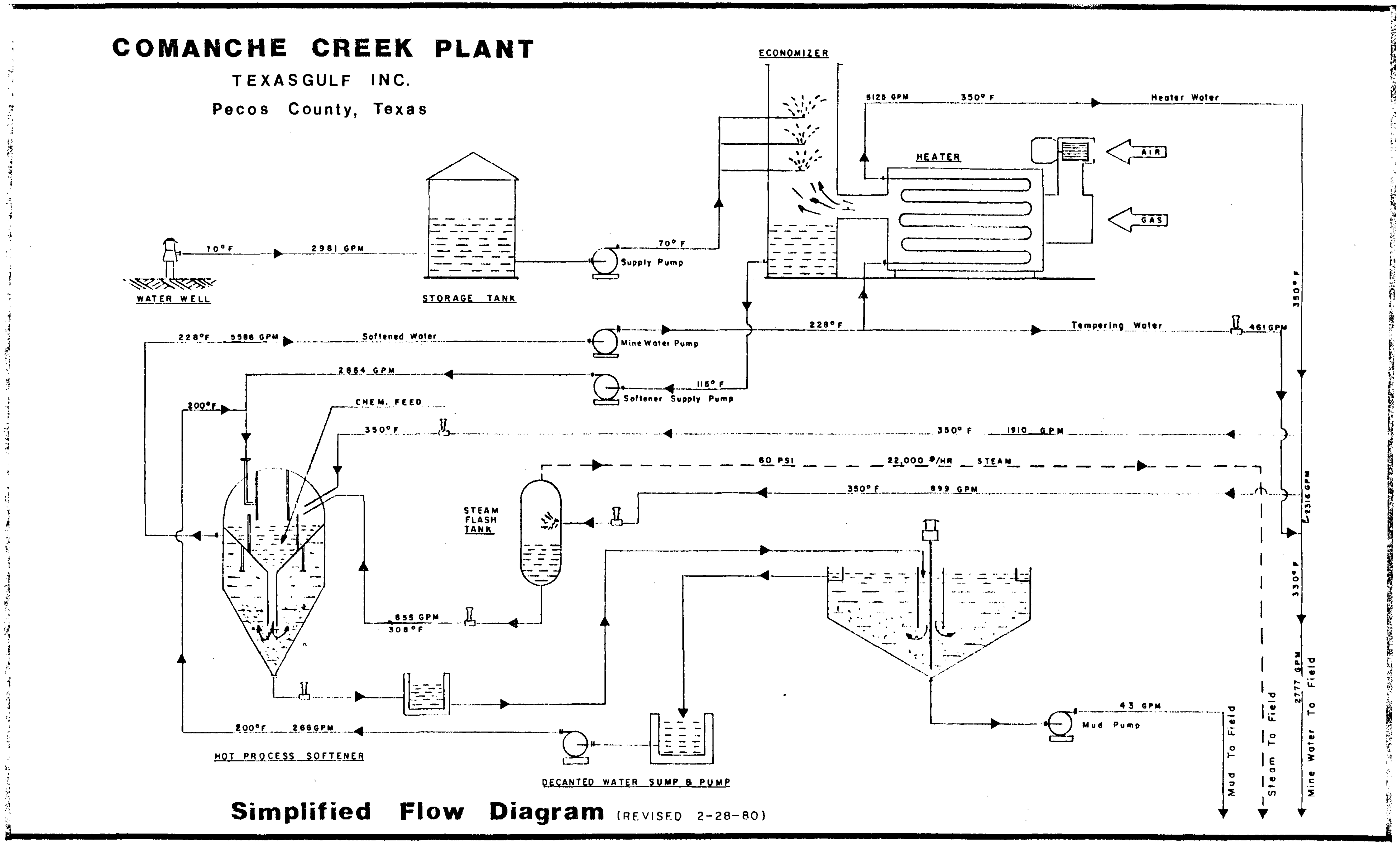


Figure 5-1. Simplified Flow Diagram – Comanche Creek Plant

Table 5-4

CONSTRUCTION COST ACCOUNT CODES

5000	Facility Cost		
	5100	Site Improvements	
		NOTE: Required land for Project to be provided by owner	
	5200	Site Facilities	
		5210	Buildings
		5220	Security
	5300	Collector Subsystem	
	5400	Receiver Subsystem	
		5410	Receiver
		5420	Tower
		5430	Up/Down Piping
	5500	Master Control Subsystem	
		5510	Master Control
		5520	Controls and Instrumentation
	5600	Fossil Energy Subsystem	
		5610	Saturated Boiler
		5620	Superheater and Accumulator
	5800	Electric Power Generating Subsystem	
	5900	Other Subsystems	
		5910	Process Heat Subsystem
		5920	Electrical Subsystem
		5930	Fluid Circulation Subsystem

Table 5-5

INDIRECT COSTS

Account

L Temporary Construction Facilities:

Includes: Temporary buildings, sheds, trailers, work areas, bays, roads, walks, parking, signs, railroads, unloading docks, utilities, personnel protection, camps, cleaning services, maintenance services, utility bills, and site maintenance

Table 5-5 (Cont'd.)

Account

M Construction Services, Supplies, and Expenses

Services:

Includes cleanup, nonproductive time, medical examinations, doctors' fees, move on and off, and construction equipment maintenance and servicing

Supplies:

Includes welding rods, oxygen, acetylene, rags, and other consumables

Field Office Supplies:

Includes office machines, telephone, telegraph, postage, computer rental, stationery, furniture

N Field Staff, Subsistence, and Expenses

Field Staff:

Includes superintendents, field engineers, cost engineers, field administrators, warehouseman, purchaser, nurse, safety engineer, timekeeper, accountant, clerks, Q/A control, watchmen, and security service personnel

Field Staff Subsistence:

Includes travel, subsistence, transportation, and relocation for field staff

Field Staff Burdens:

Includes vacation, sick leave, and holiday allowance

P Field Craft Benefits, Payroll Burdens, and Insurance

Field Craft Benefits:

Includes required contributions to funds for vacation, welfare, education, apprentice, retirement, holidays, etc.

Field Craft Travel, Transportation, or Subsistence:

Payroll Burdens for Field Craft and Field Staff:

Includes social security, workman's compensation, comprehensive PL & PD, state unemployment insurance, federal unemployment insurance

Insurance:

Includes builder's risk, performance bonds and marine insurance

Table 5-5 (Cont'd.)

Account	
Q	<u>Equipment Rental</u> Construction Equipment Rental Special Equipment Rental Small Tools Note: Special rigging equipment included in the Direct Field Accounts
R	<u>Engineering</u> Plant Engineering: Prime Contractor to design plant, subcontract construction, and start up plant R&D: For anticipated research and development required to design and produce special equipment which is not currently manufactured
S	<u>Equipment Procurement by Prime Contractor</u>
T	<u>Construction Management by Prime Contractor</u>
U	<u>Labor Productivity</u> Includes adjustment for the difference in labor efficiency between Houston and the job site
V	<u>Contingency</u> Construction Cost Contingency: Represents normal construction uncertainties in an estimate which is based on a given design Design Contingency: An allowance for possible design alternatives; used for project budgetary input
W	<u>Prime Contractor's Fee</u> Material Markups Fee on Labor and Indirects Fee on Subcontracted Work Excludes Design Contingency

Table 5-6

NOTES AND QUALIFICATIONS FOR CONSTRUCTION COST ESTIMATE

Civil

1. Basic minimal site preparation has been provided in the heliostat field. This minimal preparation assumes no aboveground or underground obstructions and a basically level site
2. We have assumed that excavated material can be dumped within 1.6 km (1 mi) of construction site
3. Costs to expand control building have been included
4. Any modifications required for the existing administration, maintenance, or storage buildings have been excluded
5. A perimeter fence with truck and personnel gates on the south side of the heliostat field has been included
6. Pipe support sleepers have been expanded or added where required
7. Costs for tower elevator have been included.

Electrical

1. Area lighting has been provided
2. .Maintenance lighting has been provided
3. Underground grounding grid has been provided
4. Aircraft warning lights for solar receiver tower have been included
5. Lightning protection for solar receiver tower has been included

General

1. Pricing is on a current-day basis for labor and material, assuming instant execution (i.e., all costs end of year, 1980).
2. Forward escalation is excluded
3. Cost of land is excluded
4. Sales and use taxes are excluded
5. Permits and licenses are assumed by others
6. Heliostat cost, installation, and other interfaces for instruments, piping, electricals, etc., are included
7. All costs are through mechanical completion
8. Start-up costs are excluded
9. Heliostat costs are the DOE recommended value of $\$260/m^2$, installed

GENERAL ELECTRIC

Table 5-7
CONSTRUCTION COST ESTIMATE

CLIENT ______ DESCRIPTION ______

LOCATION ______ CONT. NO. ______

PROJECT Texasgulf Solar Cogeneration Program MADE BY ______

APPROVED ______

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST			
			LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS					
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					
	TOTAL FIELD COSTS					
R	Engineering					
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					
U	Labor Productivity					
V	Contingency					
W	Fee					
	TOTAL CONSTRUCTION COST					

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______

Table 5-8

CONSTRUCTION COSTS

CLIENT ______________________

LOCATION ______________________

PROJECT Texasgulf Solar Cogeneration Program

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ______ DESCRIPTION 5100

LOCATION ______ SITE IMPROVEMENTS CONT. NO. ______

PROJECT Texasgulf Solar Cogeneration Program MADE BY ______ APPROVED ______

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	15,170	170,770	57,335	143,025	371,130
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	15,170	170,770	57,335	143,025	371,130
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		128,080	2865		130,945
	TOTAL FIELD COSTS		298,850	60,200		502,075
R	Engineering					70,290
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					572,365
U	Labor Productivity					
V	Contingency					122,770
W	Fee					
	TOTAL CONSTRUCTION COST					695,135

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CONSTRUCTION COSTS

CLIENT

LOCATION

PROJECT Texasgulf Solar Cogeneration Program

BY CHKD. APVD.

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5100	SITE IMPROVEMENTS												
A	CLEAR AND GRUB	41	AC	3.2	130	11.33				1,475			1,475
	ROUGH GRADE	198,841	SY	.01	1990					22,545			22,545
	SCARIFY AND COMPACT SOIL	170,174	SY	.012	2040					23,115			23,115
	SURFACE TREATMENT	170,174	SY	.05	8510					96,420		74,700	171,120
	CATCH BASINS AND COLLECTOR PIPE				960					9,765		6240	16,005
	ROADWORK				590					6,685	57,335	46,900	110,920
	DRAINAGE DITCHES				950					10,765		15,185	25,950
	TOTAL "A"				15,170					170,770	57,335	143,025	371,130

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ________ DESCRIPTION 5200

LOCATION ________ SITE FACILITIES — CONT. NO. ________

PROJECT Texasgulf Solar Cogeneration Program — MADE BY ________ APPROVED ________

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	60	685	72,160		72,845
B	Concrete	1465	14,060		35,340	49,400
C	Structural Steel	1070	12,315		66,450	78,765
D	Buildings	645	7,125	125,865	10,155	143,145
E	Machinery & Equipment	1800	20,915		246,340	267,255
F	Piping	445	5,000		8,175	13,175
G	Electrical	8520	91,470		41,540	133,010
H	Instruments					
J	Painting	120	1,325		220	1,545
K	Insulation					
	DIRECT FIELD COSTS	14125	152,895	198,025	408,220	759,140
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		114,670	9,905		124,575
	TOTAL FIELD COSTS		267,565	207,930	408,220	883,715
R	Engineering					123,720
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					1,007,435
U	Labor Productivity					
V	Contingency					190,245
W	Fee					
	TOTAL CONSTRUCTION COST					1,197,680

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ______ DESCRIPTION 5210

BUILDINGS

LOCATION ______ CONT. NO. ______

Texasgulf Solar MADE BY ______

PROJECT Cogeneration Program APPROVED ______

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	60	685			685
B	Concrete	1285	12,340		31,305	43,645
C	Structural Steel	1070	12,315		66,450	78,765
D	Buildings	645	7,125	125,865	10,155	143,145
E	Machinery & Equipment	600	6,970		104,640	111,610
F	Piping	445	5,000		8,175	13,175
G	Electrical	2400	25,200		13,590	38,780
H	Instruments					
J	Painting	120	1,325		220	1,545
K	Insulation					
	DIRECT FIELD COSTS	6625	70,960	125,865	234,525	431,350
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		53,220	6,295		59,515
	TOTAL FIELD COSTS		124,180	132,160	234,525	490,865
R	Engineering					
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					
U	Labor Productivity					
V	Contingency					
W	Fee					
	TOTAL CONSTRUCTION COST					

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GENERAL ELECTRIC

CONSTRUCTION COSTS

CLIENT ______

LOCATION ______

PROJECT Texasgulf Solar Cogeneration Program

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5210	BUILDINGS												
	T/G Building												
A	EXCAVATION & BACKFILL	270	CY		50					570			570
B	CONCRETE	115	CY		1005					9,605		23,205	32,810
C	STRUCTURAL STEEL	38.4	TN		1070					12,315		66,450	78,765
D	ROOFING & SIDING	6033	SF					5.00			30,165		30,165
	HVAC										10,000		10,000
	MISC. ARCHITECTURAL				420	11.05				4,640	56,000	7,850	68,490
E	CRANE & RAIL				600	11.62				6,970		104,640	111,610
F	PLUMBING				355	11.27				4,000		6,540	10,540
G	ELECTRICAL				1200	10.50				12,600		3,755	16,355
	Subtotal T/G Bldg.				4700					50,700	96,165	212,440	359,305
	CONTROL ROOM EXTENSION												
A	EXCAVATION & BACKFILL	30	CY		10					115			115
B	CONCRETE	60	CY		280					2,735		8,100	10,835
D	PRE FAB METAL BLDG										14,700		14,700
	HVAC										15,000		15,000
	MISC. ARCH.				225	11.05				2,485		2305	4,790
F	PLUMBING				90	11.27				1,000		1635	2,635
G	ELECTRICAL				1200	10.50				12,600		9,825	22,425
J	PAINTING				120					1,325		220	1,545
	Subtotal Cont. Rm. Est.				1925					20,260	29,700	22,085	72,045

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT

DESCRIPTION 5220

SECURITY

LOCATION

CONT. NO.

MADE BY

PROJECT Texasgulf Solar Cogeneration Program

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil			72,160		72,160
B	Concrete	180	1720		4035	5,755
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	1200	13,945		141,700	155,645
F	Piping					
G	Electrical	6120	66,270		27,960	94,230
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	7500	81,935	72,160	173,695	327,790
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		61,450	3,610		65,060
	TOTAL FIELD COSTS		143,385	75,770	173,695	392,850
R	Engineering					
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					
U	Labor Productivity					
V	Contingency					
W	Fee					
	TOTAL CONSTRUCTION COST					

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CONSTRUCTION COSTS

GENERAL ELECTRIC

CLIENT ______

LOCATION ______

PROJECT Texasgulf Solar Cogeneration Program

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5220	SECURITY												
A	FENCE										72,160		72,160
B	CONCRETE	20	CY		180					1720		4035	5,755
E	EQUIPMENT				1200					13,945		141,700	155,645
G	Lighting				650					6,825		8,885	15,710
	Communications				120					1,260		2,725	3,985
	Grounding				5350					58,185		16,350	74,535
	Subtotal Security				7500					81,935	72,160	173,695	327,790

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ________ DESCRIPTION 5300

LOCATION ________ COLLECTOR SUBSYSTEM

CONT. NO. ________

MADE BY ________

APPROVED ________

PROJECT Texasgulf Solar Cogeneration Program

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS					
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					
	TOTAL FIELD COSTS					
R	Engineering					245 000
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					8 067 478
T	Construction Management (GE	ESTIMATE)				134 000
	TOTAL OFFICE COSTS					8 446 478
	TOTAL FIELD & OFFICE COSTS					8 446 478
U	Labor Productivity					
V	Contingency					
W	Fee					
	TOTAL CONSTRUCTION COST					8 446 478

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GENERAL ELECTRIC

CONSTRUCTION COSTS

CLIENT

LOCATION

PROJECT Texasgulf Solar Cogeneration Program

BY CHKD. APVD.

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5300	COLLECTOR SUBSYSTEM												
S	588 HELIOSTATS											8067478	8067478
	AREA = 52.77 m²												
	@ $260/m²												
R	ENGINEERING (GE ESTIMATE)												245000

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ______

DESCRIPTION 5400 RECEIVER SUBSYSTEM

LOCATION ______

CONT. NO. ______

MADE BY ______

APPROVED ______

PROJECT Texasgulf Solar Cogeneration Program

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	450	5095			5095
B	Concrete	1500	14,440		32,470	46,910
C	Structural Steel	6150	70,785		716,900	787,685
D	Buildings					
E	Machinery & Equipment	12,000	139,440	125,000		264,440
F	Piping	2500	28,350		136,250	164,600
G	Electrical	1145	12,035		5,470	17,505
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	23745	270,145	125,000	891,090	1,286,235
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		20,260	625		20,885
	TOTAL FIELD COSTS		290,405	125,625	891,090	1,307,120
R	Engineering					183,000
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					1,307,130
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					2,797,250
U	Labor Productivity					
V	Contingency					270,860
W	Fee					
	TOTAL CONSTRUCTION COST					3,068,110

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT Texas Gulf, Inc.

LOCATION Fort Stockton, Tx.

PROJECT Comanche Creek

DESCRIPTION G.E. Solar Cogeneration Facility 5410 - Receiver

Cont. No.
Made By
Approved

A/C No.	Item & Description	Man Hours	Estimated Cost Labor	Subcont.	Materials	Totals
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	12,000	139,440			139,440
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	12,000	139,440			139,440
L	Temporary Construction Facilities					
M	Const. Serv., Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burden & Ins					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		104,580			104,580
	TOTAL FIELD COSTS		244,020			244,020
R	Engineering					
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					1,307,130
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					
U	Labor Productivity					
V	Contingency					
W	Fee					
	TOTAL CONSTRUCTION COST					

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GENERAL ELECTRIC

CONSTRUCTION COSTS

CLIENT ____________

LOCATION ____________

PROJECT Texasgulf Solar Cogeneration Program

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5410	RECEIVER												
E	EQUIPMENT				12000					139 440			139440
S	MAJOR EQUIPMENT PROCUREMENT												
	- RECEIVER PANEL	1									1307 130		1307130
	• MATERIAL – $692 250												
	• SHOP LABOR – 245 410												
	• ENGINEERING – 95 000												
	• FEE – 155 000												
	Total VENDER COST 1,187,660												
	• FREIGHT 19,470												
	• DESIGN 100,000												
	TOTAL PANEL COST 1,307,130												

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ____________ DESCRIPTION 5420

LOCATION ____________ TOWER CONT. NO. ____________

PROJECT Texasgulf Solar Cogeneration Program MADE BY ____________

APPROVED ____________

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST			
			LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	450	5,095			5,095
B	Concrete	1500	14,440		32,470	46,910
C	Structural Steel	6150	70,785		716,900	787,685
D	Buildings					
E	Machinery & Equipment			125,000		125,000
F	Piping					
G	Electrical	1145	12,035		5470	17,505
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	9245	102,355	125,000	754,840	982,195
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		76,765	6250		83,015
	TOTAL FIELD COSTS		179,120	131,250	754,840	1,065,210
R	Engineering					
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					
U	Labor Productivity					
V	Contingency					
W	Fee					
	TOTAL CONSTRUCTION COST					

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CONSTRUCTION COSTS

CLIENT

LOCATION

PROJECT Texasgulf Solar Cogeneration Program

BY CHKD. APVD.

GENERAL ELECTRIC

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5420	Tower												
A	EXCAVATION & CIVIL												
	– TOWER	2125	CY		415					4700			4700
	– ELEV. PIT	165	CY		35					395			395
B	CONCRETE												
	– TOWER	170	CY		1225					11,870		30,390	42,260
	– ELEV. PIT	12	CY		275					2570		2,080	4,650
C	STRUCTURAL STEEL	384.5	TN		6150					70,785		716,900	787,685
E	ELEVATOR										125,000		125,000
G	ELECTRICAL				1145					12,035		5,470	17,505

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ______ DESCRIPTION 5430

UP/DOWN PIPING

LOCATION ______ CONT. NO. ______

PROJECT Texasgulf Solar Cogeneration Program MADE BY ______ APPROVED ______

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST			
			LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping	2500	28,350		136,250	164,600
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	2500	28,350		136,250	164,600
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		21,265			21,265
	TOTAL FIELD COSTS		49,615		136,250	185,865
R	Engineering					
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					
U	Labor Productivity					
V	Contingency					
W	Fee					
	TOTAL CONSTRUCTION COST					

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CONSTRUCTION COSTS

GENERAL ELECTRIC

CLIENT ____________

LOCATION ____________

PROJECT Texasgulf Solar Cogeneration Program

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5430	MAIN FEEDWATER AND STEAM PIPING												
F	PIPING	1000	2.5		2500					28,350		136,250	164,600

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ______ DESCRIPTION 5500

LOCATION ______ MASTER CONTROL SUBSYSTEM

CONT. NO. ______

MADE BY ______

PROJECT Texasgulf Solar Cogeneration Program

APPROVED ______

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	3040	34,290		66,055	100,345
F	Piping					
G	Electrical	2950	33,275		97,830	131,105
H	Instruments	6150	69,370		145,500	214,870
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	12140	136,935		309,385	446,320
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		102,700			102,700
	TOTAL FIELD COSTS		239,635		309,385	549,020
R	Engineering					76,865
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					625,885
U	Labor Productivity					
V	Contingency					125,535
W	Fee					
	TOTAL CONSTRUCTION COST					751,420

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ______ DESCRIPTION 5510

MASTER CONTROL

LOCATION ______ CONT. NO. ______

PROJECT Texasgulf Solar Cogeneration Program

MADE BY ______

APPROVED ______

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST			
			LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	3040	34,290		66,055	100,345
F	Piping					
G	Electrical	2950	33,275		97,830	131,105
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	5990	67,565		163,885	231,450
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					
	TOTAL FIELD COSTS					
R	Engineering					
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					
U	Labor Productivity					
V	Contingency					
W	Fee					
	TOTAL CONSTRUCTION COST					

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ____________

DESCRIPTION SS20

CONTROLS AND INSTRUMENTATION

LOCATION ____________

CONT. NO. ____________

MADE BY ____________

PROJECT Texasgulf Solar Cogeneration Program

APPROVED ____________

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST: LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping					
G	Electrical					
H	Instruments	6150	69370		145,500	214,870
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	6150	69370		145,500	214,870
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					
	TOTAL FIELD COSTS					
R	Engineering					
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					
U	Labor Productivity					
V	Contingency					
W	Fee					
	TOTAL CONSTRUCTION COST					

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ____________ DESCRIPTION 5600

LOCATION ____________ FOSSIL ENERGY SUBSYSTEM

CONT. NO. ____________

MADE BY ____________

PROJECT Texasgulf Solar Cogeneration Program

APPROVED ____________

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST: LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete	160	1575		3445	5020
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	1400	16,575		1,286,200	1,302,775
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	1560	18,150		1,289,645	1,307,795
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		13,615			13,615
	TOTAL FIELD COSTS		31,765		1,289,645	1,321,410
R	Engineering					185,000
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					1,506,410
U	Labor Productivity					
V	Contingency					247,640
W	Fee					
	TOTAL CONSTRUCTION COST					1,754,050

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ______ DESCRIPTION 5610

LOCATION ______ SATURATED BOILER

PROJECT Texasgulf Solar Cogeneration Program

CONT. NO. ______
MADE BY ______
APPROVED ______

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete	65	640		1435	2075
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	800	9470		654,000	663,470
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	865	10,110		655,435	665,545
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					
	TOTAL FIELD COSTS					
R	Engineering					
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					
U	Labor Productivity					
V	Contingency					
W	Fee					
	TOTAL CONSTRUCTION COST					

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GENERAL ELECTRIC

CONSTRUCTION COSTS

CLIENT

LOCATION

PROJECT Texasgulf Solar Cogeneration Program

BY CHKD. APVD.

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5610	SATURATED BOILER												
B	CONCRETE	8	CY		65					640		1435	2075
E	MACHINERY & EQUIPMENT	1	EA		800					9470		654,000	663,470

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT

DESCRIPTION 5620

SUPERHEATER AND ACCUMULATOR

LOCATION

CONT. NO.

MADE BY

APPROVED

PROJECT Texasgulf Solar Cogeneration Program

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete	95	935		2010	2945
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	600	7105		632,200	639,305
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	695	8040		634,210	642,250
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					
	TOTAL FIELD COSTS					
R	Engineering					
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					
U	Labor Productivity					
V	Contingency					
W	Fee					
	TOTAL CONSTRUCTION COST					

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CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT Texasgulf Solar Cogeneration Program

BY ______ CHKD. ______ APVD. ______

GENERAL ELECTRIC

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5620	SUPERHEATER AND ACCUMULATOR												
B	CONCRETE	10	CY		95					935		2010	2945
E	MACHINERY & EQUIPMENT	1	EA		600					7105		632,200	639,305

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ______

DESCRIPTION 5800

ELECTRIC POWER GENERATING SUBSYSTEM

LOCATION ______

CONT. NO. ______

MADE BY ______

APPROVED ______

PROJECT Texasgulf Solar Cogeneration Program

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST: LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	40	450			450
B	Concrete	1005	9575		16,700	26,275
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	7500	87,150		1,250,000	1,337,150
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	8545	97,175		1,266,700	1,363,875
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		72,880			72,880
	TOTAL FIELD COSTS		170,055		1,266,700	1,436,755
R	Engineering					26,145
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					1,462,900
U	Labor Productivity					
V	Contingency					51,560
W	Fee					
	TOTAL CONSTRUCTION COST					1,514,460

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CONSTRUCTION COSTS

CLIENT

LOCATION

PROJECT Texasgulf Solar Cogeneration Program

BY CHKD. APVD.

GENERAL ELECTRIC

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5800	ELECTRIC POWER GENERATING SUBSYSTEM												
A	EARTHWORK	225	CY		40					450			450
B	CONCRETE	70	CY		1005					9575		16,700	26,275
E	MACHINERY & EQUIPMENT				7500					87,150		1,250,000	1,337,150

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT

DESCRIPTION 5900

OTHER SUBSYSTEMS

LOCATION

CONT. NO.

MADE BY

PROJECT Texasgulf Solar Cogeneration Program

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	70	795		590	1385
B	Concrete	3965	37,165		42,455	79,620
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	4100	47,645		565,165	612,810
F	Piping	13650	154,790		659,450	814,240
G	Electrical	8710	91,455		370,595	462,050
H	Instruments					
J	Painting					
K	Insulation	2000	21,680		32,700	54,380
	DIRECT FIELD COSTS	32495	353,530		1,670,955	2,024,485
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		265,150			265,150
	TOTAL FIELD COSTS		618,680		1,670,955	2,289,635
R	Engineering					320,550
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					2,610,185
U	Labor Productivity					
V	Contingency					485,450
W	Fee					
	TOTAL CONSTRUCTION COST					3,095,635

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ______

DESCRIPTION 5910

LOCATION ______

PROCESS HEAT SUBSYSTEM

CONT. NO. ______

MADE BY ______

APPROVED ______

PROJECT Texasgulf Solar Cogeneration Program

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete	50	485		1010	1495
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	700	8135		274,680	282,815
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	750	8620		275,690	284,310
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		6465			6465
	TOTAL FIELD COSTS		15,085		275,690	290,775
R	Engineering					40,710
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					331,485
U	Labor Productivity					
V	Contingency					55,300
W	Fee					
	TOTAL CONSTRUCTION COST					386,785

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CONSTRUCTION COSTS

GENERAL ELECTRIC

CLIENT ______

LOCATION ______

PROJECT Texasgulf Solar Cogeneration Program

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS ( ) SUB CONTRACT	COSTS ( ) MATERIAL	COSTS ( ) TOTAL
5910	PROCESS HEAT SUBSYSTEM												
B	CONCRETE	5	CY		50					485		1010	1495
E	HEAT EXCHANGER				300					3485		207,100	210,585
	CONDENSER				400					4650		67,580	72,230

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ______

DESCRIPTION 5920

ELECTRICAL SUBSYSTEM

LOCATION ______

CONT. NO. ______

MADE BY ______

APPROVED ______

PROJECT Texasgulf Solar Cogeneration Program

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	10	115		590	705
B	Concrete	580	5,660		12,685	18,345
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping					
G	Electrical	4580	48,090		329,175	377,265
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	5170	53,865		342,450	396,315
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		40,400			40,400
	TOTAL FIELD COSTS		94,265		342,450	436,715
R	Engineering					61,140
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					497,855
U	Labor Productivity					
V	Contingency					90,220
W	Fee					
	TOTAL CONSTRUCTION COST					588,075

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GENERAL ELECTRIC

CONSTRUCTION COSTS

CLIENT

LOCATION

PROJECT Texasgulf Solar Cogeneration Program

BY ____ CHKD. ____ APVD. ____

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5920	ELECTRICAL SUBSYSTEM												
A	EARTHWORK	45	CY		10					115		590	705
B	CONCRETE	65	CY		580					5660		12,685	18,345
G	ELECTRICAL				4580					48,090		329,175	377,265

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GENERAL ELECTRIC

CONSTRUCTION COST ESTIMATE

CLIENT ______ DESCRIPTION 5930

LOCATION ______ FLUID CIRCULATION SUBSYSTEM

CONT. NO. ______

MADE BY ______

APPROVED ______

PROJECT Texasgulf Solar Cogeneration Program

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	ESTIMATED COST			
			LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	60	680			680
B	Concrete	3335	31,020		28,760	59,780
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	3400	39,510		290,485	329,995
F	Piping	13,650	154,790		659,450	814,240
G	Electrical	4,130	43,365		41,420	84,785
H	Instruments					
J	Painting					
K	Insulation	2000	21,680		32,700	54,380
	DIRECT FIELD COSTS	26,575	291,045		1,052,815	1,343,860
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		218,285			218,285
	TOTAL FIELD COSTS		509,330		1,052,815	1,562,145
R	Engineering					218,700
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					
T	Construction Management					
	TOTAL OFFICE COSTS					
	TOTAL FIELD & OFFICE COSTS					1,780,845
U	Labor Productivity					
V	Contingency					339,930
W	Fee					
	TOTAL CONSTRUCTION COST					2,120,775

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GENERAL ELECTRIC

CONSTRUCTION COSTS

CLIENT

LOCATION

PROJECT Texasgulf Solar Cogeneration Program

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5930	FLUID CIRCULATION SUBSYSTEM												
A	EARTHWORK	325	CY		60					680			680
B	CONCRETE	130	CY		3335					31,020		28,760	59,780
E	PUMPS	7	EA		3000	11.62				34,860		228,355	263,215
	DEAERATOR	1	EA		400					4,650		62,130	66,780
F	PIPING				13,650	11.34				154,790		659,450	814,240
G	ELECTRICAL				4130					43,365		41,420	84,785
K	INSULATION				2000					21,680		32,700	54,380

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Table 5-9

O&M COST SUMMARY

OM100 Operations			
	OM110	Operating Personnel	186,150
OM200 Maintenance Materials			
	OM210	Spare Parts and Materials	26,514
OM300 Maintenance Labor			
	OM310	Scheduled Maintenance	39,400
Total Yearly O&M Cost			$252,064

Table 5-10

O&M COST BREAKDOWN

OM100 Operations				
	OM110	Operating Personnel		
		1 Operator 4.5 shifts/day 1 Maintenance Man 1.875 shifts/day		
		@ 8 hr/shift × 365 day/year = 18,615 man-hour × $10/hr		
				$186,150
OM200 Maintenance Materials				
	OM210	Spare Parts and Materials		
		OM211	Collector Equipment 0.1% of initial cost/yr =	$8,446
		OM212	Receiver Equipment 0.1% of initial cost/yr =	3,068
		OM213	Balance of Plant Equipment =	15,000
OM300 Maintenance Labor				
	OM310	Scheduled Maintenance		
		OM311	Subcontracted services for heliostat washing @ $50/heliostat × 588 heliostats =	$29,400
		OM312	Balance of Plant including turbine/generator service and HX-condenser tube cleaning =	$10,000

5.4 ECONOMIC DATA

The economic assumptions used to evaluate the pilot plant solar cogeneration faciliy at Comanche Creek is shown in Table 5-11. In addition, the data listed in Table 5-12 has been used (per DOE-RFP DE-RP03-80SF10768) for the alternate fuel option.

Table 5-11

PILOT PLANT ECONOMIC ASSUMPTIONS (1980$)

Factor	Value
Annual Inflation Rate	9%
Federal & State Income Tax Rate	46%
Tax Depreciation Method	DDB
Tax Depreciation Life	10 Years
Salvage Value	0
Investment Tax Credit	10% + 15%
Local Real Estate Taxes & Insurance	3%
Useful Life of Investment	20 Years
First Full Year of Operation	1986
Cost of Fuels & Power	
Natural Gas	$2.50/10^6 Btu
Purchased Power	$0.033/kWh
Escalation of Fuels & Power Above Inflation	
Natural Gas	3%
Purchased & Exported Power	1%

Table 5-12

ALTERNATE FUEL COST ASSUMPTIONS

Fuel	Cost (1980 $/MBtu)	Escalation Rate (Above General Inflation)
Coal	1.25	2%
Oil	4.00	4%

5.5 SIMULATION MODELS

This section contains a brief summary of the simulation models and computer codes used during the course of the conceptual design study.

5.5.1 Solar Model

The solar model used in the evaluation of the solar cogeneration facility performance was developed using the 1975 El Paso, Texas SOLMET data tape which was modified to reflect solar radiation differences due to Fort Stockton being at a different location (altitude and latitude). This modification, as described below, is based on a solar flux relationship taken from Ref. A.1.

The solar flux relationship is (Ref. A.1, pg 46).

$$I\ (z,\ h) = Io\ (l - ah)\ e^{-c(\sec z)^{s}} + ahIo \qquad (5\text{-}1)$$

where

I (z, h) = solar flux at zenith distance z and elevation h

Io = 1.353 kW/m^2

a = 0.14 /km

c = 0.357

s = 0.678

The zenith distance z is obtained from the expression (Ref. A.1, pg 88)

$$\cos z = \sin\lambda\ \sin\delta + \cos\lambda\ \cos\delta\ \cos t \qquad (5\text{-}2)$$

where

λ = site latitude (degrees)

δ = solar declination (degrees)

t = solar time (hours, measured from noon)

Assuming conditions corresponding to the design point (Equinox, noon) then both the solar time, t, and the solar declination, δ, are zero. Thus, eq. 5-2 reduces to

$$\cos t = \cos\lambda \qquad (5\text{-}3)$$

or the zenith distance, z, is equal to the latitude, λ. The pertinent site characteristics are given in Table 5-13.

Table 5-13

COMPARATIVE SITE CHARACTERISTICS

Site	Fort Stockton	El Paso
Altitude (km)	.913	1.250
Latitude (degrees)	30.8667	31.8

Substituting the characteristics from Table 5-13 into eq. 5-1 gives the following:

Fort Stockton Insolation = 0.7148 (Io)
El Paso Insolation = 0.7267 (Io)

and by taking the ratio we find

Fort Stockton Insolation = 0.9837 (El Paso Insolation)

Therefore, the El Paso SOLMET data tape can be used to model the solar flux at Fort Stockton if a modifying factor of 0.9837 is applied to each piece of data.

5.5.2 Performance Models

The following models will be used to design and evaluate the system performance:

1. DELSOL – Calculates the optical performance, field layout and optical system design for solar central receiver systems.
2. MIRVAL – Calculates heliostat field performance by Monte Carlo ray trace analysis. Field efficiency data used as input to STEAEC analysis.
3. WSRLOSS – Models receiver performance and calculates the incident and absorbed heat fluxes and the reflecfion, radiation and convection losses.
4. STEAEC – Models system performance with SOLMET insolation and meteorological data to provide yearly energy output.

5.5.3 Economic Model

The economic model consists of a discounted, cash flow rate of return (DCRR) analysis based on the General Electric CTAS[A.2] activities.

REFERENCES

A.1 A.B. Mienel and M.P. Meinel, "Applied Solar Energy – An Introduction," Addison-Wesley Publishing Company, 1976.

A.2 "Cogeneration Technology Alternatives Study (CTAS)," General Electric Company Final Report, No. DOE/NASA/0031-80/1, January, 1980.

Appendix B
INCREMENTAL COST OF STORAGE

Appendix B
INCREMENTAL COST OF STORAGE

Cost estimates for the six storage system concepts discussed in Section 3.5 are summarized in Table B-1. These are incremental costs — that is, the investment required beyond case 1 to procure and install the storage equipment and additional receiver/collector capacity.

Table B-1
INCREMENTAL COST OF STORAGE
(1980-$M)

Case Number	2	3	4	5		6	7
				Oil	Salt		
Cost Category:							
Storage Media	0	0	0	0.225	0.426	0.546	1.229
Storage Tanks	1.720	4.578	6.401	0.194	0.153	00.489	1.252
Heat Exchangers	0	0.124	0.233	0.776	0.238	1.787	3.015
Pumps	0.001	0.008	0.011	0.002	0.001	0.004	0.010
Indirect Costs:							
A/E Service	0.430	1.178	1.659	0.299	0.205	0.707	1.377
Constr. Contr.	0.076	0.192	0.268	0.039	0.031	0.088	0.194
Contingency	0.334	0.912	1.284	0.230	0.158	0.543	1.062
Storage Total	2.561	6.992	9.846	1.765	1.212	4.164	8.138
Receiver and Coll.	3.200	13.000	19.300	2.500	2.500	13.000	20.000
Grand Total	5.761	19.992	29.146	4.265	3.712	17.164	28.138

Storage media properties and costs (Table B-2) were taken from several sources. Oil and rock data came primarily from references B.1 and B.2, but were checked against the McDonnell Douglas solar study.[B.3] The molten salt used in this analysis is a mixture of 45% (weight) sodium nitrite and 55% potassium nitrate. This is the only mixture identified in Martin Marietta's solar study[B.4] which has a melting temperature low enough (285° F) to be used in the solar cogeneration system. Although potassium nitrate is well characterized in a number of reports, sodium nitrite data proved more difficult to find. The physical data for sodium nitrite were estimated by scaling nitrate data, while the cost was assumed to be the same as that quoted for sodium nitrate by Martin.[B.4]

Table B-2

STORAGE MEDIA PROPERTIES AND COSTS

	Caloria HT-43	Rock+Salt (2R:1S)	Molten Salt (0.45 $NaNO_3$:0.55 KNO_3)
Density (lb/ft^3)	44 (B.1)	125 d(B.1)	124 [g]
Sp. Heat (Btu/lb °F)	0.68 (B.1)	0.24 (B.1)	0.43 [h]
Th. Cond. (Btu/hr ft °F)	0.049 (B.2)	—	0.23 [i]
Viscosity (ft^2/hr)	0.21 (B.2)	—	0.08 [i]
Prandil No.	128	—	18.6
Cost ($/ton)			
Medium	600 [a]	10 [3]	213 [j]
Shipping	3 [b]	3 [b]	3 [b]
Installation, Field	0 [c]	22 [f]	22 [k]
Total	603	35	0.238
Heat Transfer Coefficient (Btu/hr ft^2 °F)	50 [m]	—	300
same basis water h=1000 f.c. h=10,000 boiling			

[a] (Ref B.1) 0.27 × 1.10 × 2000 = 600 $/ton, FOB Houston

[b] 0.015 $/ton-mile × 200 miles = 3 $/ton

[c] requires only pumping from tank car

[d] 16616/ft^3 × 0.75 (packing) = 125

[e] 7.40 $/ton (5) × $(1.10)^3$ = 10 $/ton, FOB Texas[B.3]

[f] 16.70 $/ton (5) × $(1.10)^3$ + 22 $/ton compares with 42 $/ton for concrete[B.6]

[g] 135 (8) × 0.45+116(7) × 0.55 = 124 lb/ft^3

[h] [0.45 × 135(8) × 0.54(guess)+0.55 × 116(7) × 0.32(7)]/124 = 0.54 Btu/lb °F

[i] assume same as for 40% KNO_3/60%$NaNO_3$ at 500°F

[j] (Ref. 5.4) assume $NaNO_2$ costs same as $NaNO_3$ (0.45 × 147+0.55 × 200) $(1.10)^2$ =213 $/ton, FOB Mississippi and Louisiana

[k] Cost of unloading, mixing, melting and loading at site,[B.4] 17.88 $/ton × $(1.10)^2$ = 22 $/ton

[l] $Nu = 0.023\ Pr^{0.4}\ Re^{0.8} = 0.023(18.6)^{0.4}\ (18750)^{0.8} = 194$

[m] $Nu = 0.023\ Pr^{0.33}\ Re^{0.8} = 0.23(128)^{0.33}\ (7142)^{0.8} = 138$;

Water $Nu = 0.23(0.927)^{0.33}\ (245098)^{0.2} = 459$;

h = 459 [0.38/1(2/12)] = 1046; 2.5 ft/s, 2 in. tube;
h = 138[0.049/2/12)] = 41;
h = 194[0.23/(2/12)] = 267

Table B-3 shows the format and unit costs used for estimating the storage tank costs. These data were taken from General Electric's Advanced Central Receiver study.(B.5) All of the tanks were designed to meet ASME Section VIII Division 1 rules which assume that carbon steel is the tank material. Wall thicknesses were maintained at less than 3 inches in all cases. A brief evaluation was made of prestressed cast iron vessels for the pressurized hot water storage cases(B.6) but this technology is not yet commercially available and was judged inappropriate for the very near-term solar cogeneration project.

Table B-3

STORAGE TANK COST ESTIMATE

Item	Quantity	Unit Cost	Major Comp. (M$)	Field Labor (M$)	Field Mat'l (M$)
Metal					
Raw Plate	lb	0.25 $/lb		-	-
Factory Fabrication	lb	0.25 $/lb(Field),0.40(Fact)			
Factory Rigging	lb	0.01 $/lb		-	-
Field Fabrication	lb	0.30 $/lb(Field),0(Fact)	-		-
Field Rigging	lb	0.08 $/lb			
Plate Shipping	lb	0.008 $/lb	-	-	
Insulation					
Thermal Insulation	ft^2	2.00 $\$/ft^2$	-	-	
Aluminum Jacket	ft^2	0.60 $\$/ft^2$	-	-	
Insulation Shipping	lb	0.008 $/lb	-	-	
Factory Rigging	lb	0.01 $/lb	-	-	
Field Install-Insul.	ft^2	2.00 $\$/ft^2$	-		-
Jacket	ft^2	1.50 $\$/ft^2$	-		-
Field Rigging	lb	0.25 $/lb	-		-
Trace Heaters					
Trace Heater Coils	ft	10 $/ft	-	-	
Heater Shipping	-	5%	-	-	
Field Installation	ft	7.60 $/ft	-		-
Foundation					
Concrete and rebar	yd^3	54.00 $\$/yd^3$	-	-	
Installation	yd^3	56.40 $\$/yd^3$	-		-

Heat exchangers required for charging and discharging storage were sized from the counterflow and the heat transfer coefficients listed in Table B-2. Table B-4 describes the procedure used for estimating the costs. It was assumed that carbon steel would be used in all cases except where boiling, condensation, or contact with the process liquid required low-alloy steel for corrosion resistance. The unit cost data in Table B-4 were derived primarily from ACRI,[B.5] and from the factory fabrication data supplied by Foster Wheeler in private communications.

Table B-4

HEAT EXCHANGER COST ESTIMATE

Assume that all HX are constructed from 2 in. OD × 0.25 wall thickness C.S. tubes* and are 60 ft overall length, 50 ft active length. Each tube is 1 in. from every adjacent tube and the shell is 0.5 in. thick.

Tubes	Units	Shell	Units
$A_T =$	ft²	$D_s = 0.333\sqrt{N} =$	ft
$L = A/(0.524\ ft^2/ft) =$	ft	$W_s = 3927\ D_s =$	lb
$N = L/40 =$	ft	$A_s = 188\ D_s =$	ft²
$W_T = (4.77\ lb/ft)L =$	lb	$L_{WELD} = 10\ \pi\ D_s =$	ft
Foundation		Foundation	
$W_I = 4.44\ lb/ft^2\ A_s =$	lb	$V_C = \frac{(20)^2}{27} \times 1.5 = 22$	yd³

Item	Quantity	Unit Cost	Major Comp. (M$)	Field Labor (M$)	Field Mat'l (M$)
Metal					
Raw tube	lb	0.50 $/lb*		-	-
Raw plate & forgings	lb	0.50 $/lb*		-	-
Tube welds	tubes	50$/tube		-	-
Shell welds	ft	50$/ft		-	-
Factory Fabrication	lb	1.50 $/lb		-	-
Factory Rigging	lb	0.01 $/lb		-	-
Shipping	lb	0.008 $/lb	-	-	
Field Rigging	lb	0.08 $/lb	-		-
Insulation					
Thermal insulation	ft²	2.00 $/ft²	-	-	
Aluminum Jacket	ft²	0.60 $/ft²	-	-	
Insulation Shipping	lb	0.008 $/lb	-	-	
Factory Rigging	lb	0.01 $/lb	-	-	
Field Install - Ins.	ft²	1.50 $/ft²	-		-
Jack.	ft²	1.50 $/ft²	-		-
Field Rigging	lb	0.25 $/lb	-		-
Found. Concrete & Rebar.	22 yd³	54.00 $/yd³	-	-	0.001
Installation	22 yd³	56.40 $/yd³	-	0.001	-

*HX with process water, boiling water or condensing steam use 2 1/4CR-1Mo at 1.30 $/lb.

The pump costs were estimated by applying a unit cost of 100$/HP. This number is consistent with the range of costs seen in the studies by Martin,(B.4) MDAC,(B.3) and General Electric.(B.5)

The indirect costs were estimated by using the methodology described in Table B-5. This method is a simplification of that employed in ACRI.(B.5)

Table B-5
COST ESTIMATE SUMMARY
(CASE NUMBER ____)

	Major Comp. (M$)	Field Labor (M$)	Field Mat'l (M$)	Total (M$)
Storage Media				
Storage Tanks				
Heat Exchangers				
Pumps				
Subtotals	(1)	(2)	(3)	(4)
Indirects				
General Service, Procure., Constr. Mgt.				
0.25 x (4)				
Constr. Contractor Markups				
0.18 x [(2) x (3)]			Subtotal	____
Contingency				
0.15 x Subtotal			Storage Total	____
Receiver & Collector				
			GRAND TOTAL	____

REFERENCES

B.1. *A Preliminary Screening of Thermal Storage Concepts for Water/Steam and Organic Fluid Solar Thermal Receiver Systems,* R.J. Copeland, M.E. Karpuk, J. Ullman, Solar Energy Research Institute Report SERI/TR-631-647, April 1980.

B.2. *Prediction of Yearly Fluid Replenishment Rates for Hydrocarbon Fluids in Thermal Energy Storage Systems,* V.P. Burolla, Sandia National Laboratories, Livermore, CA; SAND79-8209, April 1979.

B.3. *Central Receiver Solar Thermal Power System, Phase 1,* Volume VII, Book 1, Pilot Plant Cost and Commercial Plant Cost and Performance, McDonnell Douglas Astronautics Company-West, Huntington Beach, CA, May 1977.

B.4. *Conceptual Design of Advanced Central Receiver Power System,* Martin Marietta Corporation, Denver, CO; DOE Contract EG-77-C-03-1724 Final Report, September 1978.

B.5. *Conceptual Design of Advanced Central Receiver Power Systems,* General Electric Company, Schenectady, NY; DOE Contract DE-AC03-78ET20500, June 1979.

B.6. *Conceptual Design of Thermal Energy Storage Systems for Near-Term Electric Utility Applications,* General Electric Company, Schenectady, NY; EPRI Report EM-1218, November 1979.

Appendix C
HELIOSTAT COORDINATES

Appendix C
HELIOSTAT COORDINATES

Table C-1 presents the x,y coordinates of each of the 588 heliostats in the collector field. These coordinates (given in meters) are relative to the tower centerline which is assumed to be at x = 0, y = 0.

Table C-1
HELIOSTAT COORDINATES

Heliostat	Coordinates		Heliostat	Coordinates		Heliostat	Coordinates	
No.	x	y	No.	x	y	No.	x	y
1	0.000	52.749	36	58.899	62.910	71	49.415	106.334
2	17.314	49.826	37	-58.899	62.910	72	-49.415	106.334
3	-17.314	49.826	38	16.187	92.934	73	74.971	90.156
4	32.710	41.383	39	-16.187	92.934	74	-74.971	90.156
5	-32.710	41.383	40	34.660	87.735	75	87.823	77.691
6	9.792	58.009	41	-34.660	87.735	76	-87.823	77.691
7	-9.792	58.009	42	51.700	78.904	77	8.836	125.045
8	28.290	51.581	43	-51.700	78.904	78	-8.836	125.045
9	-28.290	51.581	44	75.332	56.779	79	26.332	122.560
10	43.653	39.437	45	-75.332	56.779	80	-26.332	122.560
11	-43.653	39.437	46	9.571	101.458	81	43.305	117.639
12	0.000	64.910	47	-9.571	101.458	82	-43.305	117.639
13	21.306	61.314	48	28.377	97.878	83	59.418	110.381
14	-21.306	61.314	49	-28.377	97.878	84	-59.418	110.381
15	40.251	50.923	50	46.130	90.845	85	74.349	100.928
16	-40.251	50.923	51	-46.130	90.845	86	-74.349	100.928
17	16.627	71.037	52	62.355	80.606	87	87.803	89.470
18	-16.627	71.037	53	-62.355	80.606	88	-87.803	89.470
19	35.083	63.967	54	76.329	67.523	89	99.512	76.234
20	-35.083	63.967	55	-76.329	67.523	90	-99.512	76.234
21	50.965	52.204	56	0.000	108.748	91	0.000	133.149
22	-50.965	52.204	57	20.337	106.830	92	18.724	131.826
23	10.033	79.577	58	-20.337	106.830	93	-18.724	131.826
24	-10.033	79.577	59	39.957	101.142	94	37.075	127.883
25	29.470	74.597	60	-39.957	101.142	95	-37.075	127.883
26	-29.470	74.597	61	58.157	91.885	96	54.690	121.399
27	47.063	64.948	62	-58.157	91.885	97	-54.690	121.399
28	-47.063	64.948	63	74.324	79.386	98	71.218	112.502
29	61.711	51.234	64	-74.324	79.386	99	-71.218	112.502
30	-61.711	51.234	65	87.859	64.086	100	86.331	101.369
31	0.000	86.178	66	-87.859	64.086	101	-86.331	101.369
32	21.390	83.481	67	15.123	116.276	102	99.728	88.222
33	-21.390	83.481	68	-15.123	116.276	103	-99.728	88.222
34	41.441	75.560	69	32.650	112.618	104	9.997	141.474
35	-41.441	75.560	70	-32.650	112.618	105	-9.997	141.474

Table C-1 (Continued)

HELIOSTAT COORDINATES

Heliostat	Coordinates		Heliostat	Coordinates		Heliostat	Coordinates	
No.	x	y	No.	x	y	No.	x	y
106	29.792	138.662	179	-98.235	149.288	252	52.427	216.024
107	-29.792	138.662	180	113.454	138.077	253	-52.427	216.024
108	48.995	133.095	181	-113.454	138.077	254	69.389	211.187
109	-48.995	133.095	182	127.403	125.322	255	-69.389	211.187
110	67.224	124.883	183	-127.403	125.322	256	85.913	205.022
111	-67.224	124.883	184	139.927	111.165	257	-85.913	205.022
112	84.118	114.189	185	-139.927	111.165	258	101.897	197.565
113	-84.118	114.189	186	0.000	189.363	259	-101.897	197.565
114	99.339	101.225	187	19.948	187.307	260	117.239	188.865
115	-99.339	101.225	188	-19.948	187.307	261	-117.239	188.865
116	112.587	86.250	189	39.672	184.649	262	131.843	178.976
117	-112.587	86.250	190	-39.672	184.649	263	-131.843	178.976
118	0.000	150.484	191	58.953	179.425	264	145.617	167.960
119	17.213	149.496	192	-58.953	179.426	265	-145.617	167.960
120	-17.213	149.496	193	77.574	172.196	266	158.475	155.887
121	45.711	143.373	194	-77.574	172.196	267	-158.475	155.887
122	-45.711	143.373	195	95.328	163.039	268	170.335	142.832
123	61.810	137.203	196	-95.328	163.039	269	-170.335	142.832
124	-61.810	137.203	197	112.015	152.059	270	181.122	128.878
125	77.099	129.233	198	-112.015	152.059	271	-181.122	128.878
126	-77.099	129.233	199	127.449	139.377	272	9.300	234.241
127	100.566	111.945	200	-127.449	139.377	273	-9.300	234.241
128	-100.566	111.945	201	141.457	125.137	274	27.841	232.766
129	112.711	99.707	202	-141.457	125.137	275	-27.841	232.766
130	-112.711	99.707	203	153.883	109.496	276	46.207	229.826
131	8.437	159.321	204	-153.883	109.496	277	-46.207	229.826
132	-8.437	159.321	205	14.504	199.016	278	64.282	225.440
133	25.218	157.539	206	-14.504	199.016	279	-64.282	225.440
134	-25.218	157.539	207	31.540	197.035	280	81.953	219.634
135	41.716	153.994	208	-31.540	197.035	281	-81.953	219.634
136	-41.716	153.994	209	48.343	193.599	282	99.108	212.445
137	57.747	148.727	210	-48.343	193.599	283	-99.108	212.445
138	-57.747	148.727	211	75.902	184.545	284	115.638	203.919
139	73.133	141.795	212	-75.902	184.545	285	-115.638	203.919
140	-73.133	141.795	213	91.458	177.345	286	131.441	194.110
141	87.700	133.278	214	-91.458	177.345	287	-131.441	194.110
142	-87.700	133.278	215	106.359	168.836	288	146.416	183.078
143	101.287	123.270	216	-106.359	168.836	289	-146.416	183.078
144	-101.287	123.270	217	129.714	151.631	290	160.470	170.894
145	113.740	111.882	218	-129.714	151.631	291	-160.470	170.894
146	-113.740	111.882	219	142.256	139.932	292	173.513	157.634
147	124.921	99.243	220	-142.256	139.932	293	-173.513	157.634
148	-124.921	99.243	221	153.746	127.200	294	185.464	143.382
149	0.000	168.896	222	-153.746	127.200	295	-185.454	143.382
150	17.839	167.951	223	8.356	210.454	296	0.000	247.236
151	-17.839	167.951	224	-8.356	210.454	297	19.601	246.458
152	35.478	165.127	225	25.014	209.129	298	-19.601	246.458
153	-35.478	165.127	226	-25.014	209.129	299	39.078	244.128
154	52.720	160.457	227	41.515	206.488	300	-39.078	244.128
155	-52.720	160.457	228	-41.515	206.488	301	58.310	240.262
156	69.373	153.991	229	57.755	202.546	302	-58.310	240.262
157	-69.373	153.991	230	-57.755	202.546	303	77.174	234.983
158	85.249	145.802	231	73.631	197.330	304	-77.174	234.883
159	-85.249	145.802	232	-73.631	197.330	305	95.553	228.025
160	100.172	135.983	233	89.043	190.872	306	-95.553	228.025
161	-100.172	135.983	234	-89.043	190.872	307	113.330	219.732
162	113.974	124.642	235	103.895	183.211	308	-113.330	219.732
163	-113.974	124.642	236	-103.895	183.211	309	130.393	210.055
164	126.502	111.907	237	118.093	174.398	310	-130.393	210.055
165	-126.502	111.907	238	-118.093	174.398	311	146.636	199.057
166	137.614	97.920	239	131.548	164.487	312	-146.636	199.057
167	-137.614	97.920	240	-131.548	164.487	313	161.956	186.805
168	9.451	178.459	241	144.174	153.540	314	-161.956	186.805
169	-9.451	178.459	242	-144.174	153.540	315	176.256	173.377
170	28.247	176.463	243	155.893	141.626	316	-176.256	173.377
171	-28.247	176.463	244	-155.893	141.626	317	189.446	158.858
172	46.727	172.492	245	166.630	128.821	318	-189.446	158.858
173	-46.727	172.492	246	-166.630	128.821	319	201.444	143.338
174	64.684	166.592	247	0.000	222.295	320	-201.444	143.338
175	-64.684	166.592	248	17.623	221.595	321	14.210	260.182
176	81.918	158.828	249	-17.623	221.595	322	-14.210	260.182
177	-81.918	158.828	250	35.136	219.500	323	30.946	258.725
178	98.235	149.288	251	-35.136	219.500	324	-30.946	258.725

Table C-1 (Continued)

HELIOSTAT COORDINATES

Heliostat	Coordinates		Heliostat	Coordinates		Heliostat	Coordinates	
No.	x	y	No.	x	y	No.	x	y
325	47.554	256.193	398	176.216	229.531	471	10.071	338.277
326	-47.554	256.193	399	-176.216	229.531	472	-10.071	338.277
327	75.172	249.491	400	189.558	218.642	473	30.176	337.079
328	-75.172	249.491	401	-189.558	218.642	474	-30.176	337.079
329	91.093	244.128	402	202.229	206.979	475	50.174	334.687
330	-91.093	244.128	403	-202.229	206.979	476	-50.174	334.687
331	106.634	237.751	404	214.133	194.582	477	69.995	331.110
332	-106.634	237.751	405	-214.133	194.582	478	-69.995	331.110
333	131.893	224.723	406	225.379	181.496	479	89.568	326.360
334	-131.893	224.723	407	-225.379	181.496	480	-89.568	326.360
335	146.100	215.757	408	235.777	167.768	481	108.824	320.454
336	-146.100	215.757	409	-235.777	167.768	482	-108.824	320.454
337	159.699	205.895	410	9.074	304.809	483	127.694	313.412
338	-159.699	205.895	411	-9.074	304.809	484	-127.694	313.412
339	181.173	187.277	412	27.190	303.729	485	146.112	305.261
340	-181.173	187.277	413	-27.190	303.729	486	-146.112	305.261
341	192.864	175.214	414	45.210	301.574	487	164.012	296.029
342	-192.864	175.214	415	-45.210	301.574	488	-164.012	296.029
343	203.753	162.422	416	63.070	298.350	489	181.332	285.748
344	-203. 753	162.422	417	-63.070	298.350	490	-181.332	285.748
345	8.173	274.551	418	80.706	294.070	491	198.009	274.455
346	-8.173	274.551	419	-80.706	294.070	492	-198.009	274.455
347	24.491	273.578	420	98.057	288.748	493	213.985	262.190
348	-24.491	273.578	421	-98.057	288.748	494	-213.985	262.190
349	40.722	271.637	422	115.060	282.404	495	229.203	248.996
350	-40.722	271.637	423	-115.060	282.404	496	-229.203	248.996
351	56.809	268.734	424	131.655	275.059	497	243.609	234.921
352	-56.809	268.734	425	-131.655	275.059	498	-243.609	234.921
353	72.695	264.878	426	147.785	266.740	499	0.000	356.433
354	-72.695	264.878	427	-147.785	266.740	500	17.231	356.016
355	88.323	260.085	428	163.391	257.476	501	-17.231	356.016
356	-88.323	260.085	429	-163.391	257.476	502	46.278	353.416
357	103.638	254.370	430	178.418	247.301	503	-46.278	353.416
358	-103.638	254.370	431	-178.418	247.301	504	63.309	350.765
359	118.586	247.754	432	192.813	236.249	505	-63.309	350.765
360	-118.586	247.754	433	-192.813	236.249	506	80.192	347.294
361	133.115	240.261	434	206.526	224.361	507	-80.192	347.294
362	-133.115	240.261	435	-206.526	224.361	508	108.316	339.576
363	147.171	231.917	436	219.506	211.678	509	-108.316	339.576
364	-147.171	231.917	437	-219.506	211.678	510	124.606	333.943
365	160.707	222.752	438	231.710	198.245	511	-124.606	333.943
366	-160.707	222.752	439	-231.710	198.245	512	140.604	327.528
367	173.673	212.797	440	243.093	184.110	513	-140.604	327.528
368	-173.673	212.797	441	-243.093	184.110	514	166.909	314.937
369	186.024	202.089	442	0.000	321.194	515	-166.909	314.937
370	-186.024	202.089	443	19.107	320.625	516	181.939	306.500
371	197.716	190.665	444	-19.107	320.625	517	-181.939	306.500
372	-197.716	190.665	445	38.146	318.921	518	196.543	297.346
373	208.708	178.566	446	-38.146	318.921	519	-196.543	297.346
374	-208.708	178.566	447	57.050	316.087	520	220.194	280.283
375	218.961	155.834	448	-57.050	316.087	521	-220.194	280.283
376	-218.961	165.834	449	75.753	312.134	522	233.487	269.311
377	0.000	289.373	450	-75.753	312.134	523	-233.487	269.311
378	17.214	288.860	451	94.186	307.074	524	246.233	257.708
379	-17.214	288.860	452	-94.186	307.074	525	-246.233	257.708
380	34.357	287.325	453	112.287	300.928	526	8.382	375.452
381	-34.357	287.325	454	-112.287	300.928	527	-8.382	375.452
382	51.398	284.772	455	129.989	293.715	528	25.129	374.704
383	-51.398	284.772	456	-129.989	293.715	529	-25.129	374.704
384	68.248	281.210	457	147.231	285.462	530	41.826	373.209
385	-68.248	281.210	458	-147.231	285.462	531	-41.826	373.209
386	84.855	276.552	459	163.952	276.198	532	58.439	370.971
387	-84.855	276.552	460	-163.952	276.198	533	-58.439	370.971
388	101.162	271.114	461	180.092	265.956	534	74.936	367.993
389	-101.162	271.114	462	-180.092	265.956	535	-74.936	367.993
390	117.111	264.616	463	195.594	254.772	536	91.284	364.282
391	-117.111	264.616	464	-195.594	254.772	537	-91.284	364.282
392	132.645	257.181	465	210.403	242.686	538	107.450	359.846
393	-132.645	257.181	466	-210.403	242.686	539	-107.450	359.846
394	147.709	248.835	467	224.457	229.740	540	123.402	354.692
395	-147.709	248.835	468	-224.457	229.740	541	-123.402	354.692
396	162.250	239.607	469	237.736	215.980	542	139.107	348.832
397	-162.250	239.607	470	-237.736	215.980	543	-139.107	348.832

Table C-1 (Continued)

HELIOSTAT COORDINATES

Heliostat	Coordinates		Heliostat	Coordinates		Heliostat	Coordinates	
No.	x	y	No.	x	y	No.	x	y
544	154.536	342.276						
545	-154.536	342.276						
546	169.657	335.039						
547	-169.657	335.039						
548	184.440	327.134						
549	-184.440	327.134						
550	198.855	318.577						
551	-198.855	318.577						
552	212.874	309.385						
553	-212.874	309.385						
554	226.459	299.577						
555	-226.459	299.577						
556	239.612	289.172						
557	-239.612	289.172						
558	0.000	395.534						
559	17.651	395.139						
560	-17.651	395.139						
561	35.268	393.958						
562	-35.268	393.958						
563	52.814	391.992						
564	-52.814	391.992						
565	70.255	389.244						
566	-70.255	389.244						
567	87.555	385.721						
568	-87.555	385.721						
569	104.682	381.430						
570	-104.682	381.430						
571	121.599	376.378						
572	-121.599	376.378						
573	138.275	370.576						
574	-138.275	370.576						
575	154.675	364.036						
576	-154.675	364.036						
577	170.767	356.771						
578	-170.767	356.771						
579	186.518	348.795						
580	-186.518	348.795						
581	201.898	340.124						
582	-201.898	340.124						
583	216.875	330.775						
584	-216.875	330.775						
585	231.421	320.767						
586	-231.421	320.767						
587	245.505	310.119						
588	-245.505	310.119						

Appendix D
ABSORBER LOSS COMPUTER PROGRAM

Appendix D

ABSORBER LOSS COMPUTER PROGRAM

A Water/Steam Receiver LOSS (WSRLOSS) computer program has been written for the General Electric Mark III time sharing system. This program provides a calculation of receiver losses due to reflection, radiation and convection. A listing of this program is given in Table D-1 and a variable list defining the symbols used in the program is given in Table D-2.

This computer program, WSRLOSS, is basically a modified version of a similar computer program used on two previous DOE contracts: the Alternate Central Receiver Program and the Solar Repowering Program. The modifications involved changing those parameters indicative of the working fluid properties. Water/steam is the current working fluid whereas sodium was used in the two previous mentioned programs.

Table D-1

COMPUTER PROGRAM WSRLOSS

```
WSRLOSS      04/30/81

      DIMENSION QS(15,15), ET(15,15), TNA(15,15), TN(15), HN(15,15),
      &          KT(15,15), U(15,15), QR(15,15), QC(15,15), EFP(15),
      &          QIP(15), QRP(15), QCP(15), TTP(15,15), TT(15,15)
      REAL KN, KT, NU
      FILENAME FLUX
      DATA TC /521./
      DATA ET /225*0.9/
      DATA TN/15*521./
      DATA DL,D,SIG,EPS,ALPHA /.75,1.72,.1714E-8,.9,.95/
      DATA PI /0.63662/
C
   5  PRINT, "FLUX PLOT FILENAME"
      READ, FLUX
      PRINT, " NUMBER OF ROWS, COLUMNS"
      READ, IX, IY
      PRINT, " GRID DIMENSIONS: DX,DY"
      READ, DX, DY
      DO 10 J = 1,IY
      READ (FLUX,500) (QS(I,J),I=1,IX)
  10  CONTINUE
  15  PRINT, "AIR TEMP., CONV. COEFF."
      READ, TA, HT
  20  PRINT, "FULL PRINT (0=SUMMARY,1=+LOSSES,2=+COEFFICIENTS)"
      READ, L
C
      DO 160 M = 1,5
      QIR = 0.
      QRR = 0.
      QCR = 0.
      DO 150 I = 1,IX
      TNA(I,1) = (TC + TN(1))/2.
      DO 130 J = 2,IY
      TNA(I,J) = (TN(J-1)+TN(J))/2.
 130  CONTINUE
```

Table D-1 (Continued)

COMPUTER PROGRAM WSRLOSS

```
440C
450       QIP(I) = 0.
460       QRP(I) = 0.
470       QCP(I) = 0.
480       DO 140 J = 1,IY
490       HN(I,J) = 5000.
500       KT(I,J) = 25.
510       U(I,J) = DL/HN(I,J)/D + DL/24./KT(I,J)*ALOG(DL/D)
520       U(I,J) = 1./U(I,J)
530       QT = CI*QS(I,J)*ET(I,J)*3.413E6/10.7636
540       TT(I,J) = TNA(I,J) + QT/U(I,J)
550       TTP(I,J) = TNA(I,J) + QT/U(I,J)/CI
560       QR(I,J) = SIG*EPS*DX*DY*10.7636*((TT(I,J)+460.)**4 -
570       &         (TA+460.)**4)/3.413E6
580       QC(I,J) = HT*DX*DY*10.7636*(TT(I,J)-TA)/3.413E6
590       ET(I,J) = ALPHA - (QR(I,J)+QC(I,J))/QS(I,J)/DX/DY
600       QIP(I) = QIP(I) + QS(I,J)*DX*DY
610       QRP(I) = QRP(I) + QR(I,J)
620       QCP(I) = QCP(I) + QC(I,J)
630 140   CONTINUE
640C
650       EFP(I) = ALPHA - (QRP(I)+QCP(I))/QIP(I)
660       QIR = QIR + QIP(I)
670       QRR = QRR + QRP(I)
680       QCR = QCR + QCP(I)
690 150   CONTINUE
700C
710       QREF = (1.-ALPHA)*QIR
720       EFR = ALPHA - (QRR+QCR)/QIR
730 160   CONTINUE
740C
750       PRINT 510,  QIR, QRR, QCR, QREF, EFR
760       PRINT 520
770       PRINT 530, (I,QIP(I),QRP(I),QCP(I),EFP(I), I=1,IX)
780       PRINT 540
790       PRINT 550, ((TT(I,J), I=1,IX), J=1,IY)
800       PRINT 560
810       PRINT 570, ((ET(I,J), I=1,IX), J=1,IY)
820       IF (L .EQ. 0)  GO TO 200
830C
840       PAUSE
850C
860       PRINT 580
870       PRINT 590, ((QS(I,J), I=1,IX), J=1,IY)
880       PRINT 600
890       PRINT 570, ((QR(I,J), I=1,IX), J=1,IY)
900       PRINT 620
910       PRINT 570, ((QC(I,J), I=1,IX), J=1,IY)
920       PRINT 720
930       PRINT 550, ((TTP(I,J), I=1,IX), J=1,IY)
940       IF (L .EQ. 1)  GO TO 200
950C
960       PAUSE
970C
980       PRINT 660
990       PRINT 550, ((HN(I,J), I=1,IX), J=1,IY)
1000       PRINT 680
1010       PRINT 550, ((U(I,J), I=1,IX), J=1,IY)
1020       PRINT 700
1030       PRINT 710, ((KT(I,J), I=1,IX), J=1,IY)
1040       PRINT 640
1050       PRINT 550, ((TNA(I,J), I=1,IX), J=1,IY)
1060 200  CONTINUE
1070C
1080       PRINT, "CONTINUE ITERATION? (YES=1,NO=0)"
1090       READ, L1
1100       IF (L1 .EQ. 1)  GO TO 20
1110       PRINT, "SAME FLUX, NEW AMBIENT DATA? (YES=1,NO=0)"
1120       READ, L2
1130       IF (L2 .EQ. 1)  GO TO 15
```

Table D-1 (Continued)

COMPUTER PROGRAM WSRLOSS

```
      PRINT, "START OVER WITH NEW FLUX PLOT? (YES=1,NO=0)"
      READ, L3
      IF (L3 .EQ. 1)  GO TO 5
C
  500 FORMAT (4X,13F7.4)
  510 FORMAT (1X,"RECEIVER SUMMARY",/
     &         1X,"INCIDENT =",F8.2," MW",/
     &         1X,"RAD. LOSS =",F8.2," MW",/
     &         1X,"CONV. LOSS =",F8.2," MW",/
     &         1X,"REFL. LOSS =",F8.2," MW",/
     &         1X,"EFFICIENCY =",F6.4,/,"0")
  520 FORMAT (1X,"PANEL",15X,"INCIDENT",2X,"RADIATION",2X,
     &         "CONVECTION",2X,"EFFICIENCY",/21X,"MW",8X,
     &         "MW",9X,"MW")
  530 FORMAT (1X,12,18X,F8.3,2X,F8.3,3X,F8.3,4X,F7.4)
  540 FORMAT (//,1X,"OUTSIDE TUBE TEMPERATURES (DEG. F)",/)
  550 FORMAT (1X,13F8.1)
  560 FORMAT (//,1X,"NODE EFFICIENCIES (P.U.)",/)
  570 FORMAT (1X,13F8.4)
  580 FORMAT (//,1X,"INCIDENT FLUX (MW/SQ.M)",/)
  590 FORMAT (1X,13F8.4)
  600 FORMAT (//,1X,"RADIATION LOSS (MW)",/)
  620 FORMAT (//,1X,"CONVECTION LOSS (MW)",/)
  640 FORMAT (//,1X,"FLUID NODE TEMPERATURES (DEG. F)",/)
  660 FORMAT (//,1X,"FLUID HEAT TRANSFER COEFFICIENTS ",
     &         "(BTU/HR-F-FT**2)",/)
  680 FORMAT (//,1X,"TUBE CONDUCTANCE (BTU/HR*F*FT**2)",/)
  700 FORMAT (//,1X,"TUBE WALL CONDUCTIVITY (BTU/HR*F*FT)",/)
  710 FORMAT (1X,13F7.1)
  720 FORMAT (//,1X,"PEAK TUBE TEMPERATURE (DEG. F)",/)
      STOP
      END
```

Table D-2

VARIABLE LIST FOR ABSORBER LOSS PROGRAM

ALPHA	= absorptivity
CI	= heat flux factor to account for two dimensional tube wall conduction
D	= tube i.d.
DX	= node width
DY	= node length
EFP(I)	= efficiency of column i
EFR	= efficiency of receiver
EPS	= emissivity
ET(I,J)	= efficiency of node i,j
HN(I,J)	= fluid side heat transfer coefficient
HT	= air side convective heat transfer coefficient
KT(I,J)	= tube wall thermal conductivity
QC(I,J)	= convection loss from node i,j
QR(I,J)	= radiative loss from node i,j
QS(I,J)	= incident solar flux on node i,j
QCP(I)	= convective loss from column i
QCR(I)	= radiative loss from column i
QIP(I)	= incident power on column i
QIR	= solar incident power on receiver
QRP(I)	= reflective loss on column i
QRR	= reflective loss from receiver
SIG	= Stefan Boltzmann Constant
TA	= ambient air temperature
TC	= fluid inlet temperature
TH	= fluid outlet temperature
TN(I)	= fluid temperature at outlet of column i, TN(O) = TC
TNA(I,J)	= average fluid temperature in node i,j
TT(I,J)	= average tube wall temperature in node i,j
U(I,J)	= tube conductance at node i,j

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