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10 MWe Solar Thermal Central Receiver Pilot Plant Total Capital Cost

H. F. Norris, Jr.

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10 MWe SOLAR THERMAL CENTRAL RECEIVER PILOT PLANT TOTAL CAPITAL COST

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ABSTRACT

This report provides a detailed breakdown of the capital cost of the 10 MWe Solar Thermal Central Receiver Pilot Plant located near Barstow, California. The total capital requirements of the pilot plant are given in four cost breakdown structures: 1) project costs (research and development, design, factory, construction, and start-up); 2) plant system costs (land, structures and improvements, collector system, receiver system, thermal transport system, thermal storage system, turbine-generator plant system, electrical plant system, miscellaneous plant equipment, and plant level); 3) elements of work costs (sitework/earthwork, concrete work, metal work, architectural work, process equipment, piping and electrical work); and 4) recurring and non-recurring costs. For all four structures, the total capital cost is the same ($141,200,000); however, the allocation of costs within each structure is different. These cost breakdown structures have been correlated to show the interaction and the assignment of costs for specific areas.

The detailed breakdown structure presented here for an actual solar facility can be useful in the understanding of the costs of future central receiver plants, and may serve as a basis for standardizing the categories of plant costs. The costs of the pilot plant cannot be scaled directly to larger future plants due to the developmental nature of the pilot plant.

ACKNOWLEDGMENTS

I appreciate the help received from a number of individuals and organizations: data were welcomed from Terry Olson--Stearns Roger, now Stearns Catalytic; Bob Gervais--McDonnell Douglas Astronautics Company; Carmen Winarski and Don Fellows--Southern California Edison (SCE); Doug Elliott--Department of Energy San Francisco Office; and Mel Frohardt and Rick Facchinello--Martin Marietta Corporation. Understanding of the cost structure was aided by Inge Kornyey of Raymond Kaiser Engineers and the work previously performed by Polydyne, Inc.

The review of the draft report by Chuck Lopez, SCE, and by Doug Elliott and Bob Gervais was helpful in keeping the details in line with the overall theme of the study.

PREFACE

This pilot plant cost analysis presents a detailed view of the costs for Solar One that were spent from the capital (construction) budgets of the U. S. Department of Energy (DOE) and the Associates (a group composed of Southern California Edison, which acts as principal; the Los Angeles Department of Water and Power; and the California Energy Commission). The total capital requirement stated is not meant to be an absolute value or exact figure for the pilot plant cost, but rather the cost associated with activities of design, construction and start-up of the plant as discussed in this report.

The cost values presented in the report were gathered from the files located at the plant, from telephone conversations and personal contacts, and from internally published memoranda. The detailed lists of costs by purchase order or contract, when available, are included in the appendices. Reviews of the report draft were made by members of most of the agencies that could contribute data or correct errors in the data.

The details of the plant description and the materials and equipment contained in the various plant systems were obtained from available documentation, including the Reports and Deliverable List (RADL) documents, and construction package specifications. These lists were verified by on-site inspections of visible items. The cost breakdown structures by plant system and elements-of-work were based on the Cost Data Management System (CDMS) developed with Polydyne, Inc., and Raymond Kaiser Engineers.

The cost account data were found in many levels of detail. Some accounts encompassed many activities or a large number of material items. Some of these costs for single entries amounted to over a million dollars. Other specific costs, amounting to less than $100 total, are known for some small items. An attempt was made to obtain greater detail on the large-value accounts where an understanding of the breakdown of these costs was deemed useful.

I have allocated costs of some accounts to a number of smaller accounts to provide a more meaningful understanding of the cost breakdown. In these cases, the method used is noted. In some cases, the understanding of the account content may not be correct. The possibility of misinterpretation of the raw data is due to the lack of description that accompanied the cost value and the difficulty of communicating cost values. However, in general, the overall values or highest level costs are correct and documented.

CONTENTS

ILLUSTRATIONS

TABLES

ABBREVIATIONS

Acronyms and Abbreviations

Organizations

Beckman	Beckman Instruments, Inc.
Cyber	Cyber Systems, Inc.
DOE	Department of Energy
Ford	Ford Motor Company
FW	Foster Wheeler
GE	General Electric
IEA/SSPS	International Energy Agency/Small Solar Power Systems
LADWP	Los Angeles Department of Water and Power
MDAC	McDonnell Douglas Astronautics Company (Solar Facility Design Integrator)
MMC	Martin Marietta Corporation
Modcomp	Modular Computer Company
Modicon	Modicon Division of Gould, Inc.
PPG	Pittsburgh Plate & Glass, Industries
Polydyne	Polydyne, Inc.
RKE	Raymond Kaiser Engineers
Rocketdyne	Rocketdyne Division of Rockwell International
SCE	Southern California Edison Company
SFDI	Solar Facility Design Integrator (McDonnell Douglas Astronautics Corporation)
SNLL	Sandia National Laboratories, Livermore (California)
S-R	Stearns Catalytic (formerly Stearns-Roger)
STMPO	DOE Solar Ten Megawatt Project Office
T&B	Townsend and Bottum

Plant Items

B	Boiler
BCS	Beam Characterization System
CP	Air Compressor
CR	Cooler
D	Mobile Demineralizer
DA	Deaerator
DARMS	Data Acquisition Remote Multiplexer System
DAS	Data Acquisition System
DE	Polishing Demineralizer
DR	Air Dryer
DS	Desuperheater
E	Equipment
EES	Electronic Environmental Shelter
F	Afterfilter
FA	Blower or Fan
H	Heater
HAC	Heliostat Array Controller
HC	Heliostat Controller

Plant Items (continued)

HFC	Heliostat Field Controller
HVAC	Heating, Ventilating and Air Conditioning
HXC	Heat Exchanger
ILS	Interface Logic System (Interlock)
JB	Junction Box
MCS	Master Control System
ME	Turning Gear Motor
Metro	Meteorological Equipment
MVCU	Multi-Variable Control Unit--the Control Loop Processor
OCS	Operational Control System
P	Pump
PR	Centrifuge
RB	Receiver Boiler Panel
RLU	Red Line Unit
RP	Receiver Preheat Panel
SDPC	System Distributed Process Control
SHIMMS	Special Heliostat Instrumentation and Meteorological Measurements System
SIL	System Integration Laboratory (at MDAC, Huntington Beach)
SWS	South Weather Station
T-G	Turbine Generator
TK	Tank
TSS	Thermal Storage System
TSU	Thermal Storage Unit
UMU	Ullage Maintenance Unit
UPS	Uninterruptible Power Source
V	Vessel

Other

	Approximately
$--	Specific cost unknown, but included in total cost
ACD	Advanced Conceptual Design
A&E	Architectural and Engineering
CFE	Contractor-Furnished Equipment
CP	Construction Package
CRTF	Central Receiver Test Facility
FDCR	Field Design Change Request
FY	Fiscal Year
G&A	General and Administrative
GFE	Government-Furnished Equipment
LLP	Long-Lead Procurement
MWe	Megawatt Electric
O&M	Operations and Maintenance
PSS	Plant Support Subsystems
RADL	Reports and Deliverable List
R&D	Research and Development
UBC	Uniform Building Code

SUMMARY

10 MWe SOLAR THERMAL CENTRAL RECEIVER
PILOT PLANT TOTAL CAPITAL COST

Summary

The cost of the 10 MWe Solar Thermal Central Receiver Pilot Plant is given in four breakdown structures: 1) project cost, 2) plant system cost, 3) elements of work cost, and 4) non-recurring and recurring costs. For each structure the total capital requirement is the same ($141,200,000), but the allocation of the costs is different. Summaries of the four cost breakdown structures are given below. However, caution should be exercised in using these summary costs without investigating further in this report as to the source, content, and circumstances associated with that cost.

The project costs (Figure 1) include R&D costs, design costs, factory costs of engineered equipment, construction costs, and start-up costs. Costs structured in this way are useful in examinations of costs of future plants, since similar parts, such as heliostats or storage tanks, may be used. The new plant may not have to pay for R&D costs since they have already been paid, or the engineering design costs may be greatly reduced.

Throughout the report, as a convenience to the reader, the actual costs are rounded-up/rounded-off to provide a common, recognizable total capital cost--$141,200,000.

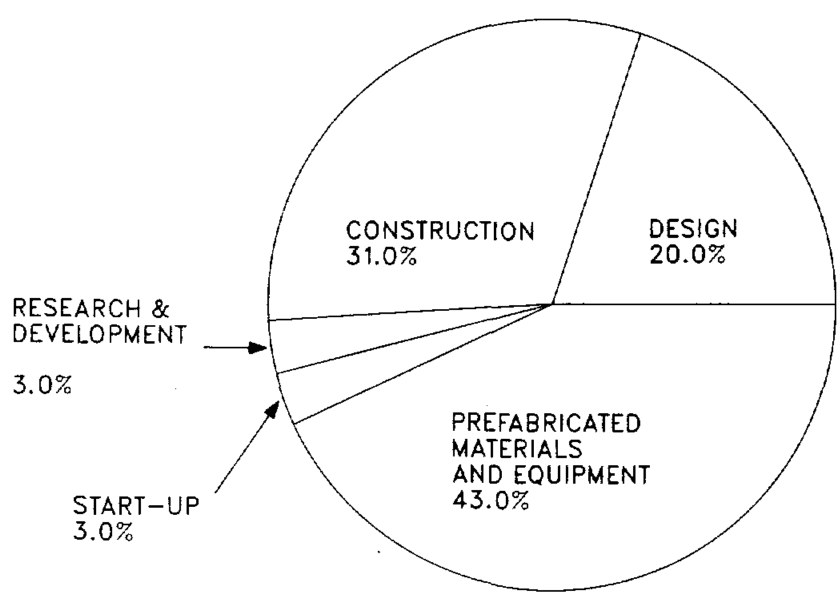


Figure 1: Capital Cost--Breakdown by Project Category

The total capital costs broken down by project category are:

Research and Development	$ 4,868,145
Design--Final and Preliminary	$ 28,804,112
Factory Costs	$ 60,095,479
Construction Costs	$ 43,011,283
Start-up Costs	$ 4,384,368
Round-up, Miscellaneous Round-off	$ 36,613
Total Capital Costs	**$141,200,000**

Plant System Cost

The plant system cost breakdown structure includes charges assigned to major parts of the plant (Figure 2). These areas consist of land, structures and improvements, the solar thermal portion of the plant, the turbine-generator plant system, the plant electrical system, miscellaneous plant equipment, and plant-level costs. The solar thermal portion can be further divided into systems, including collector, receiver, thermal transport, and thermal storage systems. The breakdown by plant systems is useful if analysis is to be performed that considers only parts of the plant. Separating costs into these plant systems allows an understanding of system costs and the possibility of comparing the costs of other technologies with those of the solar thermal central receiver concept. This breakdown is also needed if scaling of different-sized plants is attempted.

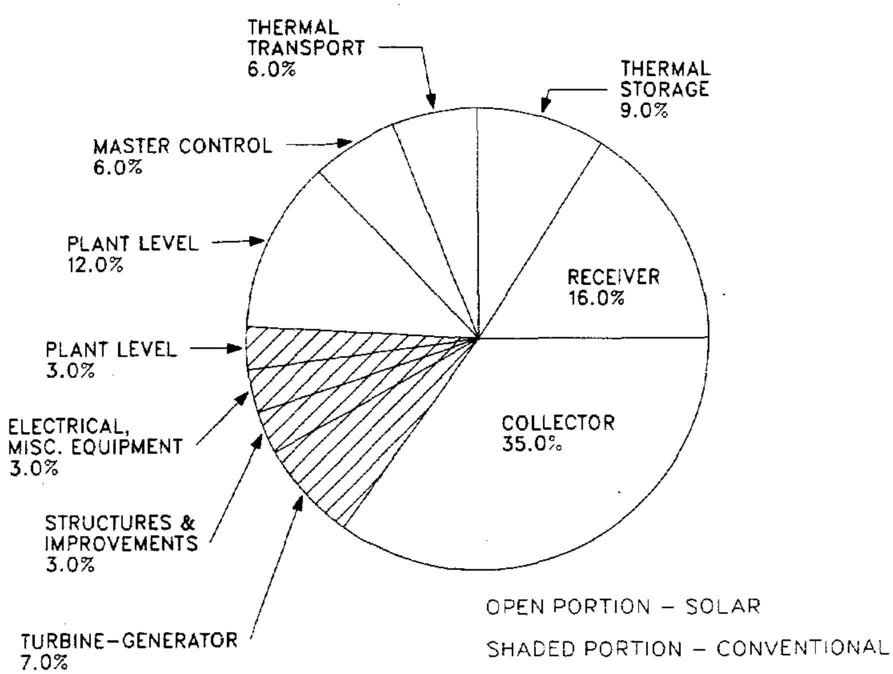


Figure 2: Capital Cost--Breakdown by Plant System

Plant-level costs are those costs that are difficult to assign to individual plant systems. A total capital cost breakdown by the <u>plant systems</u> is as follows:

Land	$ 0
Structures and Improvements	$ 4,686,315
Collector System	$ 49,211,297
Receiver System	$ 22,570,587
Thermal Transport System	$ 7,517,434
Thermal Storage System	$ 13,176,982
Turbine Generator Plant System	$ 10,140,783
Electrical Plant System	$ 11,355,488
Miscellaneous Equipment	$ 989,134
Plant Level	$ 21,515,368
Round-up	$ 36,612
Total Plant Cost	$141,200,000

<u>Elements of Work Cost</u>

The elements of work cost breakdown structure consists of sitework/earthwork, concrete work, metal work, architectural work, process equipment, mechanical and piping, electrical work and indirect cost elements. This cost breakdown is of interest to A&E firms, since many of the construction subcontracts will be organized by this breakdown. It is also useful when scaling new plants in the early design phases. The total capital cost segregated by <u>elements of work</u> categories (Figure 3) is as follows:

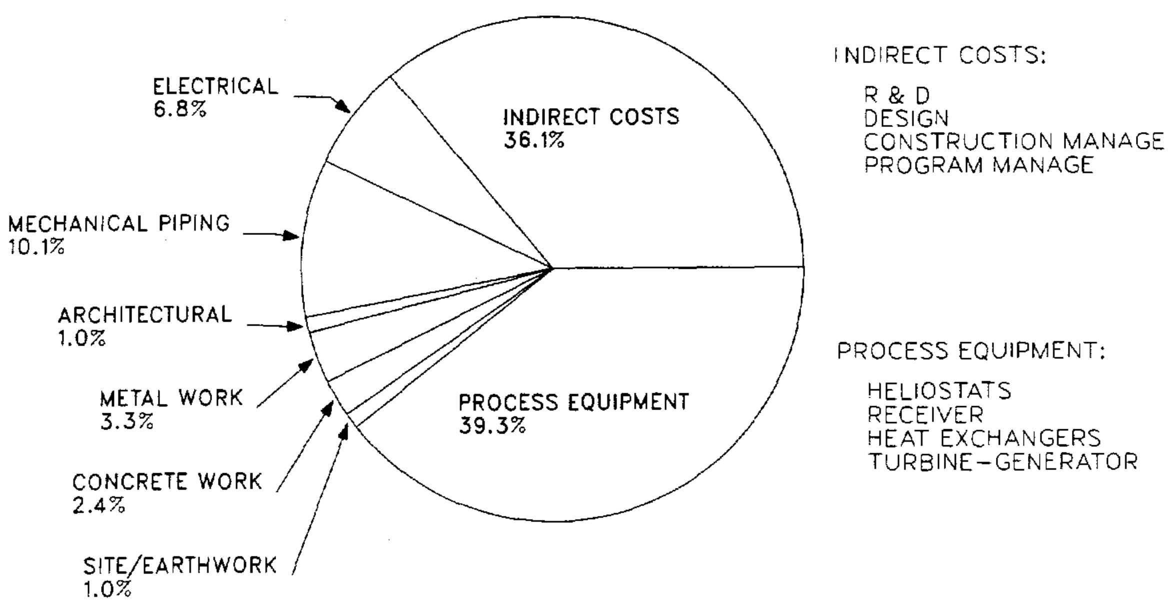


Figure 3: Capital Cost--Breakdown by Element of Work

Elements of Work Cost

Sitework/Earthwork	$ 1,272,344
Concrete Work	$ 3,417,007
Metal Work	$ 4,641,180
Architectural Work	$ 1,703,718
Process Equipment	$ 55,454,738
Mechanical/Piping Work	$ 14,199,637
Electrical Work	$ 9,528,456
Indirect Cost Elements	$ 50,946,303
Round-up, Miscellaneous Round-off	$ 36,617
Total Capital Costs	**$141,200,000**

Non-Recurring and Recurring Costs

The above three cost breakdown structures include both non-recurring and recurring costs. The non-recurring costs at the pilot plant include charges for basic research and development, special pilot plant solar system instrumentation, data-recording systems, meteorological measurement systems, excessive factory and tooling amortization, unique engineering design, and extra program and construction management. The non-recurring costs would not be expected to be incurred in future plants*. The recurring costs include charges for off-the-shelf equipment that could be purchased from several sources and installed using standard practices. Separation of the total capital costs into non-recurring and recurring costs follows:

	Non-Recurring	Recurring
Research and Development	$ 4,668,145	$ 200,000
Design--repeat 15% of design (except Visitors Center)	$24,465,336	$ 4,163,776
Pilot Plant Features		
Visitors Center w/ design	$ 583,403	$ 0
SHIMMS Factory & Construction	$ 1,115,295	$ 0
Data Acquisition System	$ 1,085,695	$ 0
Factory Planning, Tooling	$ 4,221,379	$ 744,949
Other Factory, Construction	$ 0	$82,224,589

*The selection of these non-recurring costs reflects the opinion of the author.

Non-Recurring and Recurring Cost (continued)

Start-up	$ 3,726,713	$ 657,655
Program Management	$ 3,912,416	$ 690,426
Construction Management	$ 3,397,973	$ 5,305,639
	$47,176,355	$93,987,034
Round-up, Miscellaneous Round-off		$ 36,611
Total Capital Costs		**$141,200,000**

If the non-recurring and recurring costs are allocated to the major plant systems, the results would be as follows:

	Non-Recurring	Recurring
Land	$ 0	$ 0
Structures and Improvements	$ 1,131,878	$ 3,554,437
Collector System	$11,756,630	$ 37,454,668
Receiver System	$ 5,707,596	$ 16,862,991
Thermal Transport System	$ 2,040,959	$ 5,476,475
Thermal Storage System	$ 1,777,236	$ 11,399,746
Turbine-Generator Plant	$ 2,942,967	$ 7,197,816
Electrical System	$ 7,205,608	$ 4,149,880
Miscellaneous Equipment	$ 325,515	$ 663,619
Plant Level	$14,287,966	$ 7,227,402
	$47,176,355	$ 93,987,034
Round-up, Miscellaneous Round-off		$ 36,611
Total Plant Cost		**$141,200,000**

Correlation of Cost Breakdown Structure Data

The pilot plant total capital requirements itemized above by several cost breakdown structures can be correlated to each other. This correlation is useful to show the interaction and the assignment of costs for specific areas. The cost breakdown detail is not known well enough in some areas (e.g., start-up costs for each plant system) to have entries, even though costs were incurred. The lack of this detail is not obvious in the previous sections or pie-charts, but surfaces when the cost data are correlated.

One correlation is displayed in Tables 1 and 2. These tables present the costs that are available with the project category and the elements of work shown as a fuction of plant system, respectively.

Conclusions

The majority of costs, and certainly the major ones, are included in this cost data set. Some costs, such as those for land, evaporation pond, rented equipment, and costs after April 1982 are omitted. The various breakdown structures, along with the presentation of typical items employed in a solar thermal central receiver power plant, should be of value to future builders, investors, and users of solar thermal central receiver plants.

The breakdown of the cost data should be used to understand a total cost data set. Some of the data, such as for the conventional portion of the plant, may be representative of future plants, while data for the solar portion, which contains extraordinary costs, may be useful but neither directly applicable nor scalable to future plants. The costs for this pilot plant cannot be scaled directly to arrive at the cost of a 100 MWe privately constructed plant for several reasons: 1) the pilot plant is a scale model of a 100 MWe plant and was not optimized at the 10 MWe size; 2) the indirect costs are representative of a developmental plant; 3) the high collector and receiver costs are a function of the small production quantity and early design; and 4) the interest during construction is not typical due to the government financing. A future report will examine the usefulness of the pilot plant cost data set to different-sized plants and to other solar thermal technologies.

TABLE 1
CAPITAL COST—PROJECT CATEGORY vs PLANT SYSTEM

PLANT SYSTEMS	R&D	DESIGN	FACTORY	CONSTRUCT	START-UP	SUBTOTAL	TOTAL
Structures/Improvements	0	820,265	110,003	3,756,047	—		4,686,315
Collector System							49,211,297
Field	0	253,926	688,534	3,764,738	—	4,707,198	
Heliostats	4,868,145	3,494,482	30,978,366	2,198,071	—	41,539,064	
BCS	0	550,428	416,635	182,804	416,776	1,566,643	
SHIMMS	0	283,107	316,673	798,622	—	1,398,402	
Receiver System							22,570,587
Receiver	0	3,727,093	13,779,978	3,115,890	—	20,622,961	
Tower	0	0	—	1,947,626	—	1,947,626	
Thermal Storage System	0	2,090,866	4,712,618	6,373,499	—		13,176,983
Thermal Transport System	0	2,401,128	2,402,786	2,713,520	—		7,517,434
Turbine-Generator Plant	0	3,462,314	3,698,550	2,979,919	—		10,140,783
Electrical System							11,355,487
Master Control	0	6,354,544	2,079,636	91,753	—	8,525,933	
Balance	0	741,678	558,767	1,529,109	—	2,829,554	
Miscellaneous Equipment	0	382,959	352,943	253,232	—		989,134
Plant Level	0	4,241,322	0	13,306,454	3,967,592		21,515,368
Total Cost	4,868,145	28,804,112	60,095,479	43,011,284	4,384,368		141,163,388

— Specific cost unknown, but included in total cost

TABLE 2
CAPITAL COST—ELEMENTS of WORK vs PLANT SYSTEM

PLANT SYSTEM	EARTHWORK	CONCRETE	METAL	ARCHITECT	EQUIPMENT	MECHANICAL	ELECTRICAL	INDIRECTS	SUBTOTAL	TOTAL
Structures/Imprvmt	795,646	194,989	133,309	1,703,718	24,707	889,469	124,210	820,265		4,686,313
Collector System										49,211,295
Field	476,698	1,193,945	0	0	—	0	2,782,629	253,926	4,707,198	
Heliostats	0	0	0	0	30,978,356	2,198,071	0	8,362,627	41,539,054	
BCS	0	15,097	165,752	0	612,617	159,078	63,670	550,428	1,566,642	
SHIMMS	0	39,691	73,000	—	299,644	0	702,959	283,107	1,398,401	
Receiver System										22,570,587
Receiver	0	0	0	—	13,448,173	2,122,953	1,324,742	3,727,093	20,622,961	
Tower	—	196,756	1,750,870	0	—	—	—	—	1,947,626	
Thermal Storage	—	909,098	2,256,659	—	4,519,846	2,740,341	660,172	2,090,866		13,176,982
Thermal Transport	—	60,967	252,809	—	1,041,845	3,639,884	120,800	2,401,128		7,517,433
T-G Plant	—	673,191	8,781	—	3,622,158	2,210,667	163,672	3,462,314		10,140,783
Electrical System										11,355,488
Master Control	0	0	0	—	0	0	2,171,390	6,354,544	8,525,934	
Balance	—	132,134	0	—	554,683	0	1,401,059	741,678	2,829,554	
Misc. Equipment	—	1,139	0	—	352,709	239,174	13,153	382,959		989,134
Plant Level	0	0	0	0	0	0	0	21,515,368		21,515,368
Total Costs	1,272,344	3,417,007	4,641,180	1,703,718	55,454,738	14,199,637	9,528,456	50,946,303		141,163,383

— Specific cost unknown, but included in total cost

PLANT DESCRIPTION

Pilot Plant Description

The 10 MWe Solar Thermal Central Receiver Pilot Plant (Figure 4), also known as Solar One, is the world's largest solar electric generating station (Ref. 1-5). Solar One is a cooperative effort of the Department of Energy (DOE), Southern California Edison (SCE), the Los Angeles Department of Water and Power (LADWP), and the California Energy Commission (CEC). As a pilot-scale research and development experiment, it will demonstrate technical feasibility, economic potential and environmental acceptability of the solar thermal central receiver concept. The solar portion of the facility was designed and constructed under the direction of the DOE, and the turbine-generator facilities were designed and constructed by SCE.

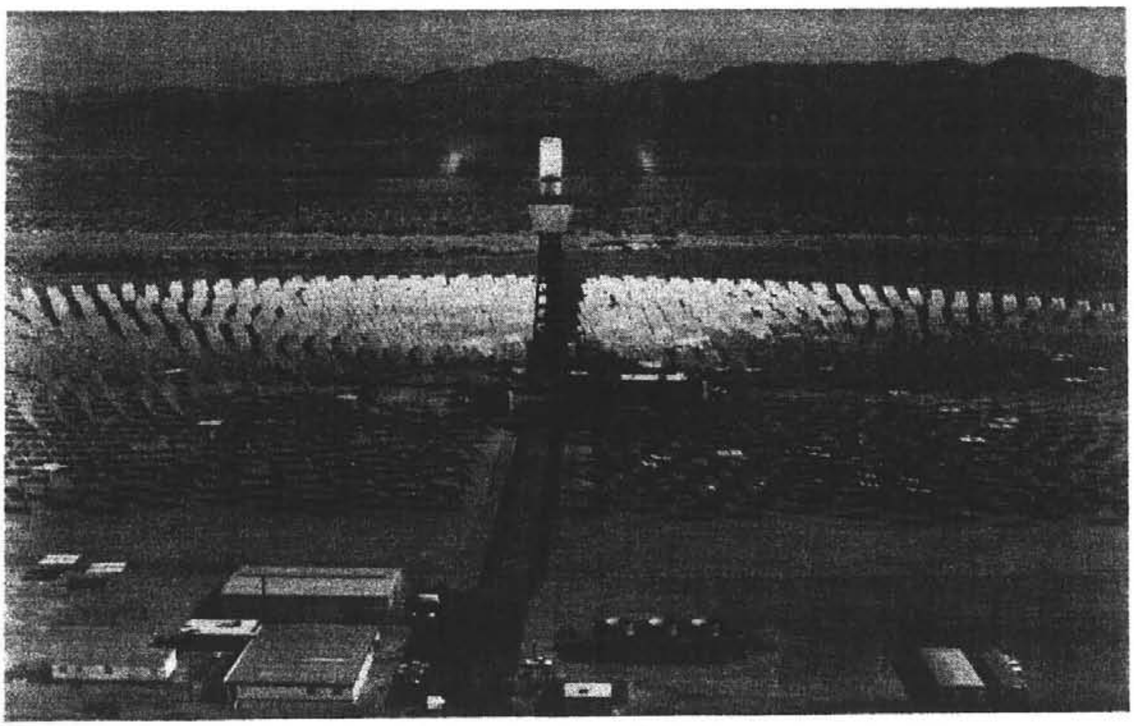


Figure 4: Pilot Plant Overview

The project has been constructed in the Mojave Desert on 130 acres (52.5 hectares) of Southern California Edison Company's Cool Water Generating Station east of Daggett, California, and approximately 12 miles (19.3 km) east of Barstow, California. The site is at a latitude of 34.87^{o} North and a longitude of 116.83^{o} West. The site is contained in the western half of Section 13, Township 9N - Range 1E, San Bernardino County: San Bernardino Meridian. The reference location for the pilot plant is N 501,260.00 E 2,349,950.00. The nominal elevation of the site is 1,946 ft (593 m) above mean sea level.

The plant is designed to produce at least 10 MWe, after supplying the plant parasitic power requirements, for a period of 4 hours on the plant "Worst Design Day" and for a period of 7.8 hours on the plant "Best Design Day." During actual plant operation, the plant capability and electrical output will depend on the current sun and atmospheric conditions. During certain periods of the year (near noon, from March through September), the plant energy production can exceed the 12.5 MWe gross turbine-generator rating. In this case, excess energy can be diverted to charge the thermal storage system.

Plant Systems

The central receiver concept being demonstrated at Solar One integrates the solar facilities with the conventional power plant facilities. Each of these facilities is composed of a number of plant systems. These systems are described briefly below.

Solar Facilities--The solar facilities (Figure 5) include the collector system (which includes the beam characterization system), the receiver system, and the thermal storage system. These systems

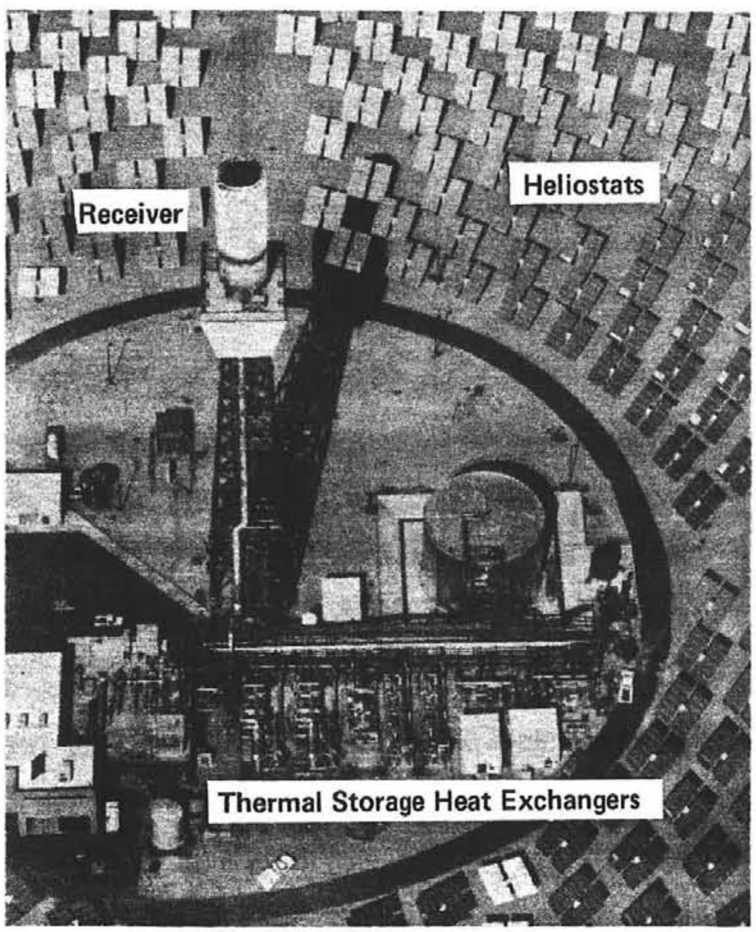


Figure 5: Solar Facilities

do not operate independently of each other. The flow of fluids is accommodated in the thermal transport system, while the coordination of operation is handled by the master control system. The thermal transport and master control systems are also integrated with the conventional turbine-generator facilities.

Collector System--The collector system directs the sunlight onto and off of the tower-mounted receiver in a controlled and safe manner. The system includes 1818 heliostats (mirrors), each 423 ft^2 (39.3 m^2) in reflective area, that reflect the sunlight on the receiver surface. With computer instructions issued every 8 seconds, the heliostats rotate in two axes, reflecting the sunlight onto the proper portion of the receiver. Each heliostat stands about 23 ft (7 m) tall and is about 21 ft (6.4 m) wide. These heliostats were made by Martin Marietta Corporation (MMC) for the Department of Energy (DOE).

To assess the characteristics of the beam reflected from the heliostat to the receiver, the beam characterization system (BCS) is used. The BCS hardware consists of four video cameras, each of which views an elevated target mounted beneath the receiver. The cameras are located in the collector field along the four access roads. The data obtained with the BCS provide tracking correction (bias) values that are input into the heliostat computers.

Receiver System--The receiver system consists of a water-steam boiler that heats the feedwater to superheated steam. The boiler is composed of 6 preheater panels and 18 boiler panels. Each preheater panel weighs about 7000 lbs (3182 kg), and each boiler panel weighs about 8500 lbs (3864 kg). The preheaters are arranged with two sets (3 panels each in parallel) in series, and the 18 single-pass-to-superheat boiler units are in parallel.

The exposed portion of the receiver panels is about 45 ft (13.7 m) tall and on the periphery of a 23 ft (7 m) diameter cylinder. The 70-tube panels incorporate Incoloy 800 tubing painted black with Pyromark. The receiver tube external walls reach temperatures up to 1150°F (621°C).

The panels can absorb as much as 0.35 MWt/m^2 over the receiver surface area, which totals about 302 m^2 (3252 ft^2). The receiver is rated at 43.4 MWt. The steam produced by the receiver is rated at 950°F (510°C) and 1465 psia (10.1 MPa) at a flow rate of 112,000 lb/hr (50,794 kg/hr).

The receiver is supported on a steel tower that holds the top of the receiver 300 ft (91.5 m) above the desert floor. The tower is anchored to a 54 ft (16.5 m) square by 4 ft (1.2 m) thick, 1500-ton concrete foundation that is approximately 9 ft (2.7 m) below the grade level.

Thermal Storage System--The thermal storage system centers around a large cylindrical tank. The storage tank or thermal storage unit (TSU) is 45 ft (13.7 m) high and 65 ft (19.8 m) in diameter. The 946,000-gallon (3,580,610 liter)-capacity tank is filled with 7,000 tons (6,349,200 kg) of rock and sand, and about 240,000 gallons (908,000 liter) of thermal oil (Caloria HT-43). The tank is heavily insulated and sits on an insulating concrete foundation. The tank wall varies in thickness from 1-1/8 in. (28.6 mm) at the bottom to 1/4 in. (6.4 mm) at the top. The insulation is 1 ft (0.3 m) thick on the sides, and 2 ft (0.61 m) thick on the top.

The thermal storage system can provide enough energy to operate the turbine-generator for a period of 4 hours at a net power level of 7 MWe. The rating is at 28 MWe-hr, but there is also capacity to provide seal steam and energy to start the plant. The oil in the thermocline tank varies from about 575^{o}F (302^{o}C) at the top to about 425^{o}F (218^{o}C) at the bottom.

The energy is transported into and out of the thermal storage system through heat exchangers. One dual-train heat exchanger transfers energy from the receiver-heated steam into the storage oil. The charging heat exchangers include condensers and subcoolers. The other dual-train heat exchanger reverses the process by transferring energy from the hot oil into steam that is fed to the admission port of the turbine-generator. The extraction heat exchangers include preheaters, boilers, and superheaters. The admission steam is at a lower temperature and pressure than the main steam from the receiver--575^{o}F (302^{o}C) and 385 psia (2.66 MPa).

The oil is circulated in the thermal storage system using two pumps for the charging trains and two for the extraction trains. Each of these pumps is driven by a 200 hp variable-speed motor.

Thermal Transport System--The specific systems such as the receiver system, the thermal storage system and the turbine-generator plant system are interconnected by the thermal transport system. It includes piping, pumps, valves, heat exchangers, thermal transport fluids and equipment to condition the thermal transport fluids.

The piping includes the riser that carries feedwater to the receiver and piping that carries feedwater to the thermal storage heat exchangers; it also includes the downcomer that carries superheated steam to the turbine and piping that carries steam from the thermal storage heat exchangers to the admission port of the turbine-generator. The main steam piping is mostly 6 in. (152 mm) and 10 in. (254 mm) diameter, while the feedwater piping is mainly 2-1/2 in. (63.5 mm) and 4 in. (101.6 mm) diameter.

Pumps included in the thermal transport system are the receiver feedwater pump and 800 hp driver and the thermal storage feedwater pump and 125 hp driver.

Heat exchangers include the desuperheaters and flash tanks used in the receiver and thermal storage systems.

Equipment used to condition the thermal transport fluid includes the inline demineralizer and the feedwater heaters and feedwater deaerator. The turbine extractions feed three feedwater heaters and one deaerator. The receiver steam and the thermal storage steam both use this equipment.

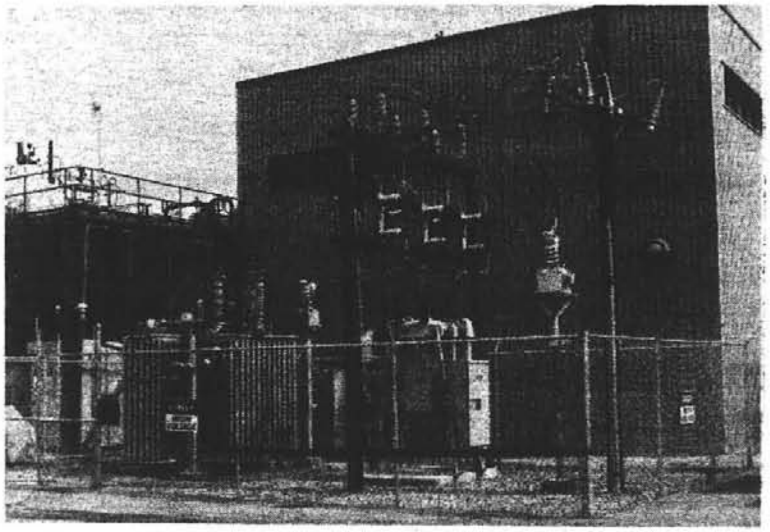
Master Control System--The master control system interconnects the various solar and conventional plant systems. The master control system is used both for control and for data acquisition. The system includes computers, graphic displays and recorders.

Conventional Power Plant Facilities--The items that make up the conventional portion of the plant include the turbine-generator, the electrical switchyard and tie-in to the SCE grid, general buildings and equipment for plant operation and maintenance, and general site improvements (Figure 6). The conventional power plant facilities are also integrated with the thermal transport system and the master control system as described above. The various major systems are described below:

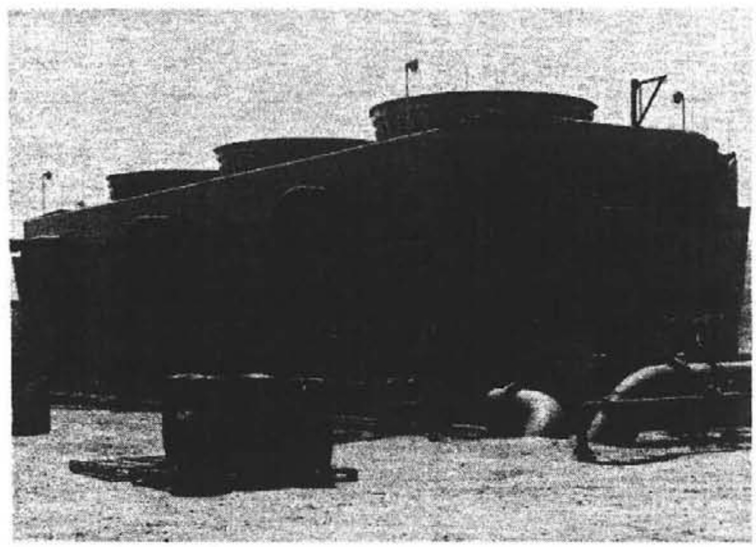
Turbine-Generator Plant System--The 12.5 MWe gross turbine-generator is a machine designed by General Electric for cyclic duty. It is the same general machine used for marine drives. The turbine has two steam inlet ports--one high-pressure port for receiver (main) steam and a lower pressure port for thermal storage (admission) steam. The rated turbine thermal-to-electric efficiency from receiver steam is 35%, and from thermal storage steam, 25%. The turbine can accept up to 112,000 lb/hr (50,794 kg/hr) of receiver steam at 950^{o}F (510^{o}C) and 1465 psia (10.1 MPa), and up to 105,000 lb/hr (47,619 kg/hr) of thermal storage generated steam at 525^{o}F (274^{o}C) and 385 psia (2.66 MPa). The turbine-generator can operate down to less than 5% of rated capacity.

The turbine condenser rejects heat to a 3-cell cooling tower that is part of the circulating water system. Each cell uses a 2-speed 60-hp fan. The circulating water is pumped between the turbine condenser and the cooling tower by two 100-hp motor drivers.

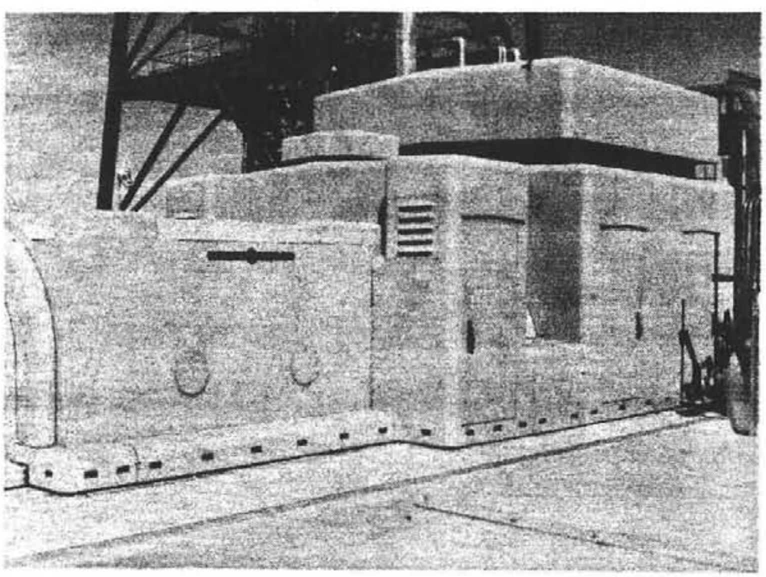
Structures and Improvements--A number of facilities are required to operate and maintain a power plant regardless of the source of the fuel. Such facilities include the administration building, security building, restroom facilities, control building, visitor center, warehouse, raw/service water building, and secondary fire pump building. Site improvements include the site fencing, parking lot and waste disposal.



Switchyard



Cooling Tower



Turbine-Generator

Figure 6: Conventional Facilities

Electrical Plant System--The electrical plant system includes the equipment and facilities to get the electricity from the generator into the SCE grid. The system also includes items to operate the plant, such as transformers and the switchyard, not associated with a specific plant system.

Miscellaneous Equipment--The miscellaneous equipment associated with the pilot plant includes items that are used on a number of the plant systems, but cannot be specifically charged to any system. These include the service and instrument air system that uses two 75-hp driven air compressors, nitrogen blanketing system, equipment cooling water system that uses a 30-hp driven pump, water sampling system, and the 1.4 MWe auxiliary steam system. The systems that use these equipment are the receiver, thermal storage, thermal transport, and turbine-generator plant.

INTRODUCTION

Introduction To Cost Analysis

The objective of the 10 MWe Solar Thermal Central Receiver Pilot Plant is twofold: (1) to establish the technical feasibility of a solar plant of the central receiver type, and (2) to obtain sufficient development, power production, and operations and maintenance (O&M) data to indicate the potential for economical operation of utility-scale power plants of a similar design. This report presents a cost analysis of the pilot plant total capital cost.

The purpose of this cost analysis is to provide both a clear, detailed breakdown structure for solar thermal central receiver plant costs and a cost data set of the pilot plant costs in this breakdown structure. The former has broad application to those who plan new power production plants, those who analyze alternate energy sources and technologies, and those who need to promote confidence in cost estimates for potential investors in central receiver systems. The latter has a narrower application, but still necessary, to those who need to understand the pilot plant costs better. The detailed costs in this report should point out why the pilot plant capital costs are not representative of the costs of future central receiver plants. The cost data set also provides a checklist of types of costs that can be incurred in building a solar plant and a traceability of the pilot plant costs.

The conceptual design of the pilot plant was completed in July 1977. The plant design was started in May 1979, and construction was completed in April 1982. The pilot plant total capital cost (up to April 1982) includes charges that can be considered final design, and perhaps preliminary design or research and development, as well as the construction costs. However, the plant was not totally complete in April 1982 and further costs have been incurred since that date.

Although the total capital requirements of the pilot plant can be identified, they cannot be understood unless they are separated into meaningful categories. The proper separation and detail can provide confidence in the cost data and the completeness of the overall charges.

In this report, total capital requirements are broken down in four structures: (1) project cost, (2) plant system cost, (3) elements of work cost, and (4) recurring and non-recurring cost. The reason for providing the cost detail in each of these structures varies, as explained below.

The <u>project cost breakdown structure</u> includes R&D costs, design costs, factory costs of engineered equipment, construction costs, and start-up costs. Costs structured in this way are useful in examinations of costs of future plants, since similar parts, such as heliostats, may be used. The new plant may not have to pay for R&D costs since they have already been paid, or the engineering design costs may be greatly reduced.

The plant system cost breakdown structure includes charges assigned to major parts of the plant. These areas consist of land, structures and improvements, solar thermal portion of the plant, turbine plant system, plant electrical system, miscellaneous plant equipment, and plant-level costs. The solar thermal portion can be further divided into systems, including collector, receiver, thermal transport and thermal storage. Plant-level costs are those costs that are difficult to assign to individual plant systems. These include program and construction management charges and architectural and engineering fees. Although total costs are known, the distribution is unknown; no attempt to distribute plant-level costs was made.

The breakdown by plant systems is useful if analysis is to be performed that considers only parts of the plant. Separating costs into these plant systems allows an understanding of system costs and the possibility of comparing the costs of other technologies with those of the solar thermal central receiver concept (Ref. 6,7). The comparisons can be made with wind, photovoltaic, nuclear, and fossil technologies if enough detail is available. This breakdown is also needed if scaling of different-sized plants is attempted.

The elements of work cost breakdown structure consists of sitework/earthwork, concrete work, metal work, architectural work, process equipment, piping and electrical work. This cost breakdown is of interest to A&E firms, since many of the construction subcontracts will be organized by this breakdown. It is also useful when scaling new plants in the early design phases.

Finally, a recurring and non-recurring cost breakdown structure is useful to assess the costs of future plants. The recurring costs include charges for off-the-shelf equipment that could be purchased from several sources and installed using standard practices. Non-recurring costs at the pilot plant include charges for basic R&D, special pilot plant solar system instrumentation, data-recording systems, meteorological measurement systems, excessive factory and tooling amortization, unique engineering design, and extra program and construction management. In order to determine the cost of another plant like the pilot plant, the costs must be identified as either recurring or non-recurring.

The costs associated with designing, building and operating this first-of-a-kind plant are not expected to be typical of a utility-scale power plant. The costs of energy from the pilot plant would no doubt be greater than those of either the next 10 MWe power plant of a similar design or a larger power plant that uses the same technology or a more advanced technology due to the non-recurring costs incurred.

TOTAL CAPITAL COST

Total Capital Requirements

The pilot plant total capital requirements amounted to about \$140,700,000. These requirements were primarily funded by the construction (capital) budgets of the DOE and SCE/LADWP. A breakdown of this source of funds is presented in this section so that future traceability and re-creation of the requirements are possible. Some funds were also provided from operating and capital equipment budgets to complete the operating plant.*

The major expenditures were made from 1978 through April 1982 (Ref. 8,9). Most of the SCE/LADWP funds were used for the conventional portion of the plant, while the DOE funds were concentrated on the solar portion. However, some funds from each participant were used for items that are considered to belong to the other part of the plant.

Funds were spent for research and development contracts, developmental equipment contracts, construction contracts, materials and equipment purchases, and services contracts. These contracts and purchases consisted of some R&D costs (heliostats and glass), some engineering design costs not directly charged to factory costs (master control and beam characterization systems), some factory costs including engineering design costs (heliostats, receiver and thermal storage components), government-furnished equipment (GFE) that are either long-lead procurement items or equipment used in previous programs, 4 DOE prime construction packages, 11 T&B prime construction packages (Ref. 10), SCE purchases, SCE construction contracts, construction management (T&B and SCE), architectural and engineering (S-R) and program management (MDAC and SCE).

Some construction contracts covered a number of plant systems--e.g., piping and mechanical, electrical and insulation. Many equipment and materials purchases incorporated R&D or extraordinary engineering design costs. Expenditures for major contracts or subcontracts were only part of the costs for the individual plant systems. For example, the MDAC/Rocketdyne receiver contract expenditure was a large fraction of, but not the total, receiver system cost.

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*One example is the use of capital equipment and operating budget funds (\$431,992) for the special heliostat instrumentation and meteorological measurement system (SHIMMS).

Some of the equipment and material (primarily long-lead items) was furnished outside the construction subcontract but was installed by the construction subcontractor; items without long-lead times were generally provided and installed by the subcontractors. The construction subcontract prices include all charges for labor and materials, some design engineering, field overhead and indirects. The prices include all field design change requests (FDCR), which numbered 291 through about February 1982.

A breakdown of the total capital requirements is as follows:

Research & Development Contracts	
Phase 1 Heliostat Development-MMC	$ 2,323,212
Phase 1 Heliostat Development-MDAC	$ 2,520,933
Glass Development-PPG	$ 24,000
Subtotal Research & Devlopment Contracts	$ 4,868,145
Developmental Equipment Contracts	
Installed Heliostats-MMC (Appendice E.2 & E.3)	$ 35,905,571
Receiver-MDAC/Rocketdyne	$ 16,003,641
Thermal Storage-MDAC/Rocketdyne	$ 5,719,877
Master Control/SHIMMS-MDAC (Appendix G)	$ 10,051,393
Beam Characterization System-MDAC (Appendix F)	$ 1,073,602
Subtotal Developmental Equipment Contracts	$ 68,754,084
Construction Contracts	
Contract Prime-DOE (Appendices A.1, A.2, A.3, and A.6)	$ 2,939,344
Contract Prime-T&B (Appendices A.4, A.5, and A.7-A.12)	$ 18,825,687
Contract Prime-SCE/LADWP (Appendix D)	$ 5,415,000
Subtotal Construction Contracts	$ 27,180,031
Equipment and Material Purchases	
Long-Lead Purchases-SFDI/S-R (Appendix B)	$ 2,764,738
Purchases-SCE/LADWP (Appendix C)	$ 5,370,000
Glass Purchase-Ford (Appendix E.1)	$ 823,818
Subtotal Equipment & Material Purchases	$ 8,958,556

Other Costs

Construction Management-T&B	$ 5,855,342
SFDI-MDAC	$ 12,056,781
Program Management-$4,602,842	
Design/Integration-$4,341,322	
Checkout/Startup -$3,112,617	
Plant Support Systems A&E-S-R	$ 2,448,937
Design and Construction Management-SCE/LADWP	$ 10,565,000
Subtotal Other Costs	$ 30,926,060
Total DOE & SCE/LADWP Construction Budget	$140,686,876
SHIMMS Capital Equipment & Operating Budget Funds	
SFDI/MDAC ($93,778 Capital Equipment, $110,315 Operating)	$ 204,093
T&B (Capital Equipment)	$ 227,899
Round-up	$ 88,132
Total Capital Requirements	$141,200,000

On the following pages, these costs are further detailed within the four breakdown structures.

PROJECT COST

Project Cost Breakdown Structure

The project cost breakdown structure for the pilot plant can be divided into several major elements. These elements exist to some degree in all major projects. (Specific charges may be placed in different elements by various accounting systems.) The divisions are:

- Research and development (R&D) costs
- Design costs
- Factory costs for equipment, assemblies, and subsystems
- Construction costs
- Start-up costs

Costs structured in this way (Figure 7) are useful in examinations of costs of future plants, since similar parts, such as heliostats or storage tanks, may be used. The new plant may not have to pay for R&D costs since they have already been paid, or the engineering design costs may be greatly reduced.

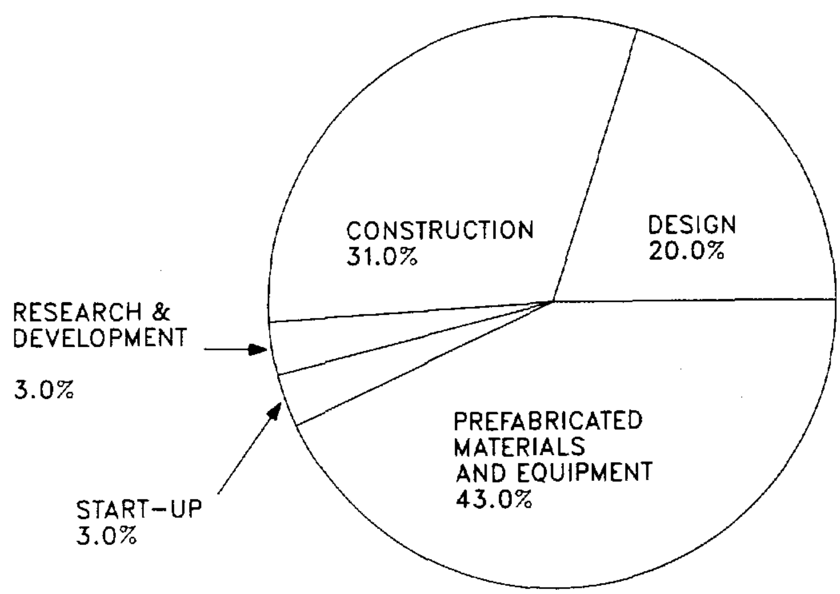

Figure 7: Capital Cost--Breakdown by Project Category

The total capital costs broken down by project category are:

Research and Development		$ 4,868,145
Design--Final and Preliminary		$ 28,804,112
Factory Costs		$ 60,095,479
Construction Costs		$ 43,011,283
Construction Packages	$27,506,758	
Installation of Heliostats	$ 2,198,071	
Construction Management (T&B)	$ 5,178,266	
Construction Management (SCE)	$ 3,316,667	
Construction Package Support	$ 208,679	
Program Management (MDAC)	$ 4,602,842	
Start-up Costs		$ 4,384,368
Round-up, Miscellaneous Round-off		$ 36,613
Total Capital Costs		**$141,200,000**

Each of the major elements is discussed in more detail in the following sections.

Research and Development Costs

Research and Development Costs

The pilot plant design, factory fabrication and assembly of major parts, and field construction were preceded by research and development funded by the DOE and private industry. Some of these R&D costs can be associated directly with the pilot plant project costs.

Other R&D expenses can be indirectly associated with the pilot plant costs, but were not (by definition) part of the DOE construction budget. Costs of this nature could apply to the Phase I heliostat development costs and the 5-tube and 70-tube tests that enabled the pilot plant receiver to be designed and built. These R&D funds, although a part of the DOE operations budget, should have reduced the actual costs of the pilot plant collector system and receiver system.

The approximate costs that were incurred in the DOE operations budget (and hence not included in the construction budget) for the fiscal years of roughly 1977 to 1980 were as follows:

Phase I Heliostat Development-	
MDAC	$ 8,571,000
MMC	$ 8,072,000
Honeywell	$ 7,509,000
Boeing (heliostat only)	$ 1,420,000
Receiver Development-	
5-Tube	$ 790,000
70-Tube	$ 950,000

The only R&D item expense included in the DOE construction budget is that for pilot plant heliostats. A competition between MMC and MDAC was held before selection of the pilot plant heliostat. Another R&D cost associated with heliostats was for glass development from Pittsburgh Plate & Glass (PPG). These costs were incurred during fiscal years 1979, 1980, and 1981, with most of the costs in FY 1979, as shown in Table 3.

TABLE 3: RESEARCH AND DEVELOPMENT COST SUMMARY

	FY1979	FY1980	FY1981	Total
MMC	2,167,527	104,751	50,934	$ 2,323,212
MDAC	2,229,879	272,725	18,329	$ 2,520,933
PPG				$ 24,000
Total Plant R&D Cost	4,397,406	401,476	69,263	$ 4,868,145

Most or all of these costs would not be incurred for a future plant since heliostats of various designs can currently be ordered from at least three heliostat manufacturers.

Some other R&D costs allowed the pilot plant costs to be directly reduced and thus are recurring rather than non-recurring costs. These include the two HAC computers that were provided to the pilot plant from the R&D effort. This cost was estimated to be $200,000 (See Appendix G.3).

The total pilot plant R&D cost charged to the total capital requirements is $4,868,145. Most projects would amortize this type of cost over many units, but here the entire cost is applied against this single pilot plant facility.

Total Research and Development Cost	$4,868,145

Design Costs

Design Costs

The design costs, even though included in many engineered equipment costs, should be separated for this first-time plant. Much of the solar-related equipment was of a developmental nature, and thus the costs were for unique items, with little history as compared with that for turbine-generators, pumps, etc. These design costs are shared not only by one-of-a-kind items, but also by small numbers of similar items such as the 1818 heliostats.

Even the conventional plant items were burdened with relatively high design costs. Necessary engineering expenses for these items are somewhat independent of the capacity of the plant item; thus the design cost is a large fraction of the total equipment cost, when the equipment capacity is small. For example, a small capacity turbine-generator set costs nearly the same to design as a larger unit.

The way the design costs are provided by the various contractors for the pilot plant is that the program management costs (as opposed to the fabrication management costs) are often stated as part of the design or engineering costs. The cost for engineered equipment required program management that was consistent (high) with the developmental nature of the products. These costs are generally not separable and are reported as a single cost in this report except for the heliostats.

The SCE design costs were for earthwork, visitor's center, office complex, control building, utilities, fencing, underground piping and electrical installations, turbine-generator procurement, and turbine-generator and equipment foundations. The SCE engineering and construction account was stated as one cost*. This cost is burdened by employee benefits, corporation overhead, and funds used during construction.

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*To separate the total SCE engineering and construction cost into accounts comparable with other pilot plant costs, the engineering design cost is assumed in this report to be two-thirds of their total engineering and construction cost. The remaining cost is assumed to be for construction management. It is also assumed that the allocation of the engineering design and construction management costs are proportional to the amount of the purchases or the construction contracts costs. Since the total engineering and construction cost is approximately the same as the total purchases and construction contracts costs, the indirect cost is nearly the same as the direct cost.

The design costs for the receiver system and the thermal storage system are based on data provided by T&B and MDAC. A system integration laboratory (SIL) was developed by MDAC to allow simulation of both the master control subsystem and the beam characterization subsystem at Huntington Beach, California. The SIL proved very useful in the design and development of the plant control system, as well as in training plant operating personnel. The cost for this facility is included in the design costs of the master control subsystem.

As in the case of the R&D accounts, the design account does not include some expenses that were incurred because of the developmental nature of the pilot plant. Several agencies were used by the DOE to manage, monitor, review, and assess the progress of the experimental program. These included SNLL, ETEC, Aerospace, and UCLA.

Part of the funds for the SHIMMS design were provided to the SFDI from the capital equipment and operations budget.

The design prices charged to the pilot plant for the various plant systems include direct labor, overhead, travel expenses, G&A and fee.

A summary of the design costs is shown in Table 4.

TABLE 4: DESIGN COST SUMMARY

Structures and Improvements	$ 820,265
Collector System	$ 4,581,943
Receiver System	$ 3,727,093
Thermal Transport System	$ 2,401,128
Thermal Storage System	$ 2,090,866
Turbine-Generator Plant	$ 3,462,314
Electrical System	$ 7,096,222
Miscellaneous Equipment	$ 382,959
Plant Level Design/Integration	$ 4,241,322
Total Plant Design Cost	$28,804,112

A breakdown of the the design costs incurred for the pilot plant are listed below:

Structures and Improvements- SCE		$ 820,265
Visitor's Center design, utilities	$ 175,000	
Other SCE design	$ 645,265	
Collector System		$ 4,581,943
Collector Field		
S-R Support	$ 153,926	
SFDI/U of Houston	$ 100,000	
Heliostats--MMC		
Engineering Design	$2,157,336	
Program Management	$1,337,146	
Beam Characterization System--MDAC		
Hardware Design	$ 236,658	
Software	$ 224,327	
S-R Support-Target	$ 89,443	
SHIMMS--SFDI		
Heliostat Instr.	$ 93,778	
Metro. Design	$ 189,329	
Receiver System--MDAC/Rocketdyne		$ 3,727,093
Steam Generator ($277,929 FW)	$ 775,612	
Core Structure	$ 83,989	
Controls & Instrumentation	$ 526,898	
Mechanical	$ 491,978	
Electrical	$ 134,560	
System Support	$ 136,144	
Indirects	$ 703,476	
S-R Support-Tower Integration	$ 460,363	
Thermal Transport System--MDAC/S-R/SCE		$ 2,401,128
S-R Support	$ 1,018,099	
SCE	$ 1,383,029	

Design Costs (continued)

Thermal Storage System--MDAC/Rocketdyne		$ 2,090,866
Heat Exchangers	$ 212,256	
Mechanical	$ 217,914	
Electrical	$ 71,195	
TSU	$ 173,876	
Controls & Instrumentation	$ 397,939	
System Support	$ 279,833	
Indirects	$ 280,351	
S-R Support	$ 457,502	
Turbine-Generator Plant--SCE		$ 3,462,314
Electrical System		$ 7,096,222
Master Control--MDAC		
Controls Devel.	$2,767,557	
Hardware Design	$ 852,856	
Software Design	$2,085,712	
SIL	$ 587,494	
S-R Support	$ 60,925	
Plant Electrical--SCE		
Miscellaneous Equipment--SCE		$ 382,959
SFDI Plant Design/Integration--MDAC		$ 4,241,322
Total Design Costs		$28,804,112

Factory Costs

Factory Costs

Factory costs of engineered equipment include product design and engineering, tooling design and fabrication, program management and planning for the factory and production, amortization of the factory facility and equipment, various factory overheads, the product materials, labor, and shipping charges to the plant site. In this report, factory costs have been segregated where possible. However, in many cases the cost of an item produced in a factory or purchased from a supplier appears as a direct material cost at the construction site.

The total costs of these individual purchased materials amount to millions of dollars and should be broken down further. Some items are standard equipment, such as a pump and driver or a transformer. These items have established costs and will have similar costs on subsequent purchases for other plants. Other items, such as heliostats, receiver panels, and thermal storage heat exchangers, are original designs made specifically for the pilot plant. Significant charges were incurred prior to fabrication and during the factory fabrication and assembly that would not be incurred again for a subsequent plant. These one-time costs need to be identified so costs for future plants of a similar design can be appropriately decreased.

In this section, the factory costs are broken down by plant systems. A summary of these costs is shown in Table 5. The factory costs for each of the plant systems are described in detail below.

TABLE 5: FACTORY COST SUMMARY

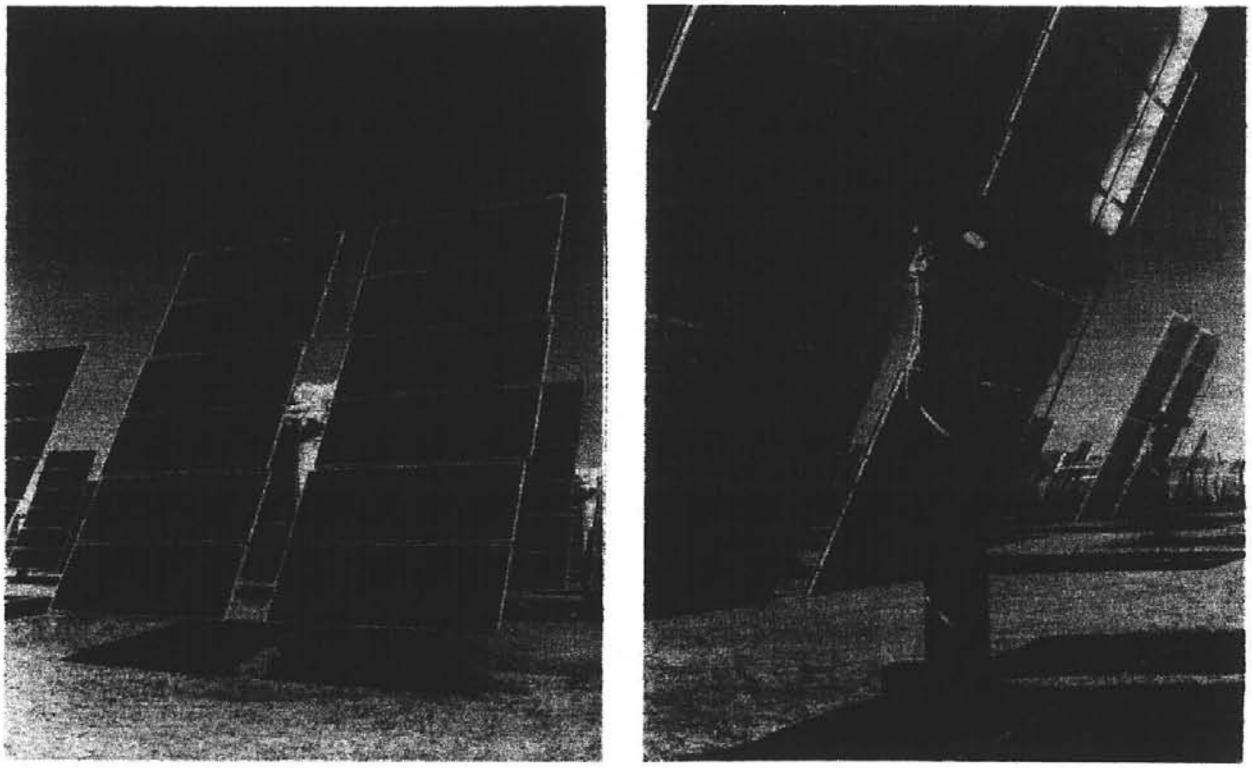
Structures and Improvements	$ 110,003
Collector System	$32,400,198
Receiver System	$13,779,978
Thermal Transport System	$ 2,402,786
Thermal Storage System	$ 4,712,618
Turbine-Generator Plant	$ 3,698,550
Electrical Plant	$ 2,638,403
Miscellaneous Equipment	$ 352,943
Total Plant Factory Costs	$60,095,479

Structures and Improvements--The structures and improvements account contains several factory-produced items that are delivered to the site for installation by a subcontractor. One example is the pumps that were provided as long-lead purchases by the SFDI but installed by a construction package subcontractor.

The structures and improvements account also includes several plant subsystems in which the equipment was furnished and installed by the subcontractor. These subsystems include raw water supply, waste drain, electrical and heating, ventilating and air conditioning (HVAC). The HVAC subsystem includes such items as air conditioners, humidifiers, fans, and other HVAC equipment that cannot be specifically charged to another system account. Few of these individual costs are known and many are not shown below, but are included in the total construction package charges in the construction section of this report.

Fire Protection	
Primary electric pump P705 (LLP)	$ 12,499
Secondary diesel pump P706 (LLP)	$ 29,601
Jockey pump P707 (LLP)	$ 1,074
Controllers for 3 pumps	
Fire extinguishers	
Power Cable (LLP)	$ 1,050
Control Cable (LLP)	$ 3,330
Raw Water Supply	
Raw water pumps (1/2 cap.) P703,P704	
Power Cable (LLP)	$ 10,253
Control Cable (LLP)	$ 431
Waste Drain	
Oil-water separator SE701	
Separator waste water pumps P711,P712	
Oil sump pump P714	
Separator sludge pump P716	
TSU area sump pump P717	
Maintenance area sump pump P718	
TSS flash tank drain pump P307	
Bldg 702 sump pump P715	
Polishing demin. sump pump P936,P937	$ 20,900
Electrical	
Motor Control Centers	
MCC C (LLP)	$ 6,651
MCC 4	
Power Panels and Transformers	
PP3, PP6, PP7	
Lighting Panels and Transformers	
LP3, LP6, LP7, LP8	
HVAC	
Other Structures & Improvements Cable (LLP)	$ 794
Misc. Directs and Distributed Indirects SCE	$ 3,807
Misc. Directs & Distributed Indirects (LLP)	$ 19,613
Total Structures & Improvements Factory Costs Identified	**$110,003**

Collector System--Items made in a factory for the collector system include parts of heliostats (Figure 8), parts of the beam characterization system, special instrumentation and parts of the heliostat electrical field wiring.



Front View   Rear View

Figure 8: Heliostat

The total collector system factory cost is summarized in Table 6.

TABLE 6: COLLECTOR SYSTEM FACTORY COST SUMMARY

Heliostats	$30,978,356
Collector Field Electrical	$ 688,534
BCS	$ 416,635
SHIMMS	$ 316,673
Collector System Total Factory Cost	$32,400,198

Heliostats--When the pilot plant heliostats were fabricated, heliostat parts for a central receiver plant located in Spain (sponsored by the International Energy Agency) were made at the same time by the same factories and under the same contract. However, the total contract expenses of the Barstow heliostats and the IEA heliostats have been allocated separately, so the total price noted in this report for the pilot plant heliostats is correct. The pilot plant heliostat cost is part of the construction funds, while the IEA heliostats were charged to the operating expense account. The method of subtracting the IEA costs for individual accounts was based on data provided in Appendix E.

Spare parts for the heliostats were provided from the operations budget as an operating expense of about $135,000.

Two major heliostat items were made in factories and delivered to the Daggett airport facility for final assembly with other parts.* These were the mirror modules made at Pueblo, Colorado, and the controllers--heliostat controllers (HC) and heliostat field controllers (HFC) made at Denver, Colorado.

Some other major parts were purchased from suppliers and also shipped to the Daggett airport facility for final assembly. These included parts for the rack assembly--torque tube and bar joists; drive mechanism assembly--gear drive, motors, encoders, control arms, cable harness and pedestal interface adapter; and pedestal assembly.

An approximate breakdown of the factory costs for the 1818 pilot plant heliostats follows. The costs for the heliostats are provided in as-spent dollars (Ref. 11). The fee is included in the costs, so the value is actually the price paid.

Mirror Module Fabrication--The mirror modules were made at Pueblo, Colorado, using subcontracted labor. The management and supervision were provided by MMC. The modules were fabricated from January 1981 through August 1981 at a rate varying from a minimum of 100 to a maximum of 200 modules per 24-hour day (3 shifts).

*Warehouse space at the Daggett airport, located about 2 miles east of the pilot plant, served as an assembly facility for the heliostat production.

The direct materials prices for the pilot plant heliostats included the following:

Aluminum honeycomb		$2,582,451
Glass (DOE contract with Ford)		$ 823,818
Silvering glass		$ 804,247
Coil steel		$ 541,219
Clips		$ 272,100
Doublers		$ 137,732
Glues and sealers		$ 646,226
Cybond	$220,087	
Dow 795	$ 74,174	
Versilok		
Base	$171,310	
Accelerator	$ 35,560	
Polyisobutylene (PIB)	$ 76,138	
Semkips	$ 68,957	
Rivnuts		$ 73,593
Miscellaneous parts		$ 150,130
Total direct materials cost		$6,031,542
Freight Cost for Materials into Pueblo		$ 194,635
Total Materials & Freight Cost @ Pueblo		$6,226,177

The cost of glass before cutting, storing, handling, and recutting was about $0.30/ft^2. Additional costs were incurred for storage, cutting, and handling to bring the total glass costs charged to the 1818 heliostats to $1.07/ft^2. About 20% of the glass that was delivered was not used in the heliostats at the pilot plant. See Appendix E2 for further details concerning the cost of the pilot plant glass.

Labor costs (including overhead and travel and relocation expenses), costs for the facility lease at Pueblo, costs for the materials used for tooling, and G&A were incurred in the production of the mirror modules.

Subcontracted manufacturing labor	$2,123,042
Management/Supervision	$ 911,309
Total Labor & Overhead	$3,034,351
Facility lease	$1,095,563
Materials for tooling	$1,328,940
G&A	$ 755,997
Total Indirects	$3,180,500
Total Price of Mirror Modules	$12,441,029

Heliostat Controller Fabrication--The 1818 heliostat controllers (HC) and 64 heliostat field controllers (HFC) were fabricated at Denver, Colorado, by MMC. The fabrication took place from November 1980 through May 1981. The two heliostat array controllers (HAC's) were furnished during the Phase I R&D program. Items other than these GFE computers ($44,544 or $24.50 per heliostat from the operations budget) are part of the controls account, as are miscellaneous other items.

The cost of the direct materials for the heliostat controls are:

HC/HFC	$1,350,320
Computer accessories	$ 195,417
Miscellaneous parts	$ 151,039
Total direct materials	$1,696,758
Freight on materials into Denver	$ 124,569
Total materials & freight	$1,821,326

The cost of labor, including overhead and travel expenses, tooling materials, manufacturing materials, and G&A for the heliostat controllers was:

Manufacturing labor	$1,035,096
Management/Supervision	$ 37,287
Tooling Materials	$ 409,177
Manufacturing Materials	$ 50,250
G&A	$ 436,775
Total Labor & Indirects	$1,968,585
Controls Price	$3,789,912

The above parts were then shipped to the Daggett assembly facility along with parts from suppliers. The major heliostat assemblies made at the Daggett facility were the reflective assembly and the drive mechanism assembly. These assemblies used the same facility and personnel; costs for each are difficult to separate, except for the direct materials.

Reflective Assembly--The reflective assembly consists of 12 mirror modules and the rack assembly. The rack assembly consists of the torque tube and four bar joists.

Final assembly took place at the Daggett airport from February 1981 through September 1981 at a rate varying from 2 to 18 assemblies per 8-hour day.

The cost for the direct materials is as follows:

Mirror modules (from the Pueblo facility)	$12,441,029
Torque tube	$ 1,349,011
Bar joists	$ 307,478
Direct materials cost for reflective assembly	$14,097,517

Drive Mechanism Assembly--This mechanism is composed of the gear drive with housing, the two gear motors and two encoders, the two control arms, the cable harness and the pedestal interface adapter. The parts were made elsewhere and were shipped to Daggett for assembly. The final assembly of the drive mechanism took place from November 1980 through July 1981 at a rate varying from 1 to 18 assemblies per 8-hour day.

The direct materials costs for the major parts of the drive mechanism assembly are as follows:

Gear drive (with housing)	$5,489,560
Motors	$ 592,959
Encoders	$ 557,690
Control arms	$ 522,730
Cable harness	$ 330,876
Pedestal interface adapter	$ 372,545
Drive mechanism assembly direct materials cost	$7,866,341

Pedestal Assembly--Factory-made pedestals were delivered to the site for installation on the foundations.

Charges for direct materials for the pedestal are:

Pedestal	$ 935,488
Miscellaneous parts	$ 262,374
Pedestal assembly direct materials cost	$1,197,862

The cost for labor at the Daggett assembly facility includes overhead and travel and relocation expenses. The MMC management/supervision cost includes expenses for final assembly as well as for the site installation. (It was assumed that one-half was for final assembly and the other half for site installation.) Other costs include freight charges for all of the material shipped into Daggett, lease charges for the airport facility, tooling materials, and G&A as follows:

Subcontracted assembly labor	$ 1,038,023
Management/Supervision	$ 573,543
Freight into Daggett	$ 752,579
Lease	$ 427,285
Tooling materials	$ 240,485
Start-up materials	$ 19,525
G&A	$ 975,284
Total cost for Daggett assembly	$ 4,026,725
Total price for heliostats before installation, including glass cost	$30,978,356

The factory cost for the heliostats is summarized by major part and cost element in Table 7.*

TABLE 7: HELIOSTAT FACTORY COST SUMMARY

Heliostat Cost by Major Part:	
Reflective Assembly	$14,097,517
Drive Mechanism	$ 7,866,341
Controls	$ 3,789,912
Pedestal	$ 1,197,862
Assembly/Indirects/Freight into Facilities	$ 4,026,725
Heliostat Total Factory Cost	$30,978,356

Heliostat Cost by Cost Element:	
Direct Material	$18,448,991
Management/Supervision Labor, Travel	$ 1,522,139
Manufacturing Labor	$ 4,196,162
Facility Lease and Equipment Depreciation	$ 1,522,848
Tooling Materials	$ 1,978,602
Manufacturing, Start-up Materials	$ 69,775
Freight into Facilities	$ 1,071,784
G&A	$ 2,168,056
Heliostat Total Factory Cost	$30,978,356

*See next page

Collector System Field Electrical--Factory-furnished electrical equipment associated with the collector system are of two types: long-lead purchases (LLP) that were provided to the electrical contractors for installation, and the equipment supplied by the electrical contractors. The contractor-supplied material costs are not known, but the LLP items are as follows:

Collector field lighting power cable		$ 9,903
5000 volt load interrupter switchgear		$ 11,064
Spare parts		$ 124
I/F control cabinets-2 each		$ 744
Heliostat power centers--14 each		$ 82,614
Spare parts		$ 359
Watt transducers		$ 5,411
Watt transducers cable		$ 4,058
Power cable--5000 V		$ 73,290
Power Distribution Cable--600 V		$146,912
4C # 4 16,000 ft	$ 32,472	
4C # 6 11,000 ft	$ 17,889	
4C # 8 3,140 ft	$ 5,478	
4C #10 105,000 ft	$ 91,073	
Coaxial Control Cable		$194,973
RG22M 190,000 ft	$191,595	
RG22 4,500 ft	$ 3,378	
Grounding Cable		
1C #10 7,000 ft		$ 759
Misc. Directs & Distributed Indirects		$158,323
Total Collector Field Electrical Factory Cost		$688,534

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*Most of the various indirect costs are charged to the pilot plant heliostats for the one-time build. Actually, 1912 heliostats were produced, with 93 being sent to Spain for the IEA/SSPS plant and one being used for testing at the CRTF. The charges for the 93 heliostats sent to Spain were based on early predictions of the total heliostat prices, and thus did not account for the actual heliostat prices. The direct materials costs for these heliostats were close to the actual costs, but the labor and indirects were underestimated.

The DOE provided a total of $1,115,027 for the Spanish heliostat parts (or $11,989.54 per heliostat) excluding computers, final assembly, shipping and installation; this total included $45,750 for the glass. These charges were paid out of operating funds and are not part of the DOE capital costs for the pilot plant.

Beam Characterization System--Another part of the collector system that incurred factory costs is the beam characterization system (BCS). Most of the factory-produced items, unless noted, were obtained by MDAC. The cable was a long-lead procurement by MDAC/S-R. The costs for BCS items made in a factory before delivery to the site were:

BCS Target & Shutter Control (LLP)	
Targets (4) & Shutters (12)	$ 96,589
Target Painting	$ 31,050
SFDI/MDAC-Supplied Equipment	$195,841
Tower-Located Equipment	
Radiometers (16)	
MODACS III A/D	
BCS Video Assembly	
Video Cameras	
Cameras Receiver Units	
BCS Camera Control	
Control Room Equipment	
Equipment Room Equipment	
Data Evaluation Room Equipment	
Electrical Equipment	
MCC 6	
BCS Power Cable (LLP)	$ 3,747
Control Cable (LLP)	$ 5,522
RG11 Coaxial Cable (LLP)	$ 32,869
Other Instrumentation Cable (LLP)	$ 247
Misc. Directs and Distributed Ind. (LLP)	$ 50,770
Total BCS Factory Cost	$416,635

Special Instrumentation--Special instrumentation was provided for meteorological weather stations and for the heliostats. Since the weather information can affect the operation of the collector system, all of the costs are listed here. It is assumed that one-half of the meteorological station expense was design and the remainder was equipment. As mentioned before, some of the SHIMMS costs ($93,778) was paid for from the capital equipment and operations budgets. These costs include:

Weather Station Power
- 4160/120 V transformer
- Power Panels PP8 & PP9

Meteorological Station	
Equipment (SFDI)	$ 189,329
Remote Aquisition Systems (6)	
Data Behavior Analyzer	
SHMS 905--Cyber	
Translator--Climet Instruments	

Special Instrumentation Costs (continued)

Spares (SFDI)	$ 7,484
Meteorological Sta Power Cable (LLP)	$ 2,888
Meteorological Sta Control Cable (LLP)	$ 10,101
Instrumentation Cable (LLP)	$ 124
Heliostat Instrumentation Equipment (SFDI)	$ 102,831
Misc. Directs & Distributed Indirects (LLP)	$ 3,916
Total SHIMMS factory cost	$ 316,673
Total Collector System Factory Cost	**$32,400,198**

Receiver System--The factory costs of the receiver system include those for a steam generator composed of six receiver preheat panels RP201-RP203 and RP222-RP224, eighteen receiver boiler and superheat panels RB204-RB221, and two spare receiver boiler/superheat panels RB225 and RB226 ($72,000 from operations budget). A core support to which the panels are mounted and a transition structure which mates the core support to the tower structure complete the receiver structure. Controls and instrumentation, other general or miscellaneous charges, and indirects are also part of the factory costs. These items were designed and fabricated before being sent to the construction site for final assembly.

Rocketdyne produced the receiver in two phases. The price of the first phase ($4,997,879) included fabrication of the various parts and the facility to produce these parts. Long-lead items were also procured. The price of the second phase ($8,016,961) included the continuing facility tooling and the fabrication and assembly of the receiver parts. The design costs are shown in the design section of this report. A breakdown of these receiver factory costs is based on data supplied by T&B.

Other factory costs were incurred. These include costs for long-lead purchases of 2-1/2 in. and larger pipe and pipe fittings and electrical cable by S-R and a distributed amount of the SDPC equipment provided by Beckman Instruments through a subcontract to the SFDI. It is assumed that the SDPC equipment cost was shared equally, in thirds, by the receiver system, the thermal storage system, and the turbine-generator plant system.

Receiver System Factory Costs

Steam generator	$ 6,423,001
Controls & instrumentation	$ 820,500
Solid state relay box	
Remote station 1 equipment	
General	
Misc. material & labor	$ 1,438,230
Engr & mfg planning	$ 1,776,592
Engr & mfg tooling design/fab	$ 1,211,134
Indirects	
Misc. directs & indirects	$ 1,345,383
Subtotal MDAC/Rocketdyne receiver factory cost	$13,014,840
2-1/2 in. and larger pipe and fittings (LLP)	$ 160,470
Power panels & associated transformers PPA, PP1, RSP1	
Remote station panel RSP3	
Power cable (LLP)	$ 7,740
Control cable (LLP)	$ 295
Other instrumentation cable (LLP)	$ 72,878
Remote station RS1 I&C cable (LLP)	$ 14,126
Misc. directs & distributed indirects (LLP)	$ 76,296
SDPC equipment (1/3 of Beckman cost)	$ 433,333
ILS 101--Beckman	
SDP 101-110--Beckman	
Subtotal other receiver system factory costs	$ 765,138
Total receiver system factory costs	**$13,779,978**

Thermal Transport System--Some items for the thermal transport system were built at a factory and delivered to the plant site for installation. Major items include feedwater pumps, and feedwater conditioning--heaters, deaerator, demineralizers, and other heat exchangers to condition the steam flow during start-up.

The costs of major factory-produced items, mostly provided by SCE, include:

Receiver feedwater pump P917 (LLP)	$ 314,216
Bingham-Willamette 800 hp	
P917 power cable (LLP)	$ 2,162
P917 control cable (LLP)	$ 86

Thermal Transport System Factory Costs (continued)

TSS feedwater pump P903 125 hp	$ 34,000
Condensate storage tank Tk902	$ 33,254
Atlas tank 24,000 gallon	
Condensate hotwell pump P907	$ 11,700
Peerless pump 75 hp	
Condensate polishing system	$ 247,400
Crane Cochrane	
Acid, caustic day tanks Tk908/Tk909	
Joor Manufacturing	
Heater H905 w/Tk909	
Acid feed pumps P931,P932 &	
Caustic feed pumps P919,P920	
Gregory Pump	
Caustic dilution water HXC E910	
In-line demineralizer vessels V901,V902	
Regeneration vessel V903	
Sluice water pumps P939, P940	
Feedwater Htrs E902,E903, E904	$ 127,600
Struthers-Wells	
Deaerator DA901 (3rd point heater)	$ 33,000
Marley Co (Chicago Heater)	
Main steam desuperheater DS901	
Graham	
Auxiliary steam desuperheater DS902	
Water treatment transfer pump P710	
Acid storage tank Tk915	$ 11,000
Joor Manufacturing	
Acid transfer pump P935	$ 2,062
Gregory Pump	
Caustic storage tank Tk916	$ 6,000
Joor Manufacturing	
Caustic transfer pump P943	$ 6,700
Condenser/Deaerator chemical feed	
J. Crowley	
Ammonia tank Tk914 & pump P934	$ 3,500
Ammonia drum & pump	
Hydrazine tank Tk913 & pump P933	$ 3,500
Hydrazine drum & pump	
Piping spools 2-1/2 in. & larger alloys (LLP)	$ 259,265
Piping (SCE)	$ 210,000
Valves	
SFDI (LLP)	$ 119,813
Valve spares (LLP)	$ 12,214
SCE (LLP)	$ 39,695
Valves (SCE)	
Non-return	$ 47,296
Relief	$ 11,800
Gate, globe, check	$ 27,500
Control	$ 50,000
Motor-operated	$ 15,000

Thermal Transport System Factory Costs (continued)

Hangers (LLP)	$ 29,623
Snubbers (LLP)	$ 103,839
Power cable (LLP)	$ 2,795
Control cable (LLP)	$ 962
Instrumentation cable (LLP)	$ 3,754
Structural steel for Aux. bay (SCE)	$ 175,300
Misc. Directs & Distributed Indirects (LLP)	$ 265,286
Misc. Directs & Distributed Indirects (SCE)	$ 192,464
Total Thermal Transport System Factory Cost	**$2,402,786**

Thermal Storage System--Much of the thermal storage system (Figure 9) was fabricated at a factory and shipped to the Barstow site on skids. The thermal storage system heat exchangers, designed by PFR Engineering for Rocketdyne, were fabricated by Wiegmann and Rose International Corporation, and assembled on skids by Southern Mechanical. The total design and fabrication task was broken into two phases. The first phase was mostly design and prefabrication, while the second phase concentrated on fabrication and assembly. Since the pilot plant thermal storage system was a unique design, considerable expense was required for design and analysis. The design costs are included in the design section of this report.

The skids contained most of the heat exchangers, pumps and drivers, accessory equipment such as the ullage maintenance unit, and steam conditioning equipment. There were ten skids of equipment shipped from factories in the overall equipment list. The balance of the equipment was not skid mounted.

The thermal storage system charging heat exchanger includes equipment such as the condenser and subcooler to heat or charge the storage oil (circulated with the two charging oil pumps) with solar-generated steam, while the extraction heat exchanger includes equipment such as the preheater, boiler and superheaters to generate steam or extract heat from the hot oil (circulated with the two extraction oil pumps). In each case there are two trains (or two of each component) to provide full capacity and a 20:1 turn-down ratio using both trains. The seal steam is provided by circulating oil with the auxiliary extraction oil pump.

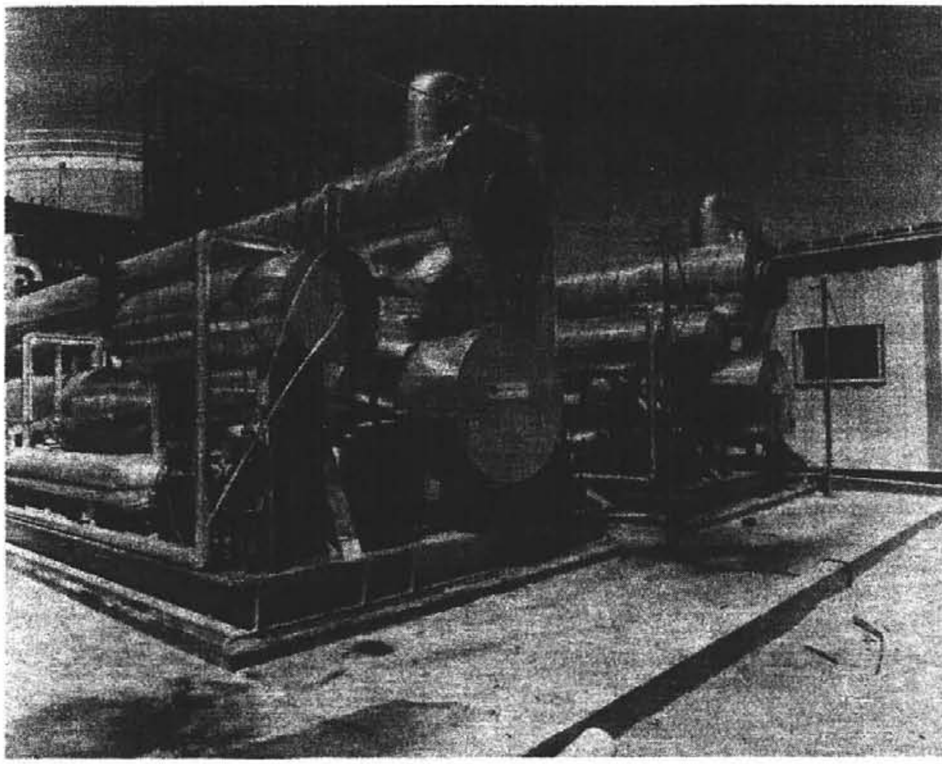

Figure 9: Thermal Storage System Skid-mounted Equipment

A detailed list of the skid-mounted equipment is shown below. The rest of the thermal storage system was assembled at the site. The factory costs shown are based on data provided by T&B. Piping and fittings, valves, electrical cable and electrical equipment were provided by S-R as long-lead procurement items.

Skid No.	Equipment	
SA 301	DS301,V304 desuperheater, flash tank	$ 157,486
SA 302	V305,V309,E301,E311 drain tank, surge tank, condenser, subcooler	$ 329,402
SA 303	V306,V310,E302,E312 drain tank, surge tank, condenser subcooler	$ 329,402
SA 304	P301,P302 charging oil pumps	$ 132,391
SA 305	E303 preheater	$ 105,350
SA 306	E304 preheater	$ 105,350
SA 307	E305,E307 boiler, superheater	$ 299,119
SA 308	E306,E308 boiler, superheater	$ 299,119
SA 309	P303,P304,P305 extraction oil pumps, auxiliary oil pump	$ 107,097
SA 311	P308,FA301/FA302,Tk302 ullage maintenance unit pump, blowers, tank	$ 124,707

Thermal Storage System Factory Cost (continued)

Thermal storage unit items	$ 69,911
Controls & instrumentation	$ 327,399
RS2 instrumentation box	
RS2-2-1 T/C reference junction box	
RS2 solid state relay box	
RLU-201--Modicon 584 programmable controller & Lambda power assembly	
SCU 201, SCU 202	
RS3 instrumentation T-box	
RS3-2-1 T/C reference junction box	
RS3 solid state relay box	
SCU 301	
Spares	$ 136,976
Indirect costs	
Misc. direct & indirect costs	$1,562,804
Subtotal for MDAC/Rocketdyne Thermal Storage System Factory Cost	$4,086,513

Hangers (LLP)	$ 5,750
Caloria make-up pump P306	
TSS blowdown tank V308	
Foam fire protection apparatus	
Load center A and transformer & LV switchgear (LLP)	$ 44,968
Low voltage non-segregated bus duct (LLP)	$ 5,671
Spare parts (LLP)	$ 7,213
Motor control centers	
MCC B	$ 9,328
MCC 1, MCC 2, MCC 3	
Power panels and transformers	
PP2, PP4, PP5	
Lighting panel LP4 and transformer	
Power cable (LLP)	$ 29,788
Control cable (LLP)	$ 2,853
Instrumentation cable (LLP)	$ 24,357
Remote station 2 RS-2 cable (LLP)	
Power cable	$ 1,472
Control cable	$ 99
Instrumentation cable	$ 7,710
Remote station 3 RS-3 cable (LLP)	
Power cable	$ 358
Control cable	$ 109
Instrumentation cable	$ 10,092
Misc. directs & distributed indirects (LLP)	$ 43,004

Thermal Storage System Factory Cost (continued)

SDPC (1/3 Beckman costs)	$ 433,333
ILS 201, ILS 301--Beckman/Modicon	
SDP 201-205--Beckman MV 8000	
DARM 201, DARM 202--Cyber	
ILS 301--Beckman/Modicon	
SDP 301-305--Beckman MV 8000	
DARM 301, DARM 302--Cyber	
Subtotal Other Thermal Storage System Factory Costs	$ 626,355
Total Thermal Storage System Factory Costs	**$4,712,618**

Turbine-Generator Plant System--The turbine-generator plant system has a number of major purchased or SCE-provided items (Ref. 12). These items were produced in a factory and shipped to the Barstow site for assembly, erection or installation.

Major Equipment--The major items of purchased engineered equipment are as follows:

Steam turbine/generator TG901 GE Lube oil system (reservoir Tk906, 10 hp AC pumps P926,P927, 7.5 hp DC pump P928, coolers E908, E909, heaters H901 A-F, reservoir vapor extractor P945, centrifuge PR901 with 2 - 1 hp motors), hydraulic oil system (pumps P938A, P938B, tank Tk923, coolers E911A, E911B, heater H903, filter and pump P944, and air dryer DR903), turning gear (1 1/2 hp) ME901, turbine lagging blowers 1/4 hp FA904, 1/2 hp FA905 A-D, generator air coolers E912 A-D, gland steam exhaust pump P941, safety release blowdown tank Tk924	$2,221,517
Condenser E901 Ecolaire & Allegeny Ludlum 2210 gallon	$ 123,500
Condenser tubing	$ 57,900
Condenser vacuum pump P910 Nash Engineering Co 40 hp	$ 37,500
Circulating water subsystem:	
Cooling tower CR901 Baltimore Aircoil Prichard	$ 153,300
Circulating water pumps P905,P906 Peerless pump 100 hp	$ 22,396
Fiberglass circulating water pipe	$ 51,499
Cooling tower transformer CTX1	$ 10,300

Turbine-Generator Factory Cost (continued)

Circulating water treatment:	
Sulphuric acid tank Tk904	$ 11,000
Joor Manufacturing	
Pump P912, Chemcon	$ 2,062
Sodium hypochlorite tank Tk922 (SCE)	$ 6,501
Pump P930 (SCE)	
Sodium polyacrylate tank Tk905, Pump P923	
Calgon Corporation	
Valves (LLP)	$ 56,486
RS4 instrumentation & control cable (LLP)	$ 2,340
Misc. directs & distributed indirects (LLP)	$ 17,566
SDPC (1/3)	$ 433,333
ILS 401-403	
SDP 400, SDP 401-406	
SCE Misc. directs & distributed indirects	$ 491,350
Total Turbine-Generator Factory Cost	**$ 3,698,550**

Electrical System--The electrical system utilizes a number of factory-produced pieces of equipment. Such items include:

Main transformer MX1	$ 48,400
(Westinghouse 33 to 4kV 10MVA)	
Circuit breaker (34.5kV 1500MVA 1200A)	$ 5,000
Station service transformer SX1	$ 10,300
(General Electric 75 kVA)	
Switchgear, MCC's, LC's	$ 152,613
480 volt switchgear B01, B02	
MCC's BOA & BOL	
4160V switchgear A01 (350MVA)	$ 12,000
15KV generator switchgear GS	$ 8,000
Auxiliary transformer AX1	$ 15,000
Federal Pacific-- from Mohave Vertical Scrubber project (13.8 to 4kV 18MVA)	
Uninterruptible power supply (UPS)	$ 73,567
Exide Electronics	
DC power system	
Battery bank & rack	$ 12,835
Battery charger	$ 4,000
DC control & distribution switchboard	$ 27,000
Power cable	$ 75,000
Control & instrumentation cable	$ 25,000
Watt transducers (LLP)	$ 4,084
SCE misc. directs & distributed indirects	$ 85,468
Electrical System Factory Subtotal	$ 558,767

The master control subsystem is considered a part of the electrical system.

Master Control Subsystem--The master control subsystem (MCS) is designed by MDAC.

The master control subsystem includes computers and associated equipment to control and assess the plant operation. Each system is charged with the necessary instrumentation and valves required to respond to the master control subsystem; however, the necessary equipment, buildings, and wiring, even if specific systems are removed, belong to the master control subsystem. Data are also recorded for use during plant evaluation. Most of this data acquisition system (DAS) would not necessarily be required for subsequent plants of equal or larger size. The DAS currently records about 705 channels of information for data evaluation while also recording data that are used by the operational control system (960 channels).

The master control subsystem includes many purchased items. These include items provided by MDAC. The cost of the SDPC by Beckman has been distributed to the Receiver (RS-1), Thermal Storage (RS-2 and RS-3), and the Turbine-Generator Plant (RS-4) systems equally in thirds ($433,333 each). Costs allocated to the master control subsystem are:

MCS fabrication/procurement--SFDI		$2,079,636
Multiplexers--Cyber		
Computers, signal conditioning and multiplexers--Modcomp		
Operation Control System (OCS)*		
OCS 601-606, OCS 701, OCS 801-802, CON 700-29/30	$ 187,105	
Data Acquisition System (DAS)		
DAS 601-610, DAS 801-812	$ 209,090	
DAS add-on equipment	$ 36,565	
Other	$1,646,876	
Subtotal Master Control Factory Cost		$2,079,636
Total Electrical System Factory Cost		**$2,638,403**

*The equipment for the master control system is numbered with the 600 series being located in the control building equipment room, the 700 series being located in the control building control room, and the 800 series being located in the control building data aquisition room.

Miscellaneous Plant Equipment--The miscellaneous plant equipment category includes:

Auxiliary steam subsystem:		
Electric auxiliary boiler B901 Hydro-Steam Industries	$	44,100
Auxiliary boiler/thermal storage pump P904 Aurora Pump (Evans Pump Equipment)	$	1,000
Auxiliary boiler transformer AXB 1500KVA	$	15,602
Equipment cooling water subsystem:		
Cooling water heat exchanger E905 Southwest Engineering	$	43,331
Cooling water pump P901 Peerless Pump	$	2,440
Cooling water surge tank Tk901 Joor Manufacturing	$	5,800
Service & instrument air subsystem:		
Air compressors CP901,CP902 Gardner Denver Air cooler/moisture separators CR902, CR903, prefilters F903, F904, air dryers DR901, DR902, and afterfilters F901, F902	$	88,991
Chemical analysis system--Beckman	$	97,098
Water sample subsystem: Sample chiller pump P925 Sample chiller unit CR907 Sample coolers SC907 through SC911		
Nitrogen vaporizer supply unit SA701 (rental) Nitrogen skid power cable (LLP)	$	234
Miscellaneous direct & distributed indirect cost (SCE)	$	54,347
Total miscellaneous equipment factory cost	**$**	**352,943**

The total factory costs	$60,097,187

Construction Costs

Construction Costs

The construction cost includes materials used or fabricated at the site, labor used for site fabrication and installation, labor used for installation of factory-supplied equipment, construction overhead and profit.

Construction costs were incurred from the beginning of construction (September 1979) until roughly April 1982.

A summary of the construction costs is shown in Table 8 and described in detail for each plant system below.

TABLE 8: CONSTRUCTION COST SUMMARY

Structures and Improvements	$ 3,756,047
Collector System	$ 6,944,235
Receiver System	$ 5,063,516
Thermal Transport System	$ 2,713,520
Thermal Storage System	$ 6,373,498
Turbine-Generator Plant	$ 2,979,919
Electrical Plant System	$ 1,620,862
Miscellaneous Equipment	$ 253,232
Plant Level Costs	$13,306,454
Total Construction Cost	$43,011,283

Land--The rectangular fenced site area designated for the facility by SCE is 130 acres. The area breakdown is as follows:

	Acres
Collector field	78.2
Core	2.8
Access roads (perimeter road, north-south and east-west spoke roads and core perimiter road)	4.2
Space between outer heliostat rows and perimeter road	16.6
Area between perimeter road and fence	28.2
Total area	130.0

The land costs are for a total of 130 acres. The cost is for unimproved land. However, the land is adjacent to the Cool Water Power Generation station and near an improved road. Approximately 60% of the land area is necessary for the heliostats; therefore, 60% could be allocated to the collector system. The remaining 40% could be allocated to the plant land account. (This separation is used in this section to allocate site improvement costs to a given plant system.) In this report, land cost is charged entirely to the land account, but is not part of the construction cost since the land was already owned by SCE.

Heliostat Field (60% of land area)	$150,385
Balance of Plant (40% of land area)	$ 99,615
Total Land Construction Cost	$ 0

Structures and Improvements--The structures and improvements account includes general plant charges that cannot be specifically allocated to other plant systems as well as charges that belong to several plant systems but cannot be easily allocated to those systems. For the SCE fencing account, 75% of the cost was allocated by the author to the collector system, and the remainder is charged to this structures and improvements account.

The Visitor Center incurred costs of $167,468 from the operating budget for exhibits, and $322,666 for operation from July 18, 1980, to September 30, 1982; the administration building was provided by SCE with only miscellaneous installation charges.

Items are listed below:

Visitor Center	
(CP4)	$ 343,403
Furnishings, supplies, audio-visual equipment--T&B	$ 50,000
Refurbish, mount scale model--SCE	$ 15,000
Administration Building BL902 (SCE)	$ 20,300
Warehouse BL703 (CP3)	$ 254,005
Wind bracing (CP5)	$ 1,036
Guard Building BL704 (SCE)	$ 1,000
Restrooms (SCE)	$ 103,220
Control Building BL901 (SCE)	$ 740,531
Control Building Elevator (SCE)	$ 40,500
Raw/service water supply building	
Foundation (CP7)	$ 44,424
BL702; 880 sq. ft (CP5)	$ 50,531

Structures and Improvements Construction Cost (continued)

Secondary fire pump building	
Foundation (CP7)	$ 59,232
BL706; 280 sq. ft (CP5)	$ 16,875
Access road and helistop (SCE)	$ 119,500
Parking and roads (CP1)	
Fine grade	$ 14,213
Paving	$ 303,170
Poles	$ 2,534
Fencing (SCE)	$ 10,925
Clearing and grubbing (CP1)	$ 44,312
Stripping alfalfa (CP1)	$ 8,034
Culverts & riprap (CP1)	$ 33,584
Concrete-lined ditch (CP1)	$ 60,594
Yard drain piping (CP7)	$ 34,172
Drainage ditches/culverts at North and East gates CP7A c/o #002	$ 5,047
Waste drainage (SCE)	
Sanitary facilities (SCE)	
Excavate, compact tower area (CP1)	$ 134,497
Excavate cooling tower area (CP1)	$ 34,237
Raw water supply	
Well A (CP1)	$ 17,308
Water well & line A electrical tie-in (SCE)	
Foundation (CP7)	$ 52,113
Raw water tank TK701 (CP10A)	$ 64,867
Misc. installation (CP9)	$ 6,471
Raw water pump cont. (CP11)	$ 7,988
General fire protection (CP9)	$ 826,932
Exterior/Interior lighting (CP11)	
Procure	$ 65,676
Install	$ 21,316
General lighting & communication Installation (SCE)	$ 43,095
Power, I&C cable installation	
Plant support instrumentation (50 channels)	
Miscellaneous direct & distributed indirect costs (SCE)	$ 105,404
Total Structures & Improvements Construction Costs	**$3,756,047**

Collector System--The collector system construction account includes field design, site improvements, foundations, field wiring, heliostat installation and checkout, BCS installation, and installation of special instrumentation and meteorological measurements.

The total heliostat field and heliostat construction cost is summarized in Table 9 and discussed in more detail below.

TABLE 9: HELIOSTAT FIELD AND HELIOSTAT CONSTRUCTION COST SUMMARY

Heliostat Field:	
Site Improvements (CP1 & SCE)	$ 476,698
Heliostat Foundations (CP6)	$1,193,945
Field Wiring (CP11A & Grounding)	$2,094,096
Heliostat:	
MMC Heliostat Installation	$2,198,071
Total Heliostat Field and Heliostat Construction Cost	$5,962,810

The heliostat layout was designed by MDAC with a subcontract to the University of Houston. The costs (about $100,000) appear in the design section of this report.

Some items required because of the large field are extra fencing, clearing, grubbing, and grading. Some of these items are allocated by contract to the collector system, while others will be estimated. For this report, 75% of the fencing cost is charged to the collector system since the heliostats necessitate roughly 75% of the periphery fencing. The cost of clearing and grubbing, stripping alfalfa and desert scrub, and grading the land occupied by the heliostats is charged to the collector system. This amounts to roughly 60% of the total clearing, grubbing and stripping costs based on the fraction of the total site area occupied by the heliostats. The grading cost for the heliostat field was charged to the collector field. However, to comply with more traditional accounting, the land is retained in the land account even though the heliostats occupy about 78 out of the 130 acres of land, or roughly 60% of the area.

The collector system site improvement account includes charges for:

Clearing and grubbing (CP1)	$ 66,469
Stripping alfalfa & desert scrub (CP1)	$ 12,051
Grading (CP1)	$362,202
Fencing (SCE)	$ 35,976
Total Heliostat Field Site Improvements Cost	$476,698

The collector system foundations contract (CP 6) included costs for heliostat foundations ($1,193,945), BCS foundations ($15,097), and SHIMMS foundations ($39,691) for a total of $1,248,733. The heliostat foundations amounted to:

1818 heliostat foundations 3 ft (0.91 m) diameter by 10 ft (3.05 m) deep	$1,167,524
14 transformer pads	$ 26,421
Total Heliostat Field Foundation Costs	$1,193,945

The heliostat field wiring (Ref. 14) and electrical costs were from several sources:

Field Wiring Contract (CP11A)	$2,005,452
Cable rodent shield grounding	$ 63,556
Grounding Update (CP11 c/o #042 FDCR 274)	$ 25,088
Total Heliostat Field Electrical Costs	$2,094,096

Heliostat parts that arrived at the site were installed in several major assemblies. After the foundations had been installed, the pedestal was bolted to the foundation. The next assembly consisted of the pedestal interface adapter--which connects the pedestal to the drive mechanism, the drive mechanism with motors, encoders and cable harness, and the control arms. This drive unit assembly was mounted on the pedestal, and the control assembly installed in the pedestal. Finally, the reflective assembly, consisting of the 12 mirror modules and the rack assembly, was installed. This reflective assembly fits on the control arms.

Installation of the collector field started in November 1980 and was completed in September 1981. The installation history of the above major assemblies is summarized below:

Assembly	Installation Start	Installation Complete	Units per Day Min	Units per Day Max
Pedestal	Nov 1980	June 1981	27	60
Drive	Nov 1980	Aug 1981	5	50
Control	Feb 1981	Sept 1981	10	40
Reflective	Feb 1981	Sept 1981	4	40

The installation of complete heliostats was as follows: 1st (February 23, 1981), 400th (May 6, 1981), 800th (June 19, 1981), 1200th (July 27, 1981) and 1818th (September 16, 1981).

The installation took about 7 months for the 1818 heliostats. This would average about 12 heliostats installed for each working day.

Installation at the site includes transporting the assemblies from the Daggett airport factory to the foundations, subcontracted installation labor, subcontracted field work on the electrical interface, and subcontracted labor to remove the front surface glass coating and perform other miscellaneous field work. Supervision was provided by MMC and includes travel and relocation expenses. As previously mentioned in the factory section of this report, one-half of the MMC supervision labor cost was allocated to the Daggett facility and the other half to the site installation activities. G&A is charged and the fee is included.

The site heliostat installation costs included:

Installation labor		$1,026,734
Other field labor		$ 461,917
electrical	$158,000	
glass coating removal, other	$303,917	
Installation supervision		$ 573,543
G&A		$ 135,877
Total Heliostat Installation Construction Cost		$2,198,071

The Beam Characterization System (BCS) is shown in Figure 10.

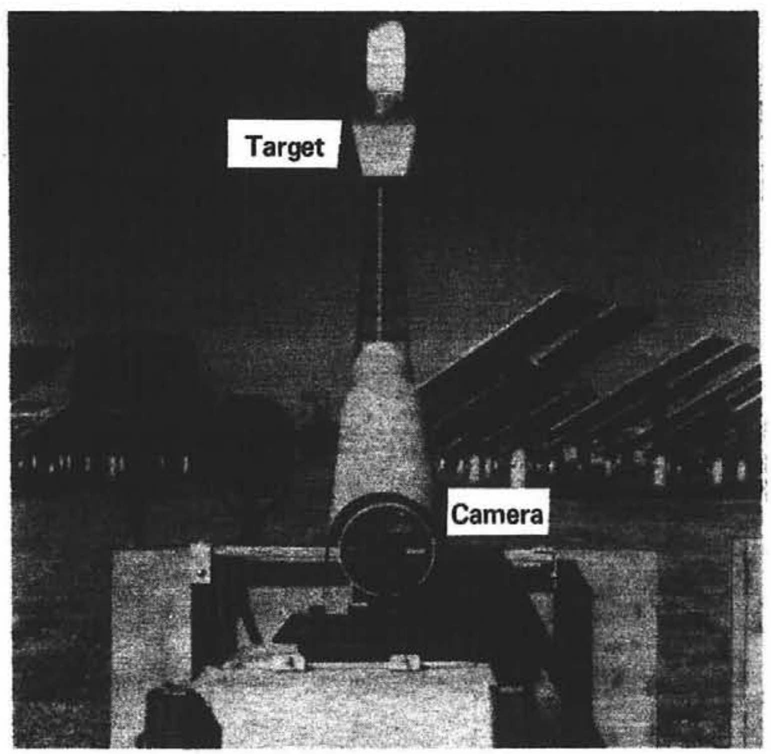

Figure 10: Beam Characterization System

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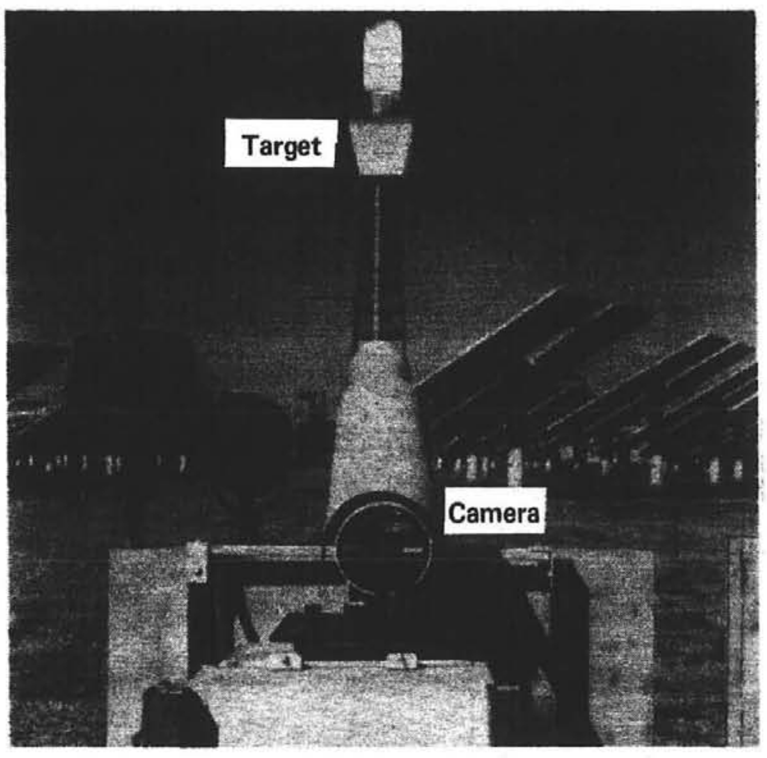

Figure 10: Beam Characterization System

For the collector system, the cost of the BCS installation was:

Target support (CP5A)		
Target installation		
Target assembly/installation (CP9)		$ 87,625
Modifications (CP9)		$ 61,024
FDCR 121	$28,457	
FDCR 159	$ 4,800	
FDCR 162	$27,767	
FDCR 207 (CP11)		$ 8,629
Insulation (CP12)		$ 10,429
Power cable installation (CP11)		
#8 4/c LLP	$ 3,747	
Instrumentation & control cable installation (CP11)		
#16 1 pair LLP	$ 247	
RG-22M LLP	$ 5,522	
GFE RG-11 LLP	$27,617	
BCS camera and equipment foundations (CP6)		$ 15,097
4 camera pads		
4 equipment pads		
Total BCS Construction Cost		$182,804

A total of 191 channels (126 + 65) are considered part of the Special Heliostat Instrumentation and Meteorological Measurement System (SHIMMS). Instrumentation includes 126 load cells on selected heliostats (3 with 36 load cells each and 3 with 6 load cells each), 46 other channels, and 65 channels of meteorological measurements. Most of the meteorological measurements deal with wind speed (25 channels), wind direction (13 channels) and insolation (12 pyranometers and 2 pyrheliometers).

Part of the cost of the installation of the SHIMMS was charged to the capital equipment budget ($227,000). The allocation was $47,899 in FY1981 and $179,101 in FY1982.

The costs for the special heliostat instrumentation amount to:

Meteorological procurement/installation	
CP11 c/o #009	$ 449,605
CP11 c/o #051 FDCR 247	$ 10,082
Heliostat instr. conduit CP11A FDCR 14	$ 64,410
EES & SWS Fnd. Mods CP11A c/o #007 FDCR 52	$ 7,961
SWS cable revisions CP11A c/o # 011 FDCR 97	$ 1,473
SHIMMS foundations (CP6)	
7 pyranometer pads	$ 7,609
Other pads	$ 32,082

SHIMMS Construction Cost (continued)

6 wind tower pads
4 weather station pads
6 hail cube pads
1 electrical environmental shelter foundation

Meteorological towers (CP5)	$ 73,000
SHIMMS electrical work (CP11)	
Procure cable c/o #001 FDCR 33	$ 108,927
Revision 2-2 c/o #014	$ 40,981
RG22 metro cable change for RG22M c/o #013 FDCR 129	$ 2,492
Power cable installation	
I & C cable installation	
Heliostat strain gages	
Meteorological equipment	
Total SHIMMS construction cost	$ 798,622
Total Collector System Construction Cost	**$6,944,235**

Receiver System--Some of the receiver system construction cost is derived from the assembly and installation of factory-made equipment that is delivered to the pilot plant site. Other materials are delivered to the site, fabricated and erected. The receiver panels are an example of the former, while the receiver tower or foundation are examples of the latter.

The receiver, tower, high-pressure piping, and supports are designed for the uniform building code (UBC) seismic zone IV. The pilot plant is located in UBC zone III. This decision was made on the basis of conservatism--the hope being that the plant would survive a probable event and remain operational. This definition implies that anything requiring long-lead procurement would not only survive, but remain operational.

The receiver system account includes cost for:

Receiver tower (CP5A)	$1,484,859
Personnel hoist (CP5A)	$ 120,047
Maintenance crane (CP5A)	$ 110,094
Crane removal, hoist work (CP11)	$ 143,557
Receiver tower B201 work (CP5)	$ 35,870
Tower foundation (CP7A)	$ 195,731
Stair pad foundation (CP7)	$ 1,025
Subtotal cost for receiver tower	$2,091,183

Receiver Construction Cost (continued)

Mechanical, piping and insulation	
Panel installation (CP9)	$ 277,195
Panel insulation (CP9)	$ 262,378
Core installation (CP9)	$ 123,441
Core piping installation (CP9)	$ 285,535
Core insulation (CP12)	$ 184,286
Heat shield installation (CP9)	$ 161,053
Misc. equipment installation (CP9)	$ 166,296
Instruments--flow--21; flux--72 (CP9)	$ 45,280
Electronics rooms (708A & 708B); 13th & 14th levels of tower	
Installation (CP9)	$ 279,082
HVAC w/(CP9 c/o #001)	$ 27,226
Fire protection equip. install. (CP9)	$ 102,793
Cabinet installation (CP11)	$ 120,905
Cable trays, conduits (CP11)	$ 728,082
Wiring (CP11)	$ 58,404
Heat tracing (CP11)	$ 74,475
Infrared camera cable conduit (CP11A)	$ 61,801
IR cable procurement CP11 c/o #003 FDCR 86	$ 14,100
Instrumentation (556 channels/16 spare)	
Power and I&C cable and SDPC (1/3) installation	
Subtotal Cost for Receiver	$2,972,332
Total Construction Cost of Receiver System	**$5,063,516**

Thermal Transport System--The thermal transport system can be discussed separately, as done in this report, or may be combined with the receiver system. All of the equipment and tanks require installation, foundations, interconnecting piping, electrical hookup and controls and instrumentation.

Items included would be the materials and installation costs of piping and valves, insulation, equipment, and cabling:

Install LLP vertical and horizontal piping (CP9)	$ 661,846
Install LLP primary hangers and snubbers (CP9)	$ 186,040
Field fabbed piping (CP9)	$ 311,530
Clean, test (CP9)	$ 84,630
Covered pipe trench (CP7)	$ 60,967
Pipe insulation (CP12)	$ 72,249
Installation of pumps, equipment	$ 197,536
Valves	
Heat tracing (CP11)	$ 74,475
In-line instrumentation (CP9)	$ 131,263

Thermal Transport System Construction Cost (continued)

Controls	
Electrical service balance (CP11)	$ 33,652
Feedwater conditioning system	
Installation w/turbine-generator cost	
Demineralizer 1st stage-mobile D701	
Polishing demineralizer 1st stage Mobile DE701 and DE702	
Demineralized water storage tank TK702 (CP10A)	$ 45,578
SCE equipment installation	$ 783,989
Polishing demineralizer 2nd stage	
In-line demineralizer V901	
In-line demineralizer V902	
Regeneration vessel V903	
Condensate storage tank TK902	
Condensate pump	
Feedwater heaters	
1st point high pressure E902	
2nd point high pressure E903	
3rd point deaerator E901	
4th point low pressure E904	
Instrumentation (50 channels, no spares)	
Miscellaneous direct & distributed indirect costs (SCE)	$ 69,765
Total Thermal Transport System Construction Cost	**$2,713,520**

Thermal Storage System--The construction cost of the thermal storage system includes the installation of ten skids of equipment that are fabricated in the factory. These skids require foundations, and the equipment requires insulation, piping and electrical hookup. Buildings to house the electronic equipment for remote stations 2 (building 710) and 3 (building 709) are also needed. Remote Station 2 generally accommodates the instrumentation for the steam-side equipment through junction box JB1951, while Remote Station 3 accommodates the instrumentation for the oil-side equipment through junction box JB1952. The thermal storage tank (Figure 11) and its foundation are major items of this account.

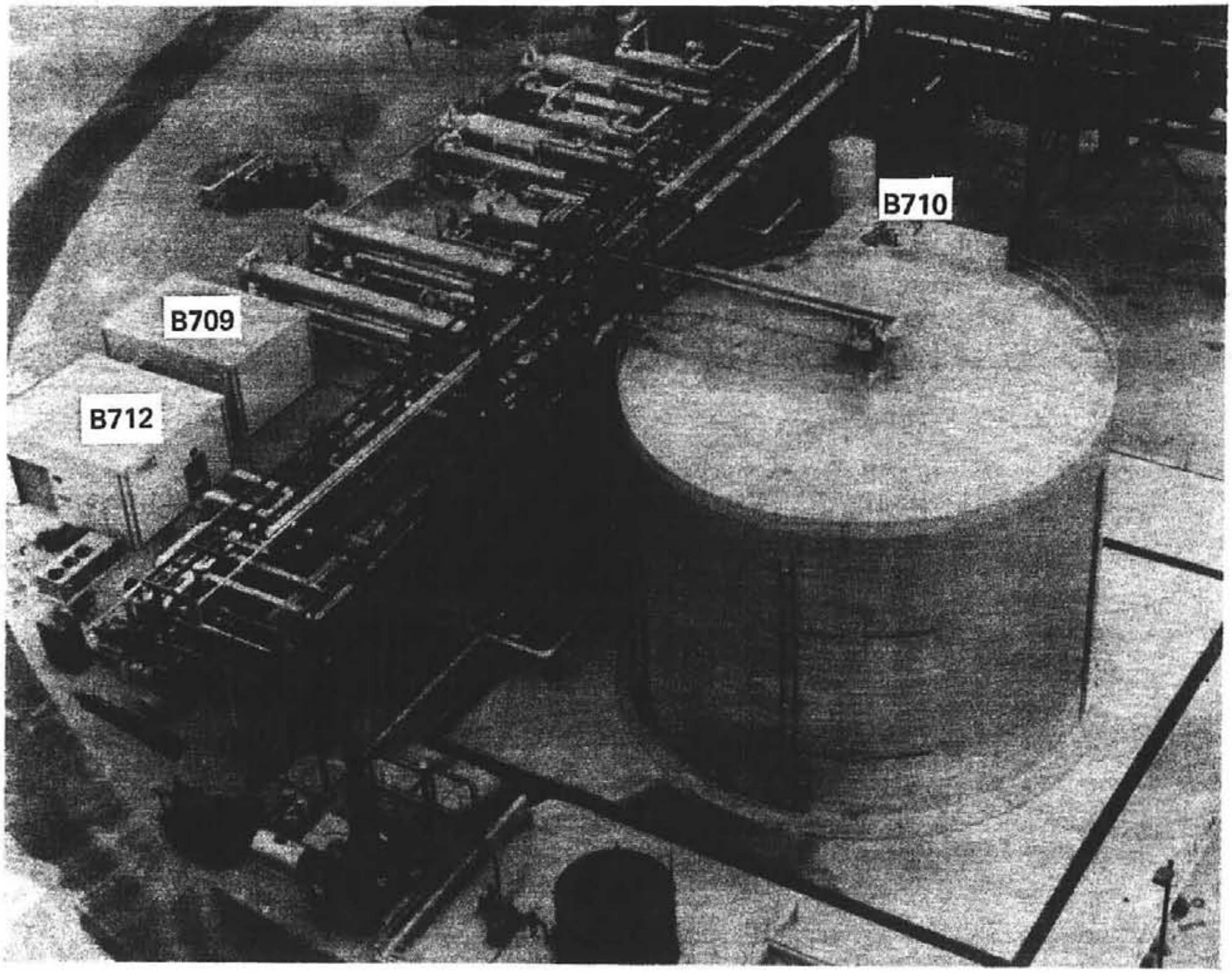

Figure 11: Thermal Storage Tank

Thermal Storage System Construction Costs

Field Fabricated Tanks	
Thermal storage unit (CP 10)	$1,853,241
Foundation for V303 (CP7)	$ 651,494
Pipe & fill w/oil (CP9)	$ 771,713
Caloria make-up tank TK301 (CP10)	$ 28,607
Foundation for TK301/P306 (CP7)	$ 6,834
Ullage Maintenance Unit (UMU)	
Foundation (CP7)	$ 1,139
Foundation for heptane tank (CP7)	$ 865
Equipment installation	
Skid-mounted equipment installation	
Foundation (CP7)	$ 123,590
Installation (CP9)	$ 233,356

installation. Also included in many of the areas are piping, valves, insulation and foundations. Instrumentation includes 691 channels.

The turbine-generator plant system construction costs include the SCE construction contracts (Ref. 12). The construction contracts include:

Turbine-Generator	
Pedestal foundation & equipment foundations	$ 310,285
Turbine-Generator installation	$1,962,661
Condenser	
Installation w/T-G cost	
Associated equipment	
Foundations w/T-G cost	
Electrical hookup	
Equipment installation w/T-G cost	
Circulating water system	
Foundation/Underground piping installation	$ 303,000
CT MCC bldg HVAC, foundation, electrical	
CT MCC bldg prefab building	$ 8,000
Instrumentation & controls	
RS 4 installation (CP11)	$ 160,633
691 channels installation	
SDPC (1/3) installation	
Misc. directs and distributed indirects SCE	$ 235,340
Total Turbine-Generator Plant System Construction Cost	**$2,979,919**

Electrical Plant System--The electrical plant system consists of the electrical components that are general to the overall plant or to many systems of the plant. This construction account includes the costs for installing many factory- produced items and pulling and terminating cable.

The master control subsystem construction costs include the installation of the equipment in the equipment room and the control room on the second floor of the control building. Only miscellaneous charges are known, so the cost is underestimated in this report.

Electrical system installation cost-SCE	$ 548,841
Electrical switchyard installation	
33 KV grid to switchyard	
Switchyard	

Electrical Plant System Construction Cost (continued)

Plant interties	
Main transformer	
Auxiliary transformer	
Plant power distribution installation	
Station service transformer SX1	
Cooling tower transformer CTX1	
4160 V switchgear	
480 V switchgear from CTX1 and SX1	
MCC A Building 901	
MCC L cooling tower area	
Emergency power installation	
UPS & DC power system	
Communication & lighting installation	
Cable installation	
Cable protection/pulling	
Electrical system installation (CP11)	$ 848,134
Concrete work (CP7)	$ 132,134
Master control miscellaneous charges (CP11)	$ 91,753
Total Electrical Plant System Construction Cost	**$1,620,862**

Miscellaneous Plant Equipment--This category includes charges for installation of the equipment that services a number of plant systems and cannot be charged to any one specific system. These include the following:

Misc. equipment installation-SCE (est. by author)	$236,404
Service and instrument air	
Installation	
Piping & accessories	
Equipment cooling water installation	
Water sampling equipment installation	
Auxiliary steam system installation	
Nitrogen blanketing system	
Foundation for nitrogen subsystem (CP7)	$ 1,139
Foundation for nitrogen skid (CP9) FDCR 146	$ 2,770
Electrical hookup (CP11) FDCR 241	$ 12,919
Total Misc. Equipment Construction Cost	**$253,232**

Plant-Level Costs--Some of the costs incurred at the plant level are for the program and construction management services and system integration expenses. Costs were incurred by the SFDI, T&B, DOE and SCE/LADWP.

The SFDI program management consisted of day-to-day management activities, project support, maintainence of implementation plans, STMPO programmatic support, and configuration and data management.

Plant-level engineering support was provided by S-R for the SFDI. Construction management was provided by T&B for the DOE.

The SCE construction management expenses of Category 2 (capital funds) costs were assumed to be one-third of the total engineering and construction costs. The other two-thirds of the total engineering and construction costs are allocated to the design account.

SCE had expenses in categories other than Category 2. Some of these were for technology transfer Category 5--$1,205,000; technical support to the DOE Category 6--$200,000; and plant operating procedures Category 7--$250,000. These are plant-level expenses, but were not part of the Category 2 costs.

The costs incurred included the following:

Program Management:			$ 4,602,842
SFDI Phase 1		$2,348,246	
Phase 2		$2,254,596	
(includes $600,000 estimated for SFDI A&E)			
Architectural and Engineering:			
SFDI Construction Package Support			$ 208,679
Construction Management:			
T&B			$ 5,178,266
Phase 1		$ 621,419	
Phase 2		$4,556,847	
Common Benefit Services	$ 271,300		
Contracts Support	$ 230,414		
Testing Services	$ 79,982		
Paleontological & Archaeological Services	$ 22,500		
Other Construction Management & Indirects	$3,952,651		

Plant-Level Construction Costs (continued)

SCE/LADWP	$ 3,316,667
Total Plant Level Costs	**$13,306,454**

Total plant construction cost	$43,011,283

Start-up Costs

Start-up Costs

As defined in this report, the start-up cost are those costs involved in start-up that were incurred before the plant construction was complete. A construction completion date of April 12, 1982, is assumed for this report; owner's costs start after that date. Costs for modifying equipment, and adding material, labor or equipment, have been merged into the construction costs. Little detail is available on the start-up cost associated with individual plant systems.

SCE does have some Category 3 (Plant Integration and Start-up) costs that are not a part of the construction costs. These costs should be mentioned, though, for completeness and overall understanding. The Category 3 costs include corporate support--$1,561,100; engineering and construction direct costs--$582,500; construction contracts--$593,000; construction indirects--$637,712; contingency--$700,688; and indirects--$1,065,100. These expenses were incurred after the construction was complete (as defined in this report).

Other costs that could be considered start-up costs are expense items in the DOE Operations budget. These include the Visitor Center operation for 5 years--$322,666; other plant operations for 5 years--$5,540,754; collector system spares for FY1981 and FY1982--$125,152 and $65,000, respectively; receiver system spares for Phase 1 activities, i.e., materials for two spare receiver panels--$71,090; SFDI spares for Phase 2 activities--$1,101,582; SFDI training for Phase 2 --$794,159; and SFDI Program Management for Phase 2--$217,828. None of these expenses are included in the construction cost in this report.

The start-up cost for the various plant systems is summarized in Table 10 and shown in more detail as follows:

Table 10: Start-up Cost Summary

Collector System--BCS	$ 416,776
Plant Level Costs	
T&B Start-up Services	$ 854,975
SFDI Start-up Activities	$3,112,617
Total Start-up Costs	$4,384,368

Start-up Costs

Land		$ 0
Structures and Improvements		$--*
Collector System--BCS		$ 416,776
Receiver System		$--
Thermal Storage System		$--
Thermal Transport System		$--
Turbine-Generator Plant		$--
Electrical System		$--
Miscellaneous Equipment System		$--
Plant Level Costs		$ 854,975
T&B Start-up		
Auxiliary Boiler	$ 117,466	
Chemical Clean	$ 102,006	
Equipment Rental	$ 57,446	
Miscellaneous Material	$ 31,399	
Labor	$ 365,740	
Travel, Subsistence	$ 70,350	
Fringe Benefits	$ 110,568	
SFDI Site Activities		$3,112,617
Checkout, Start-up, Field Liaison	$1,684,264	
Start-up (Dec. 1981-April 1982)	$1,428,353	
Total Start-up Costs		$4,384,368

*These specific costs (--) are unknown, but are included in the total cost shown.

PLANT SYSTEM COST

Plant System Cost Breakdown Structure

The plant system cost breakdown structure for the pilot plant includes a number of major systems, each of which can include subsystems. The major systems are:

- Land
- Structures and improvements
- Collector
- Receiver
- Thermal transport
- Thermal storage
- Turbine-generator plant
- Electrical plant
- Miscellaneous equipment
- Plant level costs

Subsystems include the beam characterization subsystem and special heliostat instrumentation and meteorological measurements subsystem as part of the collector system, and the master control subsystem as part of the electrical plant system.

The pilot plant system cost breakdown structure accounts (Figure 12) and the summary costs associated with each account, with subtotals for the solar plant portion and conventional plant portions, are shown in Table 11.

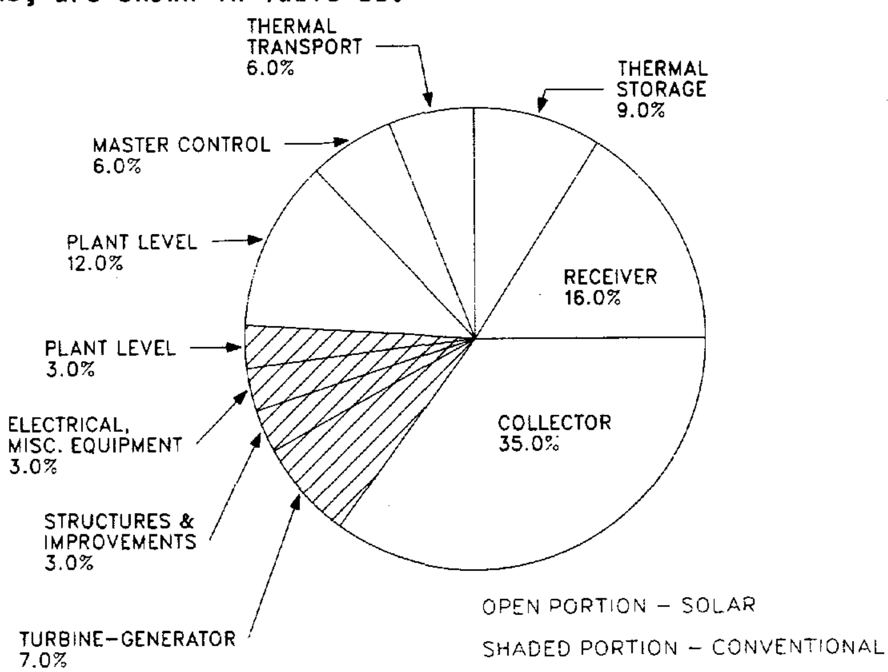

Figure 12: Capital Cost--Breakdown by Plant System

TABLE 11: PLANT SYSTEM COST SUMMARY

Solar Plant Portion--	
Collector System	$ 49,211,297
Receiver System	$ 22,570,587
Thermal Storage System	$ 13,176,982
Thermal Transport System	$ 7,517,434
Master Control Subsystem	$ 8,525,934
Plant-Level Costs	$ 18,198,701
Solar Plant Portion Subtotal	$119,200,935
Conventional Plant Portion--	
Land	$ 0
Turbine-Generator Plant System	$ 10,140,783
Electrical Plant System	$ 2,829,554
Structures and Improvements	$ 4,686,315
Miscellaneous Equipment	$ 989,134
Plant Level Cost	$ 3,316,667
Conventional Plant Portion Subtotal	$ 21,964,793
Round-up, Miscellaneous Round-off	$ 36,612
Total Capital Costs	**$141,200,000**

The plant system cost breakdown structure is compatible with the Polydyne Cost Data Management System (CDMS). The breakdown structure is adaptable to other solar technologies as well as nonsolar technologies by conforming to the basic FERC accounts shown below:

X0. Land
X1. Structures and Improvements
X2. Collector Field, Receiver, Media Transport, Storage, Supplemental Fuel and Steam Generation
X3. Turbine Plant Equipment and Power Conditioning
X4. Electrical Systems
X5. Miscellaneous Plant Equipment

The philosophy used for the pilot plant cost analysis is to charge a system with any and all costs, even if estimated, so that if a system were deleted (e.g., thermal storage) then other categories would not need to be adjusted to determine the reduction in cost. This philosophy is used where possible to identify and separate the costs by system. System costs can include their share of land (e.g., for heliostats), buildings, wiring, HVAC, foundations, controls, and instrumentation where the costs are separable. The main categories X0,X1,X3,X4,and X5 would include costs for nonsolar systems and nonseparable solar system costs.

The costs associated with each plant system are segregated as best possible. Many of the costs are hidden in total contract costs and cannot be determined or easily estimated. However, the costs if known are allocated to specific systems; if the costs are not known, they are first estimated, and then allocated to specific systems.

This section of the report essentially summarizes the costs previously discussed in the areas of design, factory, construction and start-up costs.

Land

The total land costs are based on an SCE-estimated value of the 130 acres used for the plant site. The value of $250,000 is not part of the construction budget.

Land	$ 0
Total Land Account Cost	**$ 0**

Structures and Improvements

The structures and improvements cost account includes:

R&D		$ 0
Design		$ 820,265
Factory		$ 110,003
SCE	$ 24,707	
LLP	$ 85,296	
Construction		$ 3,756,047
SCE	$ 1,199,475	
CP 1	$ 652,483	
CP 3	$ 254,005	
CP 4	$ 343,403	
CP 5	$ 68,442	
CP 7	$ 189,942	
CP 7A	$ 5,047	
CP 9	$ 833,403	
CP 10A	$ 64,867	
CP 11	$ 94,980	
T&B	$ 50,000	
Start-up		$--
Total Structures & Improvement Cost		**$ 4,686,315**

Collector System

The collector system includes all items that could be eliminated if heliostats were not the heat source for the receiver system. For example, if heliostats were not present, then the BCS would not be required, nor the heliostat instrumentation nor most of the meteorological equipment. The heliostat costs are for 1818 pilot plant heliostats, 2 spares including foundations but excluding underground wiring at the site, 2 heliostats at the CRTF, and 93 extra mirror modules.

The collector system costs include:

R&D--Heliostats			$ 4,868,145
Design			$ 4,581,943
Heliostat Field		$ 253,926	
Heliostats		$ 3,494,482	
BCS		$ 550,428	
SHIMMS		$ 283,107	
Hel. Instr.	($ 93,778)		
Metro.	($ 189,329)		
Factory			$32,400,198
Heliostat Field		$ 688,534	
Heliostats		$30,978,356	
MMC	($30,154,538)		
Glass	($ 823,818)		
BCS		$ 416,635	
MDAC	($ 195,841)		
LLP	($ 220,794)		
SHIMMS		$ 316,673	
MDAC	($ 299,644)		
Helio	$ 102,831		
Metro	$ 196,813		
LLP	($ 17,029)		
Construction			$ 6,944,235
Heliostat Field		$ 3,764,739	
CP 1	($ 440,722)		
SCE	($ 35,976)		
CP 6	($ 1,193,945)		
CP 11	($ 25,088)		
CP 11A	($ 2,005,452)		
Grndng	($ 63,556)		
Heliostats		$ 2,198,071	
BCS		$ 182,804	
CP 6	($ 15,097)		
CP 9	($ 148,649)		
CP 11	($ 8,629)		
CP 12	($ 10,429)		
SHIMMS		$ 798,621	
CP 5	($ 73,000)		
CP 6	($ 39,691)		
CP 11	($ 612,086)		
CP 11A	($ 73,844)		

Collector System Cost (continued)

Start-up		$ 416,776
Heliostats	$	
BCS--MDAC	$ 416,776	
Total Collector System Cost		**$49,211,297**

The collector system can also be listed by the major components of heliostats, BCS, and SHIMMS. These components would be:

Heliostat Field	$ 4,707,199
Heliostats	$41,539,054
BCS	$ 1,566,643
SHIMMS	$ 1,398,401

The total cost for the collector system, including all of the above accounts, is $27,069 per heliostat. Based on a reflective area of 39.3 m^2, the cost is $689/$m^2$. Excluding the BCS and SHIMMS costs would lower the heliostat cost to $647/$m^2$. The pilot plant collector system cost, without the R&D, design, or SHIMMS factory and construction costs, would be $541/$m^2$.

Receiver System

The receiver system (Figure 13) includes the receiver steam generator, the supporting tower and foundation, and the controls and instrumentation directly associated with the receiver operation and performance evaluation.

The receiver system account costs include:

R&D		$ 0
Design		$ 3,727,093
Factory		$13,779,978
Rocketdyne	$13,014,840	
LLP	$ 331,805	
SDPC	$ 433,333	
Construction		$ 5,063,516
CP 5	$ 35,870	
CP 5A	$ 1,715,000	
CP 7	$ 1,025	
CP 7A	$ 195,731	
CP 9	$ 1,730,280	
CP 11	$ 1,139,524	
CP 11A	$ 61,800	
CP 12	$ 184,286	
Start-up		$--
Total Receiver System Cost		**$22,570,587**

The receiver system account can also be broken down into subaccounts of the tower and foundation, and the receiver. These accounts would be $2,091,183 for the tower and the balance of $20,479,404 for the receiver steam generator.

The receiver (Figure 13), an external cylindrical design with an area of 302 m^2, has an nominal rating of 43.4 MWt. If the receiver areal efficiency is defined as the receiver nominal thermal rating divided by the surface area, then the pilot plant receiver areal efficiency is about 0.14 MWt/m^2. Even though the tubes can absorb as much as 0.35 MWt/m^2, the nominal absorption is about half that value.

The pilot plant receiver system cost is $74,737/$m^2$ of surface area.

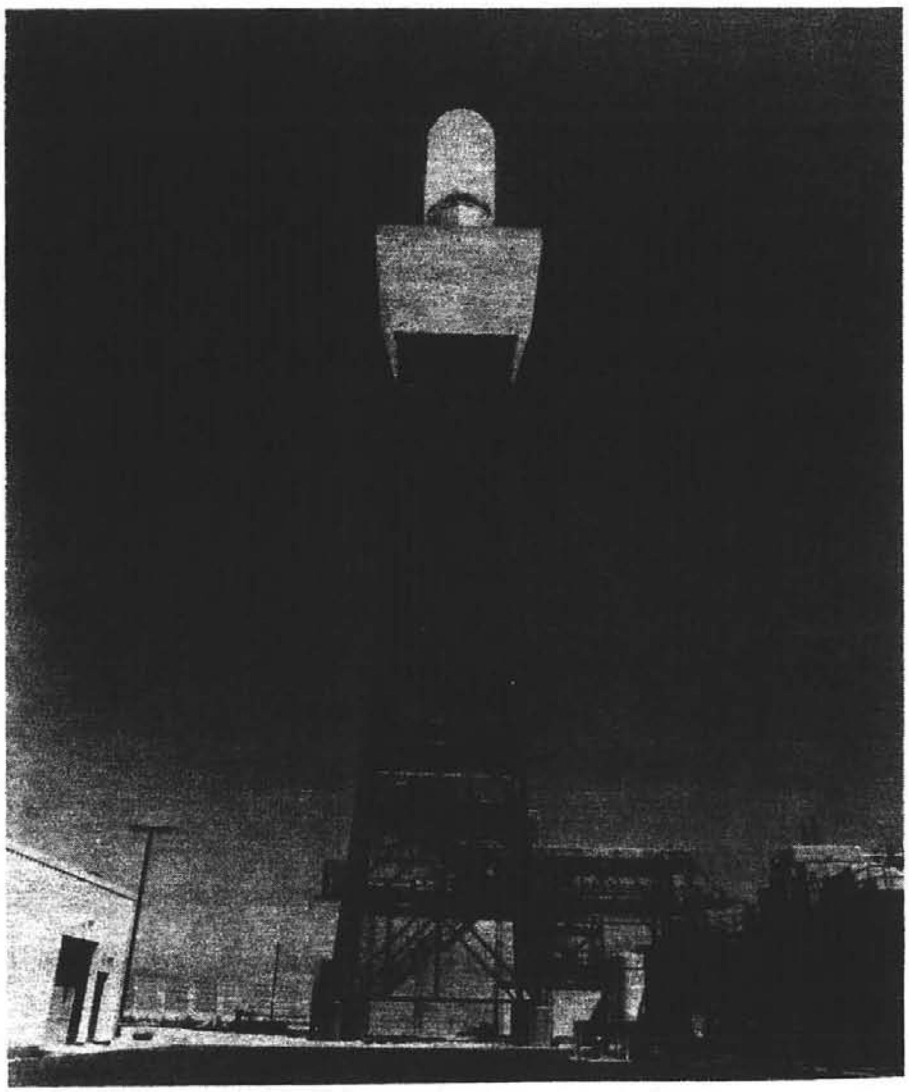

Figure 13: Receiver

Thermal Transport System

The thermal transport system consists of vertical piping and horizontal piping from the receiver feedwater pump to the receiver, and from the receiver to the turbine and condenser. The pilot plant horizontal piping is not very long, since most of the equipment that is connected together is contained in the rather compact core area.

Some solar thermal central receiver designs, as well as other technology designs, can vary considerably in the length and size of thermal transport piping. In order to differentiate these costs from the receiver costs, the thermal transport account should be stated separately. The feedwater pumps (receiver and thermal storage) are also included.

The thermal transport system account costs include:

R&D		$ 0
Design		$ 2,401,128
Factory		$ 2,402,786
LLP	$ 1,153,710	
SCE	$ 1,249,076	
Construction		$ 2,713,520
SCE	$ 853,754	
CP 7	$ 60,967	
CP 9	$ 1,572,844	
CP 10A	$ 45,578	
CP 11	$ 108,127	
CP 12	$ 72,249	
Start-up		$--
Total Thermal Transport System Cost		**$ 7,517,434**

Thermal Storage System

The thermal storage system contains all items that would be unnecessary if storage of thermal energy were not used.

The costs of the thermal storage system are:

R&D		$ 0
Design		$ 2,090,866
Factory		$ 4,712,618
Rocketdyne	$ 4,086,513	
LLP	$ 192,772	
SDPC	$ 433,333	
Construction		$ 6,373,498
CP 5	$ 374,811	
CP 7	$ 909,098	
CP 9	$ 2,347,564	
CP 10	$ 1,881,848	
CP 11	$ 467,400	
CP 12	$ 392,777	
Start-up		$--
Total Thermal Storage System Cost		**$13,176,982**

The pilot plant thermal storage cost is roughly $82/kWhr-th.

Turbine-Generator Plant System

The turbine-generator plant system includes equipment such as the turbine-generator and all its associated equipment; condenser with vacuum pumps; circulating water system including a three-cell cooling tower and its water treatment system; electrical system; and instrumentation and controls. Major pieces of equipment come from factories to the site for assembly, erection, and installation. Also included in many of the areas are piping, valves, insulation, and foundations. Instrumentation includes 691 channels.

The turbine-generator plant system includes costs as follows:

R&D		$ 0
Design		$ 3,462,314
Factory		$ 3,698,550
SCE	$ 3,188,825	
LLP	$ 76,392	
SDPC	$ 433,333	
Construction		$ 2,979,919
SCE	$ 2,819,286	
CP 11	$ 160,633	
Start-up		$--
Total Turbine-Generator Plant Cost		**$10,140,783**

Electrical Plant System

The electrical plant system consists of the electrical components that are general to the overall plant or to many systems of the plant. Included are main transformers and switchyard, master control, and instrumentation and controls that are not a part of a specific system.

The master control subsystem includes computers and associated equipment to control and assess the plant operation. Each system can be charged with the necessary instrumentation and valves required to respond to the master control subsystem, but the equipment, buildings, and wiring needed, even if specific systems are removed, belongs to the master control subsystem. The pilot plant also provides for recording data that assist in evaluating this first plant.

The electrical system account costs are:

R&D		$ 0
Design		$ 7,096,222
Master Control--MDAC	$ 6,354,544	
Balance--SCE	$ 741,678	
Factory		$ 2,638,404
Master Control--MDAC	$ 2,079,637	
Balance--SCE	$ 558,767	
Construction		$ 1,620,862
Master Control		
CP 11	$ 91,753	
Balance--SCE		
SCE	$ 548,841	
CP 7	$ 132,134	
CP 11	$ 848,134	
Start-up		$--
Master Control		
Balance		
Total Electrical System Cost		**$11,355,488**

Miscellaneous Plant Equipment

The miscellaneous plant equipment account consists of supply systems and equipment that service several plant systems. These are the nitrogen supply; auxiliary steam supply; equipment cooling water supply; service and instrument air supply systems; and the water sampling and chemical analysis equipment.

The miscellaneous plant equipment account had the following charges:

R&D		$ 0
Design--SCE		$ 382,959
Factory		$ 352,943
SCE	$ 352,709	
LLP	$ 234	
Construction		$ 253,232
SCE	$ 236,404	
CP 7	$ 1,139	
CP 9	$ 2,770	
CP 11	$ 12,919	
Start-up		$--
Total Miscellaneous Plant Equipment Cost		**$ 989,134**

Plant Level

The plant-level cost consists of charges that pertain to the entire plant or that cannot be specifically designated to particular plant systems.

The plant-level costs were:

R&D		$ 0
Design--SFDI System Integration		$ 4,241,322
Factory		$ 0
Construction		$13,306,454
Construction Package Support --SFDI	$ 208,679	
Program Management --solar only	$ 4,602,842	
Construction Management--	$ 8,494,933	
T&B- solar ($ 5,178,266)		
SCE ($ 3,316,667)		
Start-up		$ 3,967,592
SFDI	$ 3,112,617	
T&B	$ 854,975	
Total Plant-Level Cost		**$21,515,368**

Round-up, Round-off	$ 36,612
Total Cost by Plant System	$141,200,000

ELEMENTS OF WORK

Elements of Work Breakdown Structure

Another way to present construction data is in categories of the type of work performed. This type of breakdown may represent the actual way the contract was let or better allow comparisons to be made for similar items such as:

- Sitework/earthwork
- Concrete work
- Metal work
- Architectural work
- Process equipment
- Mechanical/piping work
- Electrical work
- Indirect Costs

Examples of the elements of work that apply to solar thermal central receivers are shown below. The construction packages (CP) used in the pilot plant are noted; more details are included in the Appendices.

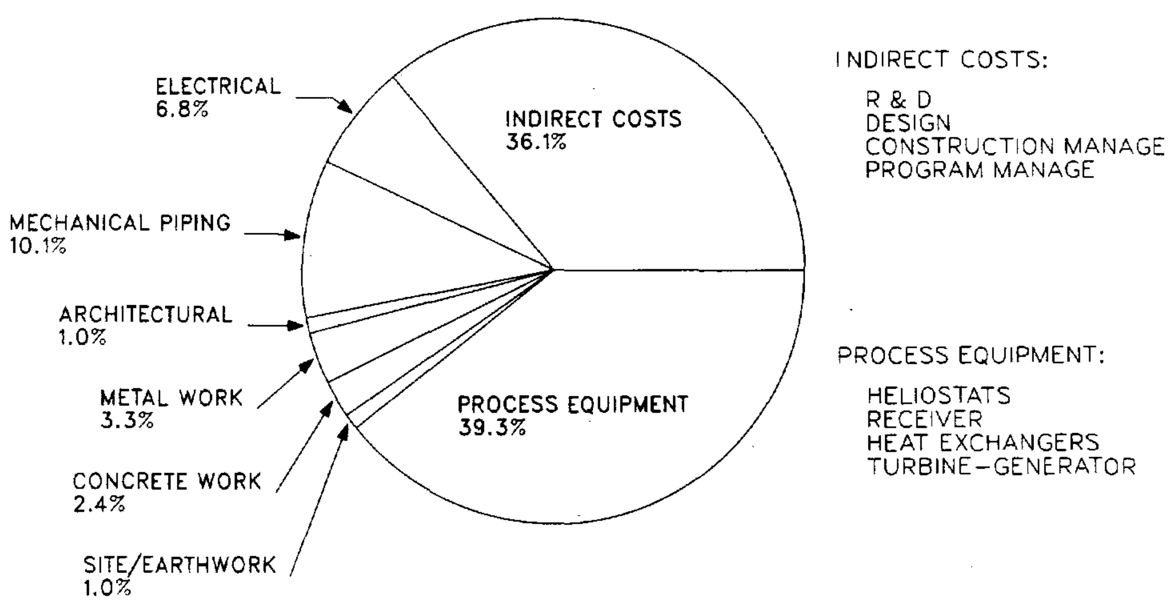

Figure 14: Capital Cost--Breakdown by Elements of Work

The plant costs arranged by elements of work are summarized in Table 12 and shown in more detail below.

TABLE 12: ELEMENTS OF WORK COST SUMMARY

Sitework/Earthwork	$ 1,272,344
Concrete Work	$ 3,417,007
Metal Work	$ 4,641,180
Architectural Work	$ 1,703,718
Process Equipment	$ 55,454,738
Mechanical/Piping Work	$ 14,199,637
Electrical Work	$ 9,528,456
Indirects	$ 50,946,303
Round-up, Round-off	$ 36,617
Total Plant Costs	$141,200,000

The plant costs presented by the elements of work category breakdown are:

Sitework/earthwork--the costs are both for the heliostat field and the overall plant.

CP1	$ 1,093,203	
SCE	$ 179,141	
		$ 1,272,344

Concrete Work--the costs are mostly for the heliostat foundations (CP6) and the thermal storage system foundations (CP7).

CP6	$ 1,248,733	
CP7	$ 1,294,305	
CP7A	$ 200,778	
SCE Civil/Underground	$ 332,597	
SCE Turbine/Pedestal	$ 340,594	
		$ 3,417,007

Elements-of-work (continued)

Metal Work--the costs are mainly for storage tanks (CP10 & CP10A) and the receiver tower (CP5A).

CP10	$ 1,881,848	
CP10A	$ 110,445	
CP5	$ 552,123	
CP5A	$ 1,715,000	
SCE Cooling Tower Motor Control Center Building	$ 8,781	
SCE Auxiliary Bay	$ 207,231	
BCS Targets (LLP)	$ 165,752	
		$ 4,641,180

Architectural Work--the major on-site cost is for the control building.

CP3 Warehouse	$ 254,005	
CP4 Visitor Center	$ 343,403	
Other Visitor Center	$ 65,000	
SCE Control Building	$ 857,322	
SCE Rest Rooms	$ 113,303	
SCE Miscellaneous	$ 70,685	
		$ 1,703,718

Process Equipment--the largest cost items are for the 1818 heliostats and the receiver.

Heliostats	$ 30,978,356	
SFDI BCS	$ 612,617	
SFDI SHIMMS	$ 299,644	
Receiver + 1/3 SDPC	$ 13,448,173	
Thermal Storage Heat Exchanger + 1/3 SDPC	$ 4,519,846	
SCE Turbine-Generator + 1/3 SDPC	$ 3,176,649	
SCE Stuctures & Improvements	$ 24,707	
SCE Thermal Transport	$ 1,041,845	
SCE Miscellaneous Equipment	$ 352,709	
SCE Electrical	$ 554,683	
		$ 55,454,738

Elements-of-work (continued)

Mechanical/Piping/Insulation-the costs include the heliostat installation (MMC) and piping for the receiver, thermal transport, and thermal storage systems (CP9) and (LLP).

CP9	$ 6,637,524	
CP12 Insulation	$ 659,741	
MMC Installation	$ 2,198,071	
SCE Turbine-Generator	$ 2,137,314	
SCE Thermal Transport	$ 853,754	
SCE Miscellaneous Equipment	$ 236,404	
LLP (Appendix H)	$ 1,478,862	
		$ 14,199,637

Electrical Work (Appendix I.1)--the costs are mostly for the master control (CP11), receiver electrical (CP11) and collector field wiring (CP11A).

CP11	$ 3,569,272	
CP11A	$ 2,141,096	
Grounding	$ 63,556	
SCE Electrical & Controls	$ 548,841	
Master Control	$ 2,079,637	
LLP (Appendices I.2 & I.3)	$ 1,126,054	
		$ 9,528,456

Indirects--much of the cost was for the pilot plant design.

R&D	$ 4,868,145	
Design	$ 28,804,112	
Construction Management	$ 9,349,908	
Construction Package Support	$ 208,679	
SFDI		
Program Management	$ 4,602,842	
Start-up	$ 3,112,617	
		$ 50,946,303

Round-up, Round-off	$ 36,617
Total Plant Cost by Elements of Work	$141,200,000

RECURRING COST

Recurring and Non-Recurring Breakdown Structure

The non-recurring costs at the pilot plant include charges for basic research and development, special pilot plant solar system instrumentation, data-recording systems, meteorological measurement systems, excessive factory and tooling amortization, unique engineering design, and extra program and construction management. The non-recurring costs would not be expected to be incurred in future plants*. The recurring costs include charges for off-the-shelf equipment that could be purchased from several sources and installed using standard practices.

A number of assumptions were made in order to assign the various cost values to recurring and non-recurring accounts. If another identical 10 MWe plant were built, using the pilot plant technology and experience, then the recurring accounts in this report would be required. The non-recurring account contains charges that may not be required or desired for another 10 MWe plant, essentially identical to the pilot plant.

The assumptions on which this breakdown is based are:

1. All design costs would be 85% non-recurring, and only 15% of these costs would be repeated;
2. None of the SHIMMS costs, including design, would be repeated;
3. The master control factory and construction costs would be half OCS and half DAS; the DAS would be non-recurring;
4. Construction management costs would be reduced by 40%;
5. Start-up costs and program management costs would be 85% non-recurring due to the developmental nature of the pilot plant; and
6. Manufacturing planning activities and tooling design and fabrication would be 85% non-recurring.

Separation of the total capital costs into non-recurring and recurring costs follows:

	Non-Recurring	Recurring
Research and Development	$ 4,668,145	$ 200,000
Design--repeat 15% of design (except Visitors Center)	$24,465,336	$ 4,163,776

*The selection of these non-recurring costs reflects the opinion of the author.

Non-Recurring and Recurring Cost (continued)

	Non-Recurring	Recurring
Pilot Plant Features		
Visitors Center w/ design	$ 583,403	$ 0
SHIMMS Factory & Construction	$ 1,115,295	$ 0
Data Acquisition System	$ 1,085,695	$ 0
Factory Planning, Tooling	$ 4,221,379	$ 744,949
Other Factory, Construction	$ 0	$82,224,589
Start-up	$ 3,726,713	$ 657,655
Program Management	$ 3,912,416	$ 690,426
Construction Management	$ 3,397,973	$ 5,305,639
	$47,176,355	$93,987,034
Round-up, Miscellaneous Round-off		$ 36,611
Total Capital Costs		**$141,200,000**

The division of the pilot plant costs into recurring and non-recurring costs based on the plant systems is summarized on Table 13 and shown in more detail as follows:

TABLE 13: NON-RECURRING/RECURRING COST SUMMARY

	Non-Recurring	Recurring
Land	$ 0	$ 0
Structures and Improvements	$ 1,131,878	$ 3,554,437
Collector System	$11,756,630	$ 37,454,668
Receiver System	$ 5,707,596	$ 16,862,991
Thermal Transport System	$ 2,040,959	$ 5,476,475
Thermal Storage System	$ 1,777,236	$ 11,399,746
Turbine-Generator Plant	$ 2,942,967	$ 7,197,816
Electrical System	$ 7,205,608	$ 4,149,880
Miscellaneous Equipment	$ 325,515	$ 663,619
Plant Level	$14,287,966	$ 7,227,402
	$47,176,355	$ 93,987,034
Round-up, Miscellaneous Round-off		$ 36,611
Total Plant Cost		$141,200,000

	Non-Recurring	Recurring	Total
Land	$ 0	$ 0	$ 0
Structures and Improvements			
Design	$ 548,475	$ 96,790	$ 645,265
Visitor Center w/design	$ 583,403		$ 583,403
Factory & Construction		$ 3,457,647	$ 3,457,647
Collector System			
Heliostat Field			
Design	$ 215,837	$ 38,089	$ 253,926
Factory		$ 688,534	$ 688,534
Construction		$ 3,764,739	$ 3,764,739
Heliostats			
R&D	$ 4,668,145	$ 200,000	$ 4,868,145
Design	$ 2,970,310	$ 524,172	$ 3,494,482
Factory			
Tooling	$ 1,681,812	$ 296,790	$ 1,978,602
Other		$29,687,755	$ 29,687,755
Construction		$ 2,198,810	$ 2,198,810
BCS			
Design	$ 467,864	$ 82,564	$ 550,428
Factory & Construction		$ 599,439	$ 599,439
Start-up	$ 354,260	$ 62,516	$ 416,776
SHIMMS			
Design	$ 283,107		$ 283,107
Factory & Construction	$ 1,115,295		$ 1,115,295
Receiver System			
Design	$ 3,168,029	$ 559,064	$ 3,727,093
Factory and construction			
Mfg. Planning, Tooling	$ 2,539,567	$ 448,159	$ 2,987,726
Other Factory, Constr.		$15,855,768	$ 15,855,768
Thermal Transport System			
Design	$ 2,040,959	$ 360,169	$ 2,401,128
Factory and construction		$ 5,116,306	$ 5,116,306
Thermal Storage System			
Design	$ 1,777,236	$ 313,630	$ 2,090,866
Factory and construction		$11,086,116	$ 11,086,116
Turbine Generator Plant System			
Design	$ 2,942,967	$ 519,347	$ 3,462,314
Factory and construction		$ 6,678,469	$ 6,678,469
Electrical Plant System			
Master Control			
Design			
Hardware & Software	$ 4,901,993	$ 865,057	$ 5,767,050
System Integration Lab	$ 587,494		$ 587,494
Factory and Construction			$ 2,171,389
OCS		$ 1,085,695	
DAS	$ 1,085,695		

Non-Recurring and Recurring Costs (continued)

	Non-Recurring	Recurring	Total
Balance of Electrical			
Design	$ 630,426	$ 111,252	$ 741,678
Factory and Construction		$ 2,087,876	$ 2,087,876
Miscellaneous Equipment			
Design	$ 325,515	$ 57,444	$ 382,959
Factory and Construction		$ 606,175	$ 606,175
Plant Level			
Design (solar)	$ 3,605,124	$ 636,198	$ 4,241,322
Program Management (solar)	$ 3,912,416	$ 690,426	$ 4,602,842
Construction Management	$ 3,397,973	$ 5,096,960	$ 8,494,933
Construction Pkg. Support		$ 208,679	$ 208,679
Start-up	$ 3,372,453	$ 595,139	$ 3,967,592
Round-up			$ 36,611
Total	$47,176,355	$93,987,034	$141,200,000

DISCUSSION

Discussion of Pilot Plant Costs

Correlation of Cost Breakdown Structure Data

The pilot plant total capital requirements itemized by several cost breakdown structures can be correlated to each other. This correlation is useful to show the interaction and the assignment of costs for specific areas. The cost breakdown detail is not known well enough in some areas (e.g., start-up costs for each plant system) to have entries, even though costs were incurred. The lack of this detail is not obvious in the previous sections or pie-charts, but surfaces when the cost data are correlated.

One correlation is displayed in Tables 14 and 15. These tables present the costs that are available with the project category and the elements of work shown as a fuction of plant system, respectively. In some cases, the zero represents a zero cost for that activity, while in others it indicates a lack of detail available to break down a larger cost to individual areas.

Conclusions

Most costs--and certainly the major ones--are included, even though a number of costs are omitted from this cost data set. The breakdown structures and the presentation of typical items employed in a solar thermal central receiver power plant should be of value to future builders, investors, and users of solar thermal central receiver plants.

The pilot plant costs include some extra charges because of the "pilot" and experimental nature of the plant. R&D and engineering design costs have been expended for the new aspect of the plant. Instrumentation costs were incurred for monitoring and recording the operation and performance of the plant. Low volumes of potentially mass-producible items, such as heliostats, and unique first-time designs of other major items, such as the receiver and thermal storage tank, also led to high costs.

Extra program and construction management payments were required as a result of the many construction packages--rather than one or a few contracts. The many small procurements also added to costs, due to the escalation of the cost of materials and labor with time. Government procurement regulations, such as the Davis Bacon Act which determined the construction craft labor rates, resulted in added construction labor wages that amounted to an estimated $1 million cost.

TABLE 14
CAPITAL COST--PROJECT CATEGORY vs PLANT SYSTEM

PLANT SYSTEMS	R&D	DESIGN	FACTORY	CONSTRUCT	START-UP	SUBTOTAL	TOTAL
Structures/Improvements	0	820,265	110,003	3,756,047	—		4,686,315
Collector System							49,211,297
Field	0	253,926	688,534	3,764,738	—	4,707,198	
Heliostats	4,868,145	3,494,482	30,978,356	2,198,071	—	41,539,054	
BCS	0	550,428	416,635	182,804	416,776	1,566,643	
SHIMMS	0	283,107	316,673	798,622	—	1,398,402	
Receiver System							22,570,587
Receiver	0	3,727,093	13,779,978	3,115,890	—	20,622,961	
Tower	0	0	—	1,947,626	—	1,947,626	
Thermal Storage System	0	2,090,866	4,712,618	6,373,499	—		13,176,983
Thermal Transport System	0	2,401,128	2,402,786	2,713,520	—		7,517,434
Turbine-Generator Plant	0	3,462,314	3,698,550	2,979,919	—		10,140,783
Electrical System							11,355,487
Master Control	0	6,354,544	2,079,636	91,753	—	8,525,933	
Balance	0	741,678	558,767	1,529,109	—	2,829,554	
Miscellaneous Equipment	0	382,959	352,943	253,232	—		989,134
Plant Level	0	4,241,322	0	13,306,454	3,967,592		21,515,368
Total Cost	4,868,145	28,804,112	60,095,479	43,011,284	4,384,368		141,163,388

— Specific cost unknown, but included in total cost

TABLE 15

CAPITAL COST--ELEMENTS of WORK vs PLANT SYSTEM

PLANT SYSTEM	EARTHWORK	CONCRETE	METAL	ARCHITECT	EQUIPMENT	MECHANICAL	ELECTRICAL	INDIRECTS	SUBTOTAL	TOTAL
Structures/Imprvmt	795,646	194,989	133,309	1,703,718	24,707	889,469	124,210	820,265		4,686,313
Collector System										49,211,295
Field	476,698	1,193,945	0	0	—	0	2,782,629	253,926	4,707,198	
Heliostats	0	0	0	0	30,978,356	2,198,071	0	8,362,627	41,539,054	
BCS	0	15,097	165,752	0	612,617	159,078	63,670	550,428	1,566,642	
SHIMMS	0	39,691	73,000	—	299,644	0	702,959	283,107	1,398,401	
Receiver System										22,570,587
Receiver	0	0	0	—	13,448,173	2,122,953	1,324,742	3,727,093	20,622,961	
Tower	—	196,756	1,750,870	0	—	—	—	—	1,947,626	
Thermal Storage	—	909,098	2,256,659	—	4,519,846	2,740,341	660,172	2,090,866		13,176,982
Thermal Transport	—	60,967	252,809	—	1,041,845	3,639,884	120,800	2,401,128		7,517,433
T-G Plant	—	673,191	8,781	—	3,622,158	2,210,667	163,672	3,462,314		10,140,783
Electrical System										11,355,488
Master Control	0	0	0	—	0	0	2,171,390	6,354,544	8,525,934	
Balance	—	132,134	0	—	554,683	0	1,401,059	741,678	2,829,554	
Misc. Equipment	—	1,139	0	—	352,709	239,174	13,153	382,959		989,134
Plant Level	0	0	0	0	0	0	0	21,515,368		21,515,368
Total Costs	1,272,344	3,417,007	4,641,180	1,703,718	55,454,738	14,199,637	9,528,456	50,946,303		141,163,383

— Specific cost unknown, but included in total cost

There are also costs that are not included in this cost data set that must be considered in a future plant. Some items were not required for the pilot plant since the facility was adjacent to an existing power plant--SCE's Cool Water Power Plant. The cost of land was not included (the pilot plant land was already owned by SCE). The cost of the administration building, the evaporation pond, and make-up water wells and pumps were not part of the construction funds, but would be required for future plants.

Other costs were not incurred as capital costs, since the anticipated plant life (5 years) was not as long as for normal power plants. Some of the equipment was rented and other equipment was not procured. The rental items include the nitrogen supply system, and the make-up demineralizer. Power production plants would employ redundant equipment for certain items that are not included in the pilot plant. The possibly shorter-than-normal plant life and the development and test nature of the plant, as well as budget limitations, led to few redundant items being included in the pilot plant.

A full complement of spare parts was not charged to the pilot plant, but should be for future plants. Maintenance equipment such as the heliostat mirror washing truck(s) should also be charged to capital equipment, but were not available when the construction was complete. Replacement of plant items before the end of the plant life should be charged to O&M.

Costs after start-up are not included, even though money had to be spent to complete systems work (control system automation and thermal storage start-up, for instance).

The data in this report can be used to understand a total cost data set. Some of the data, such as the conventional portion of plant, may be representative of any future plant; the solar portion, which contains extraordinary costs, may be useful, but is not directly applicable nor scaleable to future plants. The costs for this pilot plant cannot be scaled directly to arrive at the cost of a 100 MWe privately constructed plant for several reasons: 1) the pilot plant is a scale model of a 100 MWe plant and was not optimized at the 10 MWe size; 2) the indirect costs are representative of a developmental plant; 3) the high collector and receiver costs are a function of the small production quantity and early design; and 4) the interest during construction is not typical due to the government financing. A future report will examine the usefullness of the pilot plant cost data set to different-sized plants and to other solar thermal technologies.

APPENDICES

APPENDICES

APPENDIX A.1--CONSTRUCTION PACKAGE 1: PRELIMINARY EARTHWORK

CP 1 Preliminary Earthwork
($1,093,203)
J. R. Pope, Inc.

		Charges	Charges w/ Indirects
Structures & Improvements:			
Offsite			
Fine grade roads & parking area		$ 12,902	$ 14,213
Place aggregate base material		$ 275,203	$ 303,170
Excavate, cap & mark well #1		$ 14,775	$ 16,276
Excavate, cap & mark well #2		$ 937	$ 1,032
Move 36 poles for parking lot stop logs		$ 2,300	$ 2,534
Culverts & riprap		$ 30,486	$ 33,584
Concrete lined ditch		$ 55,004	$ 60,594
Onsite			
Excavate, compact office & cooling tower area		$ 31,079	$ 34,237
Clear and grub (40% of total)		$ 40,224	$ 44,312
Strip alfalfa & corral area (40% of total)		$ 7,293	$ 8,034
Structures & Improvements Subtotal			$ 517,986
Collector System:			
Grade collector field		$ 328,790	$ 362,202
Clear and grub (60% of total)		$ 60,337	$ 66,469
Strip alfalfa & corral area (60% of total)		$ 10,939	$ 12,051
Collector System Subtotal			$ 440,722
Receiver System:			
Excavate, compact receiver tower area		$ 122,090	$ 134,497
Misc. Direct and Distributed Indirects			
General Plant Area			
Mobilization	$ 50,000		
Engineering	$ 50,845		
		$ 100,845	
Preliminary Earthwork Construction Package Total Cost		$1,093,203	$1,093,203

APPENDIX A.2--CONSTRUCTION PACKAGE 3: WAREHOUSE

CP 3 Warehouse
($254,005)
Tee Pee Engineering, Inc.

Structures & Improvements:

Bond & mobilization	$	15,704
Earthwork	$	11,716
Rebar	$	7,229
Electrical work	$	39,385
Form work	$	15,205
Footings	$	11,466
Sump	$	17,698
Electrical vault	$	7,727
Anchor bolts	$	2,991
Building material on site	$	87,494
Building erection	$	25,924
HVAC	$	1,994
Project survey & layout	$	4,736
Credit	-$	264
Sales Tax	$	5,000
Warehouse Construction Package Total Cost	$	254,005

APPENDIX A.3--CONSTRUCTION PACKAGE 4: VISITOR CENTER

CP 4 Visitor Center
($343,403)
Tee Pee Engineering, Inc.

Structures & Improvements:

Mobilization	$	14,971
Earthwork	$	18,890
Site electrical	$	22,284
Site water	$	3,834
Septic system	$	20,777
Paving	$	48,422
Sidewalk, picnic, flagpole, signs	$	18,227
Ramps & landings	$	4,943
Modular buildings		
Deposit	$	33,955
Shop drawings	$	113,612
Field installation	$	10,924
C/o #001 dirt & building modifications	$	21,873
C/o #002 building electrical panels & drinking fountain modifications	$	1,691
Sales tax	$	9,000
Visitor Center Construction Package Total Cost	$	343,403

APPENDIX A.4--CONSTRUCTION PACKAGE 5: STRUCTURAL STEEL AND BUILDINGS

Cp 5 Structural Steel and Buildings
($552,123)
Ashby Metal Products

Structures & Improvements:	
Raw/service water pump bldg 702 (880 ft^2)	$ 51,684
Secondary fire pump bldg 706 (280 ft^2)	$ 16,875
Wind bracing for warehouse c/o #004 FDCR 70	$ 1,036
Structures & Improvements Subtotal	$ 69,595
Collector System:	
Towers; 6 wind & 7 pyronometer	$ 46,000
c/o #008 for 4 added metro towers	$ 27,000
Collector System Subtotal	$ 73,000
Receiver System:	
Receiver tower bldg 201 work	
Lvl 1 safety chain c/o #003 FDCR 72	$ 278
Lvl 14 safety chain c/o #003 FDCR 68	$ 235
Tower drain holes c/o #004 FDCR 87	$ 27,500
Elevator/crane strct. comp c/o #001	$ 7,857
Receiver System Subtotal	$ 35,870
Thermal Storage System:	
Pipe rack structure bldg 705	$173,446
Pipe rack stairs/ladder	$ 9,347
Railings ($14,430); grating ($69,077)	$ 83,507
Pipe rack revisions	
c/o #002	$ 19,497
c/o #005 including FDCR 231 ($1205)	$ 4,216
c/o #006 ($7,466); c/o #007 ($1,452)	$ 8,198
TSS electrical equipment bldg 712 (480 ft^2)	$ 27,454
TSS remote control bldgs 709 & 710 (768 ft^2)	$ 45,987
Cable tray access B709/B712 c/o #003 FDCR 62	$ 620
TSU exit ladder c/o #003 FDCR 60	$ 1,819
Thermal Storage System Subtotal	$374,811
Other Costs:	
Credit-eliminate finish painting FDCR 49	-$ 2,000
Other change orders	$ 847
Other Costs Subtotal	-$ 1,153
Structural Steel and Buildings Construction Package Total Cost	$552,123

Notes:
Detailing: $26,000 ($9,000 buildings, $1,000 towers, $16,000 pipe rack)
Materials: $374,900 ($108,200 buildings, $43,400 towers, $223,300 pipe rack)
Erection: $53,400 ($ 24,800 buildings, $1,600 towers, $27,000 pipe rack)

APPENDIX A.5--CONSTRUCTION PACKAGE 5A: RECEIVER TOWER STRUCTURAL STEEL

CP 5A Receiver Tower Structural Steel
($1,715,000)
Christoff Construction Company

Collector System:	
BCS target support structure (level 12 to level 15)	
Misc. metro equipment support booms (level 7)	
Receiver System:	
Receiver tower primary structure bldg 201 (base level to level 15)	
Mobilization	$ 108,850
Structural steel	$ 883,395
Erection & installation	$ 332,614
Revise lower beam supports c/o #004 FDCR 27	$ 35,500
Personnel hoist HS701 (base to level 13)	
Material	$ 80,083
Erection	$ 39,964
Recv. unit core support str. bldg 707 (level 15 to top)	
Receiver unit maintenance crane	
Material	$ 73,085
Erection	$ 37,009
Added aircraft/warning lights c/o #005	$ 13,500
Lightning/grounding system (tower & ground grid)	
Receiver tower personnel stair system (base to top level)	$
Other c/o #001-003; 006-008	$ 111,000
Receiver Tower Structural Steel Construction Package Total Cost	$1,715,000

APPENDIX A.6--CONSTRUCTION PACKAGE 6: COLLECTOR FIELD FOUNDATION

CP 6 Collector Field Foundation
($1,248,733)
Modern Alloys, Inc.

Collector System:

Drilled, cast-in-place, reinforced concrete pier heliostat foundations (1818 each) 10 feet x 3 feet in diameter	
Mobilization	$ 20,000
Grading	$ 41,000
Survey and layout (subcontract)	$ 68,224
Auger holes	$ 80,875
Supply water	$ 35,725
Furnish rebar	$ 132,600
Furnish bolts	$ 142,400
Furnish galvanized washers	$ 2,900
Place steel, bolts	$ 208,800
Pour, strip and cure	$ 435,000
Subtotal for 1818 heliostat foundations ($642.20 per heliostat)	$1,167,524
Heliostat power center foundations (14 each)	
Drilled pier foundations for metro towers	
6 wind towers	
7 pyronometer towers	$ 7,609
Foundations for 4 metro stations (S,W,N,E)	
Foundations for BCS field camera/equipment (4 stations w/camera & cooling equipment pad each)	
Hail cube foundations 6 each	
Electronics Environmental Station (EES)	
Misc. concrete (subcontract)	$ 73,600
Subtotal miscellaneous foundations	$ 81,209
Collector Field Foundation Construction Package Total Cost	$1,248,733

Note:
Includes 47 miscellaneous equipment pads (about 100 yards); 5990 yards of concrete--about 5% was considered waste.

APPENDIX A.7--CONSTRUCTION PACKAGE 7: PLANT SUPPORT SYSTEM AND THERMAL STORAGE SYSTEM FOUNDATIONS

CP 7 PSS and TSS Foundations
($1,294,305)
Joseph D. Gee Enterprises

	Charges	Charges w/ Indirects
Structures and Improvements:		
Raw/Service water & demineralized water tank foundations		$ 52,113
Grading for tanks	$ 45,000	
Fine grading $15,000 - c/o #013 $14,250	$ 750	
Building foundations		
Raw/Service water pump building 702		$ 44,424
Rebar $2,700 M; $1,300 L	$ 4,000	
Concrete & forming	$ 33,000	
Drain piping $1,000 M; $1,000 L	$ 2,000	
Secondary fire pump building 706		$ 59,232
Rebar $4,000 M; $1,000 L	$ 5,000	
Concrete & forming	$ 45,000	
Drain piping $1,000 M; $1,000 L	$ 2,000	
Yard drain piping $20,000 M; $10,000 L	$ 30,000	$ 34,172
Structures & Improvements Subtotal	$ 136,750	$ 189,942
Receiver System:		
Miscellaneous slabs		
Hoist, stair pad	$ 900	
Receiver System Subtotal	$ 900	$ 1,025
Thermal Transport System:		
Pipe trench		
Covered pipe trench		
Rebar $8,000 M; $4,000 L	$ 12,000	
Concrete & forming	$ 36,000	
Grating	$ 5,523	
Thermal Transport System Subtotal	$ 53,523	$ 60,967

CP 7 PSS and TSS Foundations (continued)

Thermal Storage System:

Pipe rack foundations		$ 98,294
Pipe rack foundation - 31 supports		
Engineering	$ 5,000	
Excavation	$ 20,000	
Rebar $5,000 M; $2,000 L	$ 7,000	
Concrete & forming	$ 50,000	
Lower footing c/o #002 FDCR 20	$ 4,292	
TSS skid foundations		$ 123,590
Heat exchangers		
Rebar $4,000 M; $2,000 L	$ 6,000	
Concrete & forming	$ 40,000	
Drain piping $37,000 M; $10,000 L	$ 47,000	
Protexulate insulation $12,000 M; $3,000 L	$ 15,000	
Blowdown tank	$ 500	
TSU special foundation/containment basin (includes embedded TC's)		$ 651,494
Octagonal slab 4000 psi structural concrete		
Engineering	$ 5,000	
Excavation	$ 70,000	
Rebar $60,000 M; $20,000 L	$ 80,000	
Concrete & forming	$ 150,000	
Circular Slab 400 psi insulating concrete	$ 40,000	
Foundation instrumentation - thermocouples	$ 10,000	
Accelerate TC delivery c/o #004	$ 875	
Ring		
Rebar $3,000 M; $1,000 L	$ 4,000	
Concrete & forming	$ 16,000	
Slab on grade & drainage trench		
Rebar $5,000 M; $1,000 L	$ 6,000	
Concrete & forming	$ 67,000	
c/o #008	$ 3,913	
Copper water stop $10,000 M; $5,000 L	$ 15,000	
Retaining walls		
Excavation	$ 20,000	
Rebar $10,000 M; $3,000 L	$ 13,000	
Concrete & forming	$ 50,000	
Handrail $6,000 M; $2,000 L	$ 8,000	
Containment grating	$ 13,477	
c/o #007 FDCR 24 & 28	$ 1,181	
Reduction of access ramp c/o #001	-$ 1,500	
Caloria make-up tank & pump foundation		$ 6,834
Rebar $700 M; $300 L	$ 1,000	
Concrete & forming	$ 5,000	

CP 7 PSS and TSS Foundations (continued)

Building foundations		
TSS control buildings 709 & 710		$ 14,808
Rebar $2,600 M; $1,400 L	$ 4,000	
Concrete & forming	$ 9,000	
TSS electrical equipment building 712		$ 12,074
Rebar $1,300 M; $700 L	$ 2,000	
Concrete & forming	$ 6,000	
Transformer pad	$ 2,600	
Miscellaneous slabs		$ 2,004
Ullage Maintenance Unit slab	$ 1,000	
Heptane tank slab c/o #011	$ 759	
Thermal Storage System Subtotal	$ 711,805	$ 909,098
Electrical System:		
Embedded and/or under slab piping/conduit		
Electrical duct bank/foundations		
Underground conduit $85,000 M; $25,000 L	$ 110,000	
Instrumentation and control manholes		
Manhole #4 (2,500); manhole #5 ($3,500)	$ 6,000	
Electrical System Subtotal	$ 116,000	$ 132,134
Miscellaneous Equipment:		
Nitrogen Slab	$ 1,000	
Miscellaneous Equipment Subtotal	$ 1,000	$ 1,139
Other Direct & Indirect Costs:		
General Direct Costs		
Anchor Bolts	$ 7,000	
Embedded Items Material	$ 48,000	
Other Modifications	$ 59,137	
Indirect Costs:		
Mobilization	$ 5,898	
Bond & Insurance	$ 38,000	
Other Direct & Indirect Costs Subtotal	$ 158,035	
Plant Support System and Thermal Storage System Construction Package Total Cost	$1,294,305	$1,294,305

APPENDIX A.8--CONSTRUCTION PACKAGE 7A: RECEIVER TOWER FOUNDATION

CP 7A Receiver Tower Foundation
($200,778)
Joseph D. Gee Enterprises

Structures and Improvements:	
Added drainage ditches/culverts at North and East gates c/o #002	$ 5,047
Structures and Improvements Subtotal	$ 5,047
Receiver System:	
Bond & insurance	$ 3,031
Engineering	$ 2,500
Excavation/compaction	
Excavation	$ 35,000
Backfill-compaction-finish grading	$ 17,600
Modifications c/o #001	8,600
Rebar	
Material	$ 34,000
Labor	
Slab	$ 3,000
Walls & piers	$ 3,000
Concrete & forming	
Slab	$ 56,000
Walls	$ 24,000
Piers	$ 2,000
Anchor bolts	$ 7,000
Receiver System Subtotal	$195,731
Receiver Tower Foundation Construction Package Total Cost	$200,778

APPENDIX A.9--CONSTRUCTION PACKAGE 9 PIPING AND MECHANICAL EQUIPMENT

CP 9 Piping and Mechanical Equipment
($6,637,524)
The Waldinger Corporation

	Charges	Charges w/ Indirects
Structures & Improvements:		
Raw/service water pumps		
Replace press. control on pump c/o #026 FDCR 99	$ 5,546	
Fire protection system installation		
Misc. revisions c/o #051	$ 12,331	
Primary, secondary and jockey fire pumps-GFE		
F. P. hydrants, valves, UG piping		
Deliver U/G piping	$ 81,100	
Install fire and raw water piping	$ 615,300	
Foam Fire Protection System for TSS area		
Demineralized make-up water equipment		
Subtotal Structures & Improvements	$ 714,277	$ 833,403
Collector System:		
BCS target installation-GFE		
Erect targets	$ 75,100	
c/o's #015,016,017	$ 52,301	
Subtotal Collector System	$ 127,401	$ 148,649
Receiver System:		
Receiver tower electronic equipment rooms		
Original contract	$ 174,600	
c/o #013	$ 64,590	
Halon system install--tower electronic rooms	$ 88,100	
HVAC install electronic rooms - tower	$ 12,500	
c/o #001	$ 10,834	
Receiver tower traps & accessories	$ 41,600	
Receiver unit installation complete-GFE/CFE (includes loose GFE items such as tanks, valves, and 24 panel modules)		
Receive and store 24 panels	$ 57,600	
Set 24 panels	$ 172,800	
Lift boiler modules c/o #041 FDCR 103	$ 7,173	
Modify module shields c/o #037 FDCR 255	$ 6,831	
Hardware for 21 flow meters c/o #032 FDCR 124	$ 22,888	
Core piping for 24 panels	$ 140,100	
Piping changes c/o #012	$ 127,435	
Hydrostatic clean/test--core piping	$ 18,000	
Insulation c/o #005	$ 224,874	

CP 9 Piping and Mechanical Equipment (continued)

72 heat flux transducers c/o #020	$ 15,920	
Perimeter heat shield 15th level	$ 20,000	
Receiver core modifications		
c/o #041 FDCR 199	$ 4,038	
c/o #041 FDCR 200	$ 6,924	
c/o #042 FDCR 201	$ 22,573	
Receiver core bracing c/o #027 FDCR 123	$ 24,525	
Receiver core diagonal conn. c/o #040 FDCR 190	$ 6,923	
Receiver core heat shield c/o #014	$ 99,212	
Modify heat shield on 16th, 17th c/o #045 FDCR 283	$ 11,989	
Receiver flash tank bypass c/o #045 FDCR 282	$ 3,501	
Rec. fl. tank drain pump cooling c/o #045 FDCR 286	$ 4,395	
Core area overtime c/o #010	$ 69,799	
Revisions 1-4 c/o #044	$ 23,231	
Subtotal Receiver System	$1,482,955	$1,730,280

Thermal Transport System:

Piping installation		
Shop fab'd piping (P22, heavy wall, & Incoloy-fab pipe- 2 1/2 in. and larger) GFE		
Receive, store GFE pipe, valves, etc.	$ 245,600	
Modify 4 inch pipe spool c/o #028 FDCR 186	$ 1,442	
Install primary tower piping	$ 142,100	
Install secondary tower piping	$ 178,100	
Field fab'd piping (2 in. and smaller)		
Fab misc. bldg & trench piping	$ 72,400	
Install misc. bldg piping	$ 28,000	
Install trench piping	$ 78,000	
Deliver carbon steel pipe and valves	$ 88,600	
Hangers and snubbers, inc. misc. steel GFE/CFE		
Sort and set primary hangers	$ 142,800	
Hanger accessories c/o #028 FDCR 126	$ 16,222	
Adjust arrestors c/o #028 FDCR 208	$ 426	
Control and standard valves-GFE/CFE		
In- line instrumentation equipment-GFE/CFE	$ 112,500	
Hydrostatic cleaning and testing		
Tower piping	$ 20,200	
Overtime c/o #024	$ 7,333	
System restoration after steam blows c/o #025	$ 45,000	
Receiver feed pump instln in EPGS area-GFE		
Miscellaneous loose equipment installation		
Receive, store GFE pumps, equipment	$ 169,300	
Blowdown tank and condensate pump		
Steam to condenser dump equipment-GFE/CFE		
Oil/water separator equipment installation		
Subtotal Thermal Transport System	$1,348,023	$1,572,844

CP 9 Piping and Mechanical Equipment (continued)

Thermal Storage System:

TSS skid assembly installations-GFE		
Heat exchanger skids (charging/extraction)		
SA305,SA306,SA307,SA308	$ 107,800	
SA302,SA303 c/o #037 FDCR 81	$ 2,828	
Flash tank drain pump foundation c/o #026 FDCR 161	$ 2,080	
Provision for nitrogen blanket on water/steam side of SA307,SA308 c/o #049 FDCR 279	$ 17,241	
Pump skids (charging/extraction)		
Set and pipe	$ 52,000	
Pump motor mount mods. c/o #036 FDCR 267	$ 12,188	
Add grout under pumps c/o #037 FDCR 115	$ 5,863	
UMU skid		
Desuperheater skid		
TSU tank		
TSU pipe and fill with oil	$ 605,000	
90 day storage of 265,000 gal. oil c/o #004	$ 26,345	
Rail storage of 40,000 gal. of excess oil for 7 months c/o #052	$ 13,275	
TSU piping mods. c/o #034 FDCR 89	$ 9,673	
TSU manifold mods. c/o #038 FDCR 167	$ 5,800	
TSU relief valve seat repair c/o #037 FDCR 210	$ 1,312	
HVAC Install B709/B710/B712 -TSS area	$ 66,000	
Halon System Install - B709/B710/B712	$ 107,000	
Field Fab'd Piping (2 in. and smaller)		
Fab rack piping	$ 250,000	
Install rack piping	$ 705,600	
Hydrostatic cleaning and testing		
Rack piping	$ 22,000	
Subtotal Thermal Storage System	$2,012,005	$2,347,564

Miscellaneous Equipment:

Nitrogen supply system equipment		
Nitrogen skid foundation c/o #033 FDCR 146	$ 2,374	
Subtotal Miscellaneous Equipment	$ 2,374	$ 2,770

Other Direct Charges & Indirects:

Overtime c/o #002,006,021,025	$ 381,344	
Contract extension (overhead), c/o #046,047,048	$ 61,027	
Mobilize	$ 110,000	
Other c/o's & FDCR's	$ 398,118	
Subtotal Other Direct Charges/Indirects	$ 950,489	
Total Piping and Mechanical Equipment Construction Package Cost	$6,637,524	$6,637,524

APPENDIX A.10--CONSTRUCTION PACKAGE 10: FIELD ERECTED TANKS

CP 10 Field Erected Tanks
($1,881,848)
Pittsburgh-Des Moines (PDM)

Thermal Storage System:

Thermal Storage Unit (TSU) - Designed by Rocketdyne	
Tank structure final design, fabrication and on-site erection upon foundation (by CP 7)	
Engineering ($16,800) & drafting ($10,200)	$ 27,000
Procure plate material	$ 220,300
Fab-bottom, shells	$ 85,500
c/o #001 5 vs 7 course shell	-$ 3,623
Erect-bottom, shells	$ 340,200
c/o #008 FDCR 95 add water drain	$ 1,447
c/o #010 core drilling + credit	$ 5,256
Fab-roof	$ 53,600
Erect-roof	$ 112,500
c/o #008 FDCR 143 manhole mod.	$ 2,288
c/o #008 FDCR 153 roof supports mod.	$ 3,900
Paint-roof	$ 7,300
c/o #002 foundation access ramp	$ 1,500
c/o #004 insulating concrete curb	$ 1,830
Tank insulation & lagging	
Install	$ 133,400
c/o #008 FDCR 182	$ 1,458
c/o #009 insulation & substitution	$ 24,108
Provision and installation of sensors, thermocouples, flux gages and strain gages in and on TSU	
Install thermocouples	$ 35,800
Install strain gages	$ 66,100
c/o #006 FDCR 54 strain gage mod.	$ 1,988
Provide and install j-box for termination of thermocouple wiring	
Provide conduit and install (GFE) wire between sensors and j-box	$ 98,600
Interior tank manifold fab/erect	
Fab	$ 116,000
Install	$ 46,400
Placement of rock/sand in TSU	
Rock/sand	$ 399,800
c/o #003 Barstow Sales in lieu of Owl Rock	$ 66,423
c/o #007 material segration	$ 728
Tank testing and interior surface preparation	
Miscellaneous mods. c/o #008	$ 3,438
Thermal Storage Unit Subtotal	$1,853,241

CP 10 Field Erected Tanks (continued)

Caloria make-up tank - Designed by Stearns-Roger	
Tank structure final design, fab and on-site erection upon foundation (by CP 7)	
Fab	$ 10,440
Erection	$ 16,610
c/o #004 FDCR 76 vent mod.	$ 1,557
Tank hydrostatic testing	
Caloria Make-up Tank Subtotal	$ 28,607
Field Erected Tanks Construction Package Total Cost	$1,881,848

APPENDIX A.11--CONSTRUCTION PACKAGE 10A: PLANT SUPPORT SYSTEM TANKS

CP 10A PSS Tanks
($110,445)
Brown Tank & Steel

Structures & Improvements:	
Raw water tank	
Crew mobilization & material delivery	$ 24,800
Field erection & welding	$ 24,800
Testing & x-ray	$ 6,200
Complete job (painting, etc.)	$ 6,200
Misc. tank access. c/o #002 FDCR 90	$ 2,867
Structures & Improvements Subtotal	$ 64,867
Thermal Transport System:	
Demineralized water tank (original material cost reduced by $11,800 c/o #001 FDCR 8)	
Cut & roll material	$ 8,540
Fit-up	$ 8,540
Welding	$ 8,540
Clean & x-ray	$ 4,270
Ship to jobsite	$ 4,270
Install fittings	$ 4,270
Complete job (painting, etc.)	$ 4,270
Misc. tank access. c/o #002 FDCR 53	$ 2,878
Thermal Transport System Subtotal	$ 45,578
Plant Support System Tanks Construction Package Total Cost	$110,445

APPENDIX A.12--CONSTRUCTION PACKAGE 11 & 11B: BALANCE OF ELECTRICAL

CP 11 & 11B Balance of Electrical
($3,569,272)
Lord Electric Company, Inc.

	Charges	Charges w/ Indirects
Structures & Improvements:		
Lighting installation (exterior/interior)		
Procure	$ 45,600	
Install	$ 14,800	
Miscellaneous control equipment installation		
Buildings & improvements equipment		
Raw/service water pump control FDCR 99	$ 5,546	
Subtotal Structures & Improvements	$ 65,946	$ 94,980
Collector System:		
Collector field grounding update c/o #042 FDCR 274 (separate contract FDCR 284 for hel. grounding)	$ 17,419	
BCS		
BCS equipment installation (sensors, field camera inst'lns) FDCR 226		
BCS cooling move FDCR 207	$ 5,991	
SHIMMS		
Meteorological system procure/install c/o #009	$ 312,170	
Meteorological system upgrade c/o #051 FDCR 247	$ 7,000	
Procure cable--heliostat interconnecting cable c/o #001 FDCR 33	$ 75,630	
Revision 2-2 c/o #014	$ 28,454	
RG22 cable c/o #013 FDCR 129	$ 1,730	
Subtotal Collector System	$ 448,394	$ 645,802
Receiver System:		
Miscellaneous control equipment installation		
Tower crane, elevator		
Installation c/o #002	$ 39,995	
Crane hookup overtime c/o #004	$ 4,469	
Elevator repairs c/o #006	$ 9,754	
Maintenance crane removal c/o #035 FDCR 214	$ 45,457	
Raceway, conduit and cable tray inst'ln		
Procure	$ 66,700	
Install	$ 430,800	
Cable tray change level 14 c/o #021 FDCR 135	$ 1,809	
Cable tray change MCS cab. c/o #024 FDCR 204	$ 1,153	
Tower conduit mods. c/o #010 FDCR 92	$ 5,061	

CP 11 & 11B Balance of Electrical (continued)

I & C wiring distribution/connection/termination			
Rocketdyne cable change core area FDCR 197		$ 17,505	
Core area elect restore c/o #027 $62,735/4		$ 15,684	
RB 214 cables replaced c/o #013 FDCR 144		$ 319	
RB 218 potentiometer c/o #013 FDCR 166		$ 166	
OT for receiver valve wiring c/o #029 (9/12 & 9/13/81)		$ 6,877	
IR cable purchase c/o #003 FDCR 86		$ 9,790	
Cabinet installation remote sta. 1 (GFE)		$ 22,100	
Overtime in remote stations c/o #019 $107,697/4		$ 26,924	
Revision 3 c/o #015 Remote Sta Term.$139,692/4		$ 34,923	
Heat Tracing	$ 155,129/3	$ 51,710	
Procure	$ 96,000		
Install	$ 8,000		
c/o #034 added heat tracing	$ 31,590		
c/o #045 inc. FDCR 290	$ 19,539		
Subtotal Receiver System		$ 791,196	$1,139,524

Thermal Transport System:

Core area elect restore c/o #027 $62,735/4		$ 15,684	
Miscellaneous control equipment installation			
Receiver feed water pump controller c/o #039 FDCR 278		$ 7,681	
Heat tracing	$ 155,129/3	$ 51,710	
Procure	$ 96,000		
Install	$ 8,000		
c/o #034 added heat tracing	$ 31,590		
c/o #045 inc. FDCR 290	$ 19,539		
Subtotal Thermal Transport System		$ 75,075	$ 108,127

Thermal Storage System:

MCC B & C, power panels and TSS 4160V load center A (GFE) inst'ln	$ 31,200
LCA , mod. FDCR 193	$ 224
MCC B breaker change FDCR 191	$ 2,038
B 712 xsformer relocation c/o #025 FDCR 100	$ 8,166
Conduit addition B 710 c/o #025 FDCR 256	$ 2,063
Cable tray change B 709/712 c/o #013 FDCR 63	$ 2,428
Cabinet installation remote sta. 2 (GFE)	$ 6,100
Overtime in remote stations c/o #019 $107,697/4	$ 26,924
Sta. 2 & 3 conduit revision c/o #025 FDCR 85	$ 5,030
Revision 3 c/o #015 Remote Sta Term.$139,692/4	$ 34,923

CP 11 & 11B Balance of Electrical (continued)

Cabinet installation remote sta. 3 (GFE)			$ 4,600	
Overtime in remote stations c/o #019 $107,697/4			$ 26,924	
Revision 3 c/o #015 Remote Sta Term.$139,692/4			$ 34,923	
Miscellaneous control equipment installation				
TSS equipment				
Oxygen analyzer FDCR 151, c/o #028			$ 25,045	
c/o #047			$ 11,444	
UMU skid grating FDCR 145			$ 3,579	
Rewire skids FDCR 138				
TSS skid mods. c/o #013 FDCR 93			$ 182	
Revision 5 c/o #026			$ 31,339	
Core area elect restore c/o #027 $62,735/4			$ 15,684	
Heat tracing		$ 155,129/3	$ 51,710	
Procure	$ 96,000			
Install	$ 8,000			
c/o #034 added heat tracing	$ 31,590			
c/o #045 inc. FDCR 290	$ 19,539			
Subtotal Thermal Storage System			$ 324,526	$ 467,400
Turbine-Generator Plant:				
Core area elect restore c/o #027 $62,735/4			$ 15,684	
Cabinet installation remote sta. 4 (GFE)			$ 34,000	
Overtime in remote stations c/o #019 $107,697/4			$ 26,924	
Revision 3 c/o #015 remote sta term.$139,692/4			$ 34,923	
Subtotal Turbine-Generator Plant			$ 111,531	$ 160,633
Electrical System:				
Plant Electrical				
Switchgear & inverter				
Procure			$ 40,300	
Install			$ 14,600	
Electrical power distribution (SFDI areas)				
Raceway UG ductbank and conduit inst'ln				
Power cable and wiring distribution/connections				
Install (GFE) cable			$ 231,000	
Procure wire and cable				
Initially			$ 68,700	
c/o # 007			$ 88,783	
Install procured cable and wire Rev.4			$ 149,700	
Power cable, breaker change c/o #025 FDCR 176			$ 1,259	
Receptacles and power disconnects inst'lns				
I & C wiring distribution (SFDI core areas)				

CP 11 & 11B Balance of Electrical (continued)

Equipment to J-box wiring connections (within rooms)
Testing and verification of wiring/power/grounding installations

Master Control

Installation of various subsystem and/or plant control and instrumentation electronic equipment in plant control building or other remote buildings:		
Update computer controls c/o #013 FDCR 106	$ 1,051	
MCS update FDCR 133		
c/o #031 FDCR 150	$ 35,900	
Master control console (plant control room)		
Control room A/C FDCR 148	$ 2,931	
FDCR 181	$ 1,224	
Computer equipment (equipment room-plant control bldg)		
ILS equipment		
Plant evaluation equipment (DAS room)		
Temporary DAS c/o #005 FDCR 80	$ 12,839	
SDPC (remote control rooms)		
RLU (RS/TSS equipment)		
Equipment power & grounding connections (within rooms)		
Control room grounding c/o #030 FDCR 268	$ 9,761	
Subtotal Electrical System	$ 658,048	$ 947,757
Miscellaneous Equipment:		
Miscellaneous control equipment installation		
Miscellaneous equipment		
Power to nitrogen skid c/o #029 FDCR 241	$ 8,970	
Subtotal Miscellaneous Equipment	$ 8,970	$ 12,919
Other Charges and Indirects:		
Mobilization ($100,500) & de-mobilization ($3,386)	$ 103,886	
Contract extensions		
c/o #037 10/24/81 to 12/31/81	$ 63,550	
c/o #038 1/ 1/82 to 1/31/82	$ 24,998	
c/o #043 2/ 1/82 to 2/28/82	$ 23,250	
c/o #044 3/ 1/82 to 3/15/82	$ 12,588	
SFDI checkout support 5/5 to 6/26/81 c/o #011	$ 12,382	
SFDI pre-op testing assistance 6/20 - 9/4/81 c/o #022	$ 14,563	
SFDI pre-op assistance 9/9/81	$ 492	
Added bond expense c/o #050	$ 8,438	

CP 11 & 11B Balance of Electrical (continued)

Other overtime		
c/o #008 4/27/81 to 5/29/81	$ 94,674	
c/o #012	$ 193,921	
c/o #017 Wage adjustment to c/o #012	$ 20,147	
J-box & terminal installation		
Procure	$ 83,500	
Install	$ 109,800	
UG & Grounding system install (safety/instrumentation)		
Procure	$ 58,600	
Install	$ 2,000	
Other change orders	$ 125,707	
Revision 4-1 c/o #016	$ 40,628	
Revision 4-2 c/o #023	$ 91,462	
Subtotal Other Charges/Indirects	$1,085,586	
Total Balance of Electrical Construction Package Cost	$3,569,272	$3,569,272

APPENDIX A.13--CONSTRUCTION PACKAGE 11A: COLLECTOR FIELD ELECTRICAL

CP 11A Collector Field Electrical
($2,141,096)
John Taft Electric Company

	Charges	Charges w/ Indirects
Collector System:		
Heliostats-		
Cable protection		$ 297,767
Duct banks & manholes	$ 120,000	
Added duct bank c/o #008	$ 11,308	
Duct between xformers 3 & 4 c/o #001	$ 6,439	
Duct bank revisions c/o #002 FDCR 13	$ 57,300	
PVC ducts c/o #006 FDCR 15	$ 5,642	
Roadway crossings	$ 35,000	
Direct buried conduit & hand holes	$ 40,000	
Added conduit installation c/o #012	$ 22,078	
Cable Installation		$ 742,165
Underground high voltage cable distribution-GFE	$ 50,000	
Underground I & C cable distribution-GFE cable		
Low voltage cable installation	$ 300,000	
Coaxial installation	$ 350,000	
Power, grounding and I & C terminations	$ 30,000	
Heliostat power distribution equipment installation		$ 105,000
Power centers (14 each)-GFE (4160-208Y/120 V distribution transformer 120/208 V, 3 phase distribution panel)		
Power centers 30A breakers FDCR 73 c/o #011	$ 1,896	
Install 84 each 5 KV cable termination connectors at power centers FDCR 58 c/o #008	$ 12,165	
Watt transducers (9 total -GFE)		
Install & terminate	$ 70,000	
Grounds	$ 21,000	
Heliostat I/F cabinet		
Foundations	$ 10,000	
Heliostat power load interrupter switchgear cabinet -GFE	$ 4,000	
Heliostat interface power cabinets - 2 each GFE		
Heliostat interface J-Box installation-1818 each		$ 755,970
J-boxes delivered	$ 515,000	
Installation & terminations	$ 200,000	

CP 11A Collector Field Electrical (continued)

Roadway lighting installation (43 each)		$ 38,975
Foundations	$ 10,750	
Lights installed	$ 21,500	
c/o #015	$ 4,613	
Subtotal Heliostats	$1,898,691	$2,005,451
SHIMMS-		
Special instrumentation cable provisions (empty conduit)		
SHIMMS FDCR 14 c/o #005	$ 60,020	
Electronics environmental shelter & south weather station foundation modifications c/o #007 FDCR 52	$ 7,418	
SWS breakers/wire change FDCR 97 c/o #011	$ 1,373	$ 1,473
Subtotal SHIMMS	$ 68,811	$ 73,844
Receiver System:		
IR camera conduit c/o #003	$ 57,588	$ 61,801
General & Indirects-		
GFE extra work		
c/o #004 FDCR 22	$ 3,900	
c/o #009 cable procurement to cover shortage	$ 18,992	
c/o #013 unloading GFE	$ 24,184	
Replace broken breakers, install added cable c/o #014	$ 7,830	
Temporary power to MMC test trailer c/o #010	$ 4,650	
Mobilize ($50,000) & demobilize ($6450)	$ 56,450	
Subtotal General & Indirects	$ 116,006	
Total Collector Field Electrical Construction Package Cost	$2,141,096	$2,141,096

APPENDIX A.14--CONSTRUCTION PACKAGE 12: INSULATION AND LAGGING

CP 12 Insulation and Lagging
($659,741)
Metalclad Insulation Corporation

	Charges	Charges w/ Indirects
Collector System:		
Special insulation for BCS targets		
Material ($3,000), labor ($6,500)	$ 9,500	
Subtotal Collector System	$ 9,500	$ 10,429
Receiver System:		
Receiver unit piping (including GFE Panel modules) Part of CP 9 c/o #005		
Boiler panels c/o #004 FDCR 275	$ 19,475	
Special insulation for receiver unit		
Receiver core c/o #003	$148,400	
Subtotal Receiver System	$167,875	$184,286
Thermal Transport System:		
All piping insulation/lagging for:		
Steam piping (main, admission & other) & Condensate & drain piping (hot lines)		
Tower mat ($16,100), labor ($36,000)	$ 52,100	
Tower pipe guide mods. c/o #009	$ 13,715	
Subtotal Thermal Transport System	$ 65,815	$ 72,249
Thermal Storage System:		
Hot oil lines		
Materials ($10,500), labor ($6,000)	$ 16,500	
All TSS skids' piping		
Material ($37,000), labor ($78,000)	$115,000	
c/o #005 FDCR 273,286	$ 10,929	
Misc. tanks, vessels and process equipment (exc. TSU) Mat ($15,000), labor ($47,000)	$ 62,000	
TSU oxygen analyzer c/o #008 FDCR 151	$ 10,370	
Rack mat ($45,000), labor ($98,000)	$143,000	
Subtotal Thermal Storage System	$357,799	$392,777

CP 12 Insulation and Lagging (continued)

Other Direct & Indirect:

Heat tracing c/o #002,007 FDCR 290	$ 5,492	
Schedule extension c/o #006 12/26/81-4/26/82	$ 7,760	
Material substitution c/o #001	-$ 9,200	
Mobilization, indirects		
Mobilization matl ($6,500), labor ($2,500)	$ 9,000	
Demobil. matl ($2,000), labor ($1,000)	$ 3,000	
Scaffolding matl ($5,500), labor ($8,000)	$ 13,500	
Leak Detect matl ($2,000), labor ($6,000)	$ 8,000	
Overhead matl ($14,500), labor ($6,700)	$ 21,200	
Subtotal General & Indirects	$ 58,752	
Total Insulation and Lagging Construction Package Cost	$659,741	$659,741

APPENDIX B--PLANT SUPPORT SYSTEM LONG-LEAD PROCUREMENTS

PSS Long-Lead Procurement
($2,764,738)
SFDI/Stearns-Roger

	Charges	Charges w/ Indirects
Structures & Improvements:		
Diesel & motor driven fire pumps PO #2001	$ 43,174	
Electric fire pump $12,200		
Spares $299		
Diesel driven fire pump $29,481		
Spares $120		
Electric jockey fire pump $1,036		
Spares $38		
PSS 480 V MCC C PO #4004p	$ 6,651	
Power cable PO #4005p	$ 12,061	
Control cable PO #4005p	$ 3,761	
Instrumentation cable PO #4006	$ 36	
Misc. directs and distributed indirects		$ 19,613
Subtotal Structures & Improvements	$ 65,683	$ 85,296
Collector System:		
Heliostats-		
Equipment--		
Heliostat load interrupter switchgear & I/F control cabinets (2) PO #4001		
Load interrupter switchgear	$ 11,064	
I/F control cabinets (2)	$ 744	
Spare Parts-- heliostat I/F PO #4010	$ 124	
Heliostat power centers (14) PO #4003	$ 82,614	
Spare parts for power centers PO #4009	$ 359	
Watt transducers		
Power centers 2 & 6	$ 3,012	
Heliostat power (5 each)	$ 1,565	
Primary meter equipment (2 each)	$ 834	
Power cable--		
Power cable from SCE SG to heliostat I/F switchgear		
5 kV #2/0, 1/C w/g 300' PO #4008p	$ 679	
Power cable from heliostat I/F Switchgear to power centers		
5 kV #2/0, 3/C 10,000' PO #4000p	$ 72,611	
Power cable from power centers to heliostats PO #4000p	$ 146,912	
600 V #4, 4/C 16,000' $32,472		
600 V #6, 4/C 11,000' $17,889		
600 V #8, 4/C 3,140' $5,478		
600 V #10, 4/C 105,000' $91,073		

PSS Long-Lead Procurement (continued)

Power cable for heliostat field roadway lighting 600 V #10, 2/C 12,000' PO #4000p	$ 9,903	
Watt Xducers 3,660' RG22M PO #4002p	$ 4,058	
Control cable--		
J-Box B to heliostat I/F Cab B 4160' RG22 PO #4006p (4,500')	$ 3,378	
I/F Cab B to heliostats 172,160' RG22M PO #4002p	$ 190,885	
RG22M coaxial cable balance of 190,000' PO #4002p	$ 710	
600 V cable #10 1/C 7,000' PO 4000p	$ 759	
BCS-		
BCS targets PO #2002	$ 96,589	
BCS target painting PO #6001	$ 31,050	
Power cable #8 4/C 2400' PO #4000p	$ 3,747	
Control cable RG22M 4980' PO #4002p	$ 5,522	
RG11 coaxial cable 5000' PO #4002p	$ 1,315	
RG11 coaxial cable 10,146' PO #4006p	$ 31,554	
Instrumentation cable #16 1 pr PO #4006p	$ 247	
SHIMMS-		
Metro Sta power cable EES to power centers 600 V #8 4/C 1850' PO #4000	$ 2,888	
Metro Sta control cable EES to I/F Cab B RG22M 9110' PO #4002p	$ 10,101	
Heliostat strain gages - EES to I/F Cab B RG22 2320' CP11		
Instrumentation cable #16 1 pr PO #4006p	$ 124	
Misc. directs and distributed indirects		$ 212,971
Subtotal Collector System	$ 713,224	$ 926,195
Receiver System:		
Pre-fab'd Rocketdyne piping	$ 160,470	
Power cable PO #4005p	$ 7,740	
Control cable PO #4005p	$ 295	
Remote station RS1 instrumentation cable #16 1pr (430'); #16 4pr (560'); 8pr (1620'); 12pr (560'); 20pr (1000'); triad (10,080') PO #4006p	$ 13,831	
Belden #9283 (1120') PO #4002p	$ 295	
Shielded pair/triad not allocated PO #4006 all balance of purchase	$ 60,817	
TC ext cable PO #4007p #16 1pr (3000'), #20 4pr (530'), 20 pr (480 ')--all balance of purchase	$ 12,061	
Misc. directs and distributed indirects		$ 76,296
Subtotal Receiver System	$ 255,509	$ 331,805

PSS Long-Lead Procurement (continued)

Thermal Transport System:		
Receiver feedwater pump PO #2000	$ 314,216	
FW pump power cable		
5 kV #2/0 1/C w/g 900' PO #4008p	$ 2,037	
Other power cable	$ 125	
FW pump control cable	$ 86	
Pressure seal valves PO #3000p MOV1030, MOV1031, MOV1132	$ 28,603	
Drag valve PV1001 PO #5000	$ 42,067	
Special control valves PO #5001 (PV1003 & PV1005)	$ 10,132	
PSS control valves PO #5002 (AOV1008,1009; FV1006,1007; PV1000; TV1002,1004) & SCE (LV74A,B,C,D-1,D-2; PV640,647B,647C)	$ 78,706	
Spare parts PO #5006	$ 12,163	
Spare parts PO #5005	51	
Pre-fab'd Stearns-Roger primary piping	$ 259,265	
Primary hangers and snubbers		
Hangers PO #3001	$ 29,623	
Snubbers PO #3002	$ 103,839	
Power cable PO #4005p	$ 2,795	
Control cable PO #4005p	$ 962	
Instrumentation cable		
#16 1pr PO #4006	$ 3,754	
Misc. directs and distributed indirects		$ 265,286
Subtotal Thermal Transport System	$ 888,424	$1,153,710
Thermal Storage System:		
TSS 480 V MCC B PO #4004p	$ 9,328	
LCA-4160 V xformer & LV SG PO #4004p	$ 44,968	
LV non-segregated bus duct PO #4004p	$ 5,671	
Spare parts PO #4011	$ 7,213	
5 kV power cable		
5 kV #2/0, 1/C w/g 1560' PO #4008p	$ 3,530	
Bldg 712 power cable	$ 791	
Bldg 712 control cable	$ 166	
600 V power & control cable PO #4005		
Power cable for skids	$ 11,903	
Power cable for TSS misc.	$ 2,961	
Power cable undefined	$ 10,603	
Control cable for skids	$ 940	
Control cable for TSS misc.	$ 96	
Control cable undefined	$ 1,651	

PSS Long-Lead Procurement (continued)

Instrumentation PO #4006		
Skids #16 1pr (1570'), 4 pr (2165'), 4 tr (3610'), 8 pr (680'), 12 pr (160')	$ 12,253	
TC extension cable PO #4007p	$ 12,104	
#20 4pr (1470'), 20pr (1520')		
Remote station RS2 power cable PO #4005p	$ 1,472	
Remote station RS2 control cable PO #4005p	$ 99	
Remote station RS2 instrumentation cable JB 1951 to J-Box A PO #4006p		
#16 1pr (655'), 8pr (365'), 12pr (1070'), 20pr (305'), triad (5720')	$ 7,500	
Belden #9283 (800') PO #4002p	$ 210	
Remote station RS3 power cable PO #4005p	$ 358	
Remote station RS3 control cable PO #4005p	$ 109	
Remote station RS3 instrumentation cable JB 1952 to J-Box A PO #4002p		
#16 8pr (435'); 12pr (975'); 20pr (720'); triad (7800') PO #4006p	$ 9,966	
Belden #9283 (480')	$ 126	
Misc. directs and distributed indirects		$ 43,004
Subtotal Thermal Storage System	$ 144,018	$ 187,022
Turbine-Generator Plant:		
Pressure seal valves PO #3000p (T-G area)	$ 37,006	
General service valves (T-G area)		
PO #3003	$ 15,273	
PO #3004	$ 4,207	
Remote station RS4 instrumentation cable JB 1953 to J-Box A PO #4006p		
#16 1pr (960'), triad (1240'), 12pr (60'), 20pr (180')	$ 1,730	
Belden #9283 (2200' to CT substation) PO #4002p	$ 610	
Misc. directs and distributed indirects		$ 17,566
Subtotal Turbine-Generator Plant	$ 58,826	$ 76,392
Electrical System:		
Watt Transducers 7 each PO #5003 (Gen. gross,MX1,AX1,SX1,CTX1,LCA & P917)	$ 2,259	
Spare parts for watt xducers PO #5007	$ 886	
Misc. directs and distributed indirects		$ 939
Subtotal Electrical System	$ 3,145	$ 4,084

PSS Long-Lead Procurement (continued)

Miscellaneous Equipment:		
Nitrogen skid power cable PO #4005	$ 180	
Misc. directs and distributed indirects		$ 54
Subtotal Miscellaneous Equipment	$ 180	$ 234
Other Direct Costs and Distributed Indirects:	$ 635,729	
Total Plant Support System Long-Lead Procurements Costs	$2,764,738	$2,764,738

APPENDIX C--SOUTHERN CALIFORNIA EDISON EQUIPMENT AND MATERIAL PURCHASES

SCE Equipment and Material Purchases
($5,370,000)

	Charges	Charges w/ Indirects
Structures & Improvements:		
Leasing water demineralizing system (2075)		
Pol. dem. sump pumps P936/P937 (00016)	$ 20,900	
Misc. directs and distributed indirects		$ 3,807
Subtotal Structures & Improvements	$	$ 24,707
Thermal Transport System:		
TSS feedwater pump P903 (4304)	$ 34,000	
Condenser hotwell pump P907 (4316)	$ 11,700	
Condensate storage tank Tk902 (0447)	$ 33,254	
Shop fab'd 2 1/2" and larger ferrous piping (0554)	$ 210,000	
Condensate acid storage tank Tk915 (00011)	$ 11,000	
Acid transfer pump P935 (00014)	$ 2,062	
Caustic storage tank Tk916 (Tankinetics)	$ 6,000	
Caustic storage tank heater H904		
Caustic transfer pump P943 (00014)	$ 6,700	
Deaerator DA901 (0407)	$ 33,000	
Feedwater heaters (0419)	$ 127,600	
1st point high pressure heater E902		
2nd point high pressure heater E903		
4th point low pressure heater E904		
Polishing demineralizer (0413) w/P919,P920,P931,P932,P939,P940,Tk908, Tk909,E910,H905,V901,V902,V903	$ 247,400	
Condenser/Deaerator chemical feed w/		
ammonia tank Tk914/pump P934 (00010)	$ 3,500	
hydrazine tank Tk913/pump P933 (00010)	$ 3,500	
Valves		
Non-return	$ 47,296	
Relief	$ 11,800	
Gate, globe, check	$ 27,500	
Control	$ 50,000	
Motor operated	$ 15,000	
Structural steel aux. bay structure matl	$ 175,300	
Misc. directs and distributed indirects		$ 192,464
Subtotal Thermal Transport System	$1,056,612	$1,249,076

SCE Equipment and Material Purchases (continued)

Turbine-Generator System:		
Turbine-Generator & accessories (0520)	$2,221,517	
Condenser		
Main steam condenser (4101)	$ 123,500	
Main steam condenser tubing (0456)	$ 57,900	
Vacuum pump P910 (4032) w/HXC	$ 37,500	
Circulating water system		
Cooling tower w/fans		
Design & erection (0445)	$ 153,300	
Fiberglass circulating water Pipe (2635)	$ 51,499	
Circulating water pumps P905 P906 (0434)	$ 22,396	
CT transformer CTX1 4160-480V .75MVA (0368Ap)	$ 10,300	
CT sulphuric acid tank TK904 (00011)	$ 11,000	
CT sulphuric acid pump P912 (00010)	$ 2,062	
CT sodium polyacrylate feed		
Day TK905 (00013)		
Pump P923 (00013)		
CT sodium hypochlorite		
Storage TK922 (Tankinetics)	$ 6,501	
Pump P930		
Misc. directs and distributed indirects		$ 491,350
Subtotal Turbine-Generator System	$2,697,475	$3,188,825
Electrical System:		
Switchyard		
Main transformer (MX1) 33 to 4KV 10MVA (6020p)	$ 48,400	
Circuit breaker - 34.5KV 1500MVA 1200 A (SCE)	$ 5,000	
Auxiliary transformer (AX1) 13.8 to 4KV 18 MVA (SCE)	$ 15,000	
Station service transformer SX1 750KVA (0368Ap)	$ 10,300	
Uninterruptible power system (UPS) & DC		
Battery bank & rack (0350)	$ 12,835	
Battery charger	$ 4,000	
UPS	$ 73,567	
DC control & dist. switchboard (0360)	$ 27,000	
Switchgear, MCC's, LCA's		
Switchgear & MCC's (0345)	$ 152,613	
480V Switchgear B01,B02		
MMC's BOA & BOL		
4160V Switchgear A01 350 MVA (SCE)	$ 12,000	
15KV generator switchgear GS (SCE)	$ 8,000	

SCE Equipment and Material Purchases (continued)

Protective relay switchboard		
Distribution panels		
Other miscellaneous electrical		
Instrumentation		
Cable - power, control, instrumentation		
Control, instrumentation	$ 25,500	
Power cable (6020p)	$ 75,000	
SG to MX1--UG, SG to AX1--UG, SG to Gen Bus 5 KV, 480 V		
Misc. directs and distributed indirects		$ 85,468
Subtotal Electrical System	$ 469,215	$ 554,683
Miscellaneous Equipment:		
Air compressors CP901, CP902 W/DR901, DR902,F901,F902,V904,CR902,CR903 (4216)	$ 88,991	
Feed water chemical analysis system (5047)	$ 97,098	
Equipment cooling water system		
Cooling water HXC E905 (0411)	$ 43,331	
Cooling water pump P901 (0420)	$ 2,440	
CW surge tank Tk901 (00008)	$ 5,800	
Auxiliary boiler	$ 44,100	
Auxiliary boiler transformer AXB 1500 KVA (0368)	$ 15,602	
Aux. boiler/TSS FW pump P904 (4315 or 00006)	$ 1,000	
Nitrogen supply system leasing (4245)		
Misc. directs and distributed indirects		$ 54,347
Subtotal Miscellaneous Equipment	$ 298,362	$ 352,709
Other Direct Costs:		
Spares		
Other unidentified costs or SCE provided equipment/materials	$ 827,436	
Total SCE Materials & Equipment Purchases	$5,370,000	$5,370,000

APPENDIX D--SOUTHERN CALIFORNIA EDISON CONSTRUCTION CONTRACTS

SCE Construction Contracts
($5,415,000)

	Charges	Charges w/ Indirects
Structures & Improvements:		
Control Building - Construct (0130)	$ 740,531	
Elevator, Enclosure (0105)	$ 40,500	
Rest Rooms (0176)	$ 103,220	
Security Building (0160p)	$ 1,000	
Administration Bldg. Install, w/ xfmr.,(0160p)	$ 20,300	
Buildings General		
Painting		
Insulation		
Plant Fencing (0202)	$ 43,700	
Paving Roads, and Misc. Concrete		
Access Road & Helistop (0237)	$ 119,500	
Water Well & Line A Tie in - elect. (4269)		
Water Well & Domestic Water Supply System (2110)		
Sanitary System (2636p)		
Waste Drainage Piping to Evap. Pond		
Septic Tank & Seepage Pit		
Communications & Lighting		
Communications Installation	$ 43,095	
Lighting Installation		
Misc. Directs and Distributed Indirects		$ 108,605
Subtotal Structures & Improvements	$1,111,846	$1,220,451
Thermal Transport System: (estimate by author)	$ 783,989	
Auxiliary equipment structure erection, install mechanical equipment, piping, instrumentation, insulation		
Structure Erection (6017p)		
Concrete		
Structural Steel		
Painting		
Miscellaneous		
Equipment Installation, Piping (6017p)		
Water Treatment		
Chemical Feed Equipment Installation		
Other Miscellaneous Equipment Installation		
Piping & Accessories Installation		
Feedwater Heaters, Heat Exchanger installation		
FW Heaters, HXC installation		
FW Pumps Installation		
Other Miscellaneous Installation		
Piping & Accessories Installation		

SCE Construction Contracts (continued)

Condensate System		
Condensate Storage Tank Installation		
Condensate Pump Installation		
Piping & Accessories Installation		
Instrumentation Installation (6017p)		
Misc. Directs and Distributed Indirects		$ 69,765
Turbine-Generator Plant: (estimate by author)	$1,962,661	
Turbine-Generator Installation (6017p)		
Turbine-Generator Installation		
Special Installation Equipment		
Turbine-Generator Misc. Equipment Install		
Piping & Accessories Installation		
Condenser		
Condenser Installation		
Other Miscellaneous Installation		
Circ. Water Equip., Piping Install (6017p)		
Circulating Water Pumps, Installation		
Piping and Accessories Installation		
Miscellaneous Tanks Installation		
Misc. Directs and Distributed Indirects		$ 174,653
Miscellaneous Equipment: (estimate by author)	$ 217,086	
Instrument/Service Air System Installation		
Air Compressors Installation (6017p)	$	
Miscellaneous Equipment Installation	$	
Piping & Accessories (2636p)	$	
Water Sampling System (6017p) Installation	$	
Misc. Directs and Distributed Indirects		$ 19,318
Subtotal Turbine-Generator (part) and Miscellaneous Equipment	$2,700,000	$2,963,736
Turbine-Generator Plant (cont.)		
Turbine Pedestal & Equip. Foundations (0284)	$ 310,285	
Cooling Tower Basin, Structural Foundations, and Underground Piping Installation (2636p)	$ 303,000	
Circulating Water Conduits Install (2636p)		
CT MCC Bldg., HVAC,found.,elect. (6020-A)		
CT MCC Bldg. Prefab'd Building (SCE)	$ 8,000	
Misc. Directs and Distributed Indirects		$ 60,687
Subtotal Turbine-Generator (part)	$ 621,285	$ 681,972

SCE Construction Contracts (continued)

Electrical System:	$ 500,000	
Construction Power Concrete & Grounding (6030)		
Electrical Switchyard Installation (6020-Bp)		
Switchyard installation for 33 KV grid intertie, pull & terminate power, control & instrumentation wiring		
Plant Power Distribution		
Station Service Transformer SX1 4160 to 480V		
CTX1 4160 - 480V		
Distribution Panels		
MCCA Bl 901		
MCCL Cooling Tower Area (cost w/MCCA)		
Relays & Boards		
4160V Switchgear		
480V Switchgear, from CTX1 & SX1 (cost w/MCCA)		
Plant Interties (6020p)		
Main Transformer 33KV to 4160V		
Auxiliary Transformer 13.8KV to 4160 V		
Conductors		
Wiring, Cable Pulling, Term. (3013)		
Main Bus - Generator		
Cable Protection		
Busway/Cable Trays/Raceways		
Conduit/Duct Banks		
Emergency Power Installation (6020-Bp)		
Uninterruptible Power System		
DC Power System 125V - TG		
Miscellaneous Electrical Installation		
Misc. Directs and Distributed Indirects		$ 48,841
Subtotal Electrical System	$ 500,000	$ 548,841
Miscellaneous Directs and Distributed Indirects	$ 481,869	
Total SCE Construction Contracts Cost	$5,415,000	$5,415,000

APPENDIX E.1--FORD MOTOR COMPANY GLASS PURCHASE

Glass Costs for the Pilot Plant and IEA Heliostats
(Ford Motor Company)

Glass Cost for 1,248,080 ft^2 (Tulsa Plant) cut to 48" x 134" size @ $0.45/$ft^2$ (note: glass cost $0.30/$ft^2$ + cutting)	$ 561,633
less discount for early payment	$ 9,184
Subtotal Glass Cost	$ 552,449
Storage Cost at Tulsa Plant	$ 47,459
Freight Cost from Tulsa Plant (43 truck loads)	$ 43,094
Cutting Charges (48"x134" to 43"x120")	$ 221,518
Paper Interleaving	$ 5,048
	$ 869,568
Less IEA share of Cost (all low Fe)	$ 45,750
Pilot Plant share of Cost	$ 823,818

Notes:

Total of 27,942 lites (1,001,255 ft^2) picked up by Gardner Mirror.

Cutting @ $0.1775/$ft^2$

Most Storage @ $0.03/$ft^2$

Required Glass (821,730 ft^2)-
Pilot Plant 1818 x 12 = 21,816 lites
IEA 93 x 12 = 1,116 lites

22,932

Extra Glass--about 22% (Breakage,etc.) = 5,010 lites

Cost of Glass ready for pickup by Gardner
IEA cost = $1.14/$ft^2$ (all low Fe float)
Pilot Plant cost = $1.05 (93% low Fe float; 7% med Fe float)

Silvering, freight by Gardner was $1.00/$ft^2$ of required glass area.

APPENDIX E.2--INTERNATIONAL ENERGY AGENCY HELIOSTAT COST

IEA Heliostat Cost Based on IEA Spare Parts Data
(Costs in $/heliostat)

	Matl.	Labor	Frt.In	G&A	Fee	Total
Controls						
HC	$ 607	$ 156	$ 15	$ 100	$ 106	$ 984
HFC	$ 31	$ 11	$ 1	$ 6	$ 6	$ 55
			Subtotal			$ 1039
Miscellaneous						
Miscellaneous Parts	$ 49		$ 1	$ 4	$ 6	$ 60
Denver Total						$ 1099
Reflective Assembly						
Mirror Assembly						
Mirror Modules	$2367	$ 597	$ 59	$245	$ 393	$ 3661
Glass-Ford	$ 492					$ 492
Pueblo Total						$ 4153
Rack Assembly						
Elevation Beam	$ 765		$ 15	$ 63	$ 101	$ 944
Bar Joists-short	$ 71		$ 1	$ 6	$ 9	$ 87
-long	$ 86		$ 2	$ 7	$ 11	$ 106
			Subtotal			$ 1137
Pedestal Assembly						
Pedestal	$ 640		$ 13	$ 53	$ 85	$ 791
			Subtotal			$ 791
Drive Mechanism Assembly						
Drive	$2573		$ 51	$ 213	$ 341	$ 3178
Motors	$ 312		$ 6	$ 26	$ 41	$ 385
Encoders	$ 372		$ 7	$ 31	$ 49	$ 459
Cable Harness	$ 176		$ 4	$ 15	$ 23	$ 218
Control Arms	$ 259		$ 5	$ 21	$ 34	$ 319
Pedestal Interface Adpt.	$ 203		$ 4	$ 17	$ 27	$ 251
			Subtotal			$ 4810
Daggett Total						$ 6738
Total Price	$9003	$ 764	$ 184	$ 807	$1232	$11990

International Energy Agency Heliostat Cost (continued)

Notes: 93 IEA Sets of Heliostat Parts

```
$11,497 x 93= $1,069,227 (MMC heliostat parts)
$   492 x 93= $   45,750 (Ford Glass)
              ----------
$11,990 x 93= $1,115,027 (Total as shown above)
              $   79,402 (MMC heliostat spare parts)
              ----------
              $1,194,429 (total MMC- DOE Operational Budget)
```

Prices are based on 1979 estimates.
Assumptions used in 1979:
- Freight cost into fabrication facility @ 2% of materials and labor.
- G&A @ 8.1% except HC/HFC @ 12.8%
- Fee @ 12.02%

APPENDIX E.3—MARTIN MARIETTA CORPORATION PILOT PLANT AND INTERNATIONAL ENERGY AGENCY HELIOSTAT COSTS

PRICES FOR PILOT PLANT INSTALLED HELIOSTATS AND IEA HELIOSTAT PARTS

		Engineering Design	Program Management	Fabrication Labor	Fabrication Management	Indirects	Materials + Freight	Totals
Heliostat								
System Engineering	=	$ 43,725						
Heliostat Design	=	$ 68,358						
O/M Manuals	=	$ 29,141						
Heliostat Dwgs/Spec.	=	$ 3,303						
Reviews	=	$ 7,894						
Reports	=	$ 11,925						
Material Prorate-buying	=	$ 51,227						
Logistics	=	$ 12,428						
Miscellaneous	=	$ 3,695						
Computer Charges	=	$ 106,173						
Reproduction Services	=	$ 42,011						
Management/Supervision	=		$ 65,587					
Tooling Design	=	$ 265,822						
Tooling Design Management	=		$ 88,607					
Quality Engineering								
Safety	=	$ 33,053						
Inspection	=	$ 109,756						
Quality Engineering Manage	=		$ 90,453					
Management Travel	=		$ 136,341					
Other Technical Services	=		$ 626,403					
G&A on Heliostats-General	=					$ 220,851		
Subtotal on Heliostats General	=	$ 788,582	$1,007,396			$ 220,851		$2,016,829

Martin Marietta Corporation Pilot Plant and International Energy Agency Heliostat Costs (continued)

		Engineering Design	Program Management	Fabrication Labor	Fabrication Management	Indirects	Materials + Freight	Totals
Controls								
Hardware Design	=	$ 183,997						
Software Design	=	$ 458,186						
Software Color Graphics	=	$ 30,176						
HC failure investigation	=	$ 19,623						
HC board noise problem	=	$ 79,976						
HC/HFC Fabrication	=			$ 674,138				
Tooling Labor	=			$ 283,729				
Testing Labor	=			$ 32,008				
HC/HFC Quality Control	=			$ 62,634				
HC/HFC QC Management	=		$ 12,944					
EMF Management	=		$ 26,705					
Control Hdw. fab management	=				$ 37,342			
Materials into Denver								
Controls Materials	=						$1,760,178	
Tooling Materials	=						$ 409,732	
Manufacturing Materials	=						$ 50,320	
Freight into Denver	=						$ 126,272	
G&A on Controls Manufacturing	=					$ 553,228		
Subtotal on Controls		$ 771,956	$ 39,649	$1,052,508	$ 37,342	$ 553,228	$2,346,502	$4,801,185

Martin Marietta Corporation Pilot Plant and International Energy Agency Heliostat Costs (continued)

	Engineering Design	Program Management	Fabrication Labor	Fabrication Management	Indirects	Materials + Freight	Totals
Mirror Module							
Versilok Test =	$ 8,790						
Lip Seal Change =	$ 129,467						
Mirror Delamination =	$ 165,363						
Tool Engr. Procure =	$ 107,716						
Fabrication Management =				$ 720,671			
Management Travel/Relocation =				$ 191,893			
Job Shop Fabrication Labor =			$2,183,119				
Facility Lease =					$1,097,063		
Materials into Pueblo							
Mirror Module Material =						$5,441,480	
Tooling Material =						$1,330,763	
Freight into Pueblo =						$ 200,554	
G&A on Mirror Module Mfg. =					$ 780,483		
G&A on Mirror Module Design =					$ 53,568		
Subtotal on Mirror Module =	$ 411,326		$2,183,119	$ 912,564	$1,931,115	$6,972,798	$12,410,921

Martin Marietta Corporation Pilot Plant and International Energy Agency Heliostat Costs (continued)

		Engineering Design	Program Management	Fabrication Labor	Fabrication Management	Indirects	Materials + Freight	Totals
Daggett Assembly								
Facility Design	=	$ 5,599						
Tool Engr. Procure	=	$ 24,969						
Final Assy Management	=		$ 19,539					
Management Travel	=		$ 10,889					
Job Shop Assembly Labor	=			$1,039,455				
Assembly Management Labor	=				$ 383,789			
Management Travel/Relocaton	=				$ 190,536			
Facility Lease	=					$ 427,869		
Material into Daggett								
Heliostat Material	=						$11,262,563	
Tooling Material	=						$ 240,806	
Start-up Material	=						$ 19,561	
Freight into Daggett	=						$ 764,053	
G&A on Assembly	=					$1,042,306		
G&A on Design/Pgm Management	=					$ 35,161		

Martin Marietta Corporation Pilot Plant and International Energy Agency Heliostat Costs (continued)

	Engineering Design	Program Management	Fabrication Labor	Fabrication Management	Indirects	Materials + Freight	Totals
Site Installation							
Installation Management =		$ 40,253					
Testing Management =		$ 104,189					
Management Travel =		$ 80,497					
Job Shop Installation Labor =			$1,028,132				
Job Shop Misc. Field Labor =			$ 462,543				
Installation Management Labor =				$ 383,789			
Management Travel/Relocaton =				$ 190,536			
G&A on Installation =					$ 114,030		
Subtotal on Assy/Installation	$ 30,568	$ 255,368	$2,530,130	$1,148,649	$1,619,367	$12,286,983	$17,871,065
Total Price	$2,002,431	$1,302,413	$5,765,757	$2,098,555	$4,324,561	$21,606,283	$37,100,000

APPENDIX F--BEAM CHARACTERIZATION SYSTEM COSTS

Beam Characterization System (BCS) Costs

BCS Targets & Shutter Control	
Screen (4)	
Targets LLP	$ 96,589
Erection CP9	$ 127,401
Painting LLP	$ 31,050
Mounting Structure	
Target Insulation CP12	$ 9,500
Target Radiometers/Shutters	
Pyrheliometers (16)	
Water Cooling System (E201,E202,P201)	
Electrical Mod. CP11 FDCR207	$ 5,991
MCC 6	
Shutter Assemblies (4)	
BCS101 MODACS III A/D Cabinet Modcomp 1804-1	
Cabling to MODACS III from pyrheliometers	
Cabling to MODACS III from shutter control	
Cabling from MODACS III to Modem	
BCS Video Assembly	
Video Camera System (4) N,E,S,W	
BCS901-904A Video Cameras Cohu Model 2850C-207	
BCS902-904B Camera Receiver Units Cohu Model DTMF-200	
Sun Shields Cohu, Pan/Tilt Systems	
Mounting Structures Foundations CP6 est.	$ 15,100
Cable Assembly Cohu Model AC27	
BCS Camera Control (Control Bldg Equipment Room)	
BCS601 BCS Camera Control Rack	
BCS601-1 Transmitter Cohu Model DTMF-100	
BCS601-2 Pelco Switcher Model VA-504R	
BCS601-3 Video Digitizer Quantex Model DS-12	
BCS601-4 Modem Codex 8200 (to MODACS III)	
BCS Control Equipment (Control Room)	
BCS700-1 Time Code Generator	
WWV Receiver	
BCS700-3 DTMF-100 Transmitter	
BCS700-4 Switching Matrix	
BCS700-5 Video Processor	
BCS700-8 Modem	
BCS701-2 Video Monitor CRT Cohu Model DM9-C	
BCS Data Evaluation (DAS Room)	
BCS801 CRT Graphics and hard copy Terminal HP 9845B	
Total MDAC Fabrication/Procurement Cost	$ 195,841

Beam Characterization System Costs (continued)

Field Wiring:	
J-Box A (Control Bldg.) to I/F Cab. B (1040') RG11	$ 1,315
EES-1925,A,B&C to I/F Cab.B (5340') RG11	
Cable from receiver to transmitter-RG11	$ 31,554
Cable from receiver to switches -RG11	
(note- cost of coaxial matl. only-LLP)	
Estimated cost of installation CP11A	$ 25,000
J-Box A to I/F Cab. B (1040') 1pr #16	
Hardware Design (MDAC)	$ 236,658
Software (MDAC)	$ 224,327
Integration/Test (MDAC)	$ 416,776
FY1983 Modifications	
Total Beam Characterization System Cost	$1,417,102

APPENDIX G.1--OPERATIONAL CONTROL SYSTEM EQUIPMENT COST

OCS EQUIPMENT LIST

Equipment #	Description	Cost
OCS 601	Minicomputer	
	Modcomp 7863 Classic 128 KB	$ 43,600
	Modcomp 3693 (2) 128 KB	$ 16,000
	Modcomp 3648 Mem. Exp. Chassis	$ 6,850
	Modcomp 3771 Dual Bus Input/Output Processors	$ 7,500
	Modcomp 3320 CPU Battery BU	$ 1,050
	Modcomp 3321 Mem. Exp. BU	$ 1,050
	Modcomp 3765-30 Disc & Console Controller	$ 13,250
OCS 602	Magnetic Tape System	
	Modcomp 4164-1 9 Track/ 75 IPS/ 800 BPI w/ controller, Cabinet	$ 14,700
	Modcomp 4903	$ 2,200
	30' cable 0203-B	$ 450
OCS 603	Moving Head Disc	
	Modcomp 4137 10 MB Disc	$ 9,925
	Modcomp 4143-A 67 MB Disc, Controller	$ 19,900
	30' cable 0203-B	$ 450
	Modcomp 0001 Cabinet	$ 1,325
	Modcomp 0012 Right Sideskin	$ 280
OCS 604	Peripheral Control Interface	
	Modcomp 4807-1 Asynchronous Terminal Controller	$ 5,000
	Modcomp 4903 (3)	$ 6,600
OCS 605	Interface	
	Modcomp 4824 Serial I/F to DAS	$ 2,500
	100' cable 1710-1 to DAS CPU	$ 125
	Modcomp 4911 Peripheral Interface Enclosure	$ 2,675
	Modcomp 0001 Cabinet	$ 1,325
	Modcomp 0012-1 Left Sideskin	$ 500
	Modcomp 4811-77 Asyn. Comm. IF	$ 3,600
OCS 606	Keyboard/Printer	
	Modcomp 4222	$ 2,800
	30' cable Modcomp 0210-B	$ 55
OCS 701	Logger	
	Modcomp 4228 Matrix Printer, 64-440 LPM	$ 4,140
	100' cable 0214-D	$ 265

Operational Control System Equipment Cost (continued)

OCS 801/802	B/W CRT		
	Modcomp 4612 (2)	$	5,680
	75' cable 0214-A	$	380
	Software - Operating System		
	MAXNET IV, Object	$	900
	MAXNET IV, Object, 9 Tr,800BPI	$	1,500
	MAXNET IV, Source, 9 tr,800BPI	$	1,100
	MAXNET IV, System Install	$	5,000
	Modcomp 0214-B HAC A & HAC B cables 50'	$	230
	Factory Acceptance	$	8,250
OCS	OCS Logger TI Model 810		
OCS	OCS Color Consoles AYDIN Model 5217 (2 each)		
	Total OCS Equipment Cost	$	191,115

APPENDIX G.2--DATA ACQUISITION SYSTEM EQUIPMENT COST

DAS EQUIPMENT LIST

Equipment #	Description	Cost
DAS 601	Minicomputer	
	Modcomp 7863 Classic CPU w/ 128KB Extended Arithmetic Unit	$ 40,750
	Modcomp 3109 Universal Communications Processor	
	Modcomp 3693 (2) 128 KB	$ 15,000
	Modcomp 3771 Dual Bus IOP	$ 7,025
	Modcomp 0203-A 10' I/O cables	$ 1,140
	Modcomp 3320 Back-up Batteries	$ 980
	Modcomp 3321 Back-up Batteries for Memory Expansion	$ 980
DAS 602	Peripheral Control Interface (PCI)	
	Modcomp 4905 PCI & Console Controller I/F	$ 2,580
	Modcomp 4903 PCI (4)	$ 8,240
	Modcomp 5215 4-way Bus Switch	$ 5,400
	Modcomp 4911 Peripheral Controller Enclosure (PCE)	$ 2,675
DAS 603/604	Magnetic Tape Unit	
	Modcomp 4164-1 (2) w/ Controllers & Cabinet	$ 27,400
	Modcomp 0203-A cable	$ 285
DAS 605	Interface	
	Modcomp 1930-1A Communication Chassis	
	Modcomp 1931 (9) Asynchronous RS232 I/F Modules	
	Modcomp 0230 30' cables	$ 960
	Modcomp 1937-1 Bit Synchronous I/F Modules (3) to Modems	
	Modcomp 1907-A-2	
	Modcomp 4807-1 Controller for 16 spare Asynchronous Channels	$ 4,020
DAS 606/607	Moving Head Disc	
	Modcomp 4174-2 (2) 67 MB	$ 37,000
	Modcomp 4143-A-E3 (2) Controller sets	$ 18,550

Data Acquisition System Equipment Cost (continued)

DAS 608	Keyboard/Printer Operators' Console		
	Modcomp 4222 30 cps	$	2,580
	Modcomp 3732-2 Controller		
DAS 609	Line Printer		
	Modcomp 4211 600 LPM w/ Controller	$	17,000
	Modcomp 4211-2		
DAS 610	D/A Converters MODACS III		
	Modcomp 1804-1	$	4,725
	Modcomp 4828-2 Standard Link	$	1,950
	Modcomp 0235-A 50' cable	$	375
DAS 801/802	Color CRT ISC #8901 H		
DAS 803/804	B/W CRT		
DAS 805-807	Strip Chart Recorders		
DAS 808/809	Hard Copy Units		
DAS 810	Modcomp 4226 Matrix Printer w/ Controller 60-440 LPM	$	4,950
	Matrix Printer Stand Inmac Model 4865-NI	$	145
DAS 811/812	B/W CRT		
	OCS Computer CPU Modcomp 4824 Serial Link Serial Link	$	2,500
	Other Modcomp Equipment/cables	$	39,264
	Total DAS Equipment Cost	$	246,474

APPENDIX G.3--COLLECTOR SYSTEM CONTROLS EQUIPMENT COST

Collector System Controls Equipment List

CS601	Collector System Central Processing Unit		$ 37,469
	Modcomp Classic 7861	$ 28,490	
	Modcomp Memory Module 3691	$ 7,700	
	Modcomp Battery Back-up 3320	$ 836	
	Modcomp Internal I/O Cable 3780	$ 231	
	Modcomp Classic I/O Cable 0203A	$ 212	
CS602	Collector System Disk Drive Unit		$ 15,507
	Disk Drive 4137	$ 9,000	
	0001 Cabinet	$ 1,150	
	CS Peripheral Controller Interface 4903	$ 2,500	
	Asynchronous Multiplexer 1907	$ 2,857	
	MMC Asynchronous Parallel Communications Processor		
CS603	Collector System Magnetic Tape Unit		$ 14,537
	Magnetic Tape Unit 9-track 4148-1	$ 9,180	
	0001 Cabinet	$ 1,150	
	Peripheral Control Switch 4906	$ 3,090	
	Direct Memory Processor Card Reader 4811		
	Asynchronous Communication Interface 4811	$ 1,117	
CS604	Collector System Tape Drive Controller		$ 5,807
	0001 Cabinet	$ 1,150	
	Tape Drive Controller 4148		
	Peripheral Control Interface 4903	$ 2,000	
	Asynchronous Communication Interface 4811	$ 1,117	
	Central Processing Unit Link 4824	$ 1,540	
CS605	Collector System Tape Drive Controller		$ 16,966
	0001 Cabinet	$ 1,150	
	Tape Drive Controller 4148		
	Peripheral Control Interface 4903	$ 2,000	
	Asynchronous Communication Interface 4811	$ 1,117	
	Central Processing Unit Link 4824	$ 1,540	
	Peripheral Control Switch 4906	$ 3,090	
	Asynchronous Communication Interface 4811	$ 1,117	
	Printer 4227	$ 6,952	

Collector System Controls Equipment Cost (continued)

CS606	Collector System Disk Drive Unit		$ 15,007
	Disk Drive 4137	$ 9,000	
	0001 Cabinet	$ 1,150	
	Peripheral Control Interface 4903	$ 2,000	
	Asynchronous Multiplexer 1907	$ 2,857	
	MMC Asynchronous Parallel Communications Processor		
CS607	Collector System Central Processing Unit		$ 37,469
	Modcomp Classic 7861	$ 28,490	
	Modcomp Memory Module 3691	$ 7,700	
	Modcomp Battery Back-up 3320	$ 836	
	Modcomp Internal I/O Cable 3780	$ 231	
	Modcomp Classic I/O Cable 0203A	$ 212	
CS	Collector System Tape Drive Unit		$ 10,434
	0001 Cabinet	$ 1,150	
	Tape Drive Unit	$ 9,284	
	Tape Drive Controller 4148		
CS608	Keyboard Printer TI-820		$ 4,255
CS609	Keyboard Printer TI-820		$ 4,255
CS610	Card Reader 300 cpm Modcomp 4411		$ 3,966
CS611	Line Printer Modcomp 4227		$ 6,952
CS701	CS Operator 19" CRT/Terminal & Keyboard ISC-8001G		$ 1,800
CS702	CS Graphics Display Color Graphics CRT w/ Keyboard & Floppy Disc Chromatics 1999		
CS703	CS Logger 440 lpm Matrix Printer Modcomp 4228		$ 3,300
CS801	CS Color Graphics CRT Color Graphics CRT w/ Keyboard Chromatics 1999		
	HAC Auxiliary Relay Box		
	HAC Auxiliary Relay Box		
	Disc Packs--16 each		$ 2,880
	WWV		
	Total Collector System Controls Cost		$180,604

APPENDIX H—PIPING AND VALVE DETAILS AND COST

Pipe (Spools)	Type	Length	Hangers	Snub's	Fittings 90	45	Tee	Pipe Weight	Use & Valves
Primary Piping:									
MS-2-6" (18)	QEB	461'	31	13	34	6	4	18,906+ #	From Recv to T-G via MOV1031($12,572)
			($13,664)	($27,281)					
MS-3-6 (7)	QEB	169'	7	2				6,437+ #	To DS301 via MOV1030($12,572) & UV3102 (R)
			($661)	($2969)					
MS-5-10 (1)	FEA	5'							PV1001($42,067) to DS901
MS-6-2 1/2			1						
MS-6-6 (2)	QEB	12'	2						MS-2-6 to PV1001 via V-MS-6-1 ($6946)
			($658)						
MS-7-10 (6)	FEA	130'	9					4,365+ #	DS901 to Condenser
			($938)						
MS-8-2 (1)	QEB	2'	3	6					To DS902 via PV1003($6491)
			($1320)	($6276)					
MS-8-4 (1)									EPGS
MS-9-4	FEA								AS-9-4 to DS902 via AOV1008
MS-9-6 (1)	FEA	5'	1						PV1003 to DS902 via V-MS-8-2 ($6946)
MS-10-2 (1)	QEB	5'	4						MS-2 to ST-13-3 via FV1006($6350) &
			($342)						V-MS-10-3 ($6145)
MS-10-4 (1)									EPGS
FW-2-4 (16)	MBA	408'	31	8	20		2	8,214+ #	E902 to Receiver via AOV2004
			($3367)	($10,666)					
FW-9-2 1/2 (2)	MBA	80'	6		4				FW-2-4 to TV3105 (R)
			($184)						
FW-9-4 (1)								138 #	EPGS
ST-6-2 1/2 (1)	FBA		1						To DS902 via PV1005($3641) & AOV1008($4180)
ST-9-4 (2)	FEA	19'	1 ($189)						AOV1008 to DS902 via MS-9-6
ST-13-3 (1)	FEA		2 ($75)						FV1006 to DS901
ST-14-2 (1)	FEA		1 ($27)						FV1007 to DS901 via ST-13-3
ST-17-4 (1)									EPGS
ST-18-8 (1)									EPGS
ST-19-8 (1)									EPGS

Piping and Valve Details and Cost (continued)

Pipe (Spools)	Type	Length	Hangers	Snub's	Fittings 90	45	Tee	Pipe Weight	Use & Valves
AS-7-6 (1)	FEA	2'							From DS902 via AOV1009($1690)
VT-1-2	KEB								From VT-1-4 to FV1007($4217)
VT-1-4 (15)	KEB	264'	25 ($6927)	19 ($30,912)	15			3,192+ #	From V201 to PV1001 via PV2906 & AOV2914
VT-11-10 (2)	FEA	23'	2 ($331)	2 ($2274)	9	1			To DS901 via PV1000($16,767)
VT-12-2 1/2 (7)	KEB	155'	12 ($995)	12 ($10,068)				761+ #	To DA901 via V-VT-1 ($3442), PV647B ($6300), V-VT-2 ($8570) & V-VT-3 ($925)
VT-12-6 (1)			2						
(86) + (7)									

Primary Pipe, including fittings, Cost=		
LLP's (86 spools-PPS & 7 spools-EPGS)	$ 259,265	
CP9 Install Primary Tower Piping		$ 142,100
Primary Pipe Hanger Cost=		
LLP's Hangers	$ 29,623	
LLP's Snubbers	$ 103,839	
CP9 Sort & Set		$ 142,800
Primary Valve Cost=		
LLP's SFDI Area	$ 105,873	
LLP's SCE Area	$ 32,974	
Stored Pipe, Valves Cost=		
CP9 (All GFE)		$ 245,600
	$ 531,574 +	$ 530,500 = $1,062,074

Piping and Valve Details and Cost (continued)

Pipe (Spools)	Type	Length	Hangers	Snub's	Fittings 90	45	Tee	Pipe Weight	Use & Valves
Secondary Piping:									
Hot Oil Lines:									
TO-1-4	BBA		1						TK301 to P306
TO-2-4	BBA		2						P306 to V303
TO-3-8	BBA								
TO-3-10	BBA		5	2($2875)					TSU Lwr Outlet to P301/P302 via AOV3004 (R)
TO-4-8	BBA		8						P301 to E311 via TV3411 (R)
TO-5-8	BBA		8						P302 to E312 via TV3410 (R)
TO-9-8	BBA		10						E301/E302 to TO-9
TO-9-10	BBA								TO-8 to TO-10 via AOV3001 (R)
TO-10-8	BBA		12						To P303/P304 from TO-10-10
TO-10-10	BBA								TSU Upr Outlet to P303/P304 via AOV3002 (R)
TO-11-10	BBA		2						TO-3 to TO-9 via AOV3003 (R)
TO-12-	BBA		11						P303 to E305/E307 via PV3702/TV3710 (R)
TO-13-8	BBA		12						P304 to E306/E308 via PV3802/TV3810 (R)
TO-21-8	BBA		15	2($2875)					E304 to TO-21-10
TO-21-10	BBA								E303 to TO-21-10
TO-22-4	BBA		8						TSU Aux Stm Outlet to P305 via AOV3907 (R)
TO-23-4	BBA		1						TSU Aux Steam bypass via AOV3005 (R)
TO-25-8	BBA		1						P303 to E305 via TO-12-8 & PV3702 (R)
TO-26-8	BBA		1						
Hot Water-Steam Lines: 2 1/2" and larger									
MS-4-6	KBA								From MS-4-8 to E301 via AOV3206 (R)
MS-4-8	KBA		7						DS301 to MS-4-6 & E302 via AOV3306 (R)
ST-5-6	FBA		7						E307 to ST-5-8 via AOV3717
ST-5-8	FBA								E308 to T-G via AOV3817
ST-6-2 1/2			6						
AS-10-6	BBA		8						To DA901
VT-4-6	FBA		12						From V304 to DA901 via PV647C ($7123), V-VT-4 ($1035), V-VT-5 ($3557)

Piping and Valve Details and Cost (continued)

Pipe (Spools)	Type	Length	Hangers	Snub's	Fittings 90	45	Tee	Pipe Weight	Use & Valves
									& V-VT-6 ($2244)
									or to Condenser via PV640 ($13,581),
									V-VT-7 ($1035) & V-VT-8 ($3557)
00-3-4		90'	5						V305 to V304 via PV3110 (R)
00-4-4	KBA	110'	6						V306 to V304 via PV3111 (R)
00-5-4	BBA								P307 to E903 via LV74B ($3078),
									V-00-3 ($460), & V-00-4 ($460)
									or to E901 via LV74D1 ($2651),
									V-00-1 ($460),
									& V-00-2 ($460); or to E901 via
									LV74D2 ($2163),
									& 2 each 101-2's ($360)
00-6-3 (1)		364'	1					46 #	Recv drain to Condenser (E901)
00-7-2 1/2	BBA								
00-12-2	FEA								TV1002 to DS901
00-12-2 1/2 (1)		5'						8 #	
00-15-6	BBA								V304 to P307
UG-1 thru 14			14						
2" and smaller									
ST-1			3						
ST-7-2	FBA		2						To TS Flash Tank V304 via AOV3116
ST-16-2	FBA		2						To TS Flash Tank V304 via AOV3117
AS-1-1 1/2	FBA		11						E301/E302 via AOV3218/AOV3318 (R)
00-1-2	FBA		31						From V201 to E901 via LV74C ($2398), 2 each
									101-2's ($360) or to E903 via LV74A ($2398)
									& 2 each 101-2's ($360)
00-6-1 1/2	BBA								Receiver Drain Line
00-6-3			31						
00-8-1 1/2									To DS902 via TV1004($2423)

Piping and Valve Details and Cost (continued)

Pipe (Spools)	Type	Length	Hangers	Snub's	Fittings 90	45	Tee	Pipe Weight	Use & Valves
Cold Lines:									
2 1/2" and larger									
CO-7-2 1/2	BBA		6						To DS901 via TV1002($3385)
FW-10-2 1/2	FBA		10						P903 to E303/E304 via MOV1132($3459)
FW-10-4	FBA								& FW-10-2 1/2, LV3505 (R), LV3605 (R)
2" and smaller									
FW-4-1 1/2	MBA								TV3105 to DS301
									PV647B ($6300)

Secondary Piping Costs=

Piping CP9 Carbon Steel Pipe & Fittings		$ 88,600
Rack Pipe Fabrication CP9		$ 250,000
Rack Piping Installation CP9		$ 705,600
Rack Piping Flush & Test CP9		$ 22,200
Hangers Fab'd CP9		$
Hangers (LLP's)		$ 5,750
Valves (LLP's) - SFDI Area	$ 37,739	
(LLP's) - SCE Area	$ 14,348	
CP9 Install		$ 178,100
Tower Traps & Accessories CP9		$ 41,600
Piping Flush & Test CP9		$ 20,200
	$ 52,087 +	$1,312,050 = $1,364,137

Fire Protection System:

Pipe	Type	Hangers	Use & Valves
FP-1-8	CBC	14	P705/P707 to EPGS area
FP-2-8	CQA		
FP-3-8		1	
FP-4-8	CQA		

Piping and Valve Details and Cost (continued)

Pipe (Spools)	Type	Length	Hangers	Snub's	Fittings 90	45	Tee	Pipe Weight	Use & Valves
FP-5-6	CQA								To FH#1
FP-6-6	CQA								
FP-7-4	CQA								
FP-8-6	CQA								To FH#3
FP-10-6	CQA								To FH#5
FP-12-6	CQA								To FH#6
FP-13-6	CQA								To FH#7
FP-14-6	CQA								To FH#9
FP-15-6	CQA								To FH#8
FP-16-6	CQA								
FP-17-6	CQA								To FH#12
FP-19-6	CQA								To FH#10
FP-20-6	CQA								
FP-21-6	CQA								To FH#11
FP-22-8	CBC		2						To P705
FP-23-2	CBD								To P707
FP-24-1 1/2	CBD								From P707
FP-26-6	CBC		3						
FP-27-			3						From TK701
FP-28-			1						
FP-34-6	CBC		3						
FP-38-6	AQD								To Cooling Tower From Water Wells
FP-39-21									From Cooling Tower Basin
RW-4-6	ABA		5						From Tk701 to P704
RW-4-8	ABA								From Tk701 to P704
RW-6-8	DQA								From Water Wells

Underground Piping - Raw and Fire Protection Costs:

Deliver Pipe Materials CP9	$ 81,100
Install CP9	$615,300
	$696,400

Piping and Valve Details and Cost (continued)

Pipe (Spools)	Type	Length	Hangers	Snub's	Fittings 90	Fittings 45	Fittings Tee	Pipe Weight	Use & Valves
SW-5-4	ABA		15						To Control Bldg
SW-5-6	ABA								From P703/P704
SW-8-3	ABA		5						Return to Tk701
SW-12-4	AQD								Cooling Tower
SW-15-2	AQD								P703/P704 to CT & WH & Restrooms
SW-16-2	AQD								To WH
SW-17-4	ABA								To 4"-SW-15 line
SW-29-2 1/2	ABA		1						To Blowdown Tank
DW-2-3	BSA		1						Tk702 to P710
ED-1			1						

Rocketdyne Piping:

Incoloy 800 (R-material; S-R Fab)

Pipe (Spools)	Type	Length	Hangers	Snub's	Fittings 90	Fittings 45	Fittings Tee	Pipe Weight	Use & Valves
- -4	RNX	15'							
- -2	RNX	74'							
- -1	RNX	20'			12				

2 1/2" and larger alloy

Pipe (Spools)	Type	Length	Hangers	Snub's	Fittings 90	Fittings 45	Fittings Tee	Pipe Weight	Use & Valves
MS-201-6 (2)	QEX	70'			4				
MS-2XX-4 (6)									
ST-202-4 (3)	QEX	50'			15				
CO-201-3 (7)	QEX	50'			20				
CO-222-3 (1)									
VT-208-3 (2)									
CO-201-4 (1)	KEX	20'							
VT-201-4 (2)									
ST-203-4 (1)									

Piping and Valve Details and Cost (continued)

Pipe (Spools)	Type	Length	Hangers	Snub's	Fittings 90	Fittings 45	Fittings Tee	Pipe Weight	Use & Valves
FW-200-4 (6)	MBX	100'			11		1		
FW-228-3 (1)	MBX	60'			4				
FW-228-4 (2)	MBX								
FW-2XX-2 1/2 12	MBX	220'			37	7	3		
VT-213-12 (1)	BBA	16'							
VT-214-12	BBA	inc							
VT-216-6 (1)	BBA	40'							
VT-217-6	BBA	inc							
VT-217-6	BBA	inc							
(48)									

Receiver Piping Costs=

2 1/2" and larger piping and fittings (LLP's)	$ 160,470
Rocketdyne supplied Incoloy Piping	$
Piping Flush & Test CP9	$ 18,000
Hangers (18 each)	
Shock Arrestors (8 each)	
Valves 2 1/2" and larger	
	$ 178,470
Total Costs Noted=	$3,287,743

APPENDIX I.1--PILOT PLANT ELECTRICAL SYSTEM OVERVIEW

The operation of the pilot plant is from a 4160-volt line. The power to this line can come from three sources. If the solar plant is in operation, the generator provides electrical power through the 13.8 kV switchgear (SG) to the auxiliary transformer (AX1) which converts 13.8 kV to 4160 volts. The excess power generated is supplied to the 33 kV line through the main transformer, again by way of the 13.8 kV switchgear.

When the solar plant is not in operation, the electrical power can come from the 33 kV line by way of the main transformer (MX1), which converts the 33 kV power to 13.8 kV, and then through the auxiliary transformer (AX1) to 4160 volts. The pilot plant is one of four sources that can tap the 33 kV Gale substation Bug line.

The last source of 4160-volt electrical power is from the 4 kV well-water line. The well-water line is connected through the heliostat interface load interrupter switchgear since it primarily supplies power to the heliostats if all other power sources are unavailable.

The 33 kV line is separated from the main transformer by a wood-pole-mounted 34.5 kV circuit breaker. This is the 33 kV switchyard. The 33 kV line runs underground through the plant and surfaces south of the main entrance gate where it continues overhead to the Bug line.

The plant has one 4160-volt bus, A01, and two 480 volt buses, B01 and B02. The 4160-volt bus services the following in the pilot plant through the 4160 volt switchgear:

- Station service transformer, SX1, to 480 volt bus B01
  - (to following through 480-volt switchgear)
    - Control building BL901 MCC (A or BOA)
      - Air compressors CP901,CP902; condenser hotwell pump P907; UPS; polishing demineralizer sump pumps P936, P937; receiver feed water lube oil pump P942; turbine lube oil pumps P926,P927; turbine lube oil heaters H901 A-F; condenser vacuum pump P910; turbine lube oil tank vapor extractor P945; turbine lube oil centrifuge PR901; turning gear motor ME901; turbine lagging blower FA904; turbine hydraulic oil pumps P938A, P938B; caustic storage tank heater H904; gland steam exhaust pump P941; auxiliary boiler/TSS feed water pump P904; P901 cooling water pump; P919 caustic feed pump; P920 caustic feed pump; P935 acid transfer pump; P936 & P937 polishing demineralizer sump pumps; P939 & P940 sluice water pumps; P943 caustic transfer pump; H905 caustic day tank; and many motor operated valves.

- Thermal storage feedwater pump P903
- Raw/Service Water Bldg. BL702 MCC C 480 volts
  - Demineralized water transfer pump P710
  - Fire maintenance jockey pump P707
  - Raw/service water pump P703
  - Raw/service water pump P704
  - Primary electric fire pump P705
  - Raw/service water sump pump P715
  - BL702 Exhaust Fans EF2, EF3
  - 45 kVA transformer to 480/277 volts & LP3 Lighting Panel
    - Perimeter & Roadway Lighting
  - 30 kVA xformer to 208/120 volts & PP3 Heat Trace Panel
    - EUH-5 through EUH-9
- Transformer to 480/277 volts & PPA Tower L13 Power Panel
  - ACU-1
  - H-3
  - EUH-13
  - Receiver tower elevator HS701
  - Aircraft warning lights
  - Tower level 15 MCC 6 for BCS heat flux xducer
    - BCS fluid receiver pump P201
    - BCS target heat exchanger E201
    - BCS target heat exchanger E202
  - xformer to 208/120 volts & PP1 Tower L13 Power Panel
    - ACU-2
    - H-4
    - ACU-3
  - Remote station panel RSP3
    - xformer to 208/120 V & RSP1 Remote Sta. Panel
- LP1 Lighting Panel
  - LP EML1 with Exide Centraus III HID Inverter (BL712)

Load Center A transformer to 480 volts

- Charging & extraction oil pumps P301-P304 w/starters, C.B.
- BL712 MCC B
  - Auxiliary extraction oil pump P305
  - TSS flash tank drain pump P307
  - Maintenance oil sump pump P718
  - Nitrogen supply unit SA701
  - Caloria make-up pump P306
  - Oil water separator unit SE701 with separator waste-water pumps P711, P712, separator sludge pump P716 and oil sump pump P714
  - TSU area sump pump P717
  - Motor operated valve MOV1030
  - Motor operated valve MOV1031
  - UMU blowers FA301, FA302; ullage pump P308
  - BL709 MCC 1 Motor Control Center
    - AHU-1
    - ACCU-1
    - EUH-10
    - H-1
    - 30 kVA xformer to 120/208 V & PP4 Power Panel

- BL710 MCC 2 Motor Control Center
  - AHU-2
  - ACCU-2
  - EUH-11
  - H-2
  - 30 kVA xformer to 120/208 V & PP5 Power Panel
- BL712 MCC 3 Motor Control Center
  - AHU-3
  - ACCU-3
  - EUH-12
- 30 kVA xformer to 120/208 V & LP4 Lighting Panel
- xformer to 120/208 V & PP2 Heat Trace Panel
- Receiver tower welding receptacles
- TSS skid area welding receptacles

Receiver feed pump P917

Cooling tower transformer, CTX1 to 480 volt bus B02 (to following through 480 volt switchgear)

- Circulating water pumps P905, P906
- Administration building BL701
- MCC (L or BOL) Motor Control Center
  - Cooling tower loads FA901, FA902, FA903, P930
  - Warehouse BL703
    - Transformer to 480/277 V
    - Lighting panel LP6
      - xformer to 240/120 V & PP6 Power Panel
    - Lighting panel LP7
      - xformer to 240/120 V & PP7 Power Panel
  - Secondary fire pump building BL706 MCC-4
    - EUH-1
    - EUH-2
    - EF-1
    - 5 kVA xformer to 120/240 V & LP8 Lighting Panel

Heliostat feeder #1 to 14 each xformer to 208/120 V

- Heliostat Interface Load Interrupter Switchgear
  - 112.5 kVA xformers to 208Y/120 V & Distribution Panel Boards (14 each)

Heliostat feeder #2 redundant as above

Auxiliary boiler B901

4160 to 120 volt transformer

- WNW & EES power panel PP8
  - Fan SF-1
- South weather station power panel PP9
  - AHU-4
  - ACCU-4
  - EDH-1

DC Bus

- P928 Turbine Lube Oil Emergency Pump

APPENDIX I.2--LONG-LEAD PROCUREMENT POWER AND CONTROL CABLES

The long-lead procurement of power and control cables was performed by S-R under contract to the SFDI. Most of the cables used in the plant were supplied in this manner. Other cable was provided by the electrical subcontractors for the heliostat field and the balance of plant as required. The table below shows the total feet of cable purchased by S-R, the total feet of cable used in the plant as identified, the difference in these two amounts, and the cost associated with this difference. The negative numbers indicate that these cables were supplied by other than the long-lead procurement. The positive delta feet indicate that either the cable was not identified by the author, or that excess cable was purchased and is available for use at the plant.

Cable	#	Conductors	Ft Purch	Total Ft	Delta Ft	Delta Cost
600V Power	12	1/C	1000	750	250	30.00
	12	2/C	8718	7404	1314	545.31
	12	3/C	3500	4180	-680	-350.20
	10	1/C	7000	0	7000	758.94
	10	2/C	1500	1975	-475	-261.25
	10	2/C	12000	12000	0	0.00
	10	3/C	2000	656	1344	920.64
	10	4/C	105000	112395	-7395	-6414.12
	8	3/C	1000	395	605	704.82
	8	4/C	4000	4250	-250	-390.26
	8	4/C	3140	3125	15	26.17
	6	3/C	1500	360	1140	2188.80
	6	4/C	11000	10505	495	805.02
	4	4/C	16000	14645	1355	2749.93
	2	3/C	1200	1560	-360	-1184.40
	1/0	3/C	1000	405	595	2787.57
	350	3/C	1500	1200	300	3597.00
	500	3/C	690	640	50	808.75
5KV Power	2/0	1/C	3000	2760	240	543.12
5KV Power	2/0	3/C	10000	9765	235	1706.34
Subtotal					5778	$9572.19
Control	14	3/C	9000	8730	270	109.35
	14	5/C	4000	3810	190	116.85
	14	7/C	1500	1560	-60	-44.40
	14	9/C	1000	585	415	394.25
Subtotal					815	$576.05
Total					6593	$10148.24

Long-Lead Procurement Power and Control Cables (continued)

The following listing shows the type of cable, size of cable, number of conductors, cost per foot of cable, the length of cable, and the cost of the cable used in various locations in the plant.

Cable	#	Conductors	Cost/Foot	Tower Feet	Tower Cost	B710 Feet MCC 2	B710 Cost	B709 Feet MCC 1	B709 Cost	TSS Feet	TSS Cost
600V Power	12	1/C	.12	750	90.00						
	12	2/C	.415	300	124.50	85	35.27	85	35.27	10.00	4.15
	12	3/C	.515	595	306.42	115	59.22	95	48.92	370.00	190.55
	10	1/C	.10842								
	10	2/C	.55								
	10	2/C	.82526								
	10	3/C	.685	80	54.80			40	27.40		
	10	4/C	.86736								
	8	3/C	1.165	280	326.20	20	23.30	10	11.65		
	8	4/C	1.56105								
	8	4/C	1.7447								
	6	3/C	1.92	80	153.60						0.00
	6	4/C	1.62631								
	4	4/C	2.02947								
	2	3/C	3.29	460	1513.40	20	65.80			460.00	1513.40
	1/0	3/C	4.685	80	374.80	275	1288.37	50	234.25		
	350	3/C	11.99	400	4796.00						
	500	3/C	16.175								
5KV Power	2/0	1/C	2.263							1560	3530.28
5KV Power	2/0	3/C	7.26105								
Subtotal					7739.72		1471.97		357.50		5043.68
Control	14	3/C	.405	250	101.25	135	54.67	110	44.55	1040.00	421.20
	14	5/C	.615	210	129.15	60	36.90	80	49.20	55.00	33.82
	14	7/C	.74	10	7.40	10	7.40	20	14.80		
	14	9/C	.95	60	57.00					65.00	61.75
Subtotal					294.80		98.97		108.55		516.77
Total					8034.52		1570.95		466.05		5560.45

Long-Lead Procurement Power and Control Cables (continued)

Cable	#	Conductors	Cost/Foot	SA311 Feet RS-3	SA311 Cost	SA304 Feet RS-3	SA304 Cost	SA309 Feet RS-3	SA309 Cost	P306 Feet Caloria	P306 Cost Make-up
600V Power	12	1/C	.12								
	12	2/C	.415	250	103.75	840	348.60	840	348.60		
	12	3/C	.515							250	128.75
	10	1/C	.10842								
	10	2/C	.55	380	209.00						
	10	2/C	.82526								
	10	3/C	.685			200	137.00	296	202.76		
	10	4/C	.86736								
	8	3/C	1.165								
	8	4/C	1.56105								
	8	4/C	1.7447								
	6	3/C	1.92								
	6	4/C	1.62631								
	4	4/C	2.02947								
	2	3/C	3.29								
	1/0	3/C	4.685								
	350	3/C	11.99								
	500	3/C	16.175			320	5176.00	320	5176.00		
5KV Power	2/0	1/C	2.263								
5KV Power	2/0	3/C	7.26105								
Subtotal					312.75		5661.60		5727.36		128.75
Control	14	3/C	.405	400	162.00	120	48.60	120	48.60		
	14	5/C	.615			55	33.82			240	147.60
	14	7/C	.74			175	129.50	95	70.30		
	14	9/C	.95					215	204.25		
Subtotal					162.00		211.92		323.15		147.60
Total					474.75		5873.52		6050.51		276.35

Long-Lead Procurement Power and Control Cables (continued)

Cable	#	Conductors	Cost/Foot	B712 Feet MCC 3	B712 Cost	Hel. Feet	Hel. Cost	BCS Feet	BCS Cost	Metro Ft.	Metro Cost
600V Power	12	1/C	.12								
	12	2/C	.415	190	78.85						
	12	3/C	.515	40	20.60						
	10	1/C	.10842								
	10	2/C	.55								
	10	2/C	.82526								
	10	3/C	.685	40	27.40						
	10	4/C	.86736			112395	97486.92				
	8	3/C	1.165								
	8	4/C	1.56105					2400	3746.52	1850	2887.94
	8	4/C	1.7447			3125	5452.18				
	6	3/C	1.92	50	96.00						
	6	4/C	1.62631			10505	17084.38				
	4	4/C	2.02947			14645	29721.58				
	2	3/C	3.29	130	427.70						
	1/0	3/C	4.685	30	140.55						
	350	3/C	11.99								
	500	3/C	16.175								
5KV Power	2/0	1/C	2.263			300	678.90				
5KV Power	2/0	3/C	7.26105			9765	70904.15				
Subtotal					791.10		221328.14		3746.52		2887.94
Control	14	3/C	.405	180	72.90						
	14	5/C	.615	140	86.10						
	14	7/C	.74	10	7.40						
	14	9/C	.95								
Subtotal					166.40						
Total					957.50		221328.14		3746.52		2887.94

Long-Lead Procurement Power and Control Cables (continued)

Cable	#	Conductors	Cost/Foot	Fire P Ft.	FireP Cost	R FW Pump	R FW Cost	RW/SW Feet	RW/SW Cost	SA Inst Ft	Inst Cost
600V Power	12	1/C	.12								
	12	2/C	.415	949	393.83	300	124.50	620	257.30		
	12	3/C	.515	150	77.25			480	247.20		
	10	1/C	.10842								
	10	2/C	.55							1020	561.00
	10	2/C	.82526								
	10	3/C	.685								
	10	4/C	.86736								
	8	3/C	1.165	85	99.02						
	8	4/C	1.56105								
	8	4/C	1.7447								
	6	3/C	1.92	250	480.00			30	57.60		
	6	4/C	1.62631								
	4	4/C	2.02947								
	2	3/C	3.29					30	98.70		
	1/0	3/C	4.685								
	350	3/C	11.99					800	9592.00		
	500	3/C	16.175								
5KV Power	2/0	1/C	2.263			900	2036.70				
5KV Power	2/0	3/C	7.26105								
Subtotal					1050.11		2161.20		10252.80		561.00
Control	14	3/C	.405	5485	2221.42			170	68.85		
	14	5/C	.615	840	516.60	140	86.10	420	258.30	425	261.37
	14	7/C	.74	800	592.00			140	103.60	300	222.00
	14	9/C	.95							180	171.00
Subtotal					3330.02		86.10		430.75		654.37
Total					4380.13		2247.30		10683.55		1215.37

Long-Lead Procurement Power and Control Cables (continued)

Cable	#	Conductors	Cost/Foot	TTS Feet	TTS Cost	CS Road Lt	Lite Cost	N2 Skid Ft	N2 Cost	S & I Feet	S & I Cost
600V Power	12	1/C	.12								
	12	2/C	.415	2925	1213.87					10	4.15
	12	3/C	.515	1090	561.35			350	180.25	505	260.07
	10	1/C	.10842								
	10	2/C	.55			575	316.25				
	10	2/C	.82526			12000	9903.12				
	10	3/C	.685								
	10	4/C	.86736								
	8	3/C	1.165								
	8	4/C	1.56105								
	8	4/C	1.7447								
	6	3/C	1.92								
	6	4/C	1.62631								
	4	4/C	2.02947								
	2	3/C	3.29	310	1019.90					150	493.50
	1/0	3/C	4.685								
	350	3/C	11.99								
	500	3/C	16.175								
5KV Power	2/0	1/C	2.263								
5KV Power	2/0	3/C	7.26105								
Subtotal					2795.12		10219.37		180.25		757.72
Control	14	3/C	.405	720	291.60						
	14	5/C	.615	1090	670.35						
	14	7/C	.74								
	14	9/C	.95								
Subtotal					961.95						
Total					3757.07		10219.37		180.25		757.72

APPENDIX I.3--LONG-LEAD PROCUREMENT OF INSTRUMENTATION CABLES

The long-lead procurement of instrumentation cables was performed by S-R under contract to the SFDI. Most of the cables used in the plant were supplied in this manner. Other cable was provided by the electrical subcontractors for the heliostat field and the balance of plant as required. The table below shows the total feet of cable purchased by S-R, the total feet of cable used in the plant as identified, the difference in these two amounts, and the cost associated with this difference. The negative numbers indicate that these cables were supplied by other than the long-lead procurement. The positive delta feet indicate that either the cable was not identified by the author, or that excess cable was purchased and is available for use at the plant.

Cable	#	Conductors	Ft Purch	Total Ft	Delta Ft	Del Cost
Instr 600V	16	1 pair	31000	23640	7360	1749.25
	16	1 triad	24000	25140	-1140	-526.65
	16	4 pair	3500	3655	-155	-148.68
	16	4 triad	4000	3715	285	570.00
	16	8 pair	7000	4005	2995	5153.73
	16	12 pair	4000	3190	810	2090.75
	16	20 pair	13500	2205	11295	48589.05
Belden	9283	Coaxial	5000	4720	280	73.64
Brand Rex	RG11	Coaxial	10146	8880	1266	3937.26
Brand Rex	RG22	Coaxial	4500	4160	340	255.23
Okonite	RG22M	Coaxial	190000	192230	-2230	-2472.53
TC Cable	16	1 pair	3000	0	3000	8109.00
	20	4 pair	2000	1470	530	1041.98
	20	20 pair	2000	1520	480	2909.76

Total						$71331.80

Long-Lead Procurement of Instrumentation Cables (continued)

The following listing shows the type of cable, size of cable, number of conductors, cost per foot of cable, the length of cable, and the cost of the cable used in various locations in the plant.

Cable	#	Conductors	Cost/Foot	RS-1 Feet	Cost RS-1	RS-2 Feet	Cost RS-2	RS-3 Feet	Cost RS-3	RS-4 Feet	Cost RS-4
				JB 1950		JB1951		JB 1952		JB 1953	
Instr 600V	16	1 pair	.23767	430	102.19	655	155.67			960	228.16
	16	1 triad	.46198	10080	4656.75	5720	2642.52	7800	3603.44	1240	572.86
	16	4 pair	.95925	560	537.18						
	16	4 triad	2.00								
	16	8 pair	1.72078	1620	2787.66	365	628.08	435	748.53		
	16	12 pair	2.58118	560	1445.46	1070	2761.86	975	2516.65	60	154.87
	16	20 pair	4.30182	1000	4301.82	305	1312.05	720	3097.31	180	774.32
Belden	9283	Coaxial	.263	1120	294.56	800	210.40	480	126.24	2320	610.16
Brand Rex	RG11	Coaxial	3.11								
Brand Rex	RG22	Coaxial	.7507								
Okonite	RG22M	Coaxial	1.10876								
TC Cable	16	1 pair	2.703								
	20	4 pair	1.966								
	20	20 pair	6.062								
Total					14125.64		7710.60		10092.18		2340.37

Long-Lead Procurement of Instrumentation Cables (continued)

Cable	#	Conductors	Cost/Foot	TSS Feet	TSS Cost	TSU JB Ft	TSU Cost	SA311 Feet	SA311 Cost	SA304 Feet	SA304 Cost
						RS-2		RS-3		RS3	
Instr 600V	16	1 pair	.23767	2770	658.34	400	95.06	300	71.30	415	98.63
	16	1 triad	.46198					300	138.59		
	16	4 pair	.95925	55	52.75	570	546.77	610	585.14	290	278.18
	16	4 triad	2.00			3610	7220.00				
	16	8 pair	1.72078							250	430.19
	16	12 pair	2.58118								
	16	20 pair	4.30182								
Belden	9283	Coaxial	.263								
Brand Rex	RG11	Coaxial	3.11								
Brand Rex	RG22	Coaxial	.7507								
Okonite	RG22M	Coaxial	1.10876								
TC Cable	16	1 pair	2.703								
	20	4 pair	1.966							50	98.30
	20	20 pair	6.062			1520	9214.24				
Total					711.10		17076.08		795.03		807.01

Long-Lead Procurement of Instrumentation Cables (continued)

Cable	#	Conductors	Cost/Foot	SA308 Feet RS2	SA308 Cost	SA309 Feet RS3	SA309 Cost	TTS Feet JB1750/51	TTS Cost	SA302 Feet RS-3	SA302 Cost
Instr 600V	16	1 pair	.23767			655	155.67	13010	3092.08		
	16	1 triad	.46198								
	16	4 pair	.95925					690	661.88		
	16	4 triad	2.00							65	130.00
	16	8 pair	1.72078	240	412.98	240	412.98			130	223.70
	16	12 pair	2.58118	120	309.74	40	103.24			65	167.77
	16	20 pair	4.30182								
Belden	9283	Coaxial	.263								
Brand Rex	RG11	Coaxial	3.11								
Brand Rex	RG22	Coaxial	.7507								
Okonite	RG22M	Coaxial	1.10876								
TC Cable	16	1 pair	2.703								
	20	4 pair	1.966	360	707.76	80	157.28			195	383.37
	20	20 pair	6.062								
Total					1430.48		829.18		3753.96		904.84

Long-Lead Procurement of Instrumentation Cables (continued)

Cable	#	Conductors	Cost/Foot	SA303 Feet	SA303 Cost RS-3	Hel Ctr	H Ctr Cost	BCS Feet	BCS Cost	St G Hel	St G Cost
Instr 600V	16	1 pair	.23767					1040	247.17	520	123.58
	16	1 triad	.46198								
	16	4 pair	.95925								
	16	4 triad	2.00	40	80.00						
	16	8 pair	1.72078	80	137.66						
	16	12 pair	2.58118	40	103.24						
	16	20 pair	4.30182								
Belden	9283	Coaxial	.263								
Brand Rex	RG11	Coaxial	3.11					8880	27616.80		
Brand Rex	RG22	Coaxial	.7507			4160	3122.91				
Okonite	RG22M	Coaxial	1.10876			172160	190884.12	4980	5521.62	2320	2572.32
TC Cable	16	1 pair	2.703								
	20	4 pair	1.966	120	235.92						
	20	20 pair	6.062								
Total					556.82		194007.03		33385.60		2695.91

Long-Lead Procurement of Instrumentation Cables (continued)

Cable	#	Conductors	Cost/Foot	Metro Ft	Metro Cost	Watt Feet	Watt Cost	Tower Ft	Tower Cost	R FW Ft	R FW Cost
Instr 600V	16	1 pair	.23767	1560	370.76	600	142.60	430	102.19	160	38.02
	16	1 triad	.46198								
	16	4 pair	.95925							800	767.40
	16	4 triad	2.00								
	16	8 pair	1.72078							240	412.98
	16	12 pair	2.58118								
	16	20 pair	4.30182								
Belden	9283	Coaxial	.263								
Brand Rex	RG11	Coaxial	3.11								
Brand Rex	RG22	Coaxial	.7507								
Okonite	RG22M	Coaxial	1.10876	9110	10100.80	3660	4058.06				
TC Cable	16	1 pair	2.703								
	20	4 pair	1.966								
	20	20 pair	6.062								
Total					10471.56		4200.66		102.19		1218.41

Long-Lead Procurement of Instrumentation Cables (continued)

Cable	#	Conductors	Cost/Foot	Inst Ft	Inst Cost	S & I Feet	S & I Cost
Instr 600V	16	1 pair	.23767			150	35.65
	16	1 triad	.46198				
	16	4 pair	.95925	80	76.74		
	16	4 triad	2.00				
	16	8 pair	1.72078	405	696.91		
	16	12 pair	2.58118	260	671.10		
	16	20 pair	4.30182				
Belden	9283	Coaxial	.263				
Brand Rex	RG11	Coaxial	3.11				
Brand Rex	RG22	Coaxial	.7507				
Okonite	RG22M	Coaxial	1.10876				
TC Cable	16	1 pair	2.703				
	20	4 pair	1.966	665	1307.39		
	20	20 pair	6.062				
Total					2752.15		35.65

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