MTR FILE 0115
PA 140
- 8.2

DEPARTMENT OF ENERGY

Solar Division

Contract ~~EY 76-C-03-0115~~

ATO3-76ET20550

REQUIREMENT DEFINITION

for

HIGH-TEMPERATURE LINE FOCUS (HTLF)

SOLAR LARGE POWER SYSTEM: PHASE I

MASTER

DOE/ET/20550--T15

SRI Project 7896

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I. GENERAL

1.1 Scope This specification defines the design requirements, subsystem characteristics, environmental requirements, and cost and performance evaluation techniques for the High Temperature Line Focus (HTLF) Large Solar Power System. It will be revised and re-issued, as required, so that the contractor will be working to the latest requirements.

1.2 Description

1.2.1 Collector Subsystem The collector subsystem is composed of an array of linear focusing heliostats and supporting power and control elements which interact with the master control subsystem. The heliostat array reflects solar radiation onto linear receivers in a manner which satisfies the receiver subsystem incident heat flux requirements. The basic heliostat design will have a single axis drive mechanism which can accommodate path length changes of the reflected solar energy by tracking the sun's motion so as to maintain the focal zone on the receiver. The focal length may be varied during the day. The collector subsystem interfaces with the Master Control subsystem at the drive mechanism motor terminals.

1.2.2 Receiver Subsystem The receiver subsystem consists of linear receivers (i.e., having a length much greater than the cross-sectional dimensions) which are located in the focal zone of the heliostats in the collector field. The HTLF concept consists of tower-mounted receivers which intercept reflected solar energy in the form of a line focus from all or part of the collector field. The receiver subsystem also includes pumps, bypass valves, risers and downcomers (where applicable), heat exchangers and control systems necessary to regulate the fluid flow, temperature and pressure as well as the required thermal control necessary for safe and efficient operation, start-up, shut-down, and standby of the receiver subsystem. The receiver subsystem interfaces through the riser and downcomer to the heat transport subsystem at flanges at the top of the towers.

- 1.2.3 Heat Transport Subsystem The heat transport subsystem is the means of transporting heat from the receiver to both energy storage and electrical power generation subsystem. The Heat Transport Subsystem interfaces with the Storage Subsystem at the base of the storage tank and with the EPGS at the entrance point to the EPGS building.
- 1.2.4 Energy Storage Subsystem The energy subsystem must provide a means of storing the energy which is available from the receiver. Sensible heat storage will be oil and rock unless some other storage technique peculiar to the system demonstrates special advantage in terms of overall electrical generating costs.
- 1.2.5 Electrical Power Generating Subsystem The electrical power generating subsystem shall provide the means for converting the thermal output of the working fluid from the receiver and/or the energy storage subsystem into electric power. The output from the electric power generation subsystem shall be regulated for integration into existing electrical power system networks.
- 1.2.6 Master Control Subsystem The master control subsystem shall be used to sense, detect, monitor and control all system and subsystem parameters necessary to ensure safe and proper operation of the HTLF Large Solar Power System.
- 1.2.7 Plant Support Subsystems These will include plant subsystems, such as structure and equipment.

2. DOCUMENTS

The following documents, of the issue in effect on the date of the contract award, form a part of this specification to the extent specified herein. Although the conceptual design effort required of the contractor is not expected to attain the level of details commensurate with these documents, they are referenced herein to provide guidance in design approach and in engineering judgment. To this extent, the system design shall be consistent with the intent of these representative codes.

2.1 Codes and Standards

OSHA Regulations

- OSHA Title 29, part 1910 - Occupational Safety and Health Standards

ASME Boiler and Pressure Vessel Code

- Section I - Power Boilers, including:
 - (a) ANSI B31.1-1977 Power Piping
- Section II - Materials Specifications
- Section VIII - Unfired Pressure Vessels

Uniform Building Code - 1976 Edition by International Conference of Building Officials.

Institute of Electrical and Electronic Engineers (IEEE) Codes, as applicable.

National Fire Protection Association (NFPA) National Fire Codes - 1975.

Human Engineering Design Criteria

- MIL-STD - 810C
- MIL-STD - 1472

Design, Construction and Fabrication Standards

- Standards of AISC (Am. Inst. of Steel Constr.)
- Standards of ACI (Am. Concrete Institute)
- Standards of TEMA (Tub. Exchanger Mfr. Assoc.)
- Standard 650 of API (Am. Pet. Inst.)
 - Welded Steel Tanks for Oil Storage

Environmental Legislation

- National Environmental Policy Act (NEPA)

3. REQUIREMENTS

3.1 System Design Requirements The High Temperature Line Focus (HTLF) Large Solar Power System must be designed to meet the design specifications listed in this section.

3.1.1 Electrical Power Output The HTLF system shall produce approximately 100 MW_e net when operating solely from isolation and subjected to the environments specified in Sections 4.1. Optimization of the selected concept may result in a modular size larger or smaller than 100 MW_e, but at present 100 MW shall be used as a base. The HTLF system shall have a reference capacity of 420 MW_e hours of electrical energy to the utility grid when operating solely from a fully charged energy storage. Net power from storage shall be 70 MW_e (minimum). Other plant sizes and energy storage capabilities may be considered in order to determine the minimum plant energy generation costs as a function of capacity. This rating is the minimum net output of the Plant after subtracting all plant auxiliary requirements.

The Plant shall be capable of operation at full rated power for a period of at least four hours when operating solely from insolation on the least favorable day of the year (minimum energy available to the site on a clear day).

Although thermal storage conditions similar to direct operation are desirable (100 MW_e rating, same steam conditions [temperature/pressure_e]; derating the system from storage is acceptable.

3.1.1.1 Operating Modes The Plant shall be capable of executing the following operating modes:

- 1) CS-RS driving the EPGS (TSS is not involved).
- 2) CS-RS driving the EPGS and charging the TSS (normal solar power operation).
- 3) CS-RS driving the EPGS while the TSS also discharges to share in driving the EPGS (low solar power operation).
- 4) CS-RS charging the TSS and TSS discharging to drive the EPGS (intermittent cloudiness).
- 5) CS-RS charges TSS only (thermal storage charging).
- 6) TSS discharges to drive the EPGS (extended operation).
- 7) Overnight shutdown and hold of all plant subsystems (subsystem conditioning).

3.1.1.2 Solar Utilization The Plan shall be designed to maximize within economic feasibility, the percentage of incident sunlight throughout the year, both steady state and broken sun, which is converted to electrical energy at the bus.

3.1.2 Storage Subsystem

3.1.2.1 General The HTLF Storage Subsystem shall be designed to maximize the economic and safe recovery of useful energy from storage and to minimize energy storage losses of the operating solar thermal power system. Specific size, shape and configuration constraints will be governed by minimizing the cost of electricity and by designing the power plant layout to facilitate efficient and safe operation and maintenance. The energy storage subsystem shall be designed to provide safe and reasonable access for proper inspection, maintenance and repair of the structure, fluid lines, utilities, instrumentation and controls, etc. It shall accept and execute commands from the master control subsystem during normal transient and emergency operations.

3.1.2.2 Charging Rate The storage subsystem must be capable of accepting TBD% of the thermal power from the receiver when the system is subjected to the environments specified in Section 4.1 and 4.2.

3.1.3 Collector Subsystem

3.1.3.1 Control The heliostats may be equipped with control systems which employ sensors and drive mechanisms to direct the reflected rays of the sun onto the receiver as well as to provide auxiliary functions for other methods of operational positionings.

3.1.3.2 Interface The heliostats shall respond to control signals from the Master Control Subsystem.

3.1.3.3 Field Optimization The field optimization will include consideration of shading and blocking restraints and servicing requirements. Spacing between heliostats modules must permit access by service vehicles, utility lines, and ground maintenance personnel. Heliostat design and field configuration shall be determined based on performance, cost, manufacturing, operations, maintenance, and servicing constraints, pointing accuracy requirements, and structural requirements, including wind loading. Heliostat design should provide for stored or safe position for use at night, during periodic maintenance and during adverse weather conditions.

3.1.3.4 Special Environmental Considerations The heliostats shall withstand winds at the periphery on the collector field as specified in Section 4.2. If it is determined that wind loading on interior heliostats is significantly altered by peripheral concentrators, this factor should be considered. Adequate protection shall be considered against heliostat degradation in the saltation layer (the boundary layer above the ground within which blowing particles, such as sand are concentrated), and for exposure to humidity, temperature transients, and other environmental effects specified in Section 4.0.

3.1.4 Receiver Subsystem

3.1.4.1 Modes of Operation The receiver subsystem shall provide a means for transferring the incident radiant flux energy from the collector subsystem into a suitable working fluid (1) for generation of electrical power with a turbine/generator in the electrical power generation subsystem only, (2) for conversion to stored energy only, and (3) for generation of electrical power with a turbine/generator while also charging and/or discharging the energy storage subsystem.

3.1.4.2 Control Sensing elements in the receiver subsystem shall be devised to provide the master control subsystem the information necessary to accomplish efficient and safe monitoring and control of the receiver subsystem. The receiver subsystem shall respond to control signals from the Master Control Subsystem.

3.1.4.3. General The towers shall be designed to provide access for maintenance and inspection of the structure, receiver, working fluid, instruments and controls, power conversion equipment that may be located on the tower, utilities, etc. Consideration shall be given to ease of maintenance. Adequate provisions shall be made to insure 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.

3.1.5 Heat Transport Subsystem

3.1.5.1 General The heat transport subsystem shall provide the most cost effective means of transporting heat from the receiver to the energy storage and electrical power generation subsystems.

3.1.5.2 Working Fluid Water/steam working fluid will be used.

3.1.6 Electric Power Generation Subsystem

3.1.6.1 General The electric power generation subsystem shall provide the means for transforming the thermal energy of the heat transport subsystem into electric power. The output from the electrical power generation shall be regulated for integration into existing electrical power system networks. IEEE codes will be utilized in the design of the electrical system.

3.1.6.2 Cycles(s) The conventional steam cycle is preferred; however, any other power conversion cycle that offers a greater potential for achievement of low cost electricity may be used. Strong rationale must be presented to verify that advanced cycles will be available and accepted for use by large utilities in the mid-1980's time period.

3.1.6.3 Control The electrical power generation subsystem shall accept and execute control commands from the master control subsystem during normal, transient and emergency operating conditions. Specific size, shape, and configuration constraints shall be governed by minimizing cost of electricity, by designing the plant layout to facilitate efficient and safe operation and maintenance, by minimizing the effects of thermal shock on the turbine power loop, and by providing for safe response to variations in the receiver working fluid outlet conditions.

3.1.7 Master Control Subsystem A master control subsystem, equivalent to that currently utilized by the utilities, shall be provided to sense, detect, monitor and control all system and subsystem parameters necessary to ensure safe and proper operation of the HTLF system.

3.1.7.1 Requirements The primary requirements imposed upon the MCS are simplicity, reliability, and cost-effectiveness of both design and operation. The MCS shall be designed using standard control practices and simple, well-defined interfaces between the MCS and the other subsystem controls. Primary operation shall be automatic with operator override capability.

Reliability shall be assured by use of proven designs and elimination of single point failures through redundant elements whenever it is cost-effective to do so. Failure of the MCS shall not prevent manual control of the Plant.

The MCS shall contain independent control within each Plan subsystem with the coordination of control of the subsystem provided by the central MCS.

3.1.8 Heat Rejection The HTLF system must be equipped with wet cooling type of heat rejection.

3.1.9 Lifetime The system shall be designed for a 30-year operating life.

3.1.10 Plant Availability and Reliability The system shall be designed for 90 percent plant availability based on reliability and maintainability exclusive of insolation conditions. Consideration shall be given in the design to attainment of high reliability by providing design and operating margins and utilizing sound engineering design practices.

3.1.11 Maintainability

3.1.11.1 The entire plant shall be so designed that potential maintenance locations can be easily reached and components such as electronic units, motors, drives, fittings, sensors, etc., readily replaced.

3.1.11.2 Elements subject to wear and damage, such as supporting wheels, gears, etc., should be easily serviced or replaced.

3.1.11.3 The Plant should be serviceable by personnel of skills typical of the type utilities currently use for maintenance and should require a minimum of specialized equipment or tools.

3.2 Cost Estimates Requirements The commercialization of high temperature line focus solar thermal power plants is highly dependent on the economics of the Plant. To assess the economics requires estimates of Plant cost and performance. Accurate comparison of solar plant design concepts requires cost and performance estimates based on similar assumptions. It is the intention of the cost data description that follows to gather the necessary information to verify comparability of the estimates and accurately assess cost/performance.

The cost breakdown structures for Plant capital investment costs and operations and maintenance costs (see Figures 1 and 5) are both general structures with a high level of aggregation. Cost estimates are to be provided in 1978 dollars for all items applicable to the design. These costs are to be estimated for the first commercial high-temperature line focus power plant. The operations and maintenance costs are to be for the first year of operation with an estimate of how the costs may change over the Plant life.

The analysis of cost estimates is a difficult task. It requires an understanding of the alternate methods of cost estimation as well as the inputs and assumptions used by the particular methodology. To facilitate an equitable comparison of the cost estimates and an accurate assessment of the assumptions, it is necessary to have explicit descriptions of the methodology used in formulating the estimate. For each item in the cost breakdown structures, a worksheet is to be provided showing the level of aggregation at which the cost estimates were made. The worksheet should include the inputs, assumptions, justification, and methodology used to arrive at the cost shown in the structure. These worksheets need only be provided for the line items in the structures which are at the lowest level of aggregation. The worksheets should take the form and provide the detail shown in examples in Figures 2, 3, and 4 for Plant capital investment items, and Figures 6 and 7 for operations and maintenance items. These examples are illustrative and are not intended to demonstrate methodologies of cost estimation.

With a highly aggregated structure, for certain components in the designs, it is not obvious under which component in the cost breakdown structure the cost should be included. These questions should be answered by judgment. With the detailed list and/or description of equipment provided in the worksheets for each cost item, it will be obvious in comparing the costs what is included under each item. It is also requested that a drawing or schematic of the subsystems and plant be included showing the subsystem boundaries (for subsystem piping and wiring boundary definition) and defining nomenclature used for components and parts.

4. ENVIRONMENTAL CONDITIONS

4.1 Baseline Design Environment

4.1.1 Reference Site: Barstow, California, 1976

4.1.2 Insolation: See Figure 8 for annual and daily insolation variation.

4.1.3 Dynamic Performance: The maximum rate of change of incident flux shall be assumed as that which would result from the passage of an opaque cloud across an otherwise clear sky where the sharp leading or trailing edges of the shadow move across the heliostat field at a velocity of 20 meters per second (45 mph).

4.1.4 Wind Speed 3.5 m/sec (8 mph) at a reference height of 10 m (30 ft.).

4.1.5 Temperature Wet Bulb - 23°C (74°F)
Dry Bulb - 28°C (82.6°F)

4.2 Operating Environments The system shall be capable of operating in and surviving appropriate combinations of the environments specified below:

4.2.1 Insolation The Plant shall remain operational with insolation values to 1000 Watts/ M^2 .

4.2.2 Temperature The Plant shall be able to operate in the ambient air temperature range from -30°C (-20°F) to $+50^{\circ}\text{C}$ ($+120^{\circ}\text{F}$). Performance requirements should be met throughout an ambient air temperature range selected to be consistent with minimization of the overall cost of electricity production.

4.2.3 Wind The wind speed specifications at a reference height of 10 m (30 ft) shall be:

<u>Speed, m/s</u>	<u>Frequency, Percentage</u>
0 - 2	29
2 - 4	21
4 - 6	19
6 - 8	14
8 - 10	8
10 - 12	5
12 - 14	3
	Less than 1

Operational performance specifications shall be met for the most adverse probable combination of wind and temperature conditions which are consistent with minimizing the overall cost of electricity. Maximum operational wind speed shall be selected to be consistent with minimization of the overall cost of electricity production. Wind analyses shall satisfy the requirements of ANSI A-58.1-1972.

- 4.3 Survival Environments The system shall be capable of surviving appropriate combinations of the environments specified below:
- 4.3.1 Temperature The Plant shall survive maximum ambient dry bulb temperatures of 60^oF (140^oF) and minimum temperatures of -30^oC (22^oF).
- 4.3.2 Wind The Plant shall survive winds with a maximum speed, including gusts, of 40 m/s (90 mph), without damage. An angle of attack of ± 10 degrees to the horizontal shall be assumed for the survival condition.
- 4.3.3 Wind Rise Rate A maximum wind rise rate of 0.01 m/s² (1.3 mph/min) shall be used in calculating wind loads during stowage. However, the Plant should withstand, without catastrophic failure, a maximum wind of 22 m/s (50 mph) from any direction, in any orientation resulting from unusually rapid wind rise rates, such as severe thunderstorm gust fronts.
- 4.3.4 Dust Devils Dust devils with wind speeds up to 18 m/s (40 mph) shall be survived without damage to the Plant.
- 4.3.5 Snow Survive 5 lb/ft² (240 Pa) of snow at deposition rate of 0.3 m (1 ft) in 24 hours.
- 4.3.6 Rain Average annual - 750 mm (30 in.)
Maximum 24-hr rate - 75 mm (3 in.)
- 4.3.7 Ice Survive freezing rain and ice deposits in a layer 50 mm (2 in.) thick.
- 4.3.8 Earthquake The Plant will be designed to satisfy the requirements of the Uniform Building Code (UBC, 1976 and 1978 supplements), using Seismic Zone 3 as the basis.
- 4.3.9 Hail
	<u>Any Orientation</u>	<u>Stowed</u>
Diameter	20 mm (3/4 in.)	25 mm (1 in.)
Specific Gravity	0.9	0.9
Terminal Velocity	20 m/s (65 fps)	23 m/s (75 fps)
- 4.3.10 Sandstorm Environment The Plant shall survive after being exposed to blowing dust comparable to the conditions described by Method 510. of MIL-STD 810 BC.

4.4 Lightning Considerations

- 4.4.1 Protection The Plant shall be provided with a lightning protection system which is optimized on a cost-risk basis.
- 4.4.2 Direct Hit Total destruction of a single concentrator and its controller subjected to a direct lightning strike is acceptable.
- 4.4.3 Adjacent Strike Damage to a concentrator adjacent to a direct lightning strike must be minimized within appropriate cost-risk limits. The central controller and local controllers of concentrators adjacent to a direct lightning strike must be protected or alternate control methods provided to minimize loss of collect or subsystem.

FIGURE 1: SOLAR PLANT CAPITAL INVESTMENT COST

4000 SOLAR PLANT COST

- 4100 Site, Structures and Miscellaneous Equipment
 - 4110 Site
 - 4111 Land
 - 4112 Yard Work
 - 4120 Buildings
 - 4121 Turbine Building
 - 4122 Administration Building
 - 4123 Warehouse/Maintenance Buildings
 - 4124 Control Building
 - 4125 Other
 - 4130 Miscellaneous Equipment
 - 4131 Transportation and Lifting Equipment
 - 4132 Communication Equipment
 - 4133 Other
- 4200 Turbine Plant Equipment
 - 4210 Turbine Generators and Accessories
 - 4220 Heat Rejection System
 - 4230 Condensing Systems
 - 4240 Feed-Heating or Recuperator System
 - 4250 Working Fluid Circulation, Treatment, and Auxiliary Inventory Containment Equipment
- 4300 Electric Plant Equipment
 - 4310 Switchgear
 - 4320 Station Service Equipment
 - 4330 Protective Equipment
 - 4340 Power Wiring, Electrical Structures, and Wiring Containers
 - 4350 Master Control Equipment
 - 4351 Hardware
 - 4352 Hardware Design and Engineering
 - 4353 Software Design, Development, and Test
- 4400 Heliostat Equipment
 - 4410 Reflective Unit
 - 4420 Drive Unit
 - 4421 Tracking Drive
 - 4422 Focusing Drive
 - 4423 Motors
 - 4424 Position Indicators or Encoders
 - 4425 Power Distribution and Emergency Supply

- 4430 Control and Instrumentation
 - 4431 Sensor or Calibration Equipment
 - 4432 Field Control Electronics
 - 4433 Control Signal Distribution Equipment
- 4440 Foundation and Site
- 4450 Concentrator Support and Protection
 - 4451 Concentrator Support Structure
 - 4452 Concentrator Protective Enclosure (if provided)
 - 4453 Lightning Protection
- 4460 Field Assembly and Check Out
- 4470 Design and Engineering
- 4500 Receiver Equipment
 - 4510 Receiver Unit
 - 4511 Absorber Unit
 - 4512 Support Structure
 - 4513 Receiver Circulation Equipment
 - 4514 Instrumentation and Control
 - 4515 Transportation, Field Erection, and Installation
 - 4520 Riser, Downcomer, and Horizontal Piping
 - 4530 Working Media Cost - Steam no cost
 - 4540 Towers
 - 4550 Bridges
 - 4560 Foundation
 - 4570 Steam Generator or Working Media Heat Transfer Equipment
 - 4580 Design and Engineering
- 4600 Thermal Storage Equipment
 - 4610 Media Containment Equipment
 - 4620 Media Circulation Equipment
 - 4630 Working Fluid Circulation Equipment
 - 4640 Discharging Heat Exchangers
 - 4650 Charging Heat Exchangers
 - 4660 Foundation
 - 4670 Design and Engineering
 - 4680 Media

4700 Heat Transport Subsystem

- 4710 Piping
- 4720 Insulation
- 4730 Valves
- 4740 Structure
- 4750 Foundation

4800 Distributables and Indirect Costs

- 4810 Temporary Facilities, Equipment, etc.
- 4820 Spare Parts
- 4830 Architectural Engineering Services
- 4840 Construction Management
- 4850 Plant Startup and Checkout
- 4860 Contingency

FIGURE 2: REFLECTIVE UNITS

4410 Reflective Unit

<u>Part Description</u>	<u>Quantity</u>	<u>First Unit Cost per Unit</u>	<u>Subtotal</u>	<u>Factors</u>				
				<u>Learning Curve Factor*</u>	<u>G&A</u>	<u>Overhead</u>	<u>Quality Control</u>	<u>Total</u>
Mirror .09"x100"x100" Float Glass	1000 ea.	\$35.00	\$ 35,000		1.15		1.1	\$ 44,275
Foam 2"x100"x100"	1000 ea.	10.00	10,000	.95	1.15		1.1	12,018
Steel Backing 100"x100" 26GA	1000 ea.	20.00	20,000		1.15		1.1	25,000
Adhesive 3M #69	25 gallons	50.00	1,250		1.15		1.1	1,581
Assembly and Bonding of Components	5000 hours	20.00	100,000	.90	1.25	1.75	1.1	216,563
Tooling for Bonding Tables			10,000					<u>10,000</u>
TOTAL FOR CSB 4410								\$309,737

*Define below

Notes:

o Source of Material Cost Estimates

- Mirror - quotes from PPG and Libbey, Owens, Ford
- Foam - quotes from Dupont and Monsanto
- Steel - quotes from U.S. Steel
- Adhesive - quotes from 3M

o Source of Labor Estimate

Based on five hours per reflective unit estimated from time and motion studies

- Setup .5 hrs
- Assembly of Mirror and foam with Adhesive 2.0 hrs
- Assembly of Steel to Mirror and Foam 2.0 hrs
- Remove and Transport to Stock .5 hrs

Notes (continued):

- o Tooling cost is for bonding equipment only; the factory building and miscellaneous handling equipment, etc., is included in the overhead rate. The capital investment in tooling is \$100,000 and has an estimated 30 year lifetime with no expected maintenance and repair costs. The capital recovery factor is 0.10.
- o The learning curve factor expresses the average cost of the units being costed as a fraction of the first unit cost (i.e., unit one). The units in this estimate are unit 2000 to unit 3000. The assumed learning curve rates are .99 on foam and .93 on labor. The first 2000 units are those built for the Barstow pilot plant.
- o Manufacturing labor rates are based on union labor rates in the XYZ City, Utah; the source of the labor rates is the "handbook of Manufacturing and Field Labor - 1977".

FIGURE 3: POWER WIRING, ELECTRICAL STRUCTURES,
AND WIRING CONTAINERS WORKSHEET

4340 Power Wiring, Electrical Structures and Wiring
Containers

Estimate as a fraction of the cost estimate for switch-
gear station service equipment, and protective equipment
(CBS 4310 to) based on plants ranging in size from
100 MW_e to 200 MW_e built in the past ten years.

Total estimate for CBS 4310, 4320
and 4330 65,000

Fractional Factor for Estimation x .15

TOTAL FOR CBS 4340 \$9,800

FIGURE 4: TURBINE BUILDING WORKSHEET

4121 Turbine Building

Estimated based on turbine buildings built for similar plants (100-150 MW_e) during 1970 in the Southwestern United States.

Historical Building	100,000
Escalation Factor to 1978	<u>x 1.85</u>
TOTAL FOR 4121	\$185,000

FIGURE 5: SOLAR PLANT OPERATIONS AND MAINTENANCE COSTS

- OM10 Operations
- OM200 Maintenance Materials
 - OM210 Spare Parts
 - OM211 Turbine and Electrical Plant
 - OM212 Collector Equipment
 - OM213 Receiver Equipment
 - OM214 Thermal Storage Equipment
 - OM220 Materials for Repair
 - OM230 Other
- OM300 Maintenance Labor
 - OM300 Maintenance Labor
 - OM320 Corrective Maintenance

FIGURE 6: COLLECTOR EQUIPMENT WORKSHEET

OM212 Collector Equipment

<u>Past Description</u>	<u>Expected Failures per Year per Plant</u>	<u>1st Unit Cost per Units</u>	<u>Subtotal</u>	<u>Learning Curve Factor Years 1-10</u>	<u>G&A</u>	<u>Overhead</u>	<u>Total</u>
Reflective Unit (CBS4410) (tracking)	1	\$310	\$310	.90	1.10		\$ 307
Drive (focusing) (CBS4421)	2	450	900	.90	1.10		891
Drive (CBS4422)	1	500	500	.90	1.10		495
Motors (CBS4423)	1.5	400	600	.88	1.10		581
TOTAL FOR OM212							\$2,274

Notes:

- o Failure rates are based on manufacturer specifications.
- o The learning curve factor expresses the average cost of the units being costed as a fraction of the first unit cost (i.e., unit one). The units in this estimate start with unit 3000 for first three items and unit 6000 for the motors. The learning curve rate in all cases is 0.95. The learning curve factor is estimated to change as follows for spare parts purchased over the plant life:

<u>Years of Plant Life</u>	<u>Factor for all but Motors</u>	<u>Factor for Motors</u>
1-10	.90	.88
10-20	.89	.87
20-30	.88	.87

These factors are estimated based on the manufacturing facility production rate of 1000 units per year for all but motors and 2000 units per year for motors.

FIGURE 7: SCHEDULED MAINTENANCE WORKSHEET

OM310 Scheduled Maintenance

<u>Description</u>	<u>Hours per Year</u>	<u>Unit Cost</u>	<u>Subtotal</u>	<u>G&A</u>	<u>Overhead</u>	<u>Total</u>
Mirror Washing	84	\$15	1,260	1.1	1.5	\$ 2,079
Concentrator Lubrication	500	20	10,000	1.1	1.5	16,500
Receiver Preventive Maintenance	20	20	400	1.1	1.5	660
Thermal Storage Preventive Maintenance	10	20	200	1.1	1.5	<u>330</u>
TOTAL FOR OM313						\$19,559

Notes:

- o Labor rates are based on rates quoted in "Handbook of Manufacturing and Field Labor Rates" for QRS City, Arizona, which is 30 miles from the plant site.
- o Hours per year estimates are based on time and motion studies.
- o G&A and overhead rates are based on rates at comparable size power plants (100-150 MW_e) located in Arizona.

FIGURE 8

1976 BARSTOW, CALIFORNIA SOLAR INSOLATION

DIRECT INSOLATION - WATTS/m²

1000
800
600
400
200
0

6 A.M.

8

10

NOON

2

4

6

8 P.M.

TIME

Summer Solstice

Spring Equinox

Winter Solstice