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→ TO HQ R 2073-8.2
ET 2054

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18 October 1978

BDM/TAC-78-625-TR

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RECOMMENDED REVISED SECTIONS
TO
LINE FOCUS SOLAR CENTRAL POWER SYSTEMS

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AC03 - 78ET20524
MBW

ATTACHMENT 1

RECOMMENDED REVISED SECTIONS
TO
LINE FOCUS SOLAR CENTRAL POWER SYSTEMS:
REQUIREMENT DEFINITION

Section 1.2.1 Replaced with the Following:

- 1.2.1 Concentrator Subsystem (CS) The concentrator subsystem consists of an array of linear parabolic troughs (LPT) which focus sunlight onto the receiver tube subassembly which is located at the linear focus of the LPT. The CS consists of all attached apparatus (excluding RTS) which include mounting, tracking, control, and power equipment. The CS will track in one axis with a focal image which is fixed with respect to the LPT aperture geometry.

Section 1.2.2 Replaced with the Following:

- 1.2.2 Receiver Tube Subassembly (RTS) The receiver tube subassembly (RTS) is a linear, cylindrical, apparatus assembly located at the focal region of the LPT. The RTS consists of a metallic pipe which is affixed with a selective surface exterior coating. Heat transport fluid is continually passed through the receiver pipe. A glass annulus encapsulates the entire assembly.

Section 1.2.3 Replaced with the Following:

- 1.2.3 Heat Transport Subsystem (HTS) The heat transport subsystem (HTS) provides the transport of thermal energy from the CS/RTS to the thermal energy storage subsystem (ESS) and/or to the fielded boiler/heat exchangers and from the TSS to the boilers. The HTS includes the thermal working fluid, all plumbing, circulation pumps, insulation, capacitance tanks, and apparatus required for operational heat transport.

Section 1.2.4 Replaced with the Following:

- 1.2.4 Energy Storage Subsystem (ESS) The energy storage subsystem (ESS) will provide a means of storing the thermal energy provided by the CS in the form of sensible heat storage. The ESS may be centralized or distributed but will consist of the tank structure, thermal fluid, and solid thermal energy storage media.

Section 1.2.5 Replaced with the Following:

- 1.2.5 Electrical Power Generating Subsystem (EPGS) The electrical power generating subsystem provides the areas for converting the thermal output of the CS, transported via the HTS, into electrical power. The EPGS includes the

boilers, steam transport, drum, superheater, steam turbine apparatus, and heat rejection system. The output of the EPGS will be regulated for integration into existing electrical power system networks.

Section 1.2.7 Added:

- 1.2.7 Support Equipment and Facilities Support equipment and facilities include any building structure, apparatus, or power supply required for normal or emergency system operation, which are not specifically part of the previously described subsystems.

Section 3.1.1 Replaced with the following:

- 3.1.1 Plant Design Day The plant design day shall be the most favorable day using insolation availability as specified in Section 4.1. The plant design day shall be free from cloud cover or any other illumination impediment.

Section 3.1.2 Replaced with the following:

3.1.2 Electrical Power Output

- 3.1.2.1 Power Ratings and Storage Capabilities The line focus power plant (LFPP) shall produce a minimum of 100 MW_e net when operating solely from insolation and subject to the environments specified in Sections 4.1 and 4.2. The plant will provide a minimum of 420 MW_e - hour at a minimum power rating of 70 MW_e. Further, power ratings and energy storage capacities larger than those specified above should be considered and included if more attractive economic performance results.

Section 3.1.2.2 Added:

- 3.1.2.2 Operating Modes The LFPP will be capable of providing the requisite power in any of the following operating modes:

- (1) CS-RTS directly driving the EPGS.
- (2) CS-RTS driving the EPGS and simultaneously charging the ESS.
- (3) CS-RTS driving EPGS and ESS discharging to share in driving the EPGS during intermittent cloudiness or low solar periods.
- (4) CS-RTS charging the ESS.
- (5) ESS discharging to drive the EPGS.
- (6) Overnight shutdown and hold of all plant subsystems.

Further, start-up procedures should be optimized to make maximum (practical) use of available solar energy.

Section 3.1.4.4 Replaced with the Following:

- 3.1.4.4 Special Environmental Considerations. The concentrators 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 concentrators is significantly altered by peripheral concentrators, this factor should be considered. Protection to minimize performance degradations shall be provided against concentrator 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.

Section 3.1.5.1 Replaced with the Following:

- 3.1.5.1 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 to facilitate the operation of the LFPP in any or all of the operating modes defined in Section 3.1.2.2.

Section 3.1.6.2 Replaced with the following:

3.1.6.2 Working Fluid. The working fluid shall serve as the thermal energy transport media in/from the RTS to the boilers or ESS. The fluid selected should allow maximum RTS outlet temperatures while minimizing degradation. The ease of fluid handling and maintenance should be considered in fluid selection. It is desirable to avoid any system hazards which could be presented by the working fluid. The fluid should also allow operation in the specified operating conditions.

Section 3.1.8 Replaced with the Following:

3.1.8 Master Control Subsystem. The master control subsystem (MCS) will supply all required operational and safety controls and will provide state monitoring of all subsystems. 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 operation of the Plant.

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

Section 4.3.10 -- Deleted (see 3.1.4.4)

Figure 1: Items 4422, 4511, 4513, 4520, 4530, 4540, 4550, 4640, and 4650
-- Deleted

Figure 1: New Insert

- 4700 Heat Transport System
- 4710 Piping and Supports
- 4720 Insulation
- 4730 Pumps and Circulation Equipment
- 4740 Capacitance on Relief System
- 4750 Heat Transfer Fluid
- 4760 Design and Engineering

1. GENERAL

1.1 Scope This specification defines the design requirements, subsystem characteristics, environmental requirements, and cost and performance evaluation techniques for the Line Focus Solar Central Receiver Program. It will be revised and re-issued, as required, so that all contractors will be working to the latest requirements.

1.2 Description

- 1.2.1 Concentrator Subsystem (CS) The concentrator subsystem consists of an array of linear parabolic troughs (LPT) which focus sunlight onto the receiver tube subassembly which is located at the linear focus of the LPT. The CS consists of all attached apparatus (excluding RTS) which include mounting, tracking, control, and power equipment. The CS will track in one axis with a focal image which is fixed with respect to the LPT aperture geometry.
- 1.2.2 Receiver Tube Subassembly (RTS) The receiver tube subassembly (RTS) is a linear, cylindrical, apparatus assembly located at the focal region of the LPT. The RTS consists of a metallic pipe which is affixed with a selective surface exterior coating. Heat transport fluid is continually passed through the receiver pipe. A glass annulus encapsulates the entire assembly.
- 1.2.3 Heat Transport Subsystem (HTS) The heat transport subsystem (HTS) provides the transport of thermal energy from the CS/RTS to the thermal energy storage subsystem (ESS) and/or to the fielded boiler/heat exchangers and from the TSS to the boilers. The HTS includes all plumbing, circulation pumps, insulation, capacitance tanks, and apparatus required for operational heat transport.
- 1.2.4 Energy Storage Subsystem (ESS) The energy storage subsystem (ESS) will provide a means of storing the thermal energy provided by the CS in the form of sensible heat storage. The ESS may be centralized or distributed but will consist of the tank structure, thermal fluid, and solid thermal energy storage media.
- 1.2.5 Electrical Power Generating Subsystem (EPGS) The electrical power generating subsystem provides the areas for converting the thermal output of the CS, transported via the HTS, into electrical power. The EPGS includes the boilers, steam transport, drum, superheater, steam turbine apparatus, and the heat rejection system. The output of the EPGS will be regulated for integration into existing electrical power system networks.

ATTACHMENT 2

Line Focus Solar Central Power Systems:

Requirement Definition

(Recommended Edition)

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 - 4.2 Operating Environments
 - 4.3 Survival Environments
 - 4.4 Lightning Considerations

- 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 Line Focus Solar Central Power System.
- 1.2.7 Support Equipment and Facilities Support equipment and facilities include any building and structures, apparatus, or power supply required for normal or emergency system operation, which are not specifically part of the previously described subsystems.

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. Conflict between the documents referenced herein and the contents of this specification will be resolved by DOE.

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

MIL-STD 810C (Available at Headquarters Defense Supply Agency, Cameron Station, Alexandria, Virginia 22314)

ASME Codes (as applicable)

IEEE Codes (as applicable)

U.S. Atomic Energy Commission Regulatory Guide 1.61 Dated October, 1973

3. REQUIREMENTS

- 3.1 System Design Requirements The Line Focus Solar Central Power System (LFS) must be designed to meet the design specifications listed in this section.

- 3.1.1 Plant Design Day The plant design day shall be the most favorable with insolation availability as specified in Section 4.1. The plant design day shall be free from cloud cover or any other illumination impediment.

- 3.1.2 Electrical Power Output

- 3.1.2.1 Power Ratings and Storage Capabilities The line focus power plant (LFPP) shall produce a minimum of 100 MW_e net when operating solely from insolation and subject to the environments specified in Sections 4.1 and 4.2. The plant

will provide a minimum of 420 MW -hour at a minimum power rating of 70 MW . Further, power ratings and energy storage capacities larger than those specified above should be considered and included if more attractive economic performance results.

3.1.2.2 Operating Modes The LFPP will be capable of providing the requisite power in any of the following operating modes:

- (1) CS-RTS directly driving the EPGS.
- (2) CS-RTS driving the EPGS and simultaneously charging the ESS.
- (3) CS-RTS driving EPGS and ESS discharging to share in driving the EPGS during intermittent cloudiness or low solar periods.
- (4) CS-RTS charging the ESS.
- (5) ESS discharging to drive the EPGS.
- (6) Overnight shutdown and hold of all plant subsystems.

Further, start-up procedures should be optimized to make maximum (practical) use of available solar energy.

3.1.3 Storage Subsystem

3.1.3.1 General. The LFS 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 capacity, 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. The energy storage subsystem shall be so configured and located within or adjacent to the power plant to minimize adverse interfaces with or operations of the other subsystems. It shall accept and execute commands from the master control subsystem during normal transient and emergency operations.

- 3.1.3.2 Charging Rate. The storage subsystem must be capable of accepting 100% of the thermal power from the receiver when the system is subjected to the environments specified in Section 4.1 and 4.2.

3.1.4 Concentrator Subsystem

- 3.1.4.1 Control. The concentrators 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 operation and non-operational positionings.
- 3.1.4.2 Interface. The concentrators shall respond to control signals from the Master Control Subsystem.
- 3.1.4.3 Field Optimization. The field optimization will include consideration of shading and blocking restraints and servicing requirements. Spacing between concentrator modules must permit access by service vehicles, utility lines, and ground maintenance personnel. Concentrator 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. Concentrator design should provide for stored or safe position for use at night, during periodic maintenance and during adverse weather conditions.

3.1.4.4 Special Environmental Considerations. The concentrators 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 concentrators is significantly altered by peripheral concentrators, this factor should be considered. Protection to minimize performance degradations shall be provided against concentrator 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.

3.1.5 Receiver Subsystem

3.1.5.1 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 to facilitate the operation of the LFPP in any or all of the operating modes defined in Section 3.1.2.2.

3.1.5.2 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.

3.1.5.3 General. For concepts utilizing a tower mounted receiver, the tower 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. For concepts having a moving receiver, appropriate positioning for necessary access shall be provided. 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.

3.1.6 Heat Transport Subsystem

- 3.1.6.1 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.
- 3.1.6.2 Working Fluid. The working fluid shall serve as the thermal energy transport media in/from the RTS to the fielded boilers or ESS. The fluid selected should allow maximum RTS outlet temperatures while minimizing degradation. The ease of fluid handling and maintenance should be considered in fluid selection. It is desirable to avoid any system hazards which could be presented by the working fluid. The fluid should also allow operation in the specified operating conditions.

3.1.7 Electric Power Generation Subsystem

- 3.1.7.1 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.
- 3.1.7.2 Cycle(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 the advanced cycles will be available and accepted for use by large utilities in the mid 1980's time period.
- 3.1.7.3 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.

- 3.1.8 Master Control Subsystem. The master control subsystem (MCS) will supply all required operational and safety controls and will provide state monitoring of all subsystems. 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 operation of the Plant.

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

- 3.1.9 Heat Rejection. The LFS must be equipped with wet cooling type of heat rejection.
- 3.1.10 Lifetime. The system shall be designed for a 30-year operating life.
- 3.1.11 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.
- 3.1.12 Maintainability.
- 3.1.12.1 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.
 - 3.1.12.2 Elements subject to wear and damage, such as supporting wheels, gears, etc., should be easily serviced or replaced.
 - 3.1.12.3 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 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 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
- 4.1.2 Insolation: Direct normal @950 watts/m²

See Figure X 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 concentrator 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/M².
- 4.2.2 Temperature: The plant shall be able to operate in the ambient air temperature range from -30°C (-20°F) to +50°C (+120°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, Percent</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

1976 BARSTOW, CALIFORNIA SOLAR INSOLATION

Figure X. Annual and Daily Insolation Variation

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. The wind velocity profile varies exponentially with height to the 0.15 power, where the reference height is taken as 10 m (30 ft), and shall be determined according to the model show below for calculation of wind speed as a function of receiver elevation.

$$V_H = V_1 \left(\frac{H}{H_1} \right)^C$$

Where: V_H = mean wind velocity at height H

V_1 = reference wind velocity

H_1 = reference height (assume 10 meters)

$C = 0.15$

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 °F (140 °F) and minimum temperatures of -30 °C (22 °F)

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 must survive an earthquake that would produce an acceleration on the order of 0.20 g to 0.25 g horizontal and vertical ground accelerations and shaking intensity of about VII and VIII on the Modified Mercalli Scale. The spectral distribution presented in U.S. Atomic Energy Commission (Revision 1, dated December 1973) Regulatory Guide 1.60 should be used as a guide. In addition, the plant must satisfy the requirements specified for seismic zone 3 in the Uniform Building Code.
- 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)

4.4 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 Buildings
 - 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

FIGURE 1 (continued)

- 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 & Engineering
 - 4353 Software Design, Development, and Test
- 4400 Concentrator Equipment
 - 4410 Reflective Unit
 - 4420 Drive Unit
 - 4421 Tracking 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

FIGURE 1 (continued)

- 4440 Foundation
- 4450 Concentrator Support and Protection
 - 4451 Concentrator Support Structure
 - 4452 Concentrator Protective Enclosure (if provided)
 - 4453 Lightning Protection
- 4460 Field Assembly and Check Out
- 4510 Receiver Unit
- 4512 Support Structure
- 4514 Instrumentation and Control
- 4515 Transportation, Field Erection, and Installation
- 4560 Steam Generator or Working Media Heat Transfer Equipment
- 4570 Design and Engineering

FIGURE 1 (continued)

- 4600 Thermal Storage Equipment
 - 4600 Media Containment Equipment
 - 4620 Media Circulation Equipment
 - 4630 Working Fluid Circulation Equipment
 - 4660 Foundation
 - 4670 Design and Engineering
 - 4680 Media
- 4700 Heat Transport System
 - 4710 Piping and Supports
 - 4720 Insulation
 - 4730 Pumps and Circulation Equipment
 - 4740 Capacitance on Relief System
 - 4750 Heat Transfer Fluid
 - 4760 Design and Engineering
- 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

Part Description	Quantity	1st Unit Cost per Unit	Subtotal	Factors				
				Learning Curve Factor*	G&A	Overhead	Quality Control	Total
Mirror .09"x100"x100" Float Glass	1000 ea.	\$35.000	\$ 35,000		1.15		1.1	\$ 44,271
Foam 2"x100"x100"	1000 ea.	10.00	10,000	.95	1.15		1.1	12,018
Steel Backing 100"x100" 263A	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					10,000
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 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

Estimated as a fraction of the cost estimate for switchgear 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 10 years.

Total Estimate for CBS 4310, 4320, & 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>Part 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		<u>581</u>
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.