SAN/1109-8/9

SOLAR PILOT PLANT

PHASE 1: PRELIMINARY DESIGN REPORT

Volume 7. CDRL Item 2

Pilot Plant Cost and Commercial Plant Cost and Performance

June 1, 1977

Work Performed Under Contract No. EY-76-C-03-1109

Honeywell, Incorporated
Energy Resources Center
Minneapolis, Minnesota

U.S. Department of Energy

Solar Ener

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PHASE I

PRELIMINARY DESIGN REPORT

Volume VII

Pilot Plant Cost
Commercial Plant Cost and Performance

CDRL Item 2

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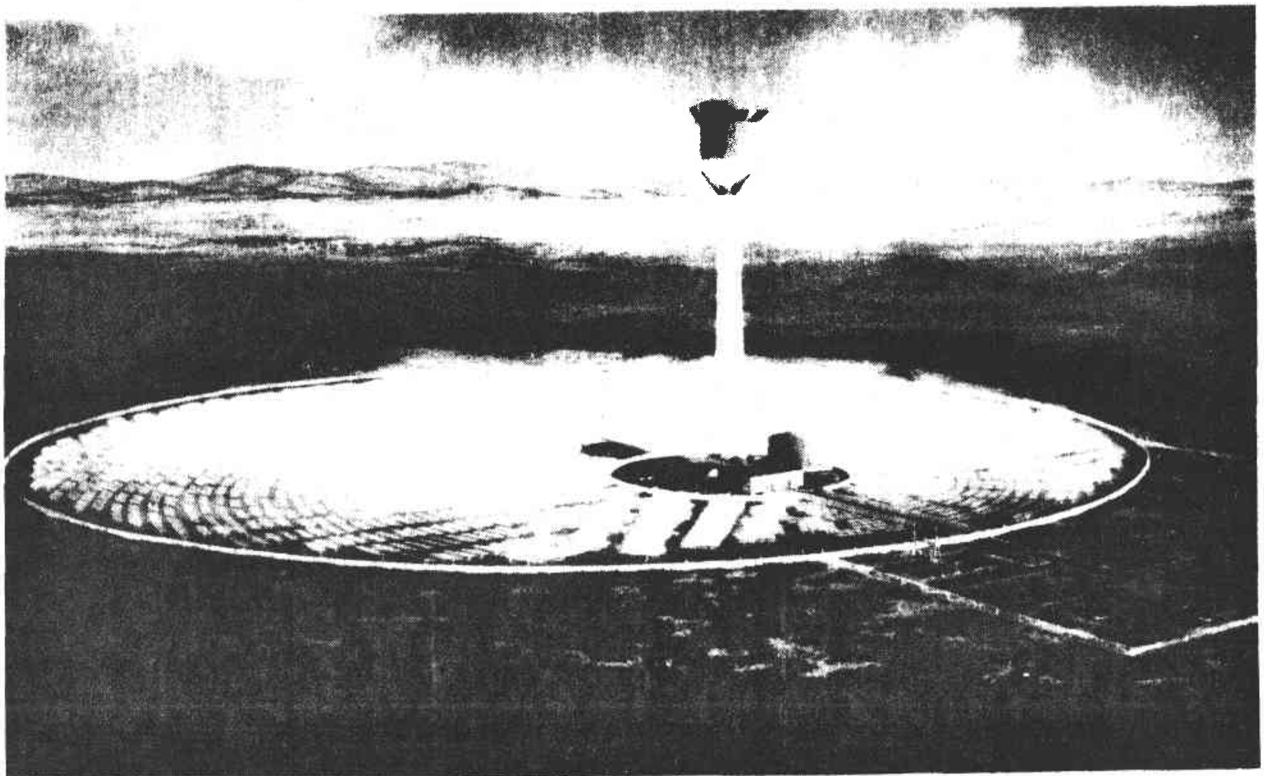
FOREWORD

This document, the last of seven volumes defining the Solar Pilot Plant Preliminary Design, contains cost estimates for the pilot plant and cost and performance projections for a commercial-scale plant. The information is submitted per Item 2 of the data requirements for ERDA Contract E(04-3)-1109.

The estimates in this document are presented as engineering data and neither makes an offer to sell nor an option to buy at specified prices.



10 MEGAWATT SOLAR PILOT PLANT
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ABSTRACT

Section 2 of this document presents cost estimates for the Solar Pilot Plant by cost breakdown structure element, with a commitment schedule and an expenditure schedule. Section 3 contains cost estimates for a Commercial Plant, including several point costs for plants with various solar multiples and storage times. Section 4 addresses specific questions (ERDA) pertaining to commercial plant design and performance data. The cost estimates are supplemented by two books of vendor and subcontractor cost data, i.e., Books 2 and 3 of Volume VII.

CONTENTS

SECTION 1
INTRODUCTION

BACKGROUND

Supplies of most conventional fuels are being depleted rapidly. Consequently, it is necessary to identify alternate sources of energy and to develop the most promising to ensure availability when needed.

An alternative with great potential is the conversion of sunlight to energy. One aspect of this usage is generating electricity through solar energy. A goal of the national energy program is to demonstrate the technical and economic feasibility of a central receiver solar power plant for generating electricity. Pursuant to that goal, the Energy Research and Development Administration (ERDA), on 1 July 1975, awarded Honeywell Inc. a two-year contract for Phase I of such a program.

The initial program phase, which is the subject of this report, consisted of developing a preliminary design for a 10 MW(e) proof-of-concept solar pilot plant. The second phase will consist of building and operating the pilot plant and projecting the information gained to larger-scale plants. This phase is scheduled to be completed in the early 1980's. The third phase will consist of designing, building, and operating two 50-100 MW(e) demonstration plants. The final phase will consist of building and operating plants in the 100-300 MW(e) range.

PHASE I PROGRAM SCOPE

The Phase I program consisted of developing a pilot plant preliminary design by first developing a preliminary baseline design to meet specified and assumed performance requirements. The baseline was then refined through analysis and experimentation, and evaluated by testing key subsystems, i.e., collector, steam generator, and thermal energy storage.

The complexity of the undertaking dictated a team approach to provide the technical and managerial skills required. The Honeywell team is identified in Figure 1-1.

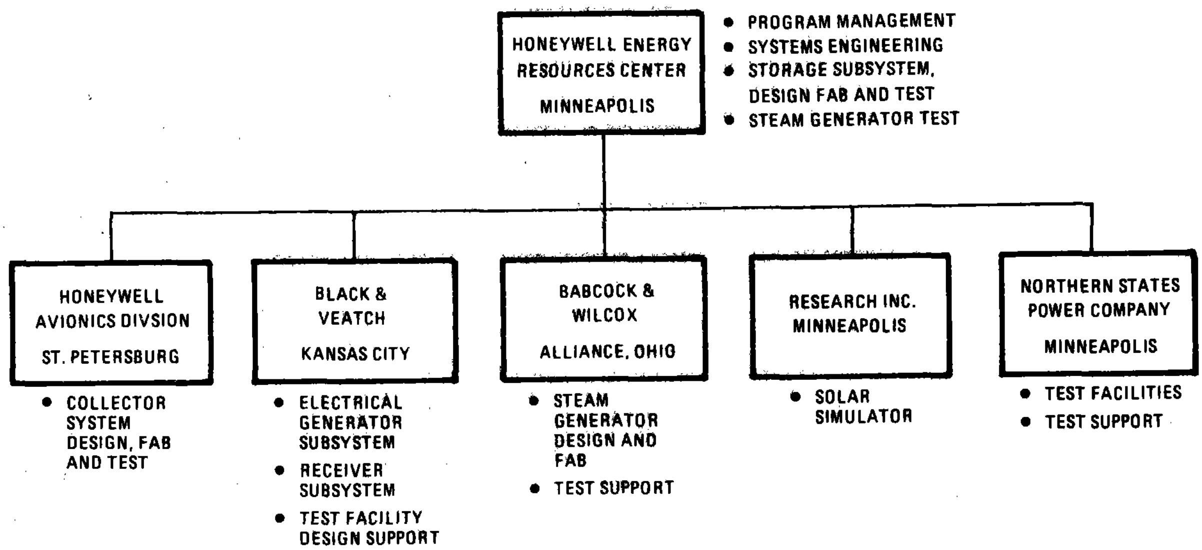


Figure 1-1. Honeywell Team for Phase I Solar Pilot Plant Program.

A unique feature of the test plan was the use of selected facilities of an operating power plant, Northern States Power's Riverside Plant in Minneapolis, Minnesota, to test the steam generator and thermal energy storage subsystems. An ERDA-directed change from latent heat (phase change) storage to sensible heat storage cancelled the storage portion of the test plan. The steam generator was tested using a solar array to simulate the insolation required to generate steam. The collector subsystem hardware, one mobile and three stationary, full-scale, four-mirror units, was field tested for performance and reaction to operating environments at Honeywell's Avionics Division facility in St. Petersburg, Florida.

The information obtained from the subsystems tests was used to complete the pilot plant preliminary design, and to project performance and cost of a 100 MW(e) plant to facilitate long-range planning.

The chronology of the work done in Phase I is summarized in Figure 1-2.

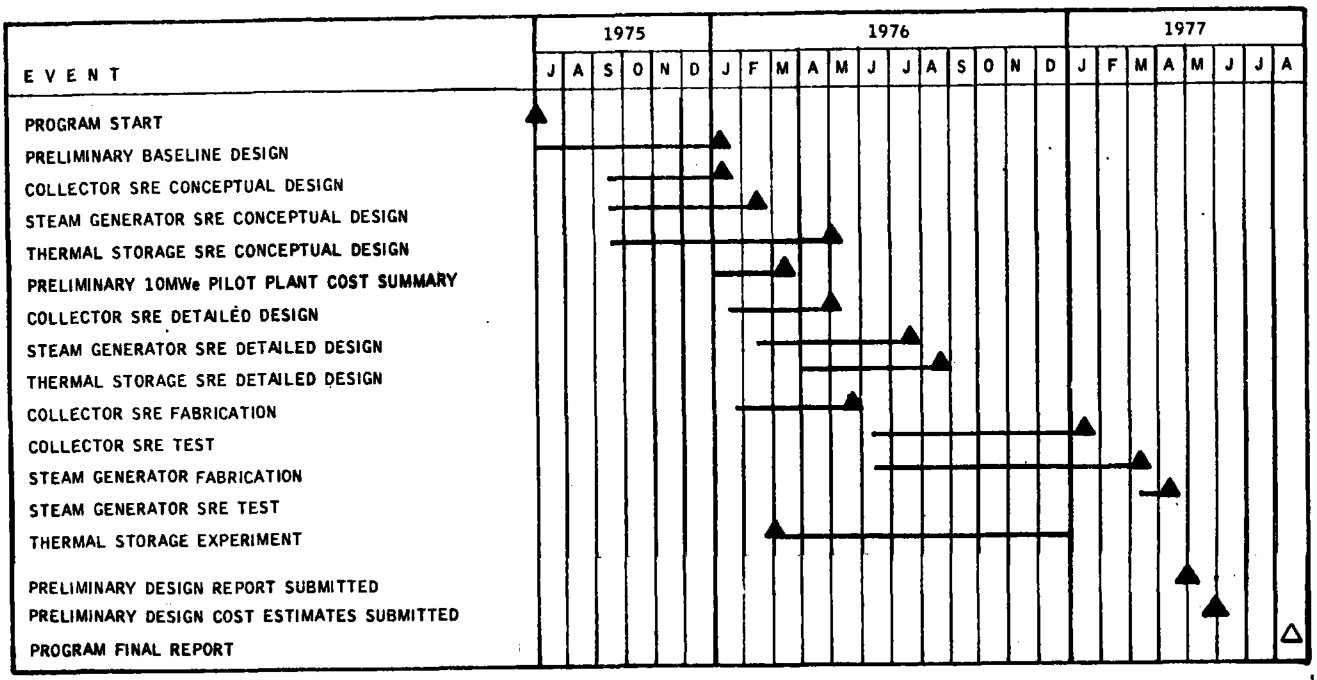


Figure 1-2. Chronology of Phase I Solar Pilot Plant Program

ORGANIZATION OF THE PRELIMINARY DESIGN REPORT

The preliminary design and supportive data resulting from the Phase I work are presented in seven volumes:

Abstracts of Volumes II through VI are presented on the following pages.

*Book 2 is Central Receiver Optical Model Users Manual
Book 3 is Dynamic Simulation Model and Computer Program Descriptions

ABSTRACTS

Vol. II SYSTEM ANALYSIS AND SYSTEM DESCRIPTION

Honeywell conducted a parametric analysis of the 10 MW(e) solar pilot plant requirements and expected performance and established an optimum system design. The main analytical simulation tools were the optical (ray trace) and dynamic simulation models. These are described in detail in Books 2 and 3 of this volume under separate cover. In making design decisions, available performance and cost data were used to provide a design reflecting the overall requirements and economics of a commercial-scale plant. This volume contains a description of this analysis/design process and resultant system/subsystem design and performance.

Vol. III COLLECTOR SUBSYSTEM

The Honeywell collector subsystem features a low profile, multifaceted heliostat designed to provide high reflectivity and accurate angular and spatial positioning of the redirected solar energy under all conditions of wind load and mirror attitude within the design operational envelope. The heliostats are are arranged in a circular field around a cavity receiver on a tower halfway south of the field center. A calibration array mounted on the receiver tower provides capability to measure individual heliostat beam location and energy periodically. This information and weather data from the collector field are transmitted to a computerized control subsystem that addresses the individual heliostat to correct pointing errors and determine when the mirrors need to be cleaned. This volume contains a detailed subsystem design description, a presentation of the design process, and the results of the SRE heliostat test program.

Vol. IV RECEIVER SUBSYSTEM

The Honeywell receiver subsystem design uses well established fossil technology and consists of a cavity receiver housing, a steam generator, a cavity barrier, piping, and a support tower. The steam generator absorbs the redirected solar energy from the collector subsystem and converts it to superheated steam which drives the turbine. The receiver is adequately shielded to protect personnel and equipment. A cavity barrier is lowered at night to conserve heat and expedite startup the following day. This volume contains the subsystem design and methodology and the correlation with the design and performance of the SRE steam generator which was fabricated and successfully tested during the program.

Vol. V THERMAL STORAGE SUBSYSTEM

The Honeywell thermal storage subsystem design features a sensible heat storage arrangement using proven equipment and materials. The subsystem consists of a main storage containing oil and rock, two buried superheater tanks containing inorganic salts (Hitec), and the necessary piping, instrumentation, controls, and safety devices. The subsystem can provide 7 MW(e) for three hours after twenty hours of hold. It can be charged in approximately four hours. Storage for the commercial-scale plant consists of the same elements appropriately scaled up. This volume contains a description of the subsystem design methodology and evolution and the subsystem operation and performance.

Vol.VI ELECTRICAL POWER GENERATION SUBSYSTEM, CONTROLS, AND BALANCE OF PLANT

The Honeywell electrical power generation subsystem centers on a General Electric dual admission, triple extraction turbine generator sized to the output requirements of the pilot plant. The turbine receives steam from the receiver subsystem and/or from the thermal storage subsystem and supplies those subsystems with feedwater. The turbine condenser is wet cooled. The plant control system consists of a coordinated digital master and subsystem digital/analog controls.

The remainder of the plant, work spaces, maintenance areas, roads, and reception area are laid out to provide maximum convenience compatible with utility and safety. Most of the activities are housed in a complex around the base of the receiver tower. This volume contains a description of the relationship of the electrical power generation subsystem to the rest of the plant, the design methodology and evolution, the interface integration and control, and the operation and maintenance procedures.

SECTION 2
PILOT PLANT SCHEDULE
AND
COST ESTIMATES

The cost estimates that follow were prepared in accordance with the cost and performance data provided December 15, 1976, as amended. Honeywell, Inc. is assumed to be prime contractor for all phases of the Pilot Plant; Detail Design, Fabrication, Assembly, Installation, and test of the hardware produced from the existing Honeywell Solar Research Experiment Team. The estimates are presented in contemplation of a cost plus fixed fee (CPFF) procurement.

An analysis of the impact of such a procurement in 1977 dollars, on the existing Honeywell rate structure has been performed. Projected material acquisition that could result from the procurement are summarized below:

Material Acquisition	Current Data Approved	Projected
Regular Material	11.0%	6.0%
Major Subcontracted Items	4.7%	3.0%

This procurement would not significantly affect the general overhead structure of any Honeywell, Inc. group. The DCAA approved general overhead projected for this procurement is 19.0% for all areas with the following exceptions. An approved partial overhead rate of 3.8% is applied to all major subcontracted items and to field support activity. No overhead is applied to 6600 computer time or to per diem.

Labor rates utilized in the preparation of these estimates are in 1977 dollars and are the DCAA approved rates for each team member. The construction labor rate applied to all construction personnel is based on labor union rates for the Riverside/San Bernadeno counties of California. Source data for the generation of this average wage of $5.00 per hour was obtained from the California Employment Service and is presented below.

LABOR CATEGORIES	EMPLOYEE QUANTITY	RANGE MIDDLE (50% PAID)	MEAN
Materials handliers	468	3.75-4.49	4.06
Truck Drivers	1142	4.25-6.93	5.53
Shippers and Packers	53	3.25-3.53	3.53
Fork Lift Operators	674	4.09-6.44	4.69
Stationary Engineers	52	5.76-8.37	7.25
Electronic Technicians	25	5.30-5.82	5.85
Electronic Maintenance	418	6.77-7.73	7.11

These rates exclude; premium pay for overtime, nonproduction bonuses, and salaries for the handicapped and apprentices. The rates include; incentive payment for piece workers, production bonuses and commission systems and cost of living allowances. The mean represents the total salaries by category divided by the number of workers in that category.

Based on these figures Honeywell selected the $5.00 per hour average rate for the labor required to perform the field assembly and installation functions. However, Honeywell Inc. will be required to pay the minimum rates as determined by Government Procurement Regulations (Davis Bacon Act) for construction of all public works.

Supporting data for the cost estimate is presented in Books 2 and 3 of Volume VII. The key to reference in these documents is the cost breakdown structure number. This source documentation provides the methodology utilized by each estimator. The estimates from subcontractors presented in these documents are at the price Honeywell, Inc. would anticipate to pay for the materials and/or services and do not have the Honeywell, Inc. rates applied as in Volume VII. Frequently this source data is two or three levels lower than requested and must be summarized for tracability to Volume VII presentations. Each "In-House" estimate is substantiated by a standardized Honeywell, Inc. form. The methodology utilized by the estimator is presented.

Rate codes for Honeywell Inc. follow:

Honeywell, Inc.
Energy Resources Center

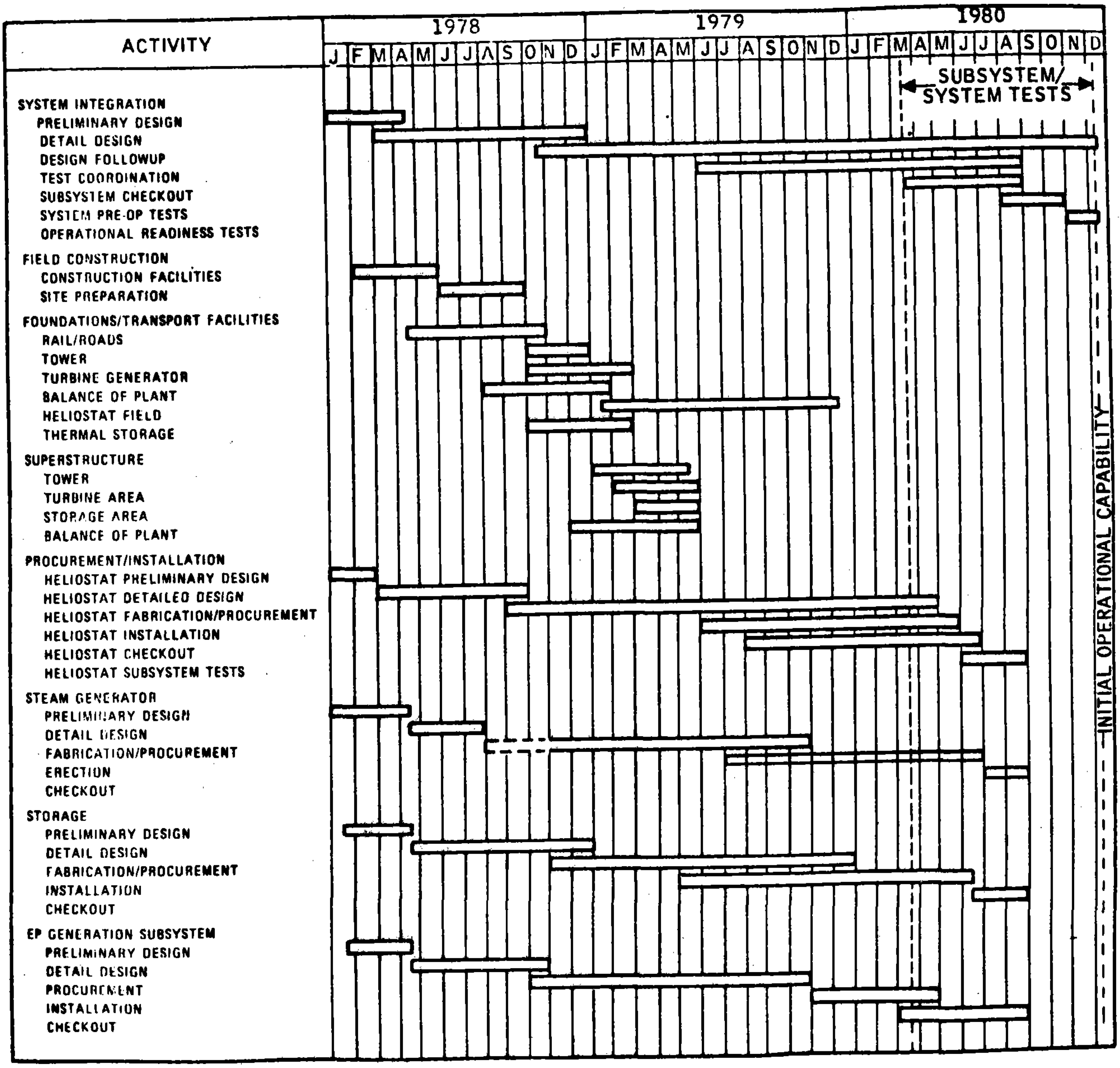
RESOURCE DESCRIPTION		CAT
Engineering III	ERC	1
Engineering II	ERC	2
Engineering I	ERC	3
Tech/Admin	ERC	4
Student G	ERC	5
Student F	ERC	6
Devel Engr III	MPLS	11
Devel Engr II	MPLS	12
Devel Engr I	MPLS	13
Drafting	MPLS	14
Tech/Admin	MPLS	15
Production Engr	MPLS	16
Quality Engr	MPLS	17
Fab Facility	MPLS	18
Field Spt Engr	MPLS	19
Field Spt Tech	MPLS	20
Computer 6600	PRICE	24

The Pilot Plant master phasing schedule is included in this section for reference to overall time phasing of the program. The schedule is keyed to the cost breakdown structure for consistency and is a GANTT representation of a PERT network. Time phasing is based on estimates for each line item and bound by constraints of other line items. The "Interface" displayed on the GANTT is the dominant constraint and may be one of many constraints. This schedule program is updated at the input level and can be reiterated based on the new data automatically. Minor modifications will be required to update the span times as a result of the final cost estimating process.

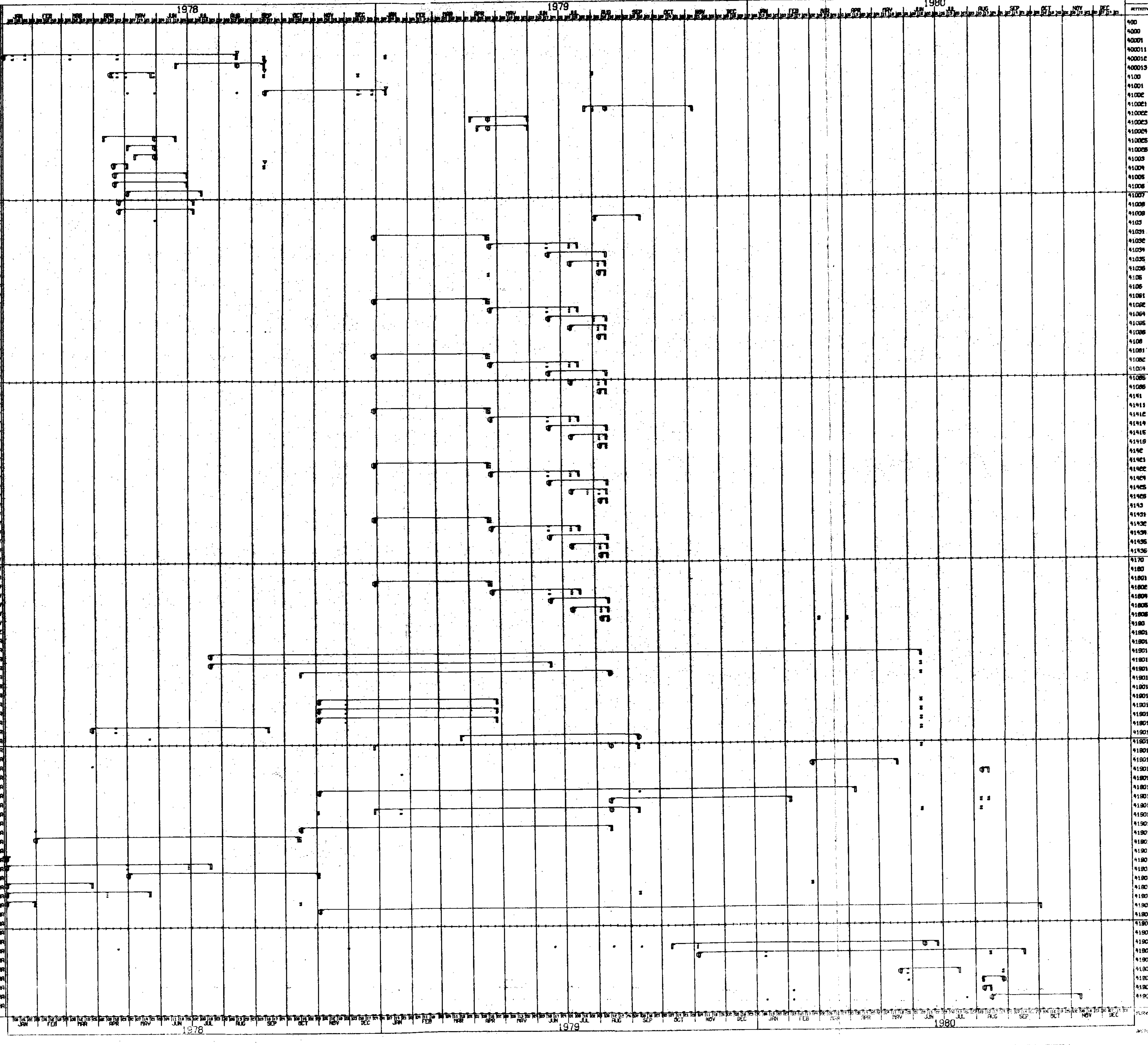
Time phased cost estimates are presented by fiscal year at the cost breakdown structure levels requested.

SOLAR PILOT PLANT SCHEDULE

1977 - 80



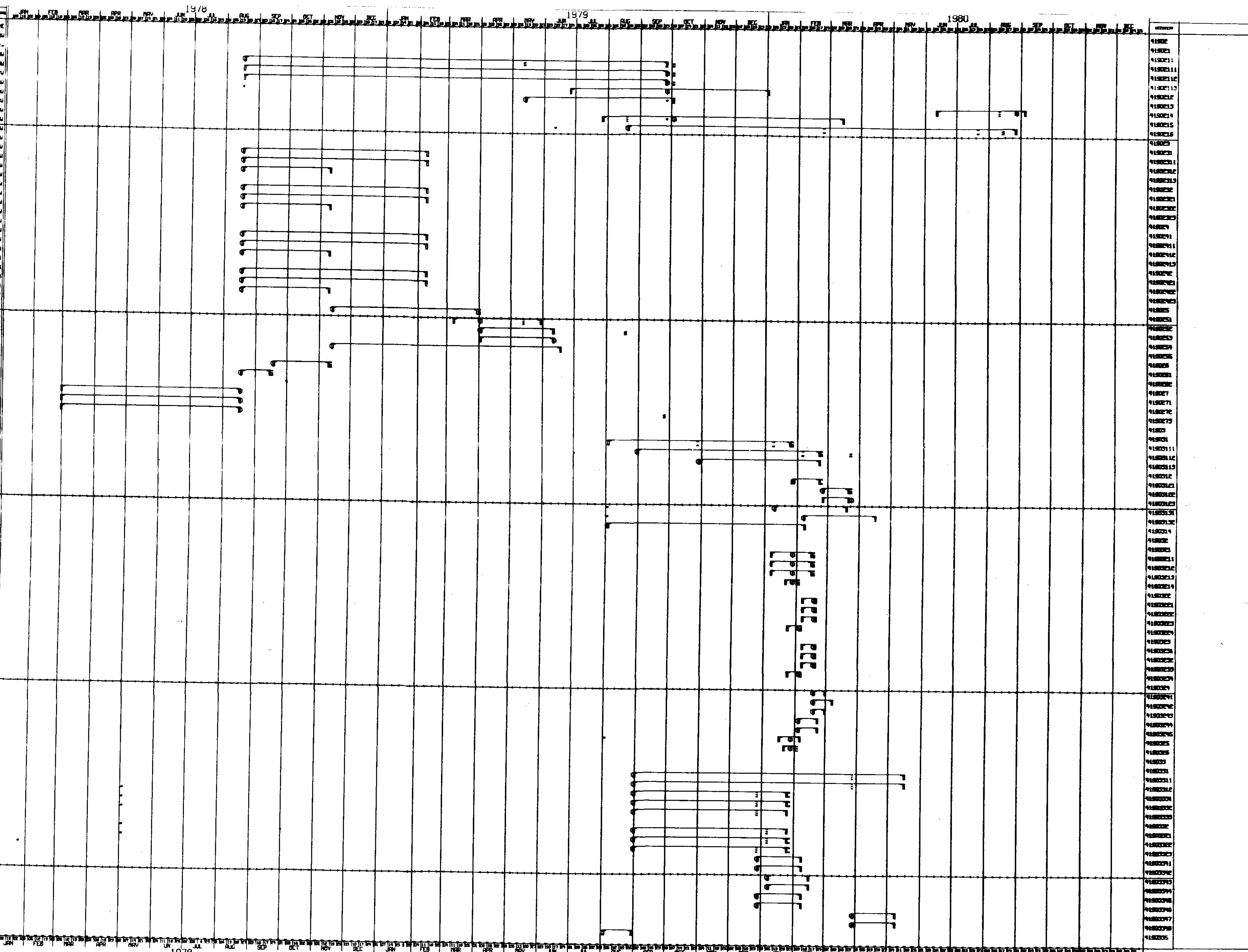
ACTIVITY WORK PACKAGE		INTERFACE							RESPONSIBILITY		
ACTIVITY	DESCRIPTION	PCT	ACTIVITY	CDE	DELAY	SUPPORTS	SPAN TIME	SAFETY	DIRECTOR	DEPT.	CLASS
400	SOLAR CENTRAL RECEIVER										1HE
4000	LAND AND LAND RIGHTS								EL DOUTY	5312	3BV
40001	LAND AND PRIVILEGE ACQUISITION								EL DOUTY	5312	3BV
400011	LAND AND SURVEY	01	JAN	78		400012	32.0	.0	EL DOUTY	5312	3BV
400012	EASEMENTS + RIGHT-OF-WAY	—	400011	70		41001	12.0	.0	EL DOUTY	5312	3BV
400013	CLEARING LAND	15	APR	78		41001	8.0	14.8	EL DOUTY	5312	3BV
4100	YARD WORK								EL DOUTY	5312	3BV
41001	GRADING, GENERAL EXCAVATION	100	400012			41903628	16.0	.0	EL DOUTY	5312	3BV
41002	ROADWAYS, FENCING+LIGHTING								EL DOUTY	5312	3BV
410021	ROADS	—	41414	20		41009	15.0		EL DOUTY	5312	3BV
410022	SIDEWALKS	—	41411	30			8.0		EL DOUTY	5612	3BV
410023	PARKING	—	41411	20			7.0		EL DOUTY	5312	3BV
410024	RETAIN WALLS, BRIDGES+CULVERT	—	400013	70			10.0		EL DOUTY	5312	3BV
410025	FENCES + GATEWAYS	—	400013	90			4.0		EL DOUTY	5312	3BV
410026	YARD LIGHTING	—	400013	85			3.0		EL DOUTY	5312	3BV
41003	SANITARY SEWER SYSTEM	10	400013	—		41001	2.0	18.2	EL DOUTY	5312	3BV
41004	YARD DRAINAGE + STORM SEWER	10	41003	—			10.0		EL DOUTY	5312	3BV
41005	WATERFRONT IMPROVEMENTS	10	41003	—			10.0		EL DOUTY	5312	3BV
41006	PROJECT ACCESS ROADS	40	400013	—			10.0		EL DOUTY	5312	3BV
41007	RAILWAY ACCESS	20	400013	—			10.0		EL DOUTY	5312	3BV
41008	WATERWAY ACCESS FACILITIES	20	400013	—			10.0		EL DOUTY	5312	3BV
41009	AIR ACCESS FACILITIES	10	410021	—			8.0		EL DOUTY	5312	3BC
4103	TURBINE BUILDING								EL DOUTY	5312	3BV
41031	SUBSTRUCTURE	90	41001	—		430012	16.0		EL DOUTY	5312	3BV
41032	SUPERSTRUCTURE	100	41031			41035	12.0		EL DOUTY	5312	3BV
41034	MECHANICAL SYSTEMS	66	41032	—			8.0		EL DOUTY	5312	3BV
41035	LIGHTING+SERVICE POWER SYSTEM	90	41032	—		41036	5.0		EL DOUTY	5312	3BV
41036	PAINTING	80	41035	---		44011	1.0		EL DOUTY	5312	3BV
4105	ADMINISTRATION BUILDING								EL DOUTY	5312	3BV
4106	CIRCULATING+SERVICE WATER PUMP								EL DOUTY	5312	3BV
41061	SUBSTRUCTURE	90	41001	—		41062	16.0		EL DOUTY	5312	3BV
41062	SUPERSTRUCTURE	100	41061			41065	12.0		EL DOUTY	5312	3BV
41064	MECHANICAL SYSTEMS	66	41062	—		45002	8.0		EL DOUTY	5312	3BV
41065	LIGHTING+SERVICE POWER SYSTEM	90	41062	—		41066	5.0		EL DOUTY	5312	3BV
41066	PAINTING	80	41065	—			1.0		EL DOUTY	5312	3BV
4108	WAREHOUSE								EL DOUTY	5312	3BV
41081	SUBSTRUCTURE	90	41001	—		41082	16.0		EL DOUTY	5312	3BV
41082	SUPERSTRUCTURE	100	41081			41085	12.0		EL DOUTY	5312	3BV
41084	MECHANICAL SYSTEMS	66	41082	—			8.0		EL DOUTY	5312	3BV
41085	LIGHTING+SERVICE POWER SYSTEM	90	41082	—		41086	6.0		EL DOUTY	5312	3BV
41086	PAINTING	80	41085	—			1.0		EL DOUTY	5312	3BV
4141	MAINTENANCE BUILDING								EL DOUTY	5312	3BV
41411	SUBSTRUCTURE	90	41001	—		41412	16.0		EL DOUTY	5312	3BV
41412	SUPERSTRUCTURE	100	41411			41415	12.0		EL DOUTY	5312	3BV
41414	MECHANICAL SYSTEMS	66	41412	—		410021	8.0		EL DOUTY	5312	3BV
41415	LIGHTING+SERVICE POWER SYSTEM	90	41412	—		41416	5.0		EL DOUTY	5312	3BV
41416	PAINTING	80	41415	—			1.0		EL DOUTY	5312	3BV
4142	WATER TREATMENT EQUIP BLDG								EL DOUTY	5312	3BV
41421	SUBSTRUCTURE	80	41001	—		41422	16.0		EL DOUTY	5312	3BV
41422	SUPERSTRUCTURE	100	41421			41425	12.0		EL DOUTY	5312	3BV
41424	MECHANICAL SYSTEMS	66	41422	—			8.0		EL DOUTY	5312	3BV
41425	LIGHTING+SERVICE POWER SYSTEM	90	41422	—		45003	5.0		EL DOUTY	5312	3BV
41426	PAINTING	80	41425	—		45004	1.0		EL DOUTY	5312	3BV
4143	SEWAGE TREATMENT BLDG								EL DOUTY	5312	3BV
41431	SUBSTRUCTURE	90	41081	—		41432	16.0		EL DOUTY	5312	3BV
41432	SUPERSTRUCTURE	100	41431			41435	12.0		EL DOUTY	5312	3BV
41434	MECHANICAL SYSTEMS	66	41432	—			8.0		EL DOUTY	5312	3BV
41435	LIGHTING+SERVICE POWER SYSTEM	90	41432	—		41436	5.0		EL DOUTY	5312	3BV
41436	PAINTING	80	41435	—			1.0		EL DOUTY	5312	3BV
4170	THERMAL STORAGE STRUCTURE								EL DOUTY	5312	3BV
4180	CONTROL BUILDING								EL DOUTY	5312	3BV
41801	SUBSTRUCTURE	90	41001	—		41802	16.0		EL DOUTY	5312	3BV
41802	SUPERSTRUCTURE	100	41801			41805	12.0		EL DOUTY	5312	3BV
41804	MECHANICAL SYSTEMS	66	41802	—			8.0		EL DOUTY	5312	3BV
41805	LIGHTING+SERVICE POWER SYSTEM	90	41802	—		41806	5.0		EL DOUTY	5312	3BV
41806	PAINTING	80	41805	—		4180342	1.0		EL DOUTY	5312	3BV
4190	SOLAR PLANT EQUIPMENT								JC POWELL	5312	1HE
41901	COLLECTOR EQUIPMENT								LP BALL	AE50	CHA
419011	REFLECTIVE UNIT								LP BALL	AE50	CHA
4190111	REFLECTIVE SURFACE(AM)	100	41901611			41901811	96.0		LP BALL	AE50	CHA
4190112	MIRROR BACK STRUCT(FRAME)	100	41901611			41901811	46.0		LP BALL	AE50	CHA
4190113	HELIOSTAT SPT STRUCT(POST)	—	4190151	100		41901811	42.0		LP BALL	AE50	CHA
4190114	PROTECTIVE ENCLOSURE								LP BALL	AE50	CHA
419012	DRIVE UNITS								LP BALL	AE50	CHA
4190121	MIRROR MODULE DRIVE	100	41901612			41901811	24.0		LP BALL	AE50	CHA
4190122	OUTER-FRAME DRIVE	100	41901612			41901811	24.0		LP BALL	AE50	CHA
4190123	MOTORS	100	41901612			41901811	24.0		LP BALL	AE50	CHA
4190124	POSITION/LIMIT INDICATORS	100	41901613			41901811	24.0		LP BALL	AE50	CHA
4190125	EMERGENCY POWER SUPPLY	—	4190128	100			24.0		LP BALL	AE50	CHA
4190128	POWER DISTRIBUTION	—	4190151	80		41901811	36.0		LP BALL	AE50	CHA
419013	CALIBRATION EQUIPMENT								LP BALL	AE50	CHA
4190133	CALIBRATION EQUIPMENT	50	4190216	—		41901821	12.0		LP BALL	AE50	CHA
4190134	WIRING TO CONTROL INSTRU MT	12.5	41901822	—			1.0		LP BALL	AE50	CHA
419014	CONTROL/INSTRUMENTATION EQUI								LP BALL	AE50	CHA
4190141	FIELD CONTROL/ELECTRONICS	100	41901612				72.0		LP BALL	AE50	CHA
4190142	COMPUTER HARDWARE	100	41806			419019	24.0		LP BALL	AE50	CHA
4190143	SIGNAL DISTRIBUTION	—	4190151	90		41901811	36.0		LP BALL	AE50	CHA
419015	FOUNDATION+SITE PREP.								LP BALL	AE50	CHA
4190151	FOUNDATION	100	4190152			4190143	42.0		LP BALL	B+V	CHA
4190152	SITE PREPARATION	100	41901615			4190151	36.0		LP BALL	AE50	CHA
419016	DESIGN-ENGINEERING								LP BALL	AE50	CHA
4190161	DESIGN	01	JAN	78		41901615	.0		LP BALL	AE50	CHA
41901611	REFLECTIVE UNIT	5	4190161	—		45001	28.0		LP BALL	AE50	CHA
41901612	DRIVE UNIT	60	41901611	—		4190162	26.0		LP BALL	AE50	CHA
41901613	SENSOR/CALIBRATION EQUIP	80	4190161	—		4190133	12.0		LP BALL	AE50	CHA
41901614	CONTROL EQUIPMENT	40	4190161	—		440201	20.0		LP BALL	AE50	CHA
41901615	FOUNDATION+SITE PREP.	65	4190161	—		4190152	4.0		LP BALL	AE50	CHA
4190162	ENGINEERING SUPPORT	100	41901612				97.0		LP BALL	AE50	CHA
419017	PACKING+TRANSPORTATION								LP BALL	AE50	CHA
419018	FIELD ASSEMBLY, INSTALLATION								LP BALL	AE50	CHA
4190181	HELIOSTAT+CONTROL EQUIP								LP BALL	AE50	CHA
41901811	FIELD ASSEMBLY	—	4190111	95		41901812	36.0		LP BALL	AE50	CHA
41901812	INSTALLATION+CHECKOUT	10	41901811	—		419019	44.0		LP BALL	AE50	CHA
4190182	SENSOR/CALIBRATION EQUIP.								LP BALL	AE50	CHA
41901821	FIELD ASSEMBLY	100	4190133			41901822	8.0		LP BALL	AE50	CHA
41901822	INSTALLATION+CHECKOUT	—	4190216	100		41901823	3.0		LP BALL	AE50	CHA
41901823	CALIBRATION	12.5	41901822	—		419019	1.0		LP BALL	AE50	CHA
419019	CALIBRATION-H/S FIELD	100	41901823				12.0		L BALL	AE50	CHA



SOLAR CENTRAL RECEIVER

J.C. POWELL

ACTIVITY	DESCRIPTION	INTERFACE REQ.	INTERFACE ACTIVITY	COND.	DELAY	SUPPORTS	SPAN TIME	SAFETY	RESPONSIBILITY DIRECTOR	DEPT.	CLASS
41902	RECEIVER+TOWER SYSTEM								J.POWELL	5312	1HE
419021	RECEIVER UNIT								W.OBERJOHN	5312	48W
4190211	ABSORBER UNIT								W.OBERJOHN	5312	48W
41902111	ABSORBER	100	4190272			4190215	56.0		W.OBERJOHN	5312	48W
41902112	DRUM	—	41902111	100		4190215	56.0		W.OBERJOHN	5312	48W
41902113	DOORS,HOUSING,LINING,INSUL	—	41902111	100		4190215	56.0		W.OBERJOHN	5312	48W
4190212	PIPING	—	41902111	50			26.0		W.OBERJOHN	5312	48W
4190213	SUPPORT STRUCTURE	80	4190252	—		4190215	20.0		W.OBERJOHN	5312	48W
4190214	INSTRUMENTATION+CONTROL	—	4190216	90		440283	12.0		W.OBERJOHN	5312	48W
4190215	PACKAGING+TRANSPORTATION	—	4190213	30		4190216	32.0		W.OBERJOHN	5312	48W
4190216	FIELD ERECTION+INSTAL.	10	4190215	—		4190214	52.0		W.OBERJOHN	5312	48W
419023	RISER+HORIZ.FEEDWATER PIPING								W.OBERJOHN	5312	48W
4190231	FROM GEN. BLDG								W.OBERJOHN	5312	48W
41902311	PIPING	100	4190273				24.0		W.OBERJOHN	5312	48W
41902312	HANGERS,VALVES,SUPPORTS	100	4190273				24.0		W.OBERJOHN	5312	48W
41902313	INSULATION	100	4190273				12.0		W.OBERJOHN	5312	48W
4190232	FROM THERMAL STORAGE								W.OBERJOHN	5312	48W
41902321	PIPING	100	4190273				24.0		W.OBERJOHN	5312	48W
41902322	HANGERS,VALVES,PIPE SUPPOR	100	4190273				24.0		O.OBERJOHN	5312	48W
41902323	INSULATION	100	4190273				12.0		W.OBERJOHN	5312	48W
419024	DOWNCOMER+HORIZ.STEAM PIPING								W.OBERJOHN	5312	48W
4190241	TO GENERATOR BLDG.								W.OBERJOHN	5312	48W
41902411	PIPING	100	4190273				24.0		W.OBERJOHN	5312	48W
41902412	HANGERS,VALVES,PIPE SUP.	100	4190273				24.0		W.OBERJOHN	5312	48W
41902413	INSULATION	100	4190273				12.0		W.OBERJOHN	5312	48W
4190242	TO THERMAL STORAGE								W.OBERJOHN	5312	48W
41902421	PIPING	100	4190273				24.0		W.OBERJOHN	5312	48W
41902422	HANGERS,VALVES,PIPE	100	4190273				24.0		W.OBERJOHN	5312	48W
41902423	INSULATION	100	4190273				12.0		W.OBERJOHN	5312	48W
419025	TOWER+PLATFORM								LE DOUTY	5312	38V
4190251	TOWER	100	4190281			419036302	18.0		LE DOUTY	5312	38V
4190252	PLATFORM	—	4190251	30		4190213	12.0		LE DOUTY	5312	38V
4190253	ELEVATOR	100	4190251			4190254	10.0		LE DOUTY	5312	38V
4190254	LIGHTING	—	4190253	100			10.0		LE DOUTY	5312	38V
4190255	LIGHTING PROTECTION	100	4190261				30.0		LE DOUTY	5312	38V
419026	FOUNDATION+SITE PREP.								LE DOUTY	5312	38V
4190261	FOUNDATION	100	4190262			4190255	8.0		LE DOUTY	5312	38V
4190262	EXCAVATION	100	4190271			4190261	4.0		LE DOUTY	5312	38V
419027	DESIGN								J.POWELL	5312	1HE
4190271	TOWER+FOUNDATION	—	400011	100		4190262	24.0		LE DOUTY	5312	38V
4190272	RECEIVER	—	400011	100		41902111	24.0		W OBERJOHN	5312	48W
4190273	RISER,DOWNCOMER	—	400011	100		41902423	24.0		W OBERJOHN	5312	48W
41903	THERMAL STORAGE SYSTEM								D. LEFROIS	5312	1HE
419031	THERMAL STORAGE UNIT								D. LEFROIS	5312	1HE
41903111	MAIN STORAGE TANK (ORT)	100	41903511			41903552	24.0		D LEFROIS	BROWN	1HE
41903112	SUPERHEAT STORAGE TANKS	100	41903512			41903553	24.0		D LEFROIS	BROWN	1HE
41903113	SUPERHEAT HEATER	50	41903111	—			16.0		D LEFROIS	FNTUB	1HE
4190312	INSULATION								D LEFROIS	API	1HE
41903121	MAIN STORAGE INSULATION	100	41903111			41903531	4.0		D LEFROIS	API	1HE
41903122	SUPERHEAT STORAGE INSULAT	100	41903112			41903532	4.0		D LEFROIS	API	1HE
41903123	OTHER INSULATION	—	41903122	100			4.0		D LEFROIS	API	1HE
41903131	OIL ULLAGE MAINT. UNIT	90	41903111	—		41903551	10.0		D LEFROIS	AIR P	1HE
41903132	HITEC ULLAGE MAINT UNIT	90	41903112	—			10.0		D LEFROIS	AIR P	1HE
4190314	OIL MAINT UNIT	100	41903524				26.0		D LDEFOIS	HOWE	1HE
419032	CIRCULATION EQUIPMENT								D LEFROIS	5312	1HE
4190321	PIPE AND SUPPORT								D. LEFROIS	5312	1HE
41903211	SUPER HEATER CHARGE LOOP	—	41903331	50		41903241	6.0		D. LEFROIS	5312	1HE
41903212	MAIN STORAGE CHARGE LOOP	—	41903332	50		41903242	6.0		D. LEFROIS	5312	1HE
41903213	SUPERHEATER DISCHARGE LOOP	—	41903323	50		41903243	6.0		D. LEFROIS	5312	1HE
41903214	MAIN STORAGE DISCHAR LOOP	—	41903322	50		41903244	2.0		D. LEFROIS	5312	1HE
4190322	VALVES								D. LEFROIS	5312	1HE
41903221	SUPERHEATER CHARGE	—	41903211	75			2.0		D. LEFROIS	5312	1HE
41903222	MAIN STORAGE CHARGE	—	41903212	75			2.0		D. LEFROIS	5312	1HE
41903223	SUPERHEATER DISCHARGE	—	41903213	75			2.0		D. LEFROIS	5312	1HE
41903224	MAINSTORAGE DISCHARGE	—	41903214	75			2.0		D. LEFROIS	5312	1HE
4190323	PUMPS								D. LEFROIS	5312	1HE
41903231	SUPERHEATER CHARGE	—	41903211	75			2.0		D. LEFROIS	5312	1HE
41903232	MAINSTORAGE CHARGE	—	41903212	75			2.0		D. LEFROIS	5312	1HE
41903233	SUPERHEATER DISCHARGE	—	41903213	75			2.0		D. LEFROIS	5312	1HE
41903234	MAIN STORAGE DISCHARGE	—	41903214	75			2.0		D. LEFROIS	5312	1HE
4190324	INSULATION								D. LEFROIS	5312	1HE
41903241	SUPERHEATER CHARGE LLOOP	100	41903211				2.0		D. LEFROIS	API	1HE
41903242	MAINSTORAGE CHARGE	100	41903212				3.0		D. LEFROIS	API	1HE
41903243	SUPERHEATER DISCHARGE LOOP	100	41903213				2.0		D. LEFROIS	API	1HE
41903244	MAINSTORAGE DISCHARGE LOOP	100	41903214				3.0		D. LEFROIS	API	1HE
41903245	WATER/STEAM PIPE INSULATIO	100	4190328				3.0		D. LEFROIS	API	1HE
4190325	CONDENSATE DRAIN TANK	—	41903332	50			3.0		D. LEFROIS	API	1HE
4190326	WATER/STEAM PPING-STOR TO	—	41903323	50		41903245	2.0		D. LEFROIS	API	1HE
419033	HEAT EXCHANGERS								D. LEFROIS	API	
4190331	DESUPERHEATERS (CHARG)								D. LEFROIS	API	1HE
41903311	RECEIVER STEAM-ATT 1	100	4190335			41903347	36.0		D. LEFROIS	A+A	1HE
41903312	CONDENSER STEAM-ATT2	100	4190335			41903348	36.0		D. LEFROIS	E+A	1HE
41903331	DESUPERHEATER-HE1	100	4190335			41903341	20.0		D. LEFROIS	M+L	1HE
41903332	CONDENSER-HE2	100	4190335			41903342	20.0		D. LEFROIS	M+L	1HE
41903333	SUBCOLLER-HE5	100	4190335			41903346	20.0		D. LEFROIS	M+L	1HE
4190332	STEAM GENERATION(DISCHG)								D. LEFROIS	M+L	1HE
41903321	PREHEATER-HE3A	100	4190335			41903343	20.0		D. LEFROIS	M+L	1HE
41903322	BOILER-HE3B	100	4190335			41903344	20.0		D. LEFROIS	M+L	1HE
41903323	SUPERHEATER-HE4	100	4190335			41903345	20.0		D. LEFROIS	M+L	1HE
41903341	HE1 INSULATION	80	41903331	—			6.0		D. LEFROIS	API	1HE
41903342	HE2 INSULATION	80	41903332	—			6.0		D. LEFROIS	API	1HE
41903343	HE3A INSULATION	85	41903321	—			6.0		D. LEFROIS	API	1HE
41903344	HE3B INSULATION	85	41903322	—			6.0		D. LEFROIS	API	1HE
41903345	HE4 INSULATION	80	41903323	—			6.0		D. LEFROIS	API	1HE
41903346	HE5 INSULATION	80	41903333	—			6.0		D. LEFROIS	API	1HE
41903347	ATT1 INSULATION	80	41903311	—			6.0		D. LEFROIS	API	1HE
41903348	ATT2 INSULATION	80	41903312	—			6.0		D. LEFROIS	API	1HE
4190335	SUPPORT STRUCTURES	100	41903521			41903323	4.0		D. LEFROIS	OSM	1HE



MARK III MANAGEMENT SYSTEM

HONEYWELL INCORPORATED
MINNEAPOLIS, MINNESOTA

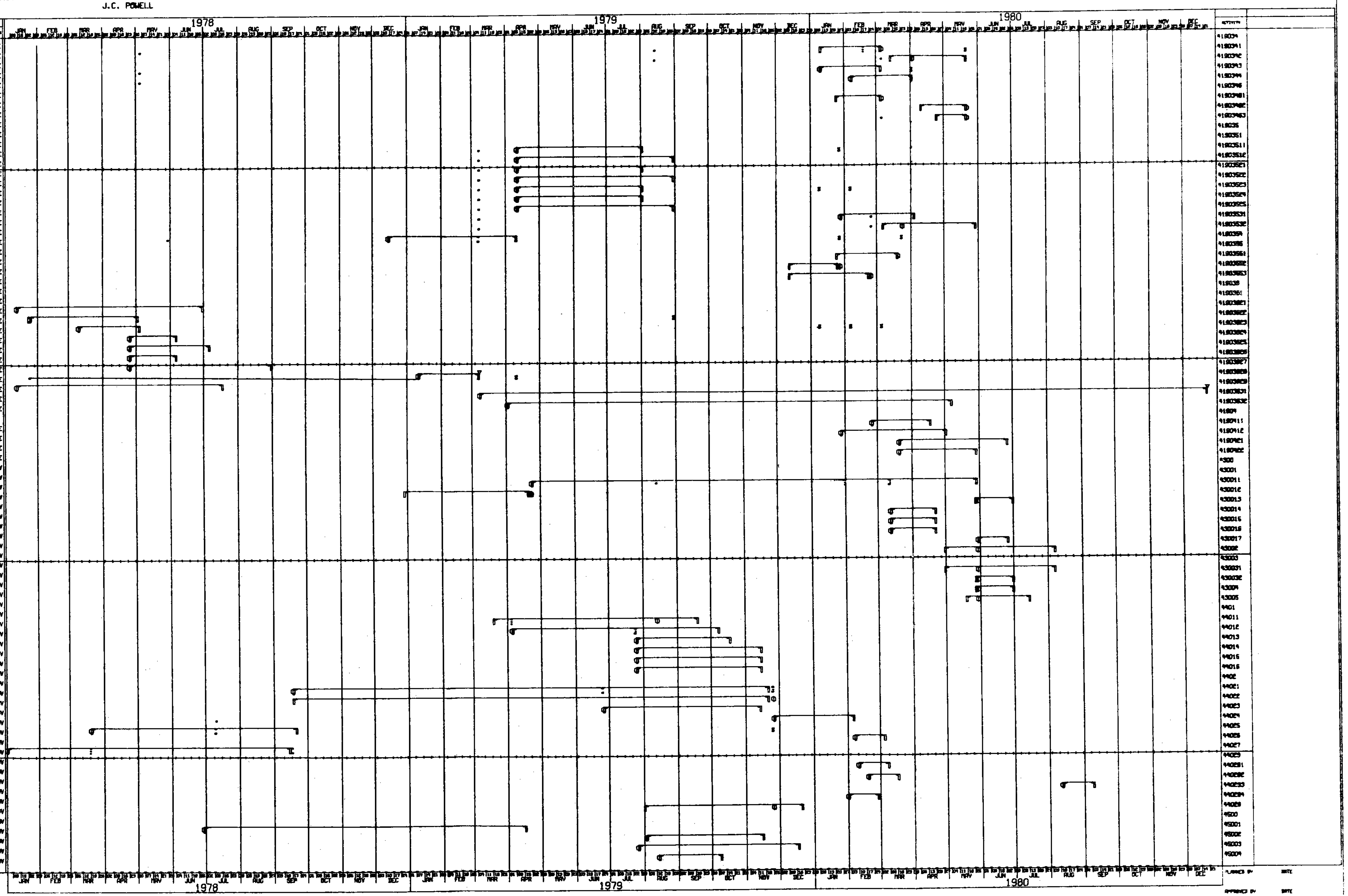
SERIAL NUMBER

DATE 04/27/77

SOLAR CENTRAL RECEIVER

J.C. POWELL

ACTIVITY	DESCRIPTION	INTERFACE REL.	INTERFACE ACTIVITY	CODE	DELAY	SUPPORTS	SPAN TIME	SAFETY	DIRECTOR	DEPT.	CLASS
419034	INSTRUMENTATION+CTL								D. LEFROIS	5312	1HE
4190341	DISPLAY PANEL	---	4190343	100		440282	8.0		D. LEFROIS	PCD	1HE
4190342	LOCAL INSTRU+ANNUNCIATOR	---	4190344	30		41903463	10.0		D. LEFROIS	OSM	1HE
4190343	ORT INSTRUMENTATION	80	41903111	---		4190342	8.0		D. LEFROIS	PCD	1HE
4190344	HITEC INSTRUMENTATION	80	41903112	---		4190342	8.0		D. LEFROIS	PCD	1HE
4190346	CONTROL+ELECT INTERFACE								D. LEFROIS	OSM	1HE
41903461	CTL JUNCTION BOX + CABLING	---	4190341	100			8.0		D. LEFROIS	OSM	1HE
41903462	LOCAL CTL STATION+CABLING	---	4190342	100			6.0		D. LEFROIS	OSM	1HE
41903463	PWR JUNCTION BOX+CABLING	---	4190342	100			4.0		D. LEFROIS	OSM	1HE
419035	FOUNDATIONS+SITE PREP								D. LEFROIS	OSM	1HE
4190351	FOUNDATIONS+SITE PREP								D. LEFROIS	OSM	1HE
41903511	MAIN STORAGE-TANK	100	4190354			4190325	16.0		D. LEFROIS	OSM	1HE
41903512	SUPERHEATER TANKS	100	4190354			41903112	20.0		D. LEFROIS	OSM	1HE
41903521	HEAT EXCHANGERS	100	4190354			4190335	16.0		D. LEFROIS	OSM	1HE
41903522	PUMP/MOTOR	100	4190354				20.0		D. LEFROIS	OSM	1HE
41903523	ULLAGE MAINTENANCE SYST	100	4190354			41903132	18.0		D. LEFROIS	OSM	1HE
41903524	OIL MAINTENANCE SYSTEM	100	4190354			4190314	16.0		D. LEFROIS	OSM	1HE
41903525	OTHER FOUNDATIONS	100	4190354				20.0		D. LEFROIS	OSM	1HE
41903531	MAINSTORAGE BEAM	100	41903111				10.0		D. LEFROIS	OSM	1HE
41903532	SUPERHEATER TANKAGE CONTAI	---	41903122	20			12.0		D. LEFROIS	OSM	1HE
4190354	SITE PREPARATION	80	41001	---		41903532	16.0		D. LEFROIS	OSM	1HE
4190355	SAFETY+PROTECTION EQUIP								D. LEFROIS	5312	1HE
41903551	OIL HANDLING SAFETY EQ.	---	41903131	100		4190422	8.0		D. LEFROIS	TBD	1HE
41903552	ROCK HANDLING SAFETY EQ.	---	41903111	100		4190412	8.0		D. LEFROIS	TBD	1HE
41903553	SALT HANDLING+SAFETY EQ.	---	41903112	100		4190411	10.0		D. LEFROIS	TBD	1HE
419038	A+E DESIGN								D. LEFROIS	5312	1HE
4190381	A+E DESIGN								D. LEFROIS	5312	1HE
41903821	TANKAGE	5	400011	---			24.0		D. LEFROIS	BROWN	1HE
41903822	HEAT EXCHANGE	10	400011	---		41903323	14.0		D. LEFROIS	OSM	1HE
41903823	CONTROL SYSTEM	30	400011	---		4190344	8.0		D. LEFROIS	OSM	1HE
41903824	AUXILIARY EQUIPMENT	50	400011	---			8.0		D. LEFROIS	OSM	1HE
41903825	ELECTRICAL	50	400011	---			10.0		D. LEFROIS	OSM	1HE
41903826	THERMAL	50	400011	---			8.0		D. LEFROIS	OSM	1HE
41903827	MECHANICAL	50	400011	---			18.0		D. LEFROIS	OSM	1HE
41903828	FOUNDATIONS+SITE PREP	100	41001			41903831	8.0	0	D. LEFROIS	OSM	1HE
41903829	OIL MAINTENANCE UNIT	5	400011	---			28.0		D. LEFROIS	NONE	1HE
41903831	DESIGN SUPPORT TO FAB	100	41903828				91.0	0	D. LEFROIS	5312	1HE
41903832	FIELD SUPPORT-INSTALL+C/O	100	4190251				58.0		D. LEFROIS	5312	1HE
41904	THERMAL STORAGE MATERIAL								D. LEFROIS	5312	
4190411	HITEC MATERIAL	100	41903553				8.0		D. LEFROIS	PARK	1HE
4190412	ROCK	100	41903552				14.0		D. LEFROIS	MANN	1HE
4190421	CALORIA HT43	100	41903551				14.0		D. LEFROIS	EXXON	1HE
4190422	OTHER ORGANIC MATL	100	41903551				10.0		D. LEFROIS	5312	1HE
4300	TURBINE PLANT EQUIPMENT								JC POWELL	5312	3BV
43001	TURBINE GENERATORS								EL DOUTY	B+V	3BV
430011	GENERATORS	100	430012			440284	58.0		EL DOUTY	B+V	3BV
430012	FOUNDATIONS	---	41031	100		430011	16.0		EL DOUTY	B+V	3BV
430013	STANDBY EXCITERS	---	430011	10			5.0		EL DOUTY	B+V	3BV
430014	LUBRICATING SYSTEMS	80	430011	---			8.0		EL DOUTY	B+V	3BV
430015	GAS SYSTEMS	80	430011	---			8.0		EL DOUTY	B+V	3BV
430016	REHEATERS	80	430011	---			6.0		EL DOUTY	B+V	3BV
430017	WATERPROOFING	100	430011				4.0		EL DOUTY	B+V	3BV
43002	HEAT REJECTION SYSTEM	---	430011	30			14.0		EL DOUTY	B+V	3BV
43003	CONDENSING SYSTEMS								EL DOUTY	B+V	3BV
430031	CONDENSATE SYSTEM	---	430011	30			14.0		EL DOUTY	B+V	3BV
430032	TURBINE BY-PASS SYSTEM	---	430011	10			5.0		EL DOUTY	B+V	3BV
43004	FEED-HEATING SYSTEM	---	430011	10			5.0		EL DOUTY	B+V	3BV
43005	WATER CIRCU TREATMENT EQUIP	---	430011	20			8.0		EL DOUTY	B+V	3BV
4401	ELECTRIC PLANT EQUIPMENT								EL DOUTY	B+V	3BV
44011	SWITCHGEAR	---	41036	80		44012	28.0		EL DOUTY	B+V	3BV
44012	STATION SERVICE EQUIPMENT	10	44011	---		44016	28.0		EL DOUTY	B+V	3BV
44013	SWITCHBOARDS	60	44012	---			12.0		EL DOUTY	B+V	3BV
44014	PROTECTIVE EQUIPMENT	60	44012	---			16.0		EL DOUTY	B+V	3BV
44015	ELECT.STRUCTURE+WIRE	80	44012	---			16.0		EL DOUTY	B+V	3BV
44016	POWER WIRING	80	44012	---			18.0		EL DOUTY	B+V	3BV
4402	PLANT MASTER CONTROL EQUIP								EL DOUTY	B+V	3BV
44021	COMPUTER	100	44027			44029	80.0		EL DOUTY	B+V	3BV
44022	PERIPHERAL EQUIPMENT	---	44021	100			80.0		EL DOUTY	B+V	3BV
44023	CONTROL PANEL+BOARDS	85	44021	---			20.0		EL DOUTY	B+V	3BV
44024	INTERFACE-SIGNAL/COMPUTER	100	44021			44026	10.0		EL DOUTY	B+V	3BV
44025	S/W DESIGN + DEVEL	30	44027	---		44024	28.0		EL DOUTY	B+V	3BV
44026	S/W + HDWE TEST	100	44024				4.0		EL DOUTY	B+V	3BV
44027	HARDWARE DESIGN	01	JAN	78		44025	36.0		EL DOUTY	B+V	3BV
44028	CONTROL WIRING								EL DOUTY	B+V	3BV
440281	COLLECTOR FIELD	70	41801814	---			4.0		EL DOUTY	B+V	3BV
440282	THERMAL STORAGE	70	4190341	---			4.0		EL DOUTY	B+V	3BV
440283	RECEIVER	70	4180214	---			4.0		EL DOUTY	B+V	3BV
440284	TURBINE GENERATOR	70	430011	---			4.0		EL DOUTY	B+V	3BV
44029	SPEC.INSTRUMENTATION	---	44021	80			20.0		EL DOUTY	B+V	3BV
4500	MISC PLANT EQUIPMENT								EL DOUTY	B+V	3BV
45001	TRANSPORTATION+LIFTING	80	41801811	---			40.0		EL DOUTY	B+V	3BV
45002	AIR+ WATER SERVICE SYSTEMS	80	41084	---			15.0		EL DOUTY	B+V	3BV
45003	COMMUNICATIONS EQUIPMENT	50	41425	---			20.0		EL DOUTY	B+V	3BV
45004	FURNISHINGS AND FIXTURES	100	41426				6.0		EL DOUTY	B+V	3BV



MARK III MANAGEMENT SYSTEM
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VAN NUYS, CALIF. 91406

HONEYWELL INCORPORATED
MINNEAPOLIS, MINNESOTA

SERIAL NUMBER

DATE 04/27/77

COMMITMENT AND EXPENDITURE SCHEDULE

Calendar Year	1978	1979	1980	1981	1982	1983	
Fiscal Year	1978	1979	1980	1981	1982	1983	
4000 Land & Rights							
4100 Yard Work	573,536	259,715	248,893				1,082,144
4103 Turbine Building		511,886					511,886
4105 Admin. Building							N/R
4106 Pump House							N/R
4108 Warehouse							N/R
4141 Maintenance Bldg.		121,236					121,236
4142 Water Treatment B		46,026					46,026
4143 Sewage Treatment			in 4100				
4170 Thermal Storage Bldg							N/R
4180 Control Bldg.		313,195					313,195
4190.1 Collector Equip.	16,429,290	10,043,503	3,532,333	1,126,824			31,131,950
4190.2 Rec'v & Tower	3,977,663	4,544,476	3,921,020				12,443,159
4190.3 Thermal Storage	2,324,076	1,087,406	2,285,267				5,696,749
4190.4 Thermal Stg. Matl		810,056					810,056
4300 Turbine Plant Equip		5,654,309					5,654,309
4401 Electric Plant Equip.		1,443,502					1,443,502
4402 Master Control Equip.		1,652,071					1,652,071
4500 Misc. Plant Equip.		1,604,187					1,604,187
5309 Transmission Plant							N/R
7000 Quality Assurance							N/Added
8000 Distributables			in 8100				
8100 Indirects	3,744,961	3,551,333	1,262,626	141,207			8,700,127
8300 Contingency	6,318,480						6,318,480
Total Pilot Plant	33,368,006	31,642,861	11,250,139	1,268,031			77,529,077
Two Year Test Program				2,951,797	3,196,206	450,979	6,598,982
Commitment Schedule	35,368,006	31,642,861	11,250,139	4,219,828	3,196,206	450,979	84,128,059
Expenditure Schedule	20,389,377	36,491,255	16,169,740	6,033,994	4,592,714	450,979	

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
	POWER PLANT						77,529,077
4000	Land and Land Rights						
4000.1	Land and Privilege Acquisition					Free	
4000.11	Land and surveys				Free		
4000.12	Easements and rights-of-way				Free		
4000.13	Clearing land, including demolition of structures				Free		
4100	Yard work					1,082,144	
4100.1	Grading, General Excavation and/or Fill, and Landscaping				138,074		
4100.2	Roadways, Fencing, and Lighting				844,162		
4100.21	Roads			561,278			
4100.22	Sidewalks			Included in 4100.4			
4100.23	Parking			Included in 4100.21			
4100.24	Retaining walls, bridges, and culverts			Not required			
4100.25	Fences and gateways			159,403			
4100.26	Yard lighting			123,481			
4100.3	Sanitary Sewer System				10,104		
4100.31	Connection to existing system						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4100.32	Septic tank			1,123			
4100.33	Distribution box						
4100.34	Tile field (drainage)			3,368			
4100.35	Piping, conduits, and manholes			5,613			
4100.4	Yard Drainage and Storm Sewer System				89,804		
4100.41	Connection to existing system						
4100.42	Manholes, catch basins, inlets, etc.						
4100.43	Outfall structure						
4100.44	Piping, conduits, open ditches						
4100.5	Waterfront Improvements, including:				Not required		
4100.51	Revetments						
4100.52	Levees						
4100.53	Breakwaters						
4100.54	Highway access						
4100.6	Roads Constructed to Connect the Project Site with Public Roads, including:				Not required		
4100.61	Grading						
4100.62	Surfacing						
4100.63	Culverts						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4100.64	Bridges, trestles, and causeways						
4100.65	Guards and signs						
4100.66	Lighting						
4100.7	<u>Railway Access</u>				Not required		
	Railroads constructed to permanently connect the site with public carriers, including:						
4100.71	Grading						
4100.72	Bridges, culverts, and trestles						
4100.73	Ballast, ties, rails, and accessories						
4100.74	Signals and interlocks						
4100.75	Switches, crossovers, and bumpers						
4100.8	<u>Waterway Access Facilities, including</u>:				Not required		
4100.81	Dredging						
4100.82	Piers, barge docks, or similar structures						
4100.9	<u>Air Access Facilities</u>				Not required		
4103	<u>Turbine Building</u>					511,886	
4103.1	<u>Substructure</u>				78,579		
4103.11	Excavation and backfill			4,490			

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4103.12	Dewatering						
4103.14	Concrete, including forms, reinforcement, embedded iron, finish surfaces, expansion joints, water proofing, and waterstops			74,089			
4103.2	<u>Superstructure</u>				260,801		
4103.21	Structural steel, misc. iron (stairways, platforms, railings, etc.)			207,673			
4103.22	Building siding (e.g., corrugated insulated metal siding, etc.)						
4103.23	Masonry walls (e.g., concrete blocks, etc.)			22,451			
4103.24	Concrete, including forms and reinforcement (e.g., columns, walls, and supported floors)			25,819			
4103.26	Doors and sash, including hardware			7,858			
4103.27	Roof deck, roofing, and flashing						
4103.28	Interior partitions millwork and finish						
4103.4	<u>Building Mechanical Systems</u>				59,495		
4103.41	Roof drains, floor drains, and sump pumps			28,064			
4103.42	Heating system (including A/C for control room if included with turbine generator building)			24,696			

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4103.43	Ventilation system, ductwork, dampers, and fans						
4103.46	Fire protection			6,735			
4103.5	Lighting and Building Service Power System				92,050		
4103.51	Conduit						
4103.52	Wire						
4103.54	Fixtures						
4103.57	Panels						
4103.58	Transformers						
4103.6	Painting				17,961		
4105	Administration Building					Not required	
4105.1	Substructure						
4105.11	Excavation and backfill						
4105.12	Dewatering						
4105.14	Concrete, including forms, reinforcement, embedded iron, finish surfaces, expansion joints, water proofing, and waterstops						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4105. 2	Superstructure						
4105. 21	Structural steel, misc. iron (stairways, platforms, railing, etc.)						
4105. 22	Building siding (e.g., corrugated insulated metal siding, etc.)						
4105. 23	Masonry walls (e.g., concrete blocks, etc.)						
4105. 24	Concrete, including forms and reinforcement (e.g., columns, walls, and supported floors)						
4105. 26	Doors and sash, including hardware						
4105. 27	Roof deck, roofing, and flashing						
4105. 28	Interior partitions millwork and finish						
4105. 4	Building Mechanical Systems						
4105. 41	Roof drains, floor drains, and sump pumps						
4105. 42	Heating system (including A/C for control room if included with turbine generator building)						
4105. 43	Ventilation system, ductwork, dampers, and fans						
4105. 46	Fire protection						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4105.5	Lighting and Building Service Power System						
4105.51	Conduit						
4105.52	Wire						
4105.54	Fixtures						
4105.57	Panels						
4105.58	Transformers						
4105.6	Painting						
4106	Circulating and Service Water Pump-house (at water source)					Not required	
4106.1	Substructure						
4106.11	Excavation and backfill						
4106.12	Dewatering						
4106.14	Concrete, including forms, reinforcement, embedded iron, finish surfaces, expansion joints, water proofing, and waterstops						
4106.2	Superstructure						
4106.21	Structural steel, misc. iron (stairways, platforms, railing, etc.)						
4106.22	Building siding (e.g., corrugated insulated metal siding, etc.)						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4106.23	Masonry walls (e.g., concrete blocks, etc.)						
4106.24	Concrete, including forms and reinforcement (e.g., columns, walls, and supported floors)						
4106.26	Doors and sash, including hardware						
4106.27	Roof deck, roofing, and flashing						
4106.28	Interior partitions millwork and finish						
4106.4	Building Mechanical Systems						
4106.41	Roof drains, floor drains, and sump pumps						
4106.42	Heating system (including A/C for control room if included with turbine generator building)						
4106.43	Ventilation system, ductwork, dampers, and fans						
4106.46	Fire protection						
4106.5	Lighting and Building Service Power System						
4106.51	Conduit						
4106.52	Wire						
4106.54	Fixtures						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4106.57	Panels						
4106.58	Transformers						
4106.6	Painting						
4108	Warehouse (permanent structure, if required)					Not required	
4108.1	Substructure						
4108.11	Excavation and backfill						
4108.12	Dewatering						
4108.14	Concrete, including forms, reinforcement, embedded iron, finish surfaces, expansion joints, water proofing, and waterstops						
4108.2	Superstructure						
4108.21	Structural steel, misc. iron (stairways, platforms, railings, etc.)						
4108.22	Building siding (e.g., corrugated insulated metal siding, etc.)						
4108.23	Masonry walls (e.g., concrete blocks, etc.)						
4108.24	Concrete, including forms and reinforcement (e.g., columns, walls, and supported floors)						
4108.26	Doors and sash, including hardware						

SOLAR CENTRAL RECEIVER
COST BREAKDOWN STRUCTURE
10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4108.27	Roof deck, roofing, and flashing						
4108.28	Interior partitions millwork and finish						
4108.4	Building Mechanical Systems						
4108.41	Roof drains, floor drains, and sump pumps						
4108.42	Heating system (including A/C for control room if included with turbine generator building)						
4108.43	Ventilation system, ductwork, dampers, and fans						
4108.46	Fire protection						
4108.5	Lighting and Building Service Power Systems						
4108.51	Conduit						
4108.52	Wire						
4108.54	Fixtures						
4108.57	Panels						
4108.58	Transformers						
4108.6	Painting						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4141	Maintenance Building					121,236	
4141.1	Substructure				15,716		
4141.11	Excavation and backfill						
4141.12	Dewatering						
4141.14	Concrete, including forms, reinforcement, embedded iron, finish surfaces, expansion joints, water proofing, and waterstops						
4141.2	Superstructure				69,598		
4141.21	Structural steel, misc. iron (stairways, platforms, railings, etc.)						
4141.22	Building siding (e.g., corrugated insulated metal siding, etc.)						
4141.23	Masonry walls (e.g., concrete blocks, etc.)						
4141.24	Concrete, including forms and reinforcement (e.g., columns, walls, and supported floors)						
4141.26	Doors and sash, including hardware						
4141.27	Roof deck, roofing, and flashing						
4141.28	Interior partitions millwork and finish						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4141.4	<u>Building Mechanical Systems</u>				20,206		
4141.41	Roof drains, floor drains, and sump pumps						
4141.42	Heating system (including A/C for control room if included with turbine generator building)						
4141.43	Ventilation system, ductwork, dampers, and fans						
4141.46	Fire protection						
4141.5	<u>Lighting and Building Service Power Systems</u>				14,593		
4141.51	Conduit						
4141.52	Wire						
4141.54	Fixtures						
4141.57	Panels						
4141.58	Transformers						
4141.6	<u>Painting</u>						
4142	<u>Water Treatment Equipment Building</u>				1,123		
4142.1	<u>Substructure</u>					46,026	
4142.11	Excavation and backfill				5,613		
4142.12	Dewatering						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4142.14	Concrete, including forms, reinforcement, embedded iron, finish surfaces, expansion joints, water proofing, and waterstops						
4142.2	<u>Superstructure</u>				25,819		
4142.21	Structural steel, misc. iron (stairways, platforms, railings, etc.)						
4142.22	Building siding (e.g., corrugated insulated metal siding, etc.)						
4142.23	Masonry walls (e.g., concrete blocks, etc.)						
4142.24	Concrete, including forms and reinforcement (e.g., columns, walls, and supported floors)						
4142.26	Doors and sash, including hardware						
4142.27	Roof deck, roofing, and flashing						
4142.28	Interior partitions millwork and finish						
4142.4	<u>Building Mechanical Systems</u>				7,858		
4142.41	Roof drains, floor drains, and sump pumps						
4142.42	Heating system (including A/C for control room if included with turbine generator building)						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4142.43	Ventilation system, ductwork, dampers, and fans						
4142.46	Fire protection						
4142.5	Lighting and Building Service Power Systems				5,613		
4142.51	Conduit						
4142.52	Wire						
4142.54	Fixtures						
4142.57	Panels						
4142.58	Transformers						
4142.6	Painting						
4143	Sewage Treatment				1,123		
4143.1	Substructure					Included in	4100.3
4143.11	Excavation and backfill						
4143.12	Dewatering						
4143.14	Concrete, including forms, reinforcement, embedded iron, finish surfaces, expansion joints, water proofing, and waterstops						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4143.2	<u>Superstructure</u>						
4143.21	Structural steel, misc. iron (stairways, platforms, railings, etc.)						
4143.22	Building siding (e.g., corrugated insulated metal siding, etc.)						
4143.23	Masonry walls (e.g., concrete blocks, etc.)						
4143.24	Concrete, including forms and reinforcement (e.g., columns, walls, and supported floors)						
4143.26	Doors and sash, including hardware						
4143.27	Roof deck, roofing, and flashing						
4143.28	Interior partitions millwork and finish						
4143.4	<u>Building Mechanical Systems</u>						
4143.41	Roof drains, floor drains, and sump pumps						
4143.42	Heating system (including A/C for control room if included with turbine generator building)						
4143.43	Ventilation system, ductwork, dampers, and fans						
4143.46	Fire protection						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4143.5	Lighting and Building Service Power Systems						
4143.51	Conduit						
4143.52	Wire						
4143.54	Fixtures						
4143.57	Panels						
4143.58	Transformers						
4143.6	Painting						
4170	Thermal Storage Structure (if required)					Not required	
4170.1	Substructure						
4170.11	Excavation and backfill						
4170.12	Dewatering						
4170.14	Concrete, including forms, reinforcement, embedded iron, finish surfaces, expansion joints, water proofing, and waterstops						
4170.2	Superstructure						
4170.21	Structural steel, misc. iron (stairways, platforms, railings, etc.)						
4170.22	Building siding (e.g., corrugated insulated metal siding, etc.)						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4170.23	Masonry walls (e.g., concrete blocks, etc.)						
4170.24	Concrete, including forms and reinforcement (e.g., columns, walls, and supported floors)						
4170.26	Doors and sash, including hardware						
4170.27	Roof deck, roofing, and flashing						
4170.28	Interior partitions millwork and finish						
4170.4	Building Mechanical Systems						
4170.41	Roof drains, floor drains, and sump pumps						
4170.42	Heating system (including A/C for control room if included with turbine generator building)						
4170.43	Ventilation system, ductwork, dampers, and fans						
4170.46	Fire protection						
4170.5	Lighting and Building Service Power Systems						
4170.51	Conduit						
4170.52	Wire						
4170.54	Fixtures						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4170.57	Panels						
4170.58	Transformers						
4170.6	Painting						
4180	Control Building (if not included in other building)					313,195	
4180.1	Substructure				46,026		
4180.11	Excavation and backfill						
4180.12	Dewatering						
4180.14	Concrete, including forms, reinforcement, embedded iron, finish surfaces, expansion joints, water proofing, and waterstops						
4180.2	Superstructure						
4180.21	Structural steel, misc. iron (stairways, platforms, railings, etc.)				175,119		
4180.22	Building siding (e.g., corrugated insulated metal siding, etc.)						
4180.23	Masonry walls (e.g., concrete blocks, etc.)						
4180.24	Concrete, including forms and reinforcement (e.g., columns, walls, and supported floors)						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4180.26	Doors and sash, including hardware						
4180.27	Roof deck, roofing, and flashing						
4180.28	Interior partitions millwork and finish						
4180.4	Building Mechanical Systems				51,638		
4180.41	Roof drains, floor drains, and sump pumps						
4180.42	Heating system (including A/C for control room if included with turbine generator building)						
4180.43	Ventilation system, ductwork, dampers, and fans						
4180.46	Fire protection						
4180.5	Lighting and Building Service Power System				37,044		
4180.51	Conduit						
4180.52	Wire						
4180.54	Fixtures						
4180.57	Panels						
4180.58	Transformers						
4180.6	Painting				3,368		

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4190	Solar Plant Equipment					50,081,914	
4190.1	Collector Equipment				31,131,950		
4190.11	Reflective Unit			12,909,178			
4190.111	Reflective surface		446,052				
4190.112	Mirror backing structure		8,432,309				
4190.113	Heliostat support structure		4,030,817				
4190.114	Protective enclosure		Not required				
4190.12	Drive Unit			7,073,154			
4190.121	Azimuth or mirror module drive		3,462,642				
4190.122	Elevation or outer frame drive		2,008,104				
4190.123	Motors		1,078,407				
4190.124	Position and/or limit indicators		297,957				
4190.125	Emergency power supply for heliostats and associated wiring		136,986				
4190.126	Power distribution equipment and wiring from electric plant		89,058				
4190.13	Sensor/Calibration Equipment			560,684			
4190.131	Sensor unit		192,574				
4190.132	Sensor tower		205,386				

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4190.133	Calibration equipment used for daily operation and/or for initial calibration at construction		162,724				
4190.134	Wiring between heliostat and sensor		762				
4190.14	Control/Instrumentation Equipment			3,273,210			
4190.141	Field control/electronics		2,441,621				
4190.142	Computer hardware only if dedicated entirely to heliostat control		474,337				
4190.143	Signal distribution equipment and wiring		357,252				
4190.15	Foundation and Site Preparation			507,109			
4190.151	Foundation--heliostat and sensor (do not include any other support structure), including excavation, backfill		507,109				
4190.152	Site preparation as required for special contouring, etc., other than general grading included in 4100.10		Not required				
4190.16	Design and Engineering Costs			4,230,366			
4190.161	Design costs		2,540,047				
4190.161S	Design costs-systems The cost for all collector subsystem design work, including that done by A/E; indicate which items are to be designed by A/E and if that cost is also included in 8100.10	646,537					

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4190.1611	Reflective unit	552,788					
4190.1612	Drive unit	226,449					
4190.1613	Sensor/calibration equipment	240,158					
4190.1614	Control equipment (include software development)	801,701					
4190.1615	Foundation and site preparation	72,414					
4190.162	Engineering support during manufacturing, installation, and checkout		1,690,319				
4190.17	Packing Containers and Transportation to Power Plant Site			153,337			
4190.171	Containers for shipping		17,993				
4190.172	Transportation		135,344				
4190.18	Field Assembly, Installation, and Checkout			2,320,727			
4190.181	Heliostat and control equipment		2,320,254				
4190.1811	Field assembly	1,833,506					
4190.1812	Installation and checkout	486,748	473				
4190.182	Sensor/calibration equipment	Included in	4190.13				
4190.1821	Field assembly	473					
4190.1822	Installation and checkout						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4190.1823	Calibration	Not required					
4190.19	Lightning Protection			104,185			
4190.2	<u>Receiver and Tower System</u>				12,443,159		
4190.21	Receiver Unit			6,863,681			
4190.211	Absorber Unit		1,315,806				
4190.2111	Absorber	1,044,115					
4190.2112	Drum	102,502					
4190.2113	Doors, housing, lining, insulation	169,189					
4190.212	Piping		451,198				
4190.213	Support structure, platforms, etc.		2,688,229				
4190.214	Instrumentation and control on receiver and tower		195,970				
4190.215	Packing and transportation		106,553				
4190.216	Field erection and installation		2,105,925				
4190.22	Steam Generator (if other than water/ steam in receiver)			Included in 4190.211			
4190.23	Riser and Horizontal Feedwater Piping to Receiver			984,153			
4190.231	From turbine generator building		797,809				
4190.2311	Piping	134,244					
4190.2312	Hangers, valves, pipe supports, etc.	619,892					

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT — COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4190.2313	Insulation	43,673					
4190.232	From thermal storage-additional piping over that in 4190.221		186,344				
4190.2321	Piping	121,236					
4190.2322	Hangers, valves, pipe supports, etc.	29,186					
4190.2323	Insulation	35,922					
4190.24	Downcomer and Horizontal Steam Piping from Receiver			1,104,499			
4190.241	To turbine generator building		692,262				
4190.2411	Piping	359,345					
4190.2412	Hangers, valves, pipe supports, etc.	266,177					
4190.2413	Insulation	66,740					
4190.242	To thermal storage--additional piping over that in 4190.231		413,729				
4190.2421	Piping	175,108					
4190.2422	Hangers, valves, pipe supports, etc.	208,927					
4190.2423	Insulation	29,694					
4190.25	Tower and Platform			1,916,201			
4190.251	Tower		Procured (Kellogg)				
4190.252	Platform		Procured (Kellogg)				

SOLAR CENTRAL RECEIVER
COST BREAKDOWN STRUCTURE
10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4190.253	Elevator and other access		Procured (Kellogg)				
4190.254	Lighting		Procured (Kellogg)				
4190.255	Lightning protection		Procured (Kellogg)				
4190.26	Foundation and Site Preparation			700,475			
4190.261	Foundation		681,392				
4190.262	Excavation		19,083				
4190.27	Design Cost			874,150			
4190.271	Tower and foundation		Procured (Kellogg)				
4190.272	Receiver		874,150				
4190.273	Riser, downcomer, horizontal piping		Included in	8100.1			
4190.3	Thermal Storage Equipment				5,696,749		
4190.31	Thermal Storage Unit			2,185,896			
4190.311	Storage tanks and heaters if required to prevent solidification, etc.		886,167				
4190.312	Insulation		118,331				
4190.313	Ullage maintenance equipment--include tanks		61,402				
4190.314	Fluid maintenance equipment--include cost for additional fluid which may be required to maintain the initial fluid during initial plant startup		1,119,996				

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4190.32	Circulation Equipment for Storage Media and Water/Steam			950,659			
4190.321	Piping and support stands for storage media		271,835				
4190.322	Valves		510,610				
4190.323	Pumps		120,610				
4190.324	Insulation		28,860				
4190.325	Steam drums and/or condensate drain tanks		5,010				
4190.326	Water/steam piping and support stands between thermal storage and turbine generator building		13,734				
4190.33	Heat Exchangers			342,865			
4190.331	Desuperheaters		22,178				
4190.332	Steam generator heat exchangers (dis-charging)		128,971				
4190.333	Thermal storage heater heat exchangers (charging)		169,485				
4190.334	Insulation		22,231				
4190.335	Support structure		Not required				
4190.34	Instrumentation and Control Located at Thermal Storage Unit -- Measurement Equipment and Sensors			417,555			

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4190.35	Foundation and Site Preparation			466,710			
4190.351	Tank foundations		119,776				
4190.352	Other foundations--heat exchangers/pumps		74,124				
4190.353	Dikes or emergency containment structures		106,642				
4190.354	Site preparation		8,978				
4190.335	Safety protection equipment		157,190				
4190.36	Design Cost			1,333,064			
4190.4	<u>Thermal Storage Material</u>				810,056		
4190.41	Inorganic Material Cost			384,911			
4190.42	Organic Material Cost			361,293			
4190.43	Delivery			63,852			
4190.44	Handling at Site, e.g., melting			Included in	4190.363		
4300	<u>Turbine Plant Equipment</u>					5,654,309	
4300.1	<u>Turbine Generators</u>				3,153,258		
4300.11	Turbine generator units and related equipment supplied with turbine generator units such as speed controllers, main stop, throttle and intercept valves, generator coolers, main and pilot exciters, moisture separators, gland seals, turning gear, crossover piping, insulation, panel boards, instrumentation, protective devices, special tools and rotor lifting slings, and special extractions.			3,030,899			

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4300.12	Foundations (includes turbine generator pedestals)			69,598			
4300.121	Concrete; including forms, reinforcing, and embedded iron		Included in	4300.12			
4300.122	Structural steel		Included in	4300.12			
4300.13	Standby Exciters			Included in	4300.11		
4300.14	Lubricating System						
4300.141	Lube oil conditioning equipment		11,226				
4300.142	Storage tanks, piping, valves, and fittings		11,226				
4300.143	Fire protection equipment		Included in	4300.152 &	4103.4		
4300.15	Gas Systems			30,309			
4300.151	Hydrogen		Not required				
4300.152	Carbon dioxide		30,309				
4300.16	Reheaters			Not required			
4300.17	Weather-proof housing (for outdoor type installations)			Included in	4300.11		
4300.2	Heat Rejection System				1,214,604		
4300.21	Heat Rejection Equipment			518,620			
4300.22	Installation Cost			156,035			
4300.23	Exhaust Duct from Turbine to Heat Rejection Equipment			323,296			

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4300.24	Evaporation Pond for Cooling Tower Blowdown			216,653			
4300.3	<u>Condensing Systems</u>				278,393		
4300.31	Condensate System			278,393			
4300.311	Pumps, drives, and controls		37,044				
4300.3111	Main condensate	37,044					
4300.3112	Condensate booster	Not required					
4300.3113	Condensate transfer	Not required					
4300.312	Condensate storage tanks (includes protective coatings and fittings)		39,289				
4300.313	Piping, valves, and fittings (main condensate piping segments between condenser hotwell and final condensate pump, and drain and vent piping for equipment in Account 4300.3)		176,241				
4300.314	Insulation		7,858				
4300.315	Foundations, supports, hangers, bases, inserts, and screens		17,961				
4300.32	Turbine Bypass System			Included in 4300.11			
4300.321	Actuating valves		Included in 4300.11				
4300.322	Pressure-reducing assemblies		Included in 4300.11				
4300.323	Piping, manifolds, and fittings		Included in 4300.11				
4300.324	Desuperheating system						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4300.325	Insulation		Included in	4300.11			
4300.326	Hangers, foundations, supports, bases, inserts, and screens		Included in	4300.11			
4300.4	<u>Feed-Heating System</u>				488,312		
4300.41	Regenerative Heat Exchangers			120.113			
4300.411	Closed heaters		39,289				
4300.412	Open heaters (includes deaerating type)		69,598				
4300.413	Insulation		11,226				
4300.414	Foundations, supports, bases, inserts, and screens		Included in	4103.			
4300.42	Pumps			175,119			
4300.421	Main feed pumps, and drives		102,153				
4300.422	Auxiliary (startup, emergency, and reserve) feed pumps, and drives		65,108				
4300.423	Drains, pumps, and drives		Included in	4190.23			
4300.424	Insulation		7,858				
4300.425	Foundations, supports, bases, inserts, and screens		Included in	4103.			
4300.43	Piping and Tanks			193,080			
4300.431	Feed piping--not to include riser and downcomer and horizontal piping to and from receiver tower(s)		74,089				
4300.432	Drains, and coolers		Included in	4300.341			
4300.433	Drains and flash tanks		Included in	4300.341			

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4300.434	Extraction, drain, and vent piping, valves and fittings (for components in Account 4300.40 only; includes flow control valves)		80,824				
4300.435	Insulation		28,064				
4300.436	Hangers, supports, and inserts		10,103				
4300.5	<u>Water Circulation/Treatment Equipment</u>				519,742		
4300.51	Make-Up Treatment System			43,779			
4300.511	Evaporator system		Not required				
4300.512	Ion exchange system		Not required				
4300.513	Filter and separator systems		Not required				
4300.514	Pumps and drives		Not required				
4300.515	Piping, valves, and fittings		Not required				
4300.516	Storage tanks (includes protective coatings and fittings)		39,289				
4300.517	Hangers, foundations, supports, bases, inserts, and screens		4,490				
4300.52	Chemical Treatment and Condensate Purification Systems			475,963			
4300.521	Chemical storage and additional equipment (for boiler treatment)		17,961				
4300.522	Condensate demineralizer and filter system		295,232				
4300.523	Condensate and demineralized stored water treatment system		Not required				

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4300.524	Resin storage, regeneration, and addition systems		Not required				
4300.525	Boiler blowdown and fluid sampling systems		162,770				
4300.526	Pumps and drives		Included in 4300.521				
4300.527	Piping, valves, and fittings		Included in 4300.				
4300.528	Insulation		Included in 4300.				
4300.529	Hangers, foundations, supports, bases, inserts, and screens		Included in 4300. & 4142				
4401	<u>Electric Plant Equipment</u>					1,433,502	
4401.1	<u>Switchgear</u>				312,070		
4401.11	Generator Circuits			60,618			
4401.111	Generator switchgear (includes circuit breakers, disconnecting switches, operating mechanisms and interlocks, integral metering and protective equipment, and accessories and enclosures for this equipment)		23,574				
4401.112	Generator neutral grounding equipment		10,103				
4401.113	Generator current and potential transformers (includes housing)		16,838				
4401.114	Generator surge arrestors or other protective equipment (includes housings)		10,103				
4401.115	Excitation switchgear for main generators (includes voltage regulators, rheostats, discharge resistors, instruments, control devices, and housings)		Included in 4300.11				

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT -- COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4401.116	Special screens, bases, foundations, inserts, or supports for above-listed equipment		Included in	4103			
4401.12	Station Service			251,452			
4401.121	Station switchgear for all types of service and all voltage classes (includes circuit breakers, disconnecting switches, operating mechanisms and interlocks, integral metering and protective equipment, current limiting reactors, current and potential transformers, voltage regulators, compensators, fault ground buses, and accessories and enclosures for this equipment)		231,246				
4401.122	Station motor control centers centrally located		20,206				
4401.123	System neutral grounding devices		Included in	4401			
4401.124	Separately mounted station service devices, such as instrument transformers and surge arrestors		Included in	4401			
4401.125	Special screens, bases, foundations, inserts, or supports for above-listed equipment		Included in	4103 & 4180			
4401.2	<u>Station Service Equipment</u> Voltage conversion equipment for station service power and lighting and emergency power sources (includes auxiliary generators and batteries and charging equipment)				263,800		

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4401.21	Station Service and Startup Transformers			48,270			
4401.211	Station service transformers		44,902				
4401.212	Station startup transformers		Included in 4401.211				
4401.213	Foundations, walls, and related structures		3,368				
4401.214	Voltage regulation equipment		Included in 4401.211				
4401.215	Insulating oil storage and treating equipment (excludes such equipment serving only the transmission plant substation equipment)		Not required				
4401.22	Low Voltage Unit Substations and Lighting Transformers			Included in 4401.121			
4401.221	Unit substations and transformers		Included in 4401.121				
4401.222	Special screens, bases, foundations, inserts, or supports		Included in 4401.121				
4401.23	Auxiliary Power Sources			215,530			
4401.231	Battery systems		72,966				
4401.2311	Batteries	46,025					
4401.2312	Chargers	26,941					
4401.232	Auxiliary generators (type is optional)		Not required				
4401.2321	Diesel-engine/generator units (includes fuel, cooling, starting, and exhaust systems)	Not required					

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4401.2322	Gas-turbine/generator units (includes fuel, cooling, starting, and exhaust systems)	Not required					
4401.2323	Steam-turbine/generator units (includes boiler and accessories)	Not required					
4401.233	Motor generator sets		142,564				
4401.3	<u>Switchboards</u>				43,780		
	Bench, relay, and recording and indicating instrument and supervisory control boards for local control; that is, not located in the control room						
4401.4	<u>Protective Equipment</u>				445,654		
4401.41	General Station Grounding System			445,654			
4401.411	Ground conductors and connectors for equipment, piping, and structural members		352,482				
4401.412	Ground wells, mats, and rods (includes excavation and backfill)		93,172				
4401.42	Fire Protection Equipment			Included in	4300.152		
	Special fire extinguishing systems exclusively for electrical equipment, including generator (e.g., CO_2 systems)						

SOLAR CENTRAL RECEIVER
COST BREAKDOWN STRUCTURE
10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4401.5	<u>Electrical Structures and Wiring Containers</u>				172,873		
4401.51	Concrete Tunnels for Cables, Trenches, and Envelopes			Included in 4100.4			
	Tunnels and/or trenches for main generator circuit extending into the switchyard, or for station service circuits between buildings. (When tunnels are part of a building or serve a dual purpose, electrical and non-electrical, they are to be included under the appropriate building subaccount in Account 4103-4190.)						
4401.511	Excavation and backfill		Included in 4100.4				
4401.512	Forms, reinforcing, and concrete		Included in 4100.4				
4401.513	Hangers, cable racks, etc.		Included in 4100.4				
4401.514	Tunnel lighting, ventilation, and location markers						
4401.515	Manholes		Included in 4100.4				
4401.52	Cable Trays and Supports			29,186			
4401.53	Conduit			143,687			
4401.54	Other Structures			Not required			
	Pipe and steel frames and supports, barriers, compartments, and structures for housing and supporting cable, bus, and electrical equipment, other than that already specified						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4401.6	Power Wiring				195,325		
4401.61	Generator Circuit Wiring			58,373			
	Bus (and enclosure) or cable between generator and switching equipment, between switching equipment and terminals (at generator voltage) of transmission system equipment or station service equipment, and between generator and generator neutral grounding equipment)						
4401.62	Station Service Power Wiring			136,952			
4401.621	All power cables and bus to and from station service equipment, switchgear, and switchboards						
4401.622	High voltage cable and bus (1 kV and above)						
4401.623	Low voltage cable and bus (below 1 kV)						
4402	Plant Master Control Equipment					1,652,071	
	Include control equipment located in control room which serves more than one subsystem and/or controls the interfacing between subsystems						
4402.1	Computer				797,014		
4402.2	Peripheral Equipment				42,657		
4402.3	Control Panels and Boards				212,163		
4402.4	Interface Equipment--Signal and Computer				179,609		

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4402.5	Software Design and Development				Included in	8100.1	
4402.6	Software/Hardware Test				Included in	8100.1	
4402.7	Hardware Design				Included in	8100.1	
4402.8	Control Wiring				150,423		
	Wiring from subsystems to control room						
4402.81	From Collector Field			24,696			
4402.82	From Thermal Storage			23,574			
4402.83	From Receiver			23,574			
4402.84	From Turbine Generator			78,579			
4402.9	Special Test Program Instrumentation (pilot plant only)				270,205		
	Any special data monitoring equipment/ instrumentation (other than master control) which is necessary for the test program but not for normal plant operation						
4500	Miscellaneous Plant Equipment					1,604,187	
	Equipment permanently associated with plant						
4500.1	Transportation and Lifting Equipment				381,723		
4500.11	Cranes, hoists, monorails, and conveyors (includes equipment for general station use)			259,310			

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4500.111	Turbine building crane		250,330				
4500.1111	Bridge and trolley						
4500.1112	Crane rails and special supports						
4500.1113	Trolley conductors or trail cable and all supporting hardware						
4500.1114	Electrical connections from extremity of feeder circuit (includes any special junction boxes)						
4500.112	Other cranes, hoists, monorails, and conveyors		8,980				
4500.12	Railway Equipment			Not required			
4500.121	Locomotives						
4500.122	Rolling stock						
4500.13	Roadway Equipment			34,799			
4500.131	Trucks						
4500.132	Cranes						
4500.133	Forklift trucks and pallet trucks						
4500.134	Tractors						
4500.135	Trailers						
4500.136	Automobiles						
4500.14	Watercraft			Not required			
4500.141	Motorized boats						
4500.142	Barges and other unpowered craft						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4500.15	Vehicle Maintenance Equipment			Not required			
4500.16	Receiver Equipment for Maintenance, Assembly, and Handling of Receiver Parts			Included in 4190.2			
4500.17	Collector Equipment for Maintenance, Assembly, and Handling of Collector Parts			87,614			
4500.18	Thermal Storage Equipment for Maintenance, Assembly, and Handling of Thermal Storage Material and Parts			Included in 4190.3			
4500.2	<u>Air and Water Service Systems</u>				702,720		
4500.21	Air Systems			241,350			
	Compressed air and vacuum cleaning systems for general station use						
4500.211	Compressed air		241,350				
4500.2111	Compressors and drives, dryers, filters, receivers, and other compressed air system accessories	61,741					
4500.2112	Piping and fittings	179,609					
4500.212	Subatmospheric air		Not required				
4500.2121	Vacuum cleaning blowers, dust catchers, and other vacuum cleaning system accessories	Not required					
4500.2122	Piping and fittings	Not required					

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4500.22	Water Systems			461,371			
	Service, domestic, and fire protection water systems (excludes makeup water treatment/purification facilities specifically for turbine working fluid, since these systems are included in Account 4300)						
4500.221	Water supply pumps, including drives and controls (type is optional and may include river, lake, or sea water pumps; or deep wells and pumps)		Not required				
4500.222	Fire pumps, drives, and accessories		33,677				
4500.2221	Main system						
4500.2222	Auxiliary or jockey system						
4500.223	Water conditioning system (includes filter bed, coagulator, etc.)		3,368				
4500.224	Storage tanks and/or reservoirs		22,451				
4500.2241	Raw water						
4500.2242	Treated water						
4500.2243	Domestic water						
4500.225	Station service pumps, drives, and accessories		46,025				
4500.226	Domestic water treating equipment		Not required				
4500.227	Domestic water pumps, drives, and accessories		Not required				

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4500.228	Water heating equipment		24,696				
4500.229	Water distribution systems, indoors and outdoors (includes fire hydrants; all piping, valves and fittings; and connection to an existing system, if made)		331,154				
4500.3	<u>Communications Equipment</u>				229,001		
4500.31	Local Communication Systems			4,490			
4500.311	General purpose telephone system (includes connection to commercial system)		Leased				
4500.312	Special telephone circuits (includes sound powered systems)		Leased				
4500.313	Wireless facilities (microwave and radio)		Leased				
4500.314	Telegraph and Telex facilities		Leased				
4500.315	Public address systems and intercommunication systems		4,490				
4500.32	Signal Systems			224,511			
4500.321	Fire alarm system (except for indoor portion included in building accounts)						
4500.322	Security alarm and watchman tour systems						
4500.323	Evacuation alarm systems						
4500.324	Coded-typecall systems						
4500.325	Other signal systems						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4500.4	Furnishings and Fixtures				290,743		
4500.41	Safety Equipment			24,696			
4500.411	Fire trucks and accessories						
4500.412	Portable fire extinguishers						
4500.413	Respirators and other rescue equipment						
4500.414	First aid stations						
4500.415	Hospital or infirmary equipment						
4500.42	Shop, Laboratory, and Test Equipment			92,050			
4500.421	Mechanical						
4500.4211	Portable and hand tools						
4500,4212	Machine shop						
4500.4213	Welding shop						
4500.4214	Pipe shop						
4500.4215	Sheet metal shop						
4500.422	Electrical						
4500.4221	Electrical shop						
4500.4222	Instrument shop						
4500.4223	Portable and hand tools						
4500.423	Chemical laboratory						
4500.43	Office Equipment and Furnishings			33,677			

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4500.44	Environmental Monitoring Equipment--Meteorological			134,707			
4500.45	Dining Facilities (if present)			5,613			
4500.451	Kitchen equipment						
4500.452	Dining room furnishings						
4500.46	Cleaning Equipment			Included in 8100.1			
4500.461	Cleaners, mops, polishers, etc.						
4500.462	Janitorial supplies						
5309	<u>Transmission Plant (commercial plant only)</u>					Not required	
5309.1	<u>Substation and Switch Station</u>						
5309.11	Main Power Transformer						
5309.111	Foundations						
5309.112	Main transformers						
5309.113	Lightning arrestors						
5309.114	Fire protection (water spray)						
7000	<u>Quality Assurance</u>					No added cost	
	List here (1) costs for quality assurance already not included in other items; (2) an estimate of the percentage of the total engineering cost attributable to quality assurance. This is to include only on-site quality assurance costs.						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
8000	Distributables					Included in	8100.1
8030	Contractor Field Office Personnel and Supplies						
8030.1	Support of Construction						
8030.2	Construction Supervision						
8030.3	Engineering Staff						
8030.4	Accounting Staff						
8030.5	Other Staff						
8030.6	Office Supplies						
8030.7	Furniture, Rentals, Reproduction, Central Files Maintenance, and Repair Salvage						
8030.8	Medical, First Aid						
8040	Other Construction Items					Included in	8100.1
8040.1	Insurance, injuries, and damage (excludes Workmen's Compensation Insurance, which is included in the labor charges associated with the Direct Costs)				Included in	8100.1	
	Employer's liability insurance						
	Public liability and property damage insurance						
	Fire and theft insurance						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
8040.2	Insurance, Construction Equipment, and Autos				Included in	8100.1	
8040.3	Temporary Construction				Included in	8100.1	
	Includes only net cost of items which are removed or dismantled after completion of construction; items which are a permanent part of the plant are to be included under other accounts.						
8040.31	Site Access and Improvements			Included in	8100.1		
8040.32	Buildings and Structures			Included in	8100.1		
8040.321	Field offices						
8040.322	Warehouses, storage sheds, and garages						
8040.323	Shops, change rooms, and work areas						
8040.324	Guard houses and fences						
8040.325	Dormitories, houses, apartments, dining halls, commissary, and medical and recreation facilities						
8040.326	Other buildings or structures						
8040.33	Electricity and water (temporary power lines, pipe lines, and equipment for providing service during the construction period)			Included in	8100.1		
8040.34	Communications Equipment			Included in	8100.1		

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
8040.35	Aggregate Plant (includes equipment for quarrying or receiving, crushing, classifying, and washing sand, stone, and rock aggregates)			Included in 8100.1			
8040.36	Concrete Batch Plant			Included in 8100.1			
8040.4	Construction Equipment				Included in 8100.1		
	Includes net cost or rental expense of equipment used during the construction of the plant and thereafter removed from the site						
8040.41	Transportation, Lifting, and Unloading Equipment						
8040.42	Welding Equipment						
8040.43	Air Compressors						
8040.44	Steam Generators						
8040.45	Chemical Cleaning Facilities						
8040.46	Scaffolds, Ladders, and Stairways						
8040.47	Building Furnishings and Fixtures						
8040.48	Miscellaneous items (signs, barricades, rope, tarpaulins, plastic sheeting, office and drafting supplies, small tools, welding rod, and other expendable items)						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
8040.5	<u>Construction Services</u>				Included in 8100.1		
8040.51	Purchased Utilities			Included in 8100.1			
8040.511	Electric power						
8040.512	Water						
8040.513	Sewage disposal						
8040.514	Steam						
8040.515	Compressed air						
8040.516	Fuel for engines, turbines, or boilers						
8040.517	Communications (includes postage, telephone, Telex, telegraph)						
8040.518	Refuse and waste disposal						
8040.52	Security Watchmen and Guards			Included in 8100.1			
8040.53	Education and Testing Programs for Labor Force			Included in 8100.1			
8040.54	Materials Receiving and Storage (pertains only to receiving and handling miscellaneous materials at the plant site; costs of unloading and handling specific items or plant components should be associated with those items or components when the costs are identifiable)			Included in 8100.1			
8040.55	Inspection and Testing of Construction Materials			Included in 8100.1			

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
8040.56	Site Cleanup (includes general cleanup operations during construction and final job cleanup)			Included in	8100.1		
8040.57	Operation and Maintenance of Construction Facilities and Equipment			Included in	8100.1		
8040.58	Snow Removal			Included in	8100.1		
8040.6	<u>Spare Parts</u>				See detail		
	Only that required to start plant operation						
8040.61	Turbine Plane Equipment			Included in	4300		
8040.62	Electrical Plant Equipment			Included in	4401		
8040.63	Collector Equipment			Included in	4190.1		
8040.64	Receiver Equipment			Included in	4190.2		
8040.65	Thermal Storage Equipment			Included in	4190.3		
8040.7	<u>Federal and State Taxes--Field Payroll</u>				Included in	8100.1	
8040.8	<u>Foreign Duties and Taxes</u>						
8100	<u>Indirects</u>					8,700,127	
8100.1	<u>Architectural Engineer Services</u>				2,802,412		
8100.11	Preliminary Design Services (Title I)			Included in	8100.1		
8100.12	Detailed Design Services (Title II)			Included in	8100.1		

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
8100.13	Engineering Support During Construction (Title III)			Included in	8100.1		
8100.2	Construction Management				Included in	8100.1	
8100.21	C.M. Support During Design			Included in	8100.1		
8100.22	Construction Management during Construction			Included in	8100.1		
8100.221	Construction headquarters expenses						
8100.2211	Engineering, clerical, and design assistance salaries, and expenses						
8100.2212	Consultants and purchased services						
8100.2213	Computer services						
8100.2214	Scheduling						
8100.2215	Purchasing and expediting						
8100.2216	Estimating						
8100.2217	Accounting						
8100.2218	Communications and Reproduction						
8100.222	Overhead allowance						
8100.223	Federal and State Taxes--Headquarters payroll						
8100.3	Solar Subsystem Integration Contractor				6,115,745		
8100.4	Engineering and Design of Solar Subsystems[1]				(6,395,954)	(From Sub	system Cost

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

10 MW(e) Pilot PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
8100.41	Collectors			(4,230,366)			
8100.42	Receivers			(832,524)			
8100.43	Storage			(1,333,064)			
8100.5	Master Control Design[1]				Included in	8100.1	
8100.51	Software Design			Included in	8100.1		
8100.52	Hardware Design			Included in	8100.1		
8100.53	Software/Hardware Test			Included in	8100.1		
8100.6	Plant Startup and Checkout				Included in	8100.1	
8300	Contingency					6,318,480	
8500	Escalation[2]					Not required	
8600	Interest During Construction[2]					Not required	
	Two Year Test Program (pilot plant only, assuming one shift per day)						6,598,982
1000	Operations and Maintenance					4,170,025	
2000	Test Program Technical Support					2,188,263	
3000	Spare Parts -- need for two years of operation; beyond that included in initial plant startup cost. Include thermal storage makeup fluid required for the two-year test program.					240,694	
							84,128,059

ıese costs were included under the appropriate subsystem cost, list here so note to avoid double counting.

ɜd not be estimated for pilot or commercial plant cost estimate.

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SECTION 3

COMMERCIAL PLANT COST ESTIMATES

This section provides respectively the commercial cost estimates as a function of solar multiple and storage capacity, the estimate summary by major cost breakdown element, and the complete cost versus breakdown structure.

PLANT COST VERSUS SOLAR MULTIPLE

Page 8 of the "Brune" letter specifies that the estimates are to be provided as a function of solar multiple and hours of storage (duration). Figure 3-1 provides this information. The following is provided as background in the derivation of Figure 3-1:

- The total Commercial Plant cost in 1977 dollars is \$543.6 million for a solar multiple of 1.7 and 3 hours storage duration

- The collector subsystem cost for 1.7 solar multiple (SM) is \$274.6 million. Hence the collector cost at arbitrary solar multiple is

$$C\,(SM) = \left(\frac{C\,(1.7)}{1.7}\right) SM = \left(\frac{274.6}{1.7}\right) SM = 161.5\ SM$$

  This is a good approximation over the range of interest.

- The receiver subsystem cost for 1.7 solar multiple is \$157.5 m. Hence the receiver cost at arbitrary solar multiple is

$$R\,(SM) = \left(\frac{R\,(1.7)}{1.7}\right) SM = \left(\frac{157.5}{1.7}\right) SM = 92.6\ SM$$

  This is a good approximation over the range of interest.

COMMERCIAL PLANT COST ESTIMATE

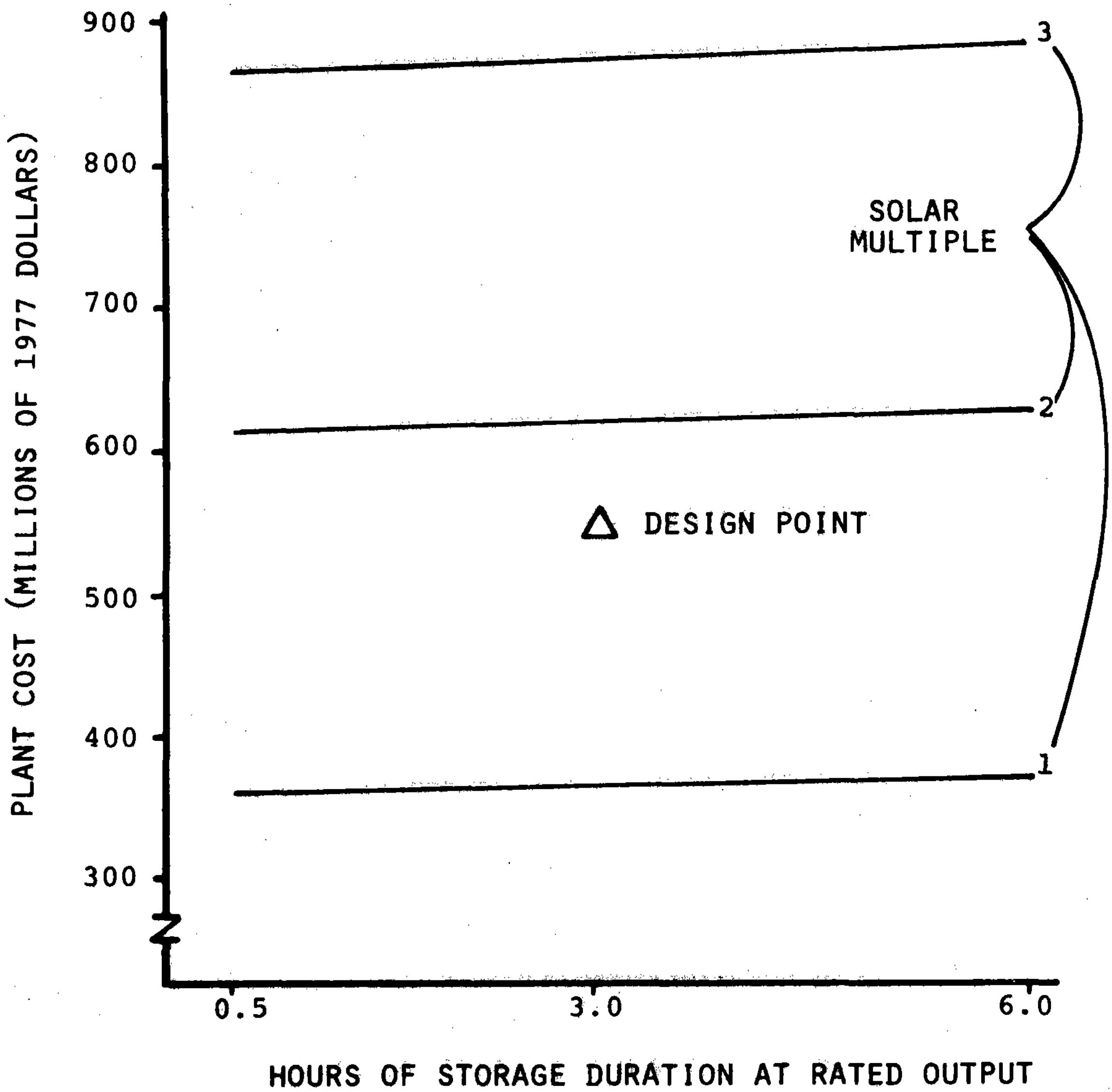

FIGURE 3-1

- The thermal storage cost at 1.7 solar multiple is \$18.1 m. (TS_o) for three hours (D_o) in the solar multiple (SM) and duration (D) effect the charging and capacity portions of the subsystem. The remaining part is therefore invariant.

The invariant fraction can be expressed as,

$$0.563\ TS_o$$

The charging fraction being independent of duration can be expressed as,

$$0.116\ TS_o \left(\frac{SM}{SM_o}\right)$$

Likewise, the capacity fraction can be expressed as,

$$0.321 \left(\frac{D}{D_o}\right) TS_o$$

Summing the three fractions gives the estimated thermal storage price at various solar multiples and storage durations as,

$$TS\ (SM,\ D) = TS_o \left[0.563 + 0.116\left(\frac{SM}{SM_o}\right) + 0.321\left(\frac{D}{D_o}\right)\right]$$

for $0.5 \leqslant D \leqslant G$ and $1 \leqslant SM \leqslant 3$

- The electric power generation subsystem cost (for the purposes of this exercise only) was taken to be the **total** plant cost of \$443.6 m. less the cost of the rest of the subsystems. Hence,

$$E = 543.6 - C\ (1.7) - R\ (1.7) - TS\ (1.7, 3)$$
$$= 543.6 - 274.6 - 157.5 - 18.1 = \$93.4\ m.$$

which is independent of solar multiple and storage duration. This is considered a good approximation.

Due to the scope of work and the extreme lead time for the production and installation of commercial plants, Honeywell, Inc. declines to estimate potential cost reductions that might be realized from increasing the production rate.

SOLAR CENTRAL RECEIVER
COMMERCIAL PLANT COST ESTIMATE

CBS ITEM	NON RECURRING COSTS	RECURRING COSTS Labor	Material	TOTAL COSTS
4000.			1,072,080	1,072,080
4100.		4,203,035	5,844,896	10,047,931
4103.		765,557	832,222	1,597,779
4105.		177,562	203,216	382,778
4106.				Not required
4108.				Not required
4141.		107,522	107,522	215,044
4142.		136,553	136,553	273,106
4143.				Not required
4170.				Not required
4180.		245,150	260,203	505,353
4190.1	4,053,421	23,806,967	246,763,663	274,624,051
4190.2	899,014	100,522,912	56,050,528	157,472,454
4190.3	967,698	4,670,139	12,291,295	18,052,584
4190.4			5,358,552	5,358,552
4300.		5,039,556	19,850,712	24,890,268
4401.		2,136,463	3,178,350	5,314,813
4402.		547,287	1,593,476	2,140,763
4500.		1,408,038	1,682,144	3,090,182
5309.		208,151	562,780	770,931
7000.		1,449,770	665,876	2,115,646

SOLAR CENTRAL RECEIVER
COMMERCIAL PLANT COST ESTIMATE

CBS ITEM	NON RECURRING COSTS	RECURRING COSTS Labor	Material	TOTAL COSTS
8000.				Items provided by burden & overhead generated
8100.		19,366,241		19,366,241
8300.		11,348,563	4,995,617	16,344,180
TOTAL	5,920,133	181,853,447	353,153,617	543,634,737

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

100 MW(e) Commercial PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
	POWER PLANT						543,634,737
4000	Land and Land Rights					1,072,080	
4000.1	Land and Privilege Acquistion						
4000.11	Land and surveys						
4000.12	Easements and right-of-way						
4000.13	Clearing land, including demolition of structure						
4100	Yard Work					10,047,931	
4103	Turbine Building					1,597,777	
4105	Administration Building					382,778	
4106	Circulating and Service Water Pump-house (at water source)						
4108	Warehouse (permanent structure, if required)						
4141	Maintenance Building					215,044	
4142	Water Treatment Equipment Building					273,106	
4143	Sewage Treatment					Included in	4100.3
4170	Thermal Storage Structure(if required)						
4180	Control Building					505,353	

SOLAR CENTRAL RECEIVER
COST BREAKDOWN STRUCTURE
100 MW(e) Commercial PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4190	Solar Plant Equipment					455,507,641	
4190.1	Collector Equipment				274,624,051		
4190.11	Reflective unit			129,889,508			
4190.111	Reflective surface		6,443,978				
4190.112	Mirror backing structure		69,429,999				
4190.113	Heliostat support structure		54,015,531				
4190.12	Drive Unit			82,906,060			
4190.121	Azimuth or mirror module drive		40,994,432				
4190.122	Elevation or outer frame drive		25,599,293				
4190.123	Motors		13,113,283				
4190.124	Position and/or limit indicators		3,199,052				
4190.125	Emergency power supply for heliostats and associated wiring						
4190.126	Power distribution equipment and wiring from electric plant		899,760				
4190.13	Calibration Equipment			2,174,405			
4190.131	Sensor unit		789,350				
4190.132	Sensor tower		881,124				

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

100 MW(e) Commercial PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4190.133	Calibration equipment used for daily operation and/or for initial calibration at construction		500,784				
4190.134	Wiring between heliostat and sensor		3,147				
4190.14	Control/Instrumentation Equipment			39,896,459			
4190.141	Field Control Electronics		35,232,512				
4190.142	Computer hardware only if dedicated entirely to heliostat control		1,535,682				
4190.143	Signal distribution equipment and wiring		3,128,265				
4190.15	Foundation & Site Prepation			7,136,183			
4190.151	Foundation--heliostat and sensor (do not include any other support structure), including excavation, backfill		7,031,238				
4190.152	Site preparation as required for special contouring, etc., other than general grading included in 4100.10		104,945				
4190.16	Design and Engineering Costs			2,473,752			
4190.161	Design costs The cost for all collector subsystem design work, including that done by A/E; indicate which items are to be designed by A/E and if that cost is also included in 8100.10		1,059,389				

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

100 MW(e) Commercial PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4190.162	Engineering support during manufacturing, installation, and checkout		1,414,363				
4190.17	Packing Containers and Transportation to Power Plant Site			1,966,794			
4190.18	Field Assy., Installation & Checkout			6,657,607			
4190.181	Heliostat and control equipment		6,684,235				
4190.182	Sensor/calibration equipment		3,372				
4190.19	Lightning Protection			1,523,283			
4190.2	Receiver and Tower System				157,472,454		
4190.21	Receiver Unit			103,492,267			
4190.211	Absorber Unit		46,610,239				
4190.2111	Absorber (boiler)	43,037,662					
4190.2112	Drum	2,662,941					
4190.2113	Doors, housing, lining, insulation	909,636					
4190.212	Piping		3,698,757				
4190.213	Support structure, platforms, etc.		25,618,192				
4190.214	Instrumentation and control on receiver and tower		2,696,942				
4190.215	Packing and transportation		1,498,959				

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

100 MW(e) Commercial PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4190.216	Field erection and installation		23,369,178				
4190.23	Riser and Horizontal Feedwater Piping to Receiver			5,209,220			
4190.231	From turbine generator building		4,886,654				
4190.232	From thermal storage-additional piping over that in 4190.221		322,566				
4190.24	Down Comer & Horizontal Piping			12,822,853			
4190.241	To turbine generator building		12,485,234				
4190.242	To thermal storage-additional piping over that in 4190.231		337,619				
4190.25	Tower and Platform			15,492,845			
4190.26	Foundation and Site Preparation			17,380,931			
4190.27	Design Cost			3,074,338			
4190.271	Tower and foundation		Included in	4190.25 & 8100.1			
4190.272	Receiver		3,074,338				
4190.273	Riser, Downcomer, horizontal piping		Included in	8100.1			

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

100 MW(e) Commercial PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4190.3	Thermal Storage Equipment				18,052,584		
4190.31	Thermal Storage Unit			7,508,971			
4190.311	Storage tanks and heaters if required to prevent solidification, etc.		4,244,171				
4190.312	Insulation		2,023,684				
4190.313	Ullage maintenance equipment-include tanks		93,351				
4190.314	Fluid maintenance equipment-include cost for additional fluid which may be required to maintain the initial fluid during initial plant startup		1,147,765				
4190.32	Circulation Equipment for Storage Media and Water/Steam			5,070,597			
4190.321	Piping and support stands for storage media		400,498				
4190.322	Valves		3,763,270				
4190.323	Pumps		175,476				
4190.324	Insulation		21,504				
4190.325	Steam drums and/or condensate drain tanks						

SOLAR CENTRAL RECEIVER
COST BREAKDOWN STRUCTURE
100 MW(e) Commercial PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4190.326	Water/steam piping and support stands between thermal storage and turbine generator building		344,070				
4190.33	Heat Exchangers			2,945,013			
4190.331	Desuperheaters		39,493				
4190.332	Steam generator heat exchangers (discharging)		1,046,974				
4190.333	Thermal storage heater heat exchangers (charging)		1,104,821				
4190.334	Insulation		753,725				
4190.335	Support structure						
4190.34	Instrumentation and Control Located at Thermal Storage Unit--Measurement Equipment and Sensors			641,996			
4190.35	Foundation and Site Preparation			918,309			
4190.351	Tank Foundations		441,513				
4190.352	Other foundations--heat exchangers/pumps		80,642				
4190.353	Dikes or emergency containment structures		96,770				

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

100 MW(e) Commercial PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4190.354	Site preparation		75,265				
4190.355	Safety protection equipment		224,119				
4190.36	Design Cost			967,698			
4190.4	Thermal Storage Material				5,358,552		
4190.41	Inorganic Material Cost			4,296,579			
4190.42	Organic Material Cost			752,654			
4190.43	Delivery			309,319			
4190.44	Handling at Site, e.g., melting						
4300	Turbine Plant Equipment					24,890,268	
4300.1	Turbine Generators				13,702,604		
4300.11	Turbine generator units and related equipment supplied with turbine generator units such as speed controllers, main stop, throttle and intercept valves generator coolers, main and pilot exciters, moisture separators, gland seals, turning gear, crossover piping, insulation, panel boards, instrumentation, protective devices, special tools and rotor lifting slings, and special extractions.			13,117,684			

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

100 MW(e) Commercial PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4300.12	Foundation (includes turbine generator pedestals)			407,508			
4300.13	Standby Exciters			Included in	4300.11		
4300.14	Lubricating System			47,310			
4300.15	Gas Systems			130,102			
4300.16	Reheaters						
4300.17	Weather-proof housing (for outdoor type installations)						
4300.2	Heat Rejection System				7,066,346		
4300.21	Heat Rejection Equipment			2,571,926			
4300.22	Installation Cost			866,627			
4300.23	Exhaust Duct from Turbine to Heat Rejection Equipment			2,168,719			
4300.24	Evaporation Pond for Cooling Tower Blowdown			1,459,074			
4300.3	Condensing Systems				679,539		
4300.31	Condensate System			679,539			
4300.32	Turbine Bypass System			Included in	4300.11		

SOLAR CENTRAL RECEIVER
COST BREAKDOWN STRUCTURE
100 MW(e) Commercial PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
4300.4	Feed-Heating System				1,813,896		
4300.41	Regenerative Heat Exchangers			483,849			
4300.42	Pumps			895,658			
4300.43	Piping and Tanks			434,389			
4300.5	Water Circulation/Treatment Equipment				1,627,883		
4300.51	Make-Up Treatment System			795,663			
4300.52	Chemical Treatment and Condensate purification Systems			832,220			
4401	Electric Plant Equipment					5,314,813	
4401.1	Switchgear				1,740,781		
4401.11	Generator Circuits			53,761			
4401.12	Station Service			1,687,020			
4401.2	Station Service Equipment Voltage conversion equipment for station service power and lighting and emergency power sources (includes auxiliary generators and batteries and charging equipment)				747,278		

SOLAR CENTRAL RECEIVER
COST BREAKDOWN STRUCTURE
100 MW(e) Commercial PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	4	3	2	1	0
4401.21	Station Service and Startup Transformers			378,327			
4401.22	Low Voltage Unit Substations and Lighting Transformers			Included in 4401.12			
4401.23	Auxiliary Power Sources			370,951			
4401.3	Switchboards				110,748		
	Bench, relay, and recording and indicating instrument and supervisory control boards for local control; that is, not located in the control room						
4401.4	Protective Equipment				758,030		
4401.41	General Station Grounding System			727,924			
4401.42	Fire Protection Equipment			Included in 4300.152			
	Special fire extinguishing systems exclusively for electrical equipment, including generator (e.g., CO_2 systems)						
4401.43	Electrical Freeze Protection			30,106			
4401.5	Electrical Structures and Wiring Containers				966,623		
4401.6	Power Wiring				991,353		
4402	Plant Master Control Equipment					2,140,763	

SOLAR CENTRAL RECEIVER
COST BREAKDOWN STRUCTURE
100 MW(e) Commercial PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4402 (cont.)	Include control equipment located in control room which serves more than one subsystem and/or controls the interfacing between subsystems						
4402.1	Computer				953,720		
4402.2	Peripheral Equipment				64,513		
4402.3	Control Panels and Boards				254,827		
4402.4	Interface Equipment-Signal and Computer				405,358		
4402.5	Software Design and Development				Included in	8100.1	
4402.6	Software/Hardware Test				Included in	8100.1	
4402.7	Hardware Design				Included in	8100.1	
4402.8	Control Wiring Wiring from subsystems to control room				462,345		
4500	Miscellaneous Plant Equipment Equipment permanently associated with plant					3,090,182	
4500.1	Transportation and Lifting Equipment				432,238		

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

100 MW(e) Commercial PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
4500.2	Air and Water Service Systems				1,679,494		
4500.3	Communications Equipment				463,420		
4500.4	Furnishing and Fixtures				515,030		
5309	Transmission Plant (commercial plant only)					770,931	
7000	Quality Assurance List here (1) costs for quality assurance already not included in other items; (2) an estimate of the percentage of the total engineering cost attributable to quality assurance. This is to include only on-site quality assurance costs.					2,115,646	
8000	Distributables					Provided by rate structure	
8040.1	Insurance, injuries, and damage (excludes Workmen's Compensation Insurance, which is included in the labor charges associated with the Direct Costs) Employer's liability insurance Public liability and property damage insurance Fire and theft insurance						

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

100 MW(e) Commercial PLANT – COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL					
		5	4	3	2	1	0
8040.2	Insurance, Construction Equipment, and Autos						
8040.3	Temporary Construction Includes only net cost of items which are removed or dismantled after completion of construction; items which are a permanent part of the plant are to be included under other accounts.						
8040.4	Construction Equipment Includes net cost or rental expense of equipment used during the construction of the plant and thereafter removed from the site						
8040.5	Construction Services						
8040.6	Spare Parts Only that required to start plant operation						
8040.61	Turbine Plane Equipment						
8040.62	Electrical Plant Equipment						
8040.63	Collector Equipment						
8040.64	Receiver Equipment						

SOLAR CENTRAL RECEIVER
COST BREAKDOWN STRUCTURE
100 MW(e) Commercial PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
8040.65	Thermal Storage Equipment						
8040.7	Federal and State Taxes-Field Payroll						
8040.8	Foreign Duties and Taxes						
8100	Indirects					19,366,241	
8100.1	Architectural Engineer Services				18,816,350		
8100.11	Preliminary Design Services(Title I)						
8100.12	Detailed Design Services (Title II)						
8100.13	Engineering Support During Construction (Title III)						
8100.2	Construction Management				Procured		
8100.3	Solar Subsystem Integration Contractor				Procured		
8100.4	Engineering and Design of Solar Subsystems[1]				(6,279,240)		
8100.41	Collectors			(2,473,752)			
8100.42	Receivers			(3,074,338)			
8100.43	Storage			(731,150)			
8100.5	Master Control Design[1]				Procured		

SOLAR CENTRAL RECEIVER

COST BREAKDOWN STRUCTURE

100 MW(e) Commercial PLANT - COST ESTIMATE

CBS STRUCTURE	ELEMENT DESCRIPTION	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	LEVEL 0
8100.51	Software Design						
8100.52	Hardware Design						
8100.53	Software/Hardware Test						
8100.6	Plant Startup and Checkout				519,891		
8300	Contingency					16,344,181	

SECTION 4
COMMERCIAL PLANT PERFORMANCE DATA

COMMERCIAL PLANT SUMMARY DESCRIPTION

The configuration of the commercial plant is illustrated in the following figures:

Figure 4-1	Site Plan
Figure 4-2	Receiver Tower and Foundation
Figure 4-3	Plant Arrangement (Ground Floor)
Figure 4-4	Plant Arrangement (Mezzanine Floor)
Figure 4-5	Plant Arrangement (Operating Floor)
Figure 4-6	Plant Arrangement (Deaerator Platform)
Figure 4-7	Solar Receiver Housing
Figure 4-8	Main Steam Piping Layout
Figure 4-9	Electrical Power Generating-Subsystem Schematic
Figure 4-10	Thermal Storage Subsystem

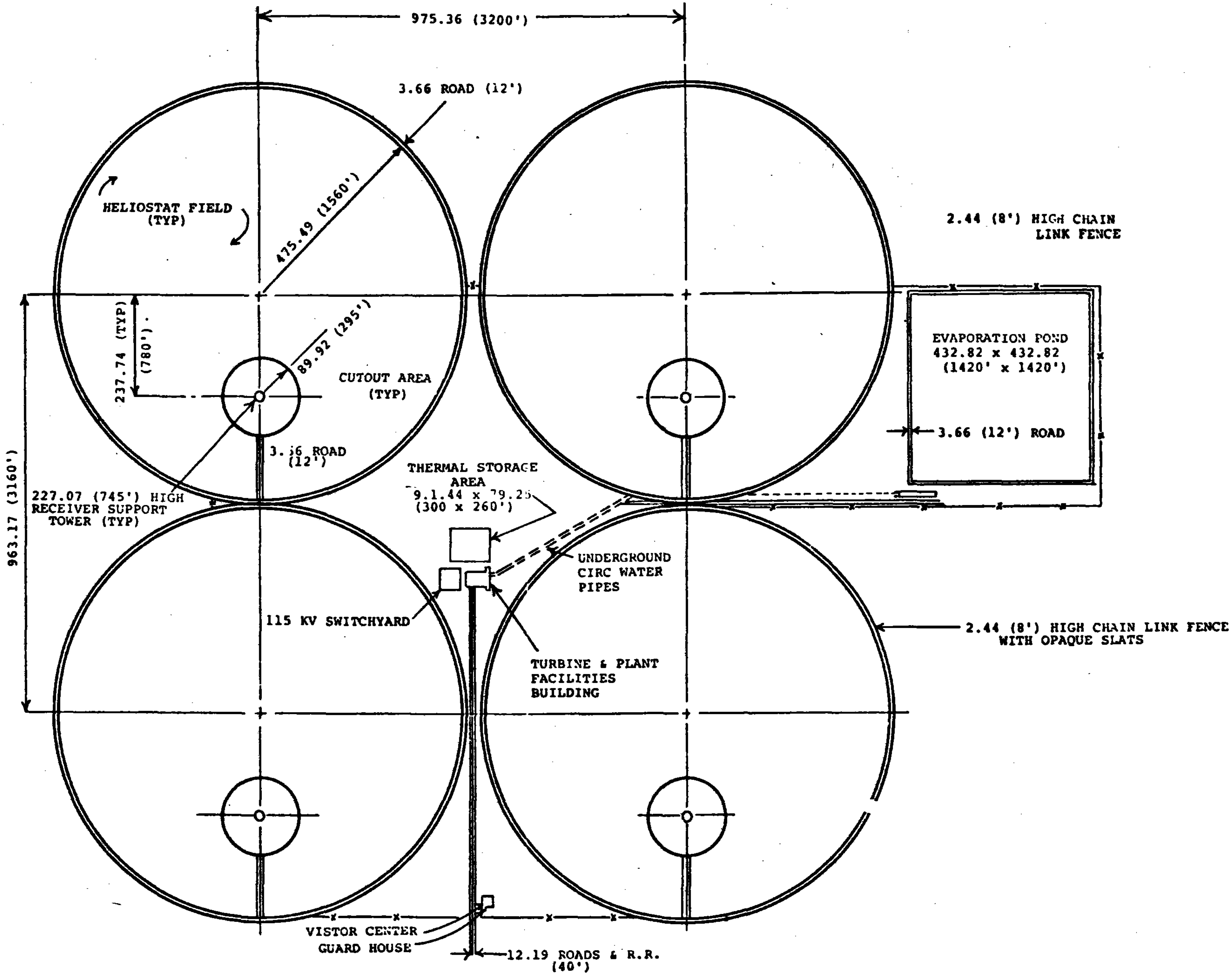

Figure 4-1. Site Plan

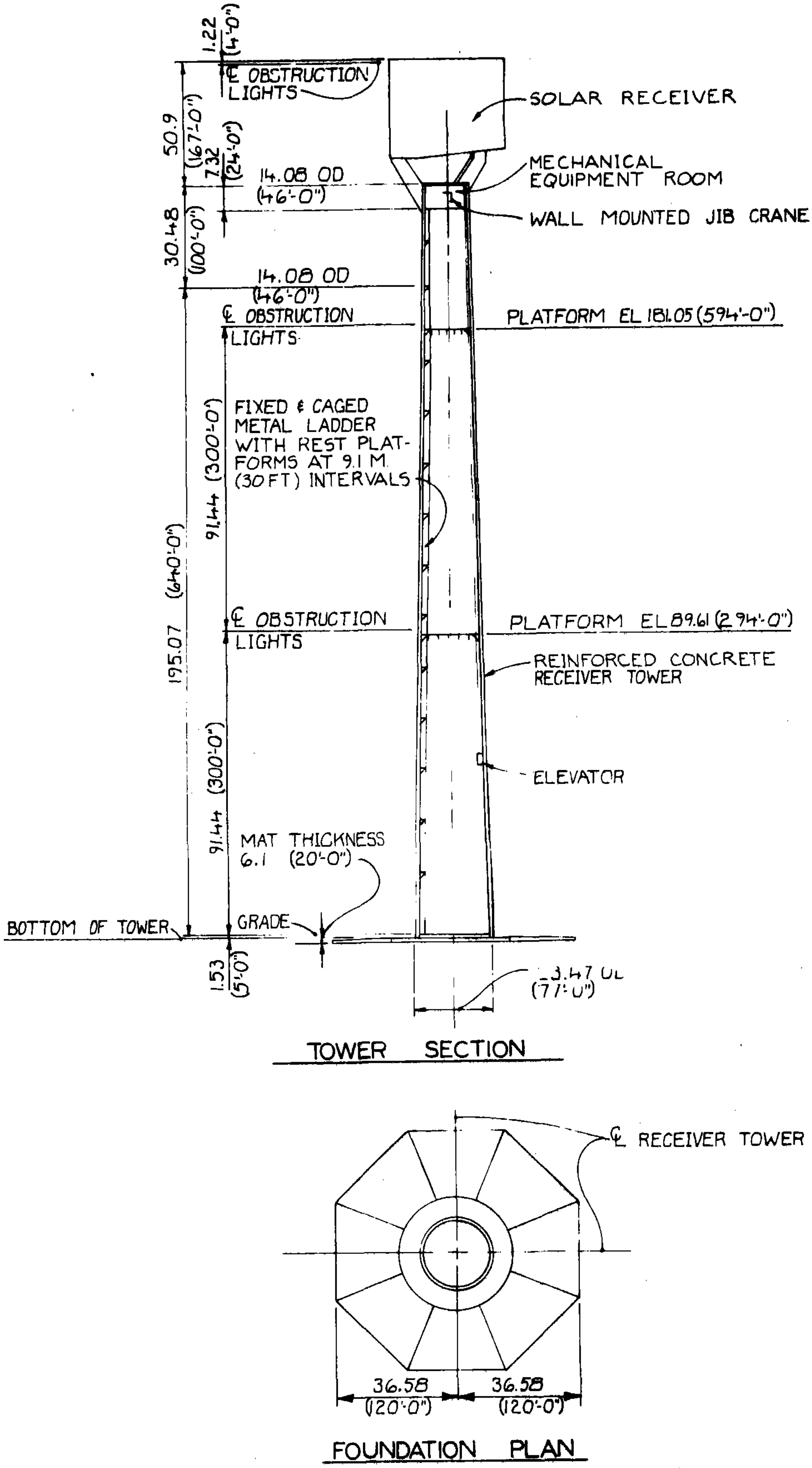

Figure 4-2. Receiver Tower and Foundation

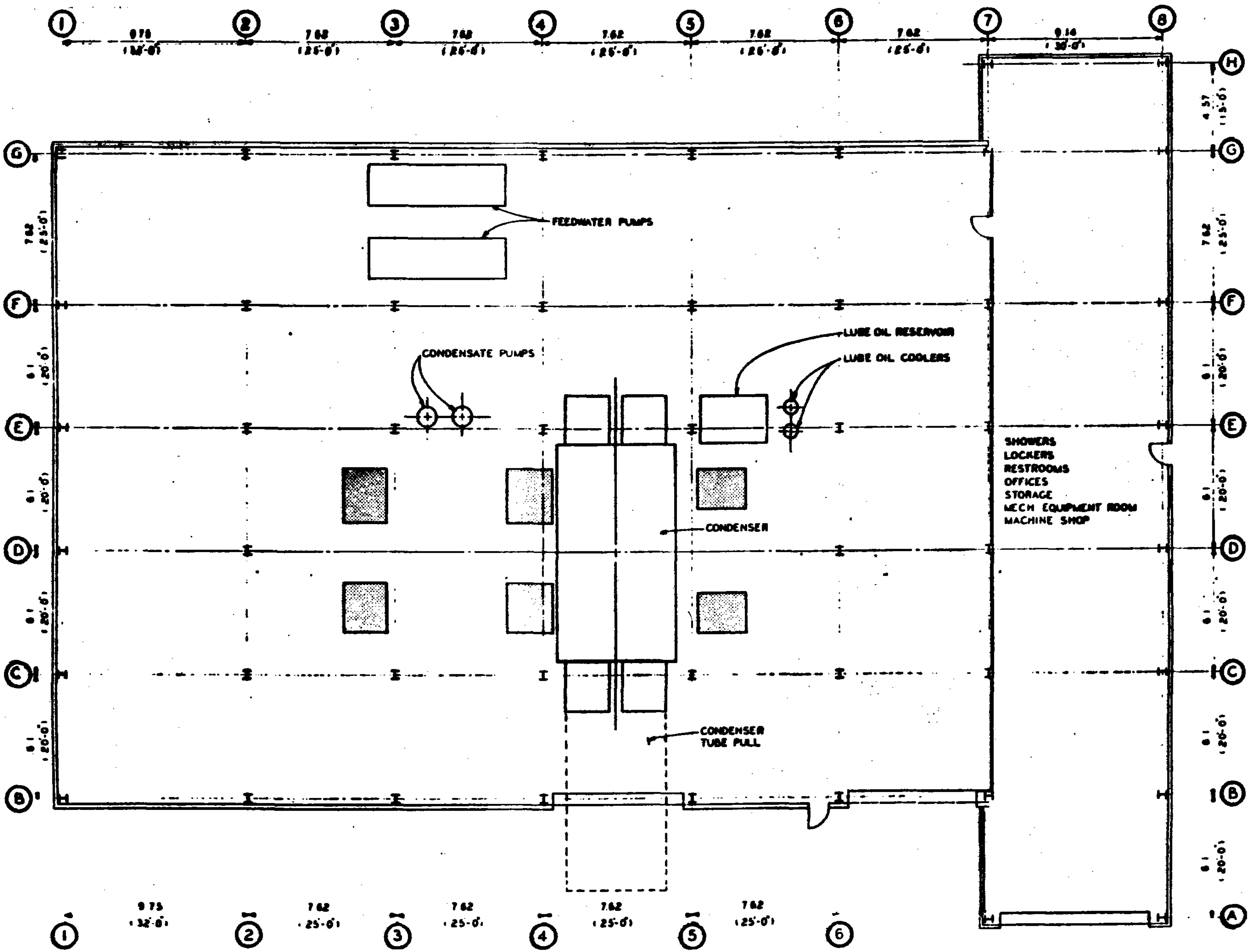

Figure 4-3. Plant Arrangement (Ground Floor)

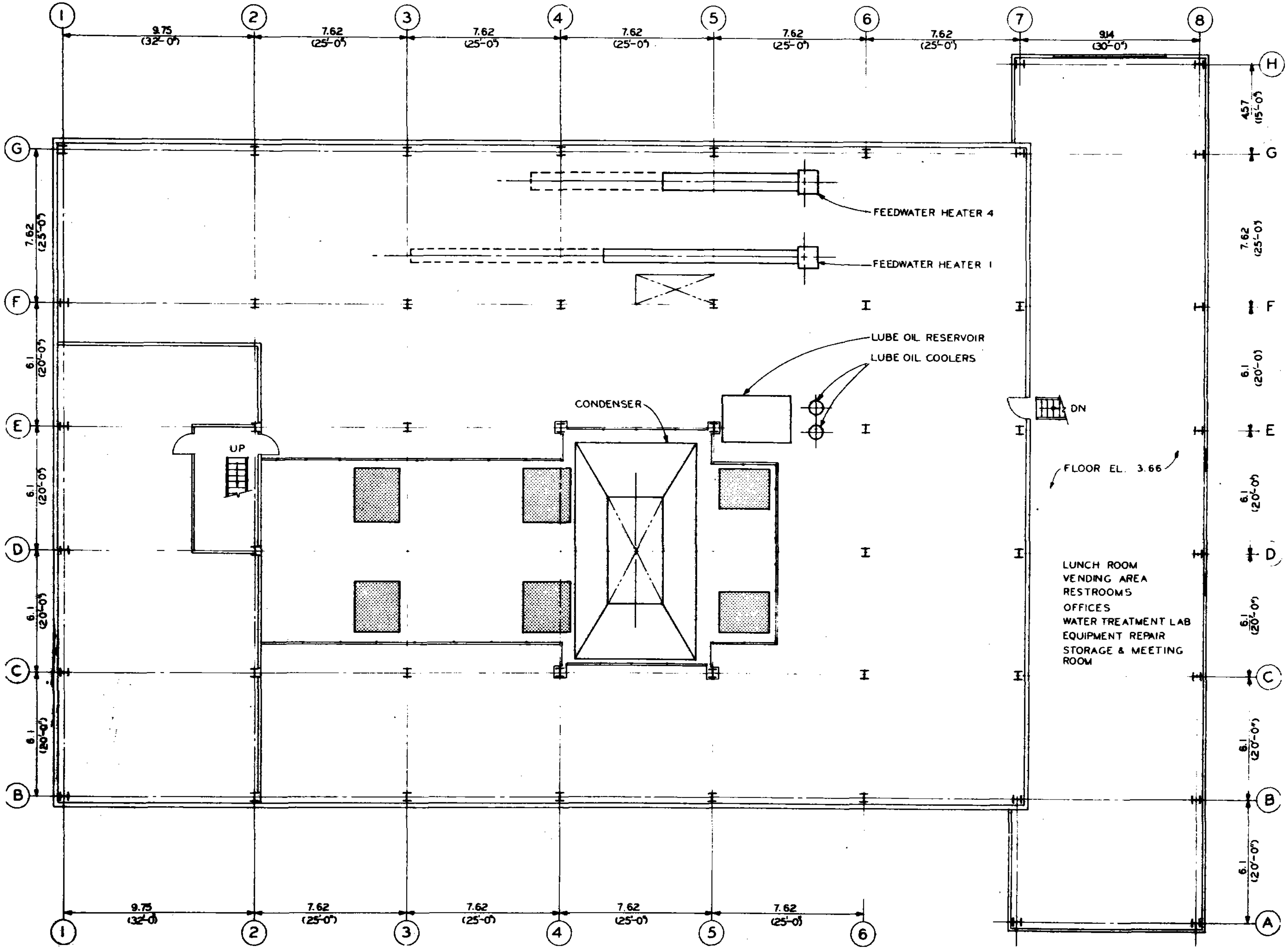

Figure 4-4. Plant Arrangement (Mezzanine Floor)

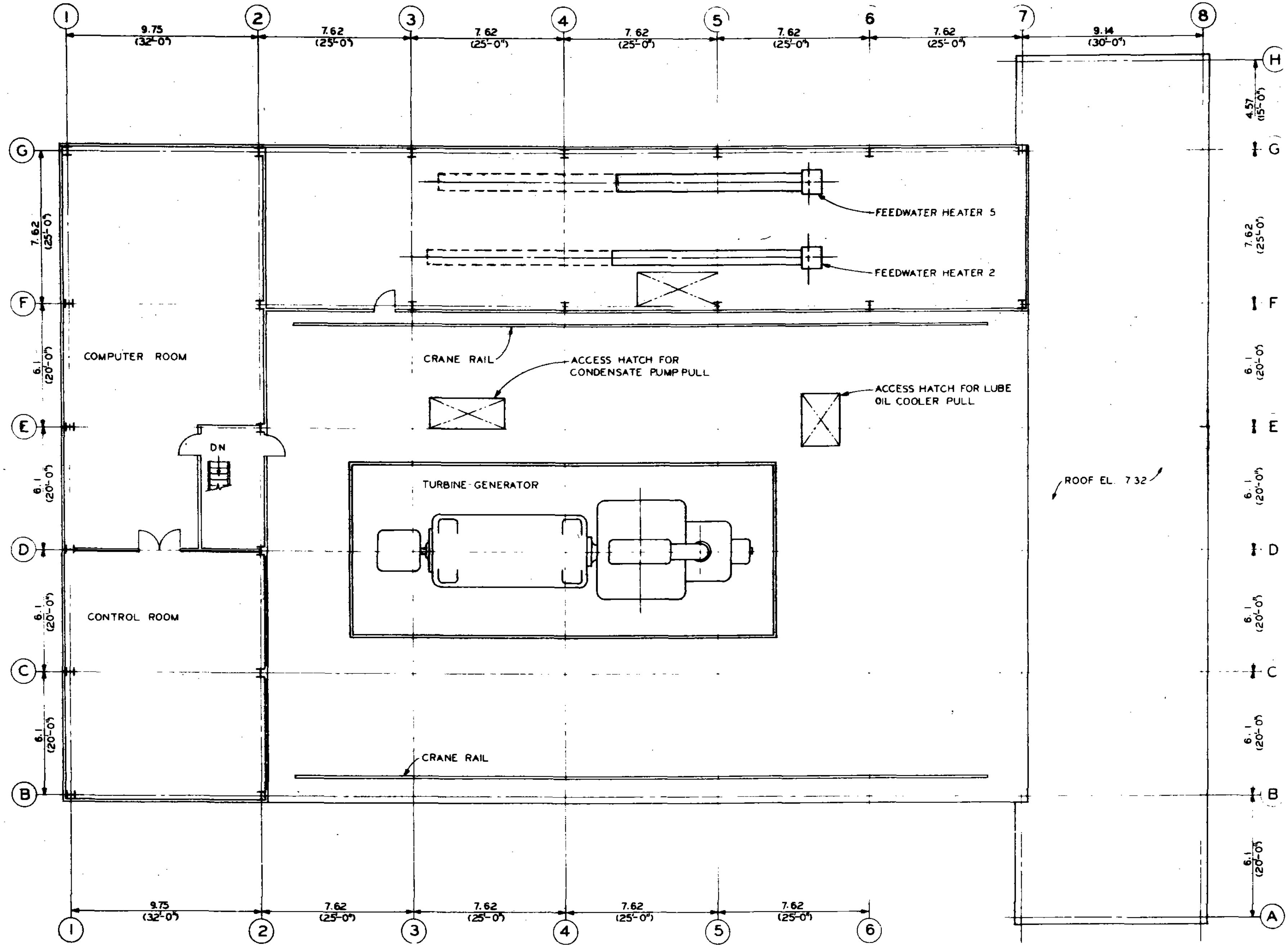

Figure 4-5. Plant Arrangement (Operating Floor)

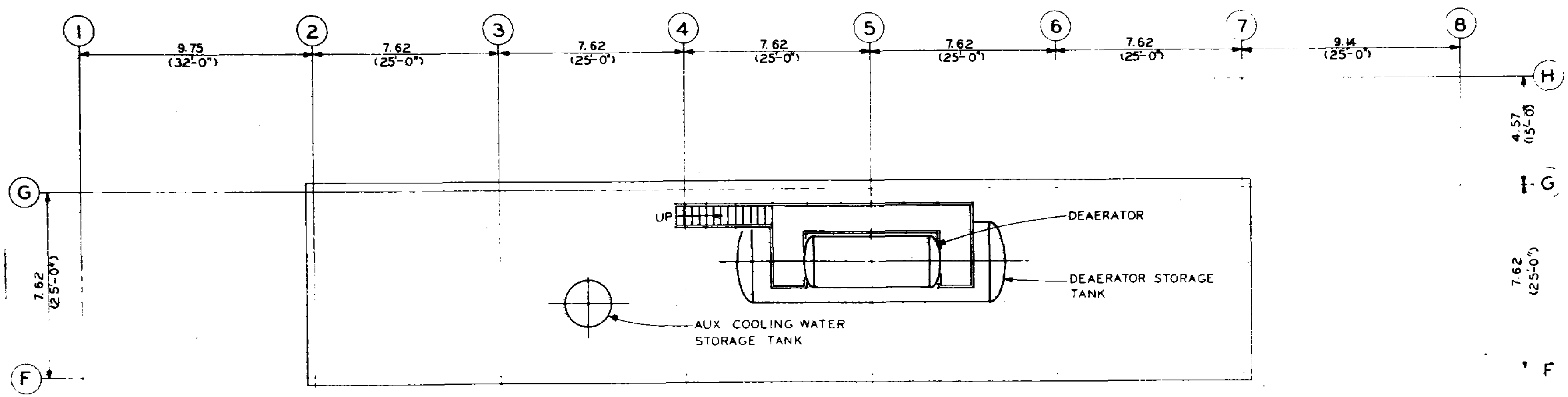

Figure 4-6. Plant Arrangement (Deaerator Platform)

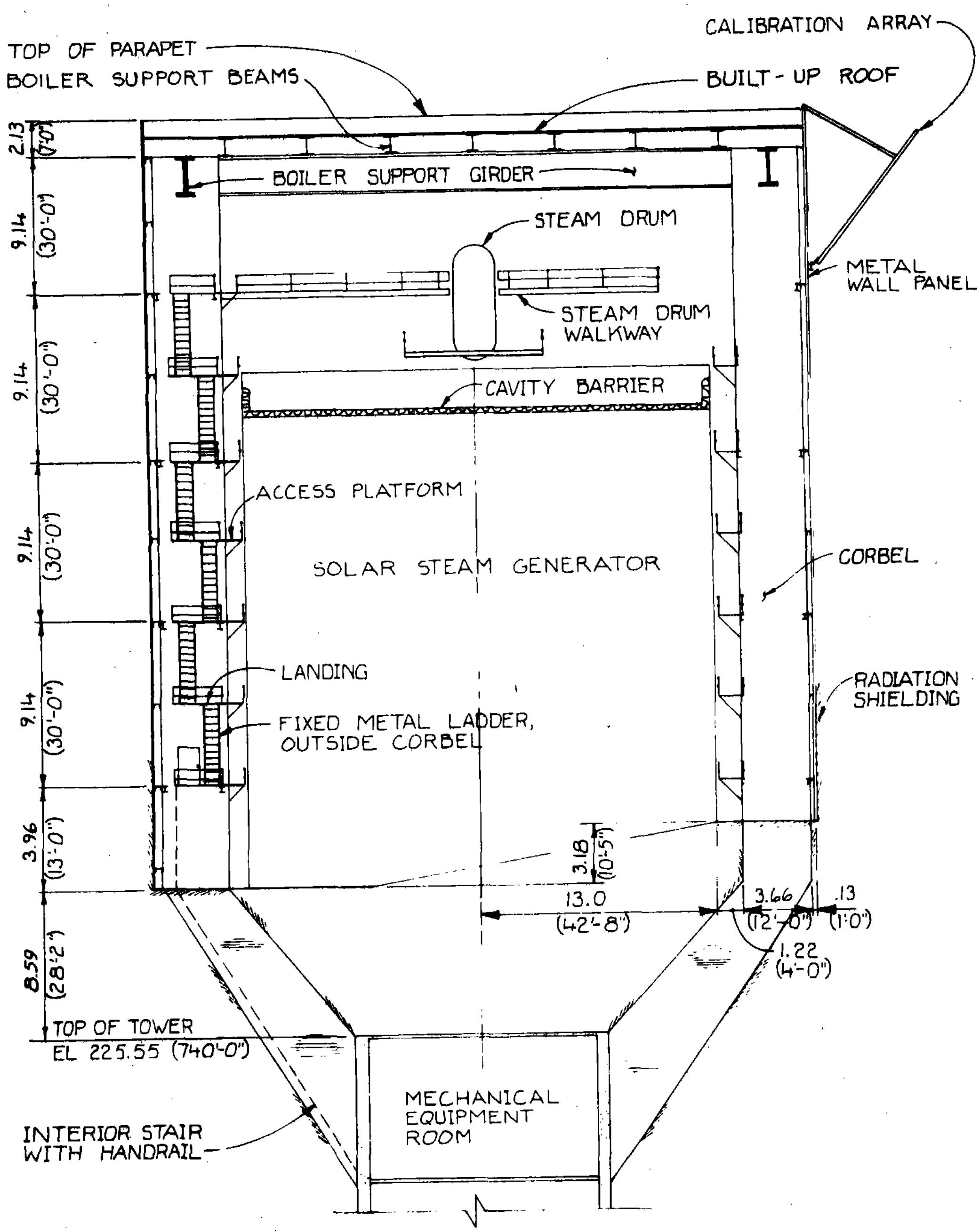

Figure 4-7. Solar Receiver Housing

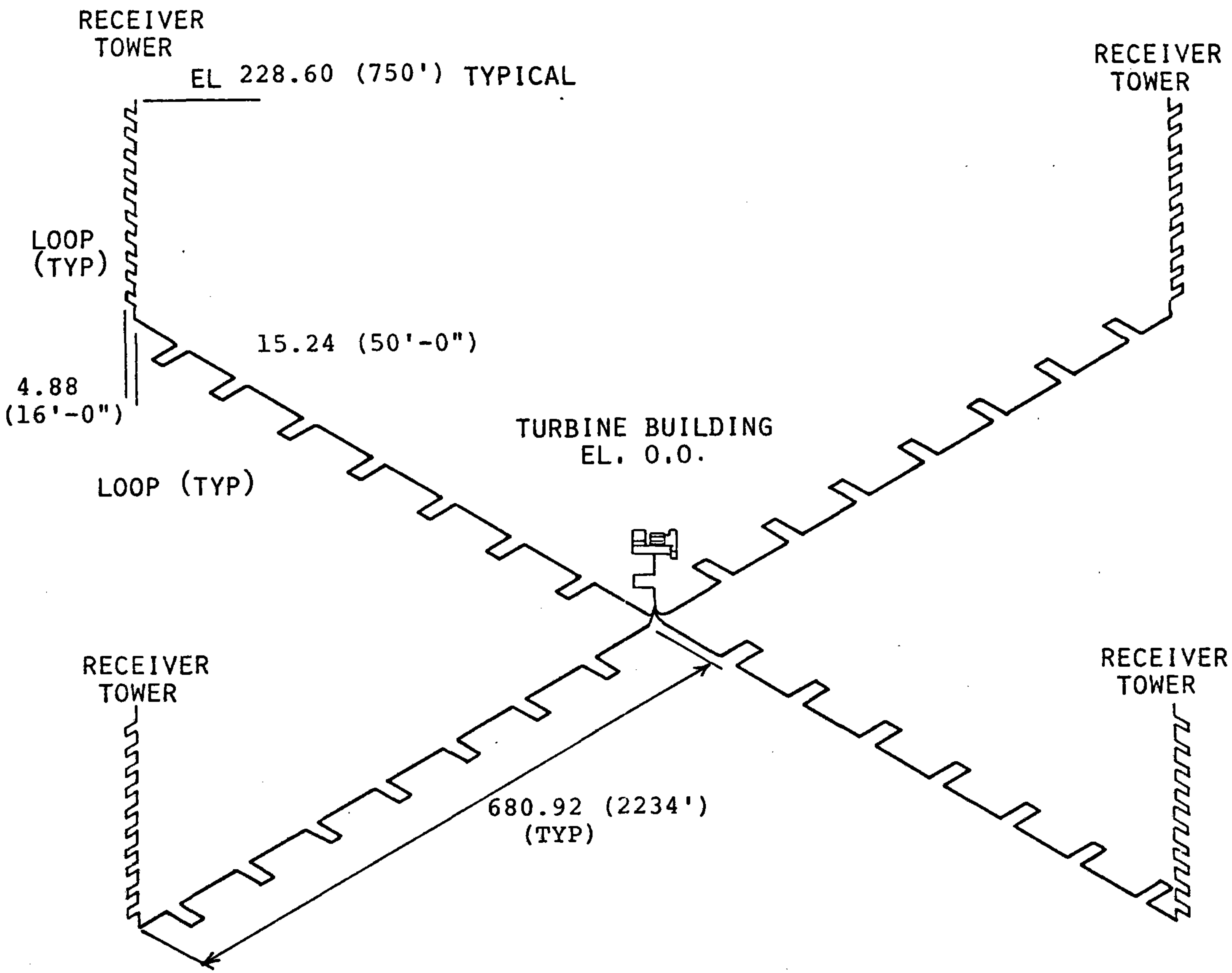

Figure 4-8. Main Steam Piping Layout

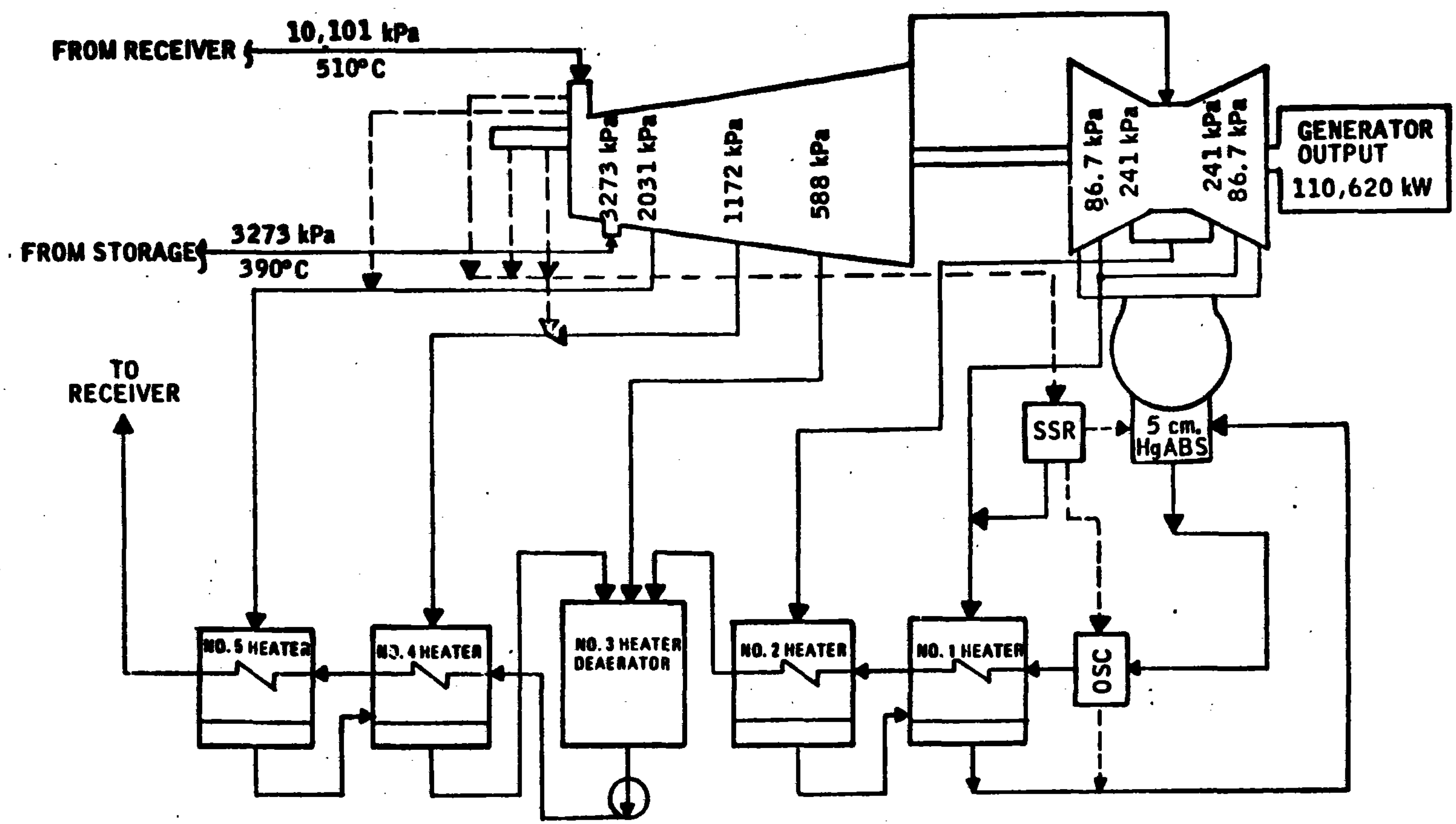

Figure 4-9. Electrical Power Generating-Subsystem Schematic

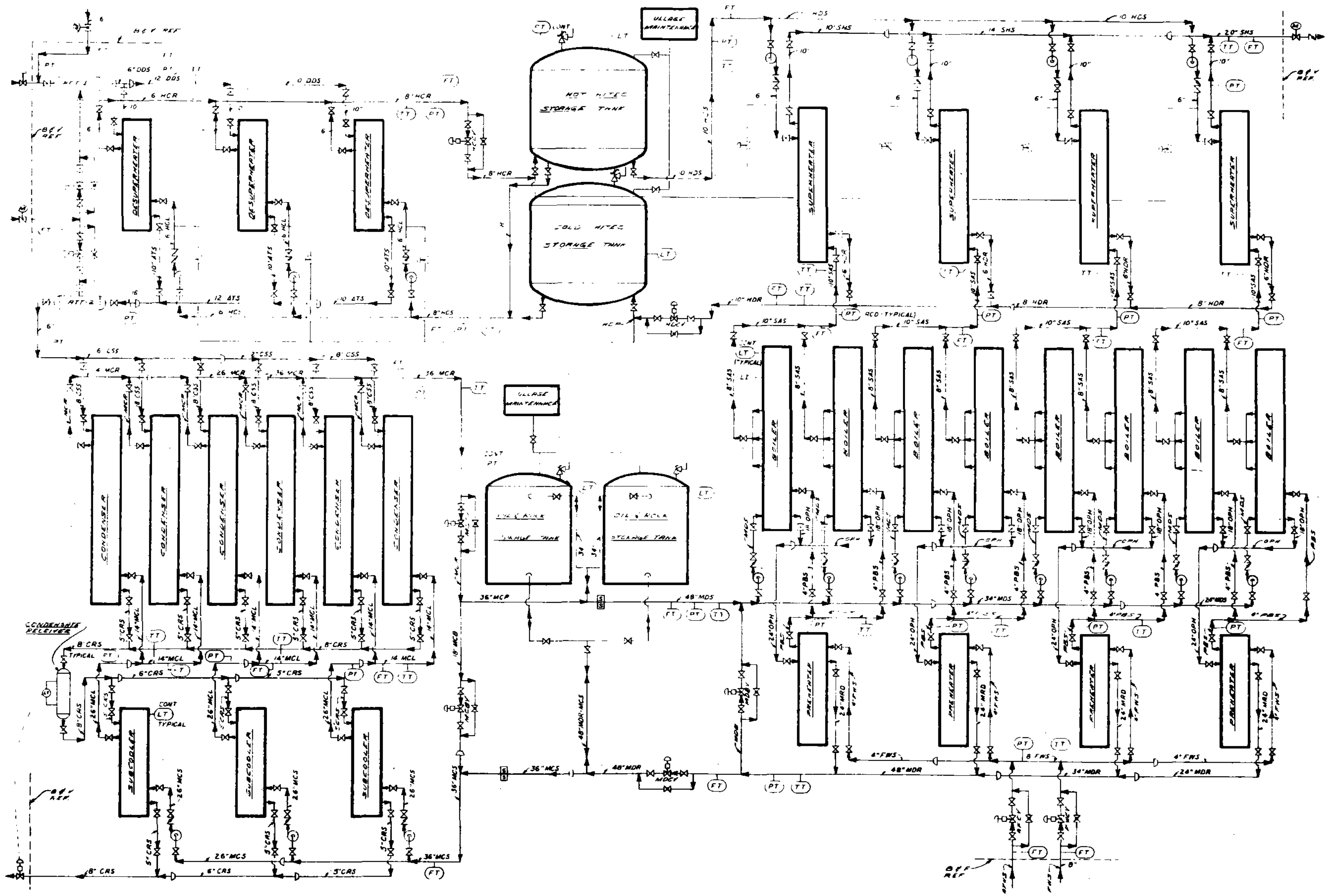

Figure 4-10. Thermal Storage Subsystem

COMMERCIAL PLANT SPECIFICATION SUMMARY

Number of collector fields	4
Field outer radius	475.5 m (1560 ft.)
Field inner radius	39.9 m (295 ft.)
Field form	circular
Receiver tower location	1/2 radius so. of center
Number of heliostats per field	5055
Average ground cover	0.29
Total mirror area (4 fields)	808,800 m^2 (8.7 x 10^6 ft^2)
Number of receiver subsystems	4
Cavity diameter	26 m (85 ft.)
Cavity height (major)	28 m (93 ft.)
(minor)	25 m (83 ft.)
Receiver tower height (tower top)	226 m (740 ft.)
(housing top)	277 m (907 ft.)
Aperture area (net)	574 m^2 (6178 $ft.^2$)
Storage capacity	961 MW hr (th)
(after 20 hr. hold)	70 MW hr (e) + sealing & tracing
Number of main storage tanks	2
Number of superheater storage tanks	2
Number of storage superheaters	4
Number of storage boilers	8
Number of stroage desuperheaters	3
Number of storage condensers	6
Turbine type	Dual Admission 5 feedwater heat stages
Turbine gross capacity	110 MW (e)

Complete specifications can be found in Volume II Appendix B.

COMMERCIAL PLANT PERFORMANCE DATA
(IN RESPONSE TO SANDIA LETTER OF 12-15-76)

1. Collector Subsystem Performance

Percent of direct normal insolation into the cavity - Honeywell has used the expression of overall tracking efficiency to define the collector subsystem performance. The overall tracking efficiency is defined by the total redirected power which enters the cavity divided by the direct normal intensity times the mirror area. Thus, the overall tracking efficiency includes the power losses due to;

- Cosine effect
- Tower shading
- Mirror and frame shading and blocking
- Aperture misses

Figure 4-11 shows the overall tracking efficiency as a function of the sun's azimuth and elevation angles.

There are several points to be made about the curves of Figure 4-11. First, the mirror specular reflectance is assumed to be 1.0. The effect of mirror reflectances less than 1.0 can be accounted for by simply multiplying the data supplied in the curves by the specular reflectance of the mirror. As a baseline, we have commonly used a specular reflectance of 0.90 for clean mirrors. As mirrors get dirty, the reflectance value will decrease. For example, a mirror exposed to a combination of rain, dew and dust for one week can be expected to have a "dirty" mirror reflectance of approximately 0.70.

We anticipate that the entire field will be washed weekly and thus an average field reflectivity of 0.80 is recommended for annual energy calculations.

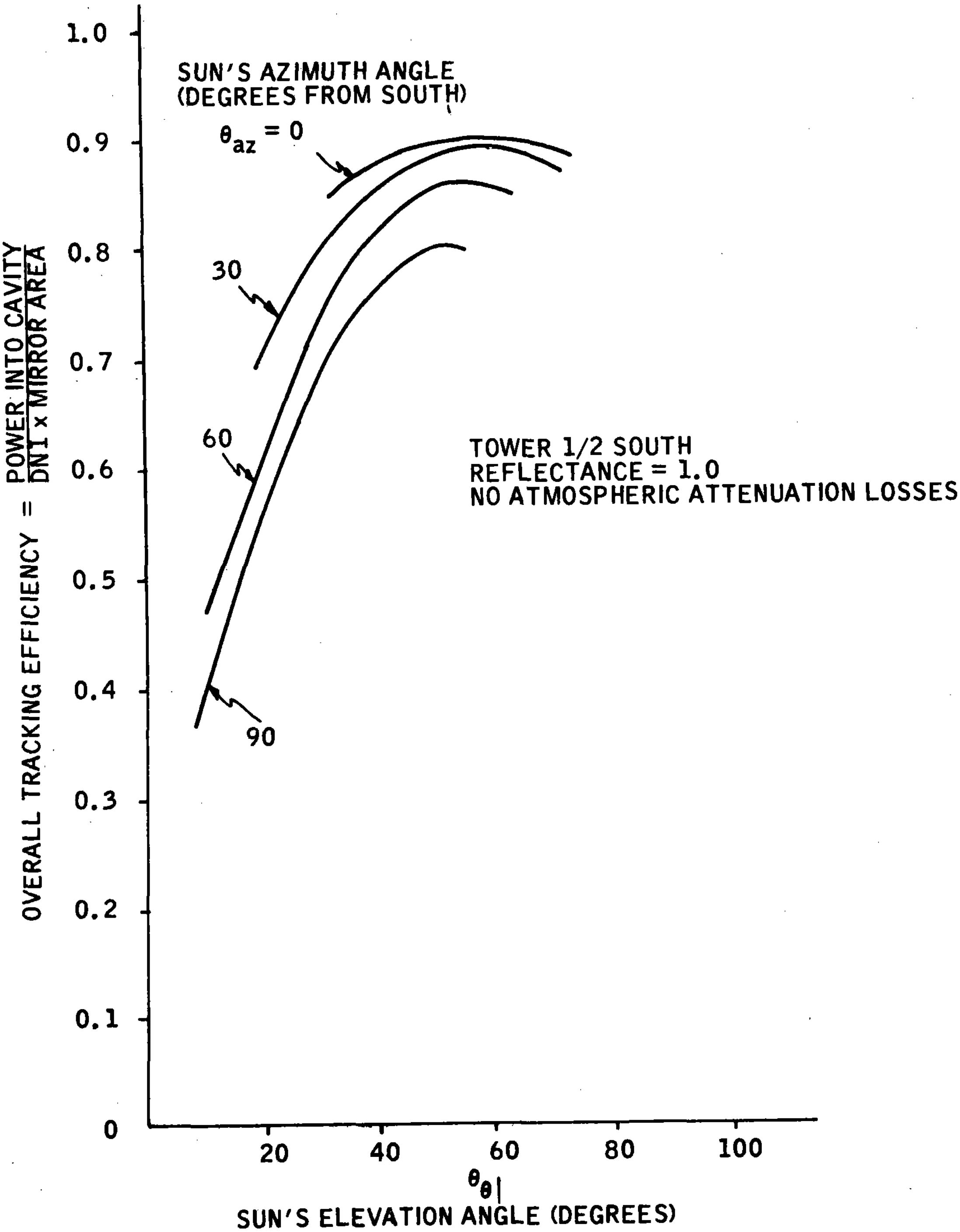

Figure 4-16. Tracking Efficiency

A second factor not included in the overall tracking efficiency data is the power lost due to atmospheric attenuation of the redirected beam. The attenuation losses are a function of the sun's angles as well as local meteorological conditions. Specifically, Honeywell has a computer program to estimate the losses as a function of the sun position, the relative humidity, and "seeing" conditions as defined by local visibility. Because of a lack of data to define relative humidity and visibility and because these factors vary independently of the sun angles, no attempt was made to include attenuation losses in the overall tracking efficiency curves. Instead, if the atmospheric attenuation loss fraction is known, the efficiency data may easily be reduced by this fraction. In fact, in sizing the commercial plant field we allowed for approximately a 7 percent loss due to atmospheric attenuation between the mirror field and the cavity aperture. This is our best estimate of a realistic loss for the commercial plant at the design point. For annual energy estimates we recommend that a loss of 5 - 7 percent be used.

A final comment on the overall tracking efficiency curves concerns the power which is lost at the aperture opening. Power lost at the aperture is a factor accounted for in the efficiency curves. Aperture losses include missed power as well as power which hits the support structures or the tower or receiver housing. To determine these losses, the pattern of redirected power from the heliostat field is determined by a Monte Carlo ray trace simulation code. This code and the optical modeling involved is described in detail in Volume II - Book 2. Basically, the image size, flux distribution and image location with respect to the aperture are determined by the solar disc size, the mirror surface shape and surface errors and heliostat tracking errors. The mirror surface imperfections can cause an image spread due to an error in the mirror normal at any point. For the ray trace code, the mirror surface errors were modeled by assuming that the mirror normal at any point can be represented by a normal distribution of slope errors about the perfect mirror normal. A 1-sigma error of 0.9 milliradians was assumed. Similarly, the tracking error was modeled as being known only statistically with a normal distribution of angular error about each axis. A 1-sigma error of 2 milliradians was used for each tracking axis. The same error budgets and normal distributions were used for all sun positions represented in the overall tracking efficiency curves. The 1-sigma values are expected to fall within all operating winds, temperatures and heliostat alignment errors or gravity loadings which will normally be encountered. Obviously, at some times the wind will not be a factor, temperature gradients will be negligible and the heliostats may, on the average, be oriented to minimize tracking errors. The overall tracking efficiency could then be higher than plotted because of a decrease in the power spilled at the aperture. At other times the efficiency may be lower. However, the aperture spillage losses are a relatively small portion of the redirected power (1 - 3 percent). Changes in the tracking efficiency due to wind etc. would also be small. In addition, the problem of accurately determining the change in spillage with wind and temperature effects is quite complex. The problem is one of integrating error sources over the entire field of heliostats where wind speed and direction and the heliostat orientation are all factors in the calculation. Further, the errors can only be known in terms of a most probable value. To simplify the problem, a normal distribution, with a mean error of zero, was used to represent the heliostat tracking and surface errors everywhere in the field.

Error Summary - A summary heliostat error budget for the tracking drives is given in Figure 4-12 in Honeywell's format. The accuracy in tracking shown is based on a combination of analytical model results and SRE test results. All values are given in terms of 1 sigma and 3-sigma deviations due to wind are given for an operating wind of 13.5 m/s. Temperature effects are given for expected operating temperature differentials. Other error sources are for expected worst case operating conditions. The total RSS value is well within the error budget 1 sigma values used in the ray trace code analysis. It must be pointed out, however, that three SRE heliostats cannot provide statistically valid tracking error data.

Source \ Subtotal	Deviations (milliradians)			
	Outer Axis 3σ	Inner Axis 3σ	Outer Axis 1σ	Inner Axis 1σ
Wind	0.39	0.99	0.39	0.99
Temperature	0.20	0.15	0.20	0.15
Gravity	0.25	0.09	0.25	0.09
Independent	1.04	0.97	0.35	0.325
RSS/Axis	1.16	1.40	0.61	1.06
Total RSS	1.82		1.22	

DESIGN GOAL 2 MILLIRADIANS (1σ)

Figure 4-12. Heliostat Accuracy Analysis Summary

We are unable to provide an error summary table in the format requested by the previously referenced letter. The format requested asks that errors be summarized in terms of percent of power which misses the cavity entrance due to each error source. In fact, if error sources are broken down to the many possible components, only the wind effects by themselves will be sufficient to cause any spillage at all. Instead, it is the totality of the various errors which leads to a power spillage. As already discussed, the calculation of power spillage is a difficult problem and we have not addressed this in detail for the many possible combinations of wind, temperature, and heliostat orientations. As a guideline, we can point out that a combination of high wind, worst case temperature differentials, and worst case heliostat orientations can lead to a power spillage of 3-5 percent. Under no wind, no severe loading conditions, the power spillage will approach zero.

2. <u>Receiver Subsystem Performance</u>

- Maximum permissible power into the cavity is 165 $MW_{(t)}$ for each receiver, or a total of 660 $MW_{(t)}$ for the entire commercial plant.

- Thermal power losses due to radiation from the receiver can be estimated by the following equation:

$$P_o = 0.0456\, P_I + 4.622$$

where,

P_o = Power lost in $MW_{(t)}$

P_I = Power into the cavity in $MW_{(t)}$

This expression represents the expected steady-state receiver reradiation and conduction losses. Reradiation is due to both solar reflected losses and infrared radiation losses.

- Convection losses from the receiver can be estimated by the following:

$$P_c = 0.00483\, V^{0.8} (413 - T_{amb})$$

where,

P_c = Power lost in $MW_{(t)}$

V = Wind speed at the cavity aperture in M/S

T_{amb} = Ambient temperature in °C

The equation assumes that the receiver is up to rated steam conditions and operating in a steady-state mode. The power input into the cavity has no effect on the convection losses.

- Figure 4-13 shows piping thermal losses from the receiver to the turbine building. The added piping thermal loss in routing steam from the turbine building to the thermal storage is shown in Figure 4-14.

3. <u>Mass Flow Rate</u>

- The thermal power at the entrance of the turbine building as a function of steam flow defends on the mode in which the plant is operated. To provide the thermal power steam

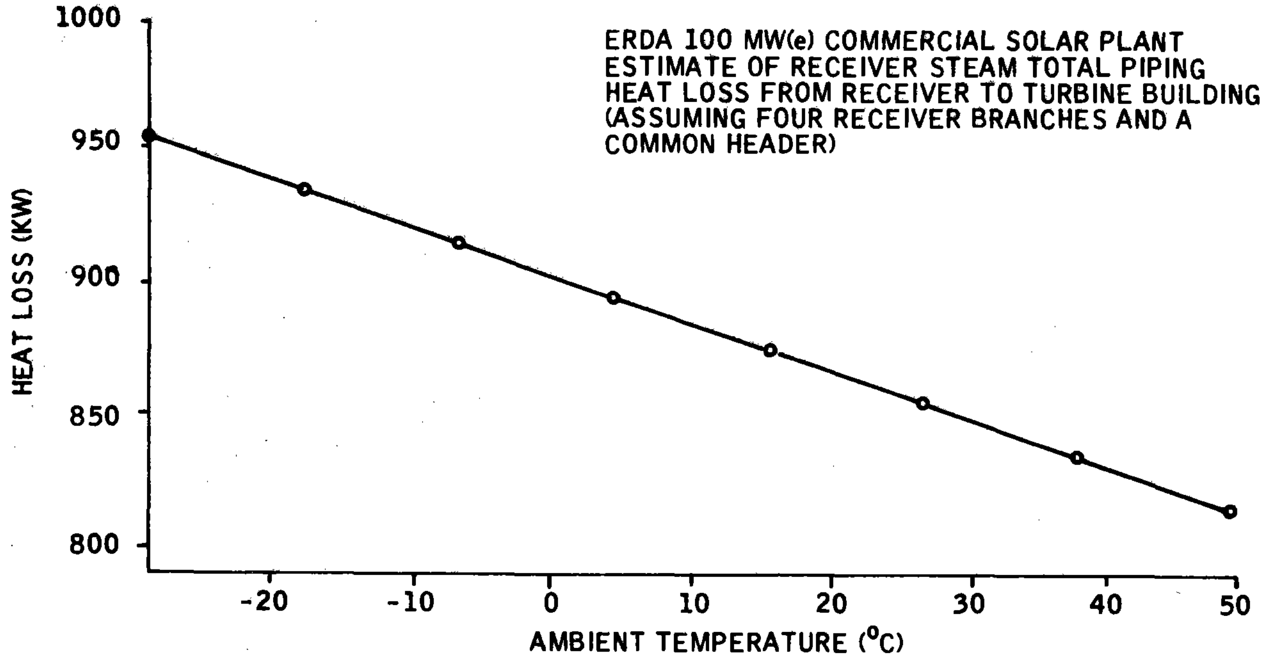

Figure 4-13. Piping Thermal Losses

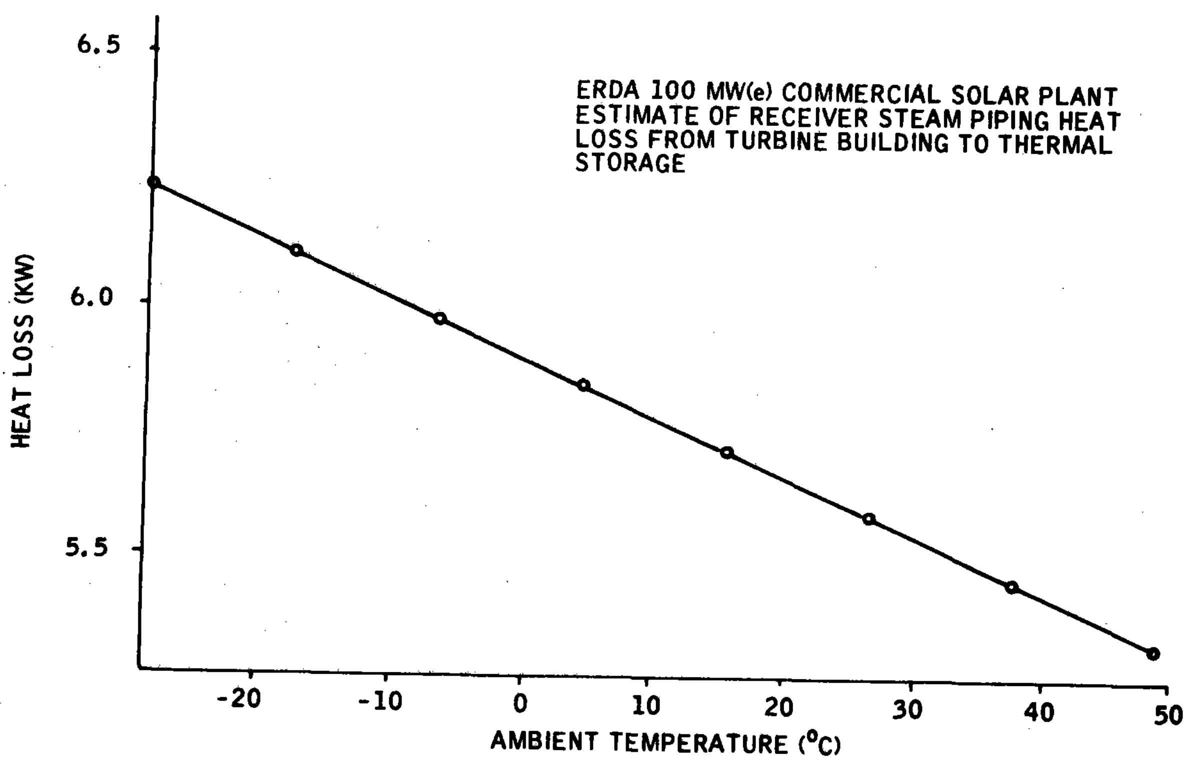

Figure 4-14. Added Piping Thermal Loss

flow rate data, we assumed that the thermal storage was not being used to drive the turbine. The reason for this assumption is that for a given receiver steam flow driving the turbine an infinite number of combinations of storage steam flow simultaneously driving the turbine are possible. For each combination of steam flows, a different final feedwater enthalpy results and the power and flow rates are affected by the feedwater conditions.

We also assumed that power losses inside the turbine building are negligible.

Figure 4-15 shows the estimated thermal power versus steam mass flow rate for the commercial plant. The maximum receiver power at the turbine building is 650 $MW_{(t)}$.

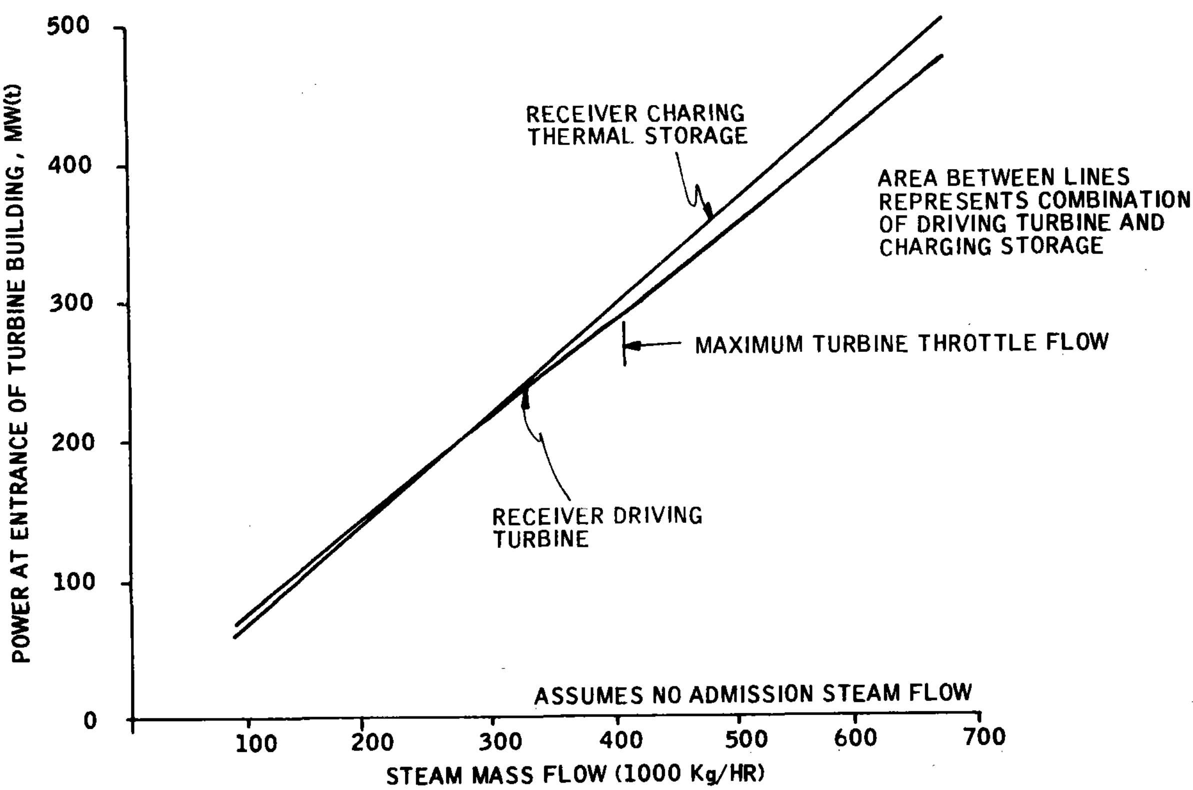

Figure 4-15. Commercial Plant Power at Entrance of Turbine Building versus Steam Mass Flow

4. Thermal Storage Charging Efficiency

The thermal input rate from the receivers is 247.3 MW(t). The storage can absorb up to 207.2 MW(t), which gives a charge efficiency of 83.8 percent. The difference in heat rates is due to the difference in the condensate temperature out of storage and the feedwater temperature at the receiver inlet.

5. Gross Cycle Efficiency (Figure 4-16)

Following is an estimate of gross cycle efficiency of the thermal electric conversion as a function of mass flow rate for both operation directly from the receiver and from thermal storage. The design point ambient temperature is assumed (28°C).

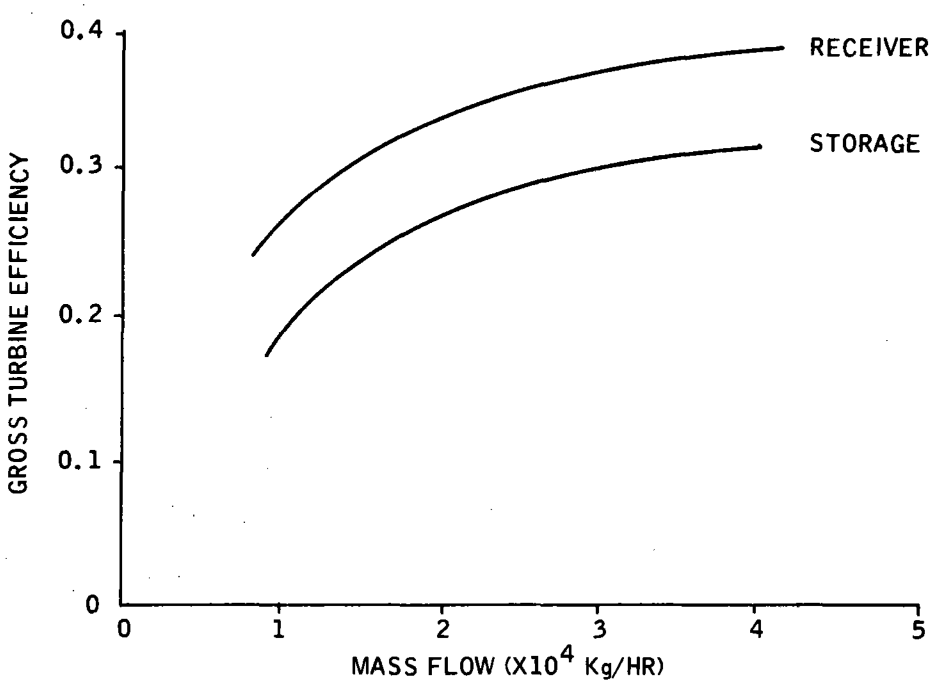

Figure 4-16. Gross Cycle Efficiency for Both Operation Directly from Receiver and from Thermal Storage

The maximum turbine mass flow is defined as the steam flow to the turbine throttle when the generator has a continuous net electrical output capacity of 100 MWe plus the output to operate the plant auxiliaries. The minimum mass flow is the steam flow to the turbine throttle for the minimum load condition at which the unit can operate satisfactorily without damage.

The turbine cycle arrangement is assumed to consist of five stages of extraction feedwater heating which is typical of 100 MWe size units. With the turbine throttle steam and condensing conditions being the same as the pilot plant design, the first, third, and fifth extraction stage steam conditions are assumed to be the same as the three stages of the pilot plant. Intermediate steam conditions are assumed for the second and fourth extraction stages to provide an approximate balance of heat loads between the feedwater heaters.

The minimum load for operating satisfactorily for extended periods of time without damage to a 100 MWe size unit is defined by General Electric Company as approximately 5 percent of the nominal rated electrical load. The corresponding steam mass flow to the turbine is approximately 20 percent of the flow at the rated load due to decreased turbine efficiency at low loads.

The maximum turbine mass flow, when operating on main steam from the receiver, is 412,070 Kg/hr and, when operating on admission steam from thermal storage, is 411,135 Kg/hr. The steam flow rate through the low-pressure stages is the same in both cases. The minimum turbine mass flow when operating on main steam from the receiver is approximately 82,409 Kg/hr and when operating on admission steam from thermal storage is 82,227 Kg/hr.

The maximum turbine mass flows correspond to generator output power levels of 115,000 kW when operating on steam from the receiver and 94,000 kW when operating on steam from thermal storage. The minimum turbine mass flows are 20 percent of the respective maximum turbine mass flows.

6. Net Cycle Efficiency - Receiver Operation

An estimate of the net thermal electric conversion efficiency as a function of output power level and ambient temperature for operation directly from the receiver is shown in Figure 4-17. This includes all auxiliary power requirements except that required for operating the receiver feed pumps, charging thermal storage, and operating the collector field. The maximum allowable output power is 115 MWe and minimum is 8 MWe.

7. Net Cycle Efficiency - Storage Operation

An estimate of the net thermal electric conversion efficiency when operating from thermal storage as a function of output power level and ambient temperature is shown in Figure 4-17. This includes all parasitic losses except that required for operating the receiver feed pumps, charging thermal storage, and for operating the collector field, and is to include losses in extraction from storage. The maximum allowable output power is 94 MWe and minimum is 8 MWe.

8. Maximum Rate of Change of Turbine Generator Output

Based on data received from a General Electric representative, and on the load change capability of units of similar size and larger, it is expected that the 100 MWe Commercial Solar Plant will be capable of a ramp increase in load at the rate of 4 percent per minute. Further, the plant can accept an instantaneous, or step function, change in load of ±10 percent within its normal range of operation or output.

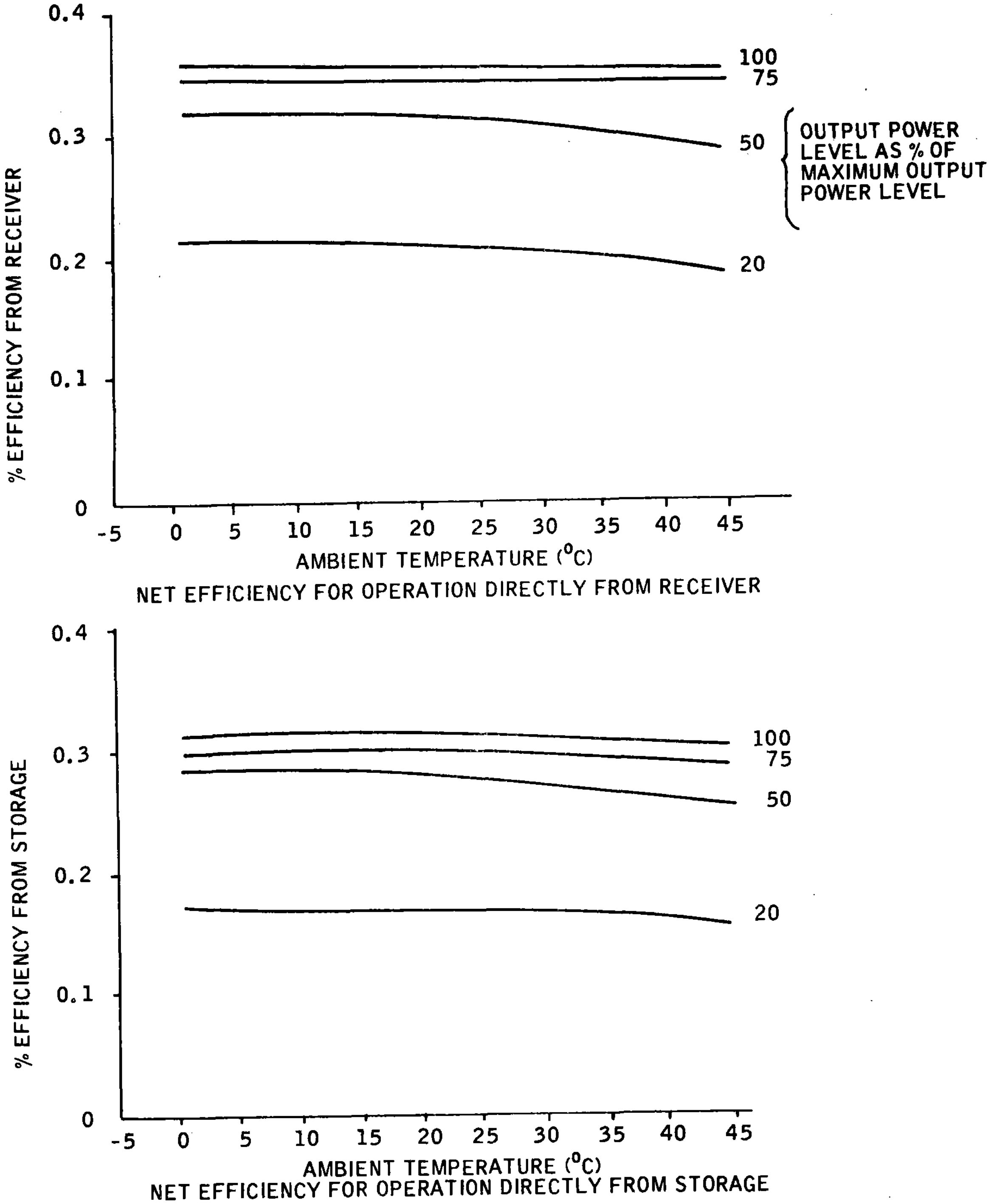

Figure 4-17. Net Efficiency for Operation Directly from Storage

9. Auxiliary Power Requirements for Charging Thermal Storage

The oil and hitec pumps consume a major portion of the auxiliary power during charging. For a constant speed pump (e.g. hitec pumps) the power requirements do not change much with the flow rate. The oil pumps, however have been designed to run at two different speeds, for flows greater than and less than 50 percent. Figure 4-18 shows the variation of auxiliary power with input rate.

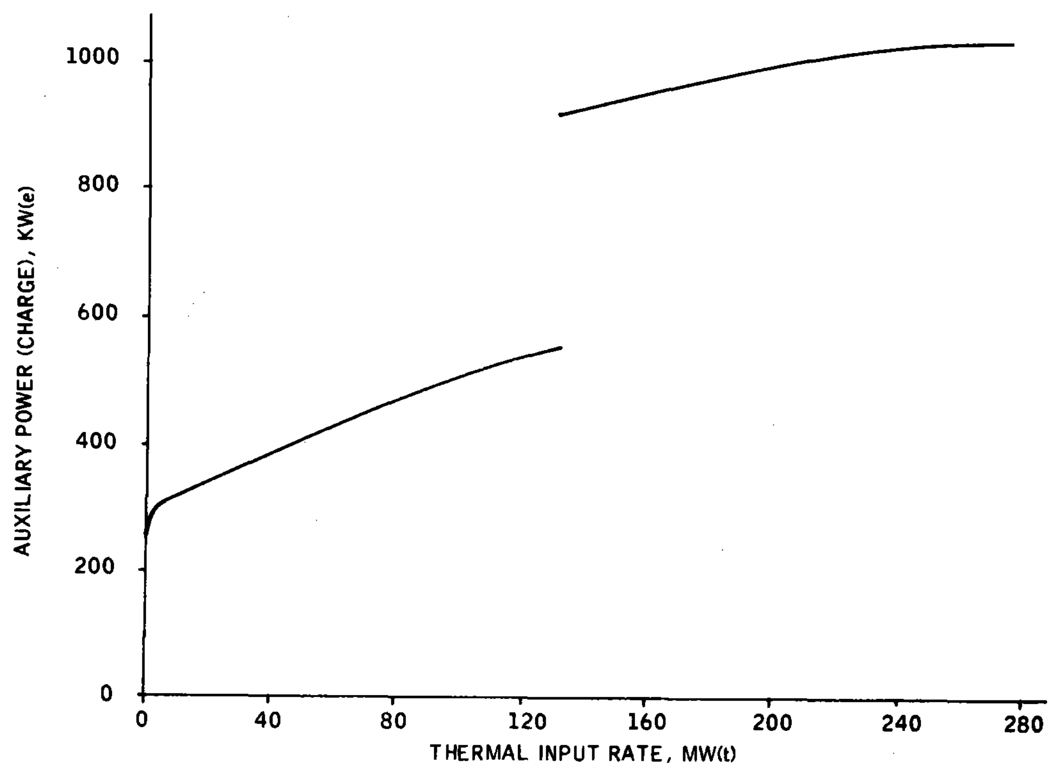

Figure 4-18. Variation of Auxiliary Power with Input Rate

10. Auxiliary Power for Receiver Feed Pumps

To obtain total feedwater pumping power, main and booster feedwater pump powers are added. Pump efficiencies at different flow rate operations are assumed based on similar pump selections. Piping lengths and fittings are assumed based on the site plan layout and preliminary pipe routing. The pressure drop is calculated based on design flow and varied with the square of the flow. Pump horsepower is calculated from the flow, pressure drop and pump efficiency.

A plot of the auxiliary power requirement for receiver feedwater pumps versus mass flow rate showing feedwater booster pump power, main feedwater pump power and total feedwater pumping power is shown in Figure 4-19.

11. Collector Field Auxiliary Power

The estimated collector field auxiliary power required for all times of normal operation is 708 KWe.

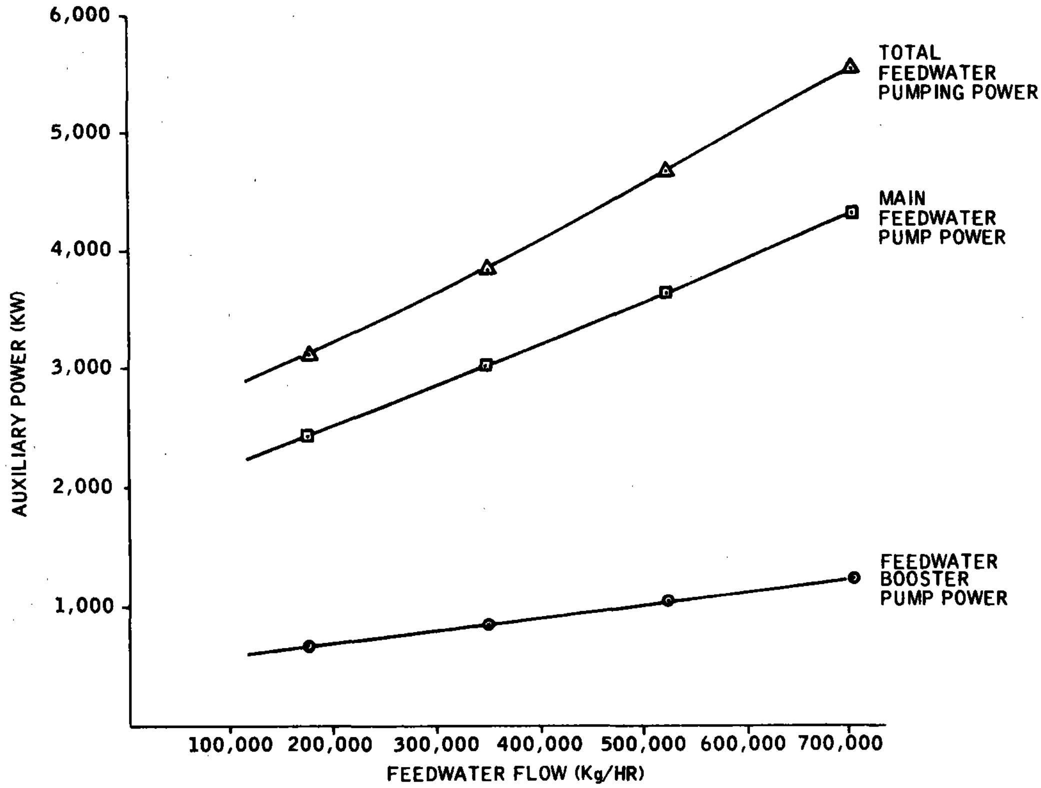

Figure 4-19. Auxiliary Power Requirement for Receiver Feedwater Pumps versus Mass Flow Rate

12 and 13. Time to Start-up From Receiver

Plant start-up procedures, sequencing and time estimates are discussed in some detail in Volume VI and results simulating a typical start-up are presented in Volume II of this report. We will not repeat this information here. However, to clarify the meaning of the start-up times we will give, it is necessary to discuss the general start-up strategy. For a warm start from the receiver, the turbine is started using a variable pressure start-up strategy. No flow from the receiver is routed to the storage subsystem during a typical warm start-up. Instead, the steam generated is bypassed directly to the condensor until the generated steam reaches a temperature which matches the turbine temperature. For example, after a normal overnight cool down of the receiver and turbine, the receiver drum pressure is approximately 1380 kPa with a corresponding saturation temperature of 193°C. The turbine is at 371°C. At sunrise, the aperture doors are opened and the boiler starts to generate steam. After approximately 32 minutes the steam temperature has risen to 371°C and the drum pressure is still at 1380 kPa. This steam may now be admitted to the turbine and the turbine/ generator can begin to produce power. Note that the turbine must be synchronized by this time. This is accomplished by using the storage discharge system during the receiver warm-up. After the turbine is started it takes approximately an additional 14 minutes to bring the steam to rated temperature. The steam is then ramped up to rated pressure. Thus a typical warm start-up does not have a waiting period where steam is sent to thermal storage. Of course, the generated steam may be sent to storage if desired, however, the pressure must be brought up to rated conditions in order to charge the main storage tank. To charge the superheater storage tanks, the steam temperature must exceed the Hitec temperature.

For our normal warm start-up, a time and events schedule is shown in Figure 4-20.

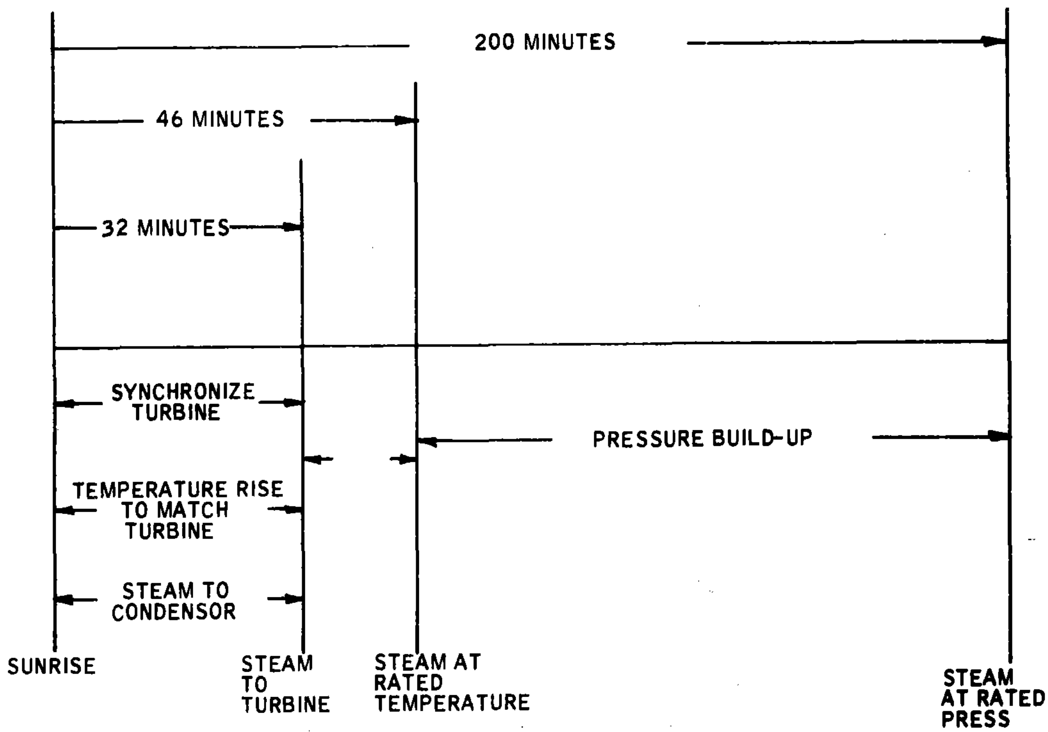

Figure 4-20. Start-Up Time

14. Time to Start up from Storage

- The only constraint on the start-up time is the time required to roll the turbine off the turbine gear and synchronize the generator. Assuming storage is ready, this can be accomplished in approximately 30 minutes. The turbine may then be ramped up to the desired load.

15. Estimate of Mode Switching Time Lags

- Switching from turbine operation on receiver steam only to operation on receiver and storage steam.

  The Hitec discharge pump and the preheater-boiler discharge pump are started. Simultaneously the valves from both (Hitec and oil) storage systems are opened along with the feedwater valve. The time lag is determined principally by motor start-up time and valve actuation time.

  Estimated switching time is 20 seconds.

- Switching from turbine operation on receiver steam only to operation on storage steam only.

  The Hitec and main oil discharge pumps are started. The admission steam control valve is opened. Turbine throttle valve is closed.

  Estimated switching time is 40 seconds. (Note: This value is true if turbine load is the same before and after switching. If the loads are not the same; turbine load ramp rates of 4 percent per minute or 10 percent step must not be exceeded.)

- Switching from turbine operation on storage steam only to operation on receiver steam only.

  Open throttle valves and close admission valves. Switching time is 20 seconds. Time is governed by valve operation time. Turbine ramp rates must be considered as in the preceeding paragraph above.

- Switching from charging thermal storage to discharging thermal storage or vice versa.

  The storage system can be simultaneously charged and discharged, discharged only, charged only, or left in hold.

  The estimated maximum switching time for any combination of mode changes is estimated not to exceed 40 seconds.

16. <u>Commercial Plant Charge/Discharge</u>

- The commercial plant is capable of simultaneously charging and discharging thermal storage.

17. <u>Thermal Energy Required for Various Start-Up, Shut Down, and Holding Conditions</u>

- Thermal energy required for starting up and shutting down the turbine from a warm start when operating from the receivers only.

  The thermal energy required in starting up the commercial size solar plant is scaled up from the 10 MWe Solar Pilot Plant (see Figure 4-21).

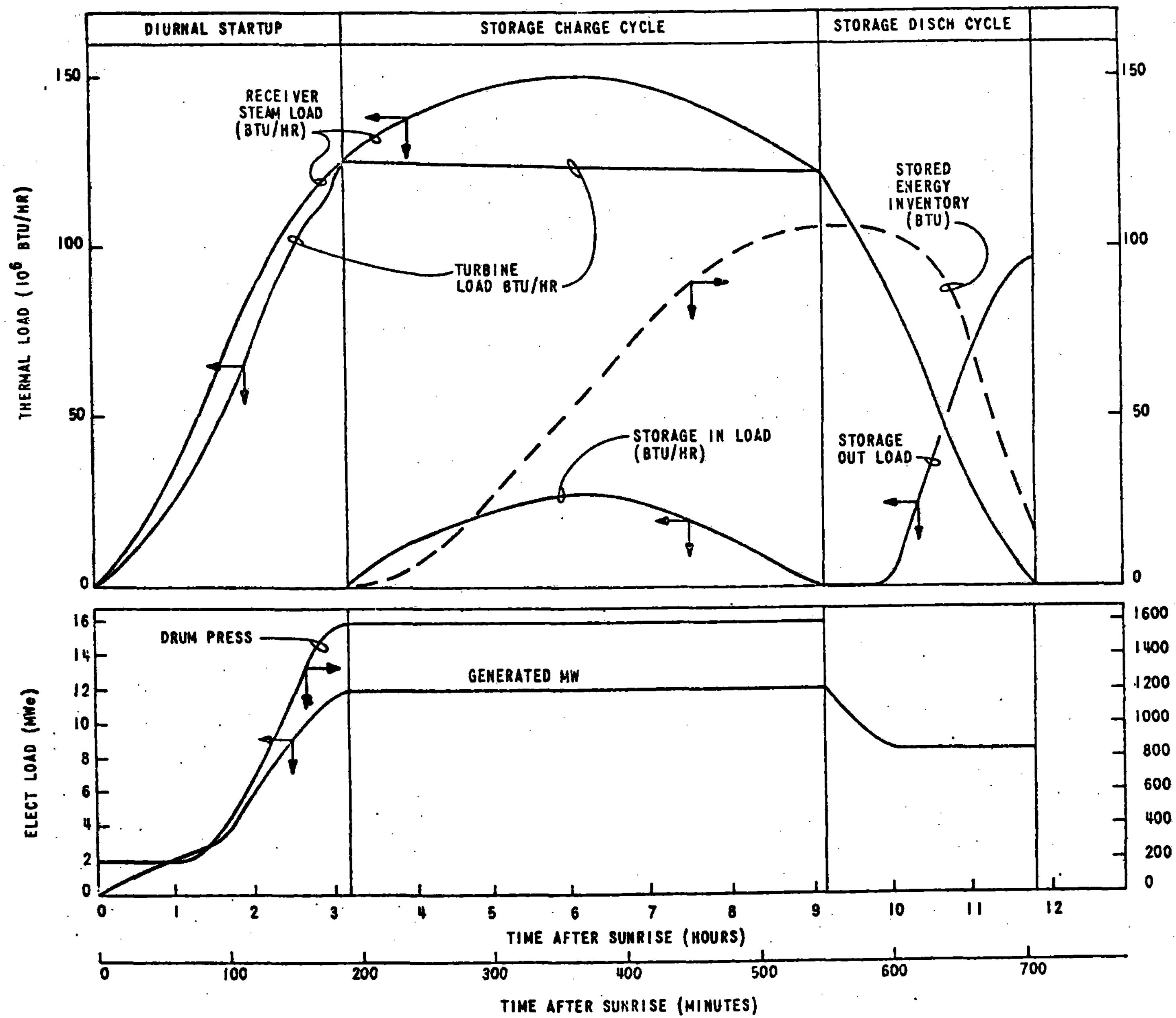

Figure 4-21. Thermal Energy Requirement for Startup

It is assumed that the receiver and turbine are available for start-up at sunrise after a shutdown period of from 12 to 72 hours. The receiver boiler drum pressure is assumed to be 200 psia and the turbine metal temperature is assumed to be between 300 F and 700 F.

The heliostats are first focussed only on the boiler section of the steam generator. Superheater heliostats are not focussed until after steam flow is established.

The turbine is found to be limited by the receiver steam generation rate to a load ramp of approximately 1 percent per minute.

The turbine shutdown procedure for the commercial unit is assumed to be the same as the procedure for the pilot unit. The load is reduced at an approximate rate of 4 percent (rated load) per minute during the last 20 minutes of plant operation and the unit is then tripped from essentially zero loads. The only thermal energy required during the shutdown period is the steam for the turbine steam seal system.

The estimated thermal energy required during starting up is 1722.3×10^6 Btu, as listed in Table 4-1.

The thermal energy required during shutdown is determined from the seal steam requirements and is estimated to be 2.4×10^6 Btu/hr.

Table 4-1. Estimate of Thermal Energy Used in Starting up The Turbine From Warm Start on Receiver

Time, from sunrise minutes	Thermal Load BTU/HR x 10^6	Energy BTU x 10^6
0	0	
10	25	2.08
20	60	7.08
30	100	13.33
40	140	20
50	200	28.33
60	240	36.66
70	300	45
80	360	55
90	440	66.66
100	520	80
110	600	94.16
120	710	110
130	810	126.6
140	890	141.6
150	980	155.8
160	1050	169
170	1110	180
180	1170	190
190	1250	201
Total Energy		1722.30 x 10^6 BTU

- The thermal energy required in starting up and shutting down the turbine from a warm start while operating the turbine from thermal storage.

Plant start-up on thermal storage generated steam is assumed to be the operations and time required to bring the turbine-generator from a hot standby, tripped condition to rated electrical output for thermal storage operation.

For the start-up, it is assumed that thermal storage is fully charged and capable of supplying steam at a pressure and temperature of 474.7 psia and 703°F to the turbine. The turbine metal temperature is assumed to be between 300°F and 700°F.

The turbine is loaded at a rate of approximately 4 percent per minute. The power to the turbine with respect to generated MWe is scaled up from the operation of the 10 MWe Solar Pilot Plant on storage generated steam.

The turbine shutdown procedure for the commercial unit is assumed to be the same as the procedure of the pilot unit. The load is reduced at an appropriate rate of 4 percent (rated load) per minute during the last 20 minutes of plant operation and the unit is tripped from essentially zero load. The only thermal energy required during the shutdown period is the steam for the turbine steam seal system.

The estimated thermal enrgy required during start-up is 246.5×10^6 Btu, as listed in Table 4-2.

The thermal energy required during shutdown is determined from the seal steam requirements and is estimated to be 2.4×10^6 Btu/hr.

Table 4-2. Estimate of Thermal Energy Used in Starting Up the Turbine from Warm Start on Thermal Storage

Time, from Sunrise (minutes)	Thermal Load Btu/hr x 10^6	Energy Btu x 10^6
0	0	0
2.97	171	4.23
5.95	288	11.39
8.93	426	17.73
11.91	564	24.59
14.89	687	31.06
17.87	825	37.93
22.34	1031	69.14
25	1244	50.43
	Total Energy	246.5×10^6 Btu

- The thermal energy required to maintain the receivers and turbine for a warm start.

Start-up classifications are defined by the General Electric Company for steam turbines in terms of the length of time (t) after unit trip and turbine metal temperature (T) as follows.

Cold start	$t > 72$ hrs	$0 \leq T \leq 300°F$
Warm start	$12 \leq t \leq 72$ hrs	$301 \leq T \leq 700°F$
Hot start	$t \leq 12$ hrs	$700 \leq T \leq 1000°F$

A typical General Electric double shell turbine cooling curve, (Figure 4-22) included herein which verified the above relationship between time and temperature.

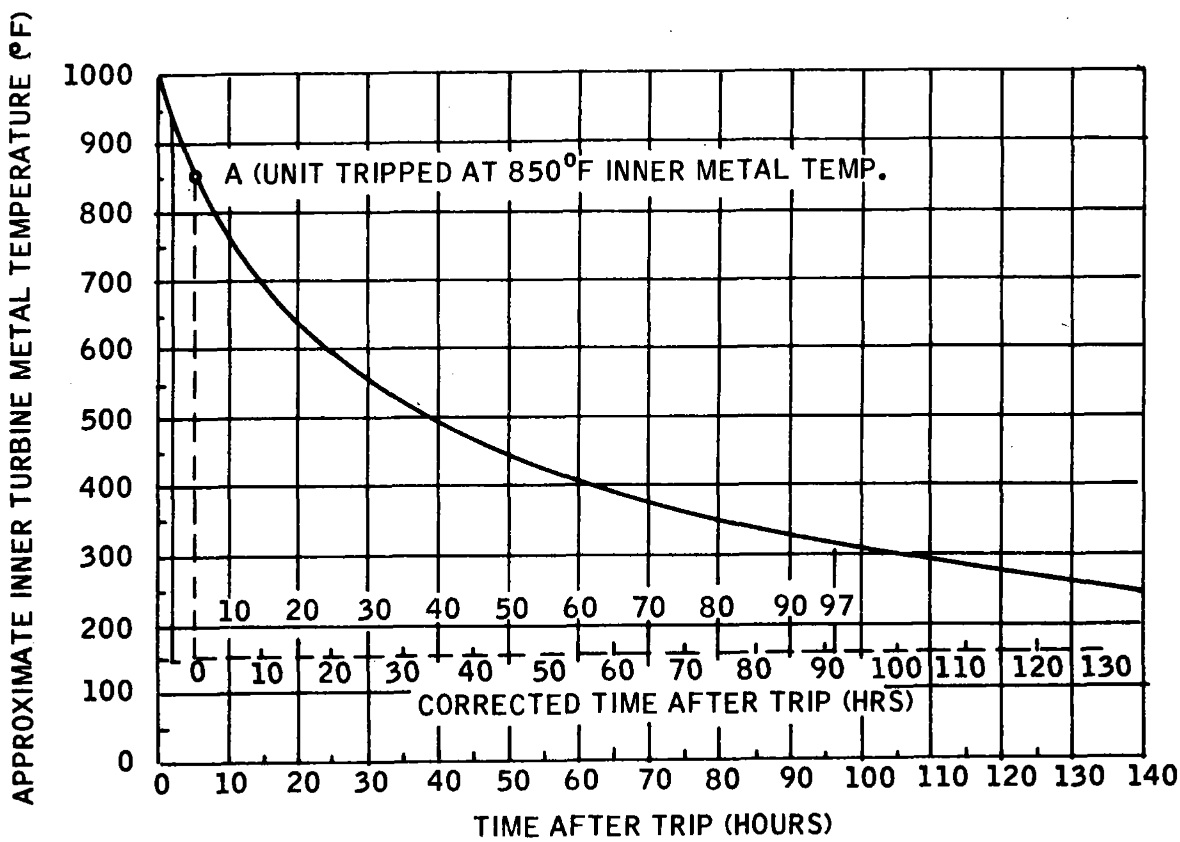

Figure 4-22. Typical General Electric Double Shell Turbine Cooling Curve

For the solar plant, diurnal operation will include shutting down the plant following operation of the turbine-generator on thermal storage steam. At that time, the turbine temperature can be assumed to be approximately 730°F. The General Electric typical cooling curve indicates that after shutdown period of 12 hours, the temperature of the turbine will have decreased to approximately 580°F. Hence, the turbine remains in a warm start condition during the overnight shutdown.

With reference to the receiver steam generator temperature, after the heliostats have been redirected from the steam generator, the temperatures within the receiver cavity will decrease from a high of approximately 1250°F to approximately 600°F, which corresponds to the saturation temperature at the steam generator drum pressure. The receiver cavity closure barrier is then lowered into place to seal the cavity for the overnight shutdown. During the shutdown, the temperature of the receiver steam generator is expected to decrease to around 350°F. Other than the insulation provided by the cavity barriers, no attempt is made to maintain the receiver at a higher temperature during the shutdown period.

The major uses of energy to maintain the plant ready for diurnal (warm) start-up are the main steam lines and the turbine steam seal system. The temperature of the steam lines from the receiver steam generators to the turbine is allowed to decrease during nighttime shutdown from its normal operating temperature of approximately 950°F to a temperature of approximately 700°F. At the point the steam line temperature reaches 700°F, electric heating of the line is initiated. To reduce the energy required, a double thickness of insulation, relative to the standard practice, is to be placed on the steam lines.

The steam required for the turbine steam seal system is the only other major requirement for thermal energy to maintain the plant during the overnight shutdown for a warm start at sunrise. This energy requirement is estimated from known requirements for similar size fossil field units.

Based on estimates made for the pilot plant, and scaled for the commercial plant steam piping runs, the hourly energy required to maintain the steam lines of the commercial plant for a diurnal warm start is approximately 990 kW.

The energy required to maintain the turbine steam seal system is approximately 2.4×10^6 Btu/hr.

- Minimum storage capacity required for diurnal equipment protection only.

  The minimum storage capacity required is 12 MW hr (th) to provide 20 hours of standby protection. This thermal energy is used for providing turbine sealing steam, tracing the Hitec storage lines, overcoming storage thermal losses, and maintaining a reserve for a start-up and shutdown.

- The time and thermal energy required for turbine start-up from a cold start.

The receiver and turbine are available for start-up at sunrise after a shutdown of 72 hours or longer. The receiver temperature is assumed to be 70°F and the turbine metal temperature is assumed to be below 300°F. The weight of the steam generator is scaled from the pilot plant steam generator weight.

Initially, the heliostats are focused on the boiler only until sufficient steam flow for cooling the superheater tubes is developed.

The turbine is assumed to roll off turning gear at a boiler drum pressure of 200 psia. The turbine is loaded at a rate of 4 percent per minute.

The estimated start-up time is approximately 180 minutes from sunrise to full load. The estimated thermal energy required is indicated in Figure 4-23. Tables 4-3 and 4-4 summarize events and times.

Engineering Observations -- Comparison of this analysis withthe results for a warm start-up indicate that both will require approximately the same time to reach full load. This implies that the availability of solar energy limits both the cold and the warm start-up sequences. Nevertheless, a warm start-up of the plant offers two major advantages over a cold start-up. With a warm start-up, a daily electrical power output approximately 5.8 percent greater than with a cold start-up is realized since the turbine-generator is placed in the sun following mode more rapidly. Further, the extreme cyclic stress on the receiver steam generator is eliminated with a warm start-up and, hence, the steam generator design criteria are less severe.

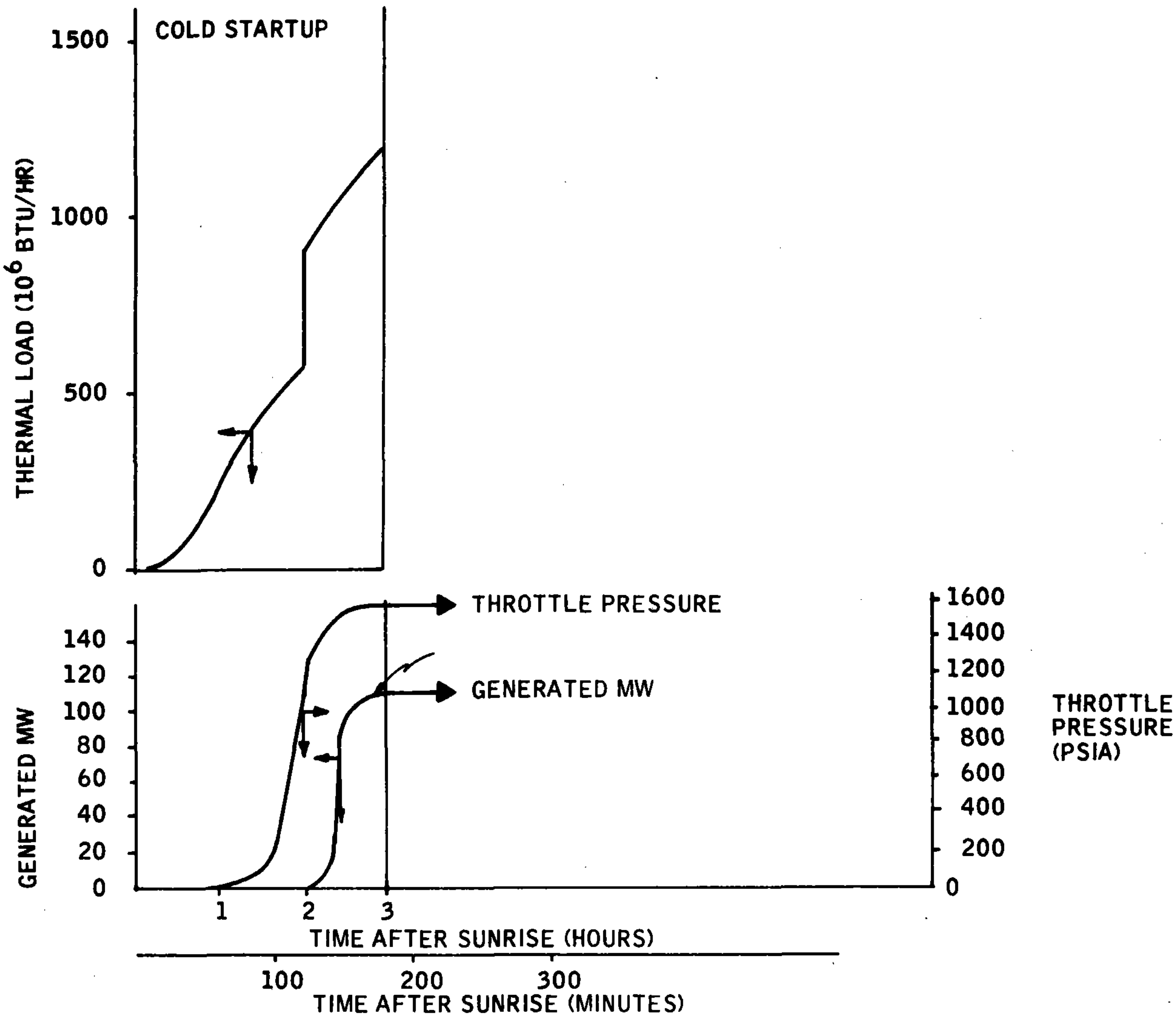

Figure 4-23. Cold Startup

Table 4-3. Calculation of Diurnal Startup Boiler Pressure/Temperature Ramp

Time From Sunrise, Minutes	Total Power Absorbed BTU/HR x 10^6	Absorbed Power Per Cent	Receiver Energy BTU/HR x 10^6	Integrated Energy to Receiver BTU x 10^6	Enthalpy Change BTU/LB	Boiler Enthalpy BTU/LB	Boiler Press PSIA	Boiler Temp °F
0	0	0	0			38.04	14.46	70
10	10	.765	7.65	.6	.63	38.1	14.46	70.5
20	20	.755	15.1	1.8	1.89	39.99	14.46	72
30	100	.743	74.3	7.4	7.84	47.83	14.46	79
40	170	.73	124.1	16.5	17.37	65.2	14.46	98
50	240	.725	174	24.8	26.11	91.31	14.46	123
60	320	.705	225.6	33.3	35.06	126.37	14.46	159
70	430	.7	301	43.8	46.12	172.49	14.46	204
80	530	.695	368	55.7	58.7	231.19	36.7	262
90	600	.68	428	66.3	69.84	301	103	330
97*	703	.68	457	51.6	54.4	355.4	200	381
			Total	301.8 x 10^6 BTU				

*At 97 minutes after sunrise the turbine is rolled off turning gear and accelerated to synchronous speed in 34 minutes (at 131 minutes after sunrise).

Table 4-4. Calculation of Diurnal Startup Boiler Pressure/ Temperature/Turbine Load Ramp

Time From Sunrise Minutes	Total Power Absorbed BTU/HR x 10^6	Absorbed Power Per Cent	Receiver Energy BTU/HR x 10^6	Turbine Energy BTU/HR x 10^6	Integrated Energy to Receiver BTU x 10^6	Thermal Energy to Storage BTU/HR x 10^6	Enthalpy Change BTU/LB	Boiler Enthalpy BTU/LB	Boiler Press PSIA	Boiler Temp °F	Turbine Load MW
97	703	.68	457	------							0
100	725.4	.675	478.82	10.83	23.39		24.62	380.0	262	405	0
110	825.6	.67	542.32	10.83	85.09		89.60	469	590	484	0
120	882.9	.655	567.47	10.83	92.48		97.38	566	1175	564	0
125.7	895.1	.65	571	10.83	54.15		57	624	1600	604	0
131	910	1.0	910	10.83	74.05	809.2	0	624	1600	604	0
133	930	1.0	930	100	30.66	830	0	624	1600	604	5
135	950	1.0	950	250	5.83	700	0	624	1600	604	15
140	1000	1.0	1000	550	33.33	450	0	624	1600	604	45
150	1040	1.0	1040	960	125	80	0	624	1600	604	90
151	1046	1.0	1046	1046	17.38	0	0	624	1600	604	97
155	1070	1.0	1070	1070	70.53	0	0	624	1600	604	100
160	1100	1.0	1100	1100	90.41	0	0	624	1600	604	102
165	1130	1.0	1130	1130	92.91	0	0	624	1600	604	104
170	1160	1.0	1160	1160	95.42	0	0	624	1600	604	108
180	1190	1.0	1190	1190	195	0	0	624	1600	604	110

Total 1085.13 x 10^6

From Table 1 301.80 x 10^6

Total 1386.93 x 10^6 BTU

18. Thermal Energy Losses from Thermal Storage

The heat loss rate varies as temperature difference between the storage temperature and ambient. For a change in the ambient temperature from -20 to 50°C (i.e. 70°C) the heat loss rate decreases by only 20 percent. Figure 4-24 shows the heat loss rate as a function of ambient temperature. The heat loss as percent of storage capacity increases with decrease in number of storage hours, since the surface area per unit storage volume increases with decrease in volume.

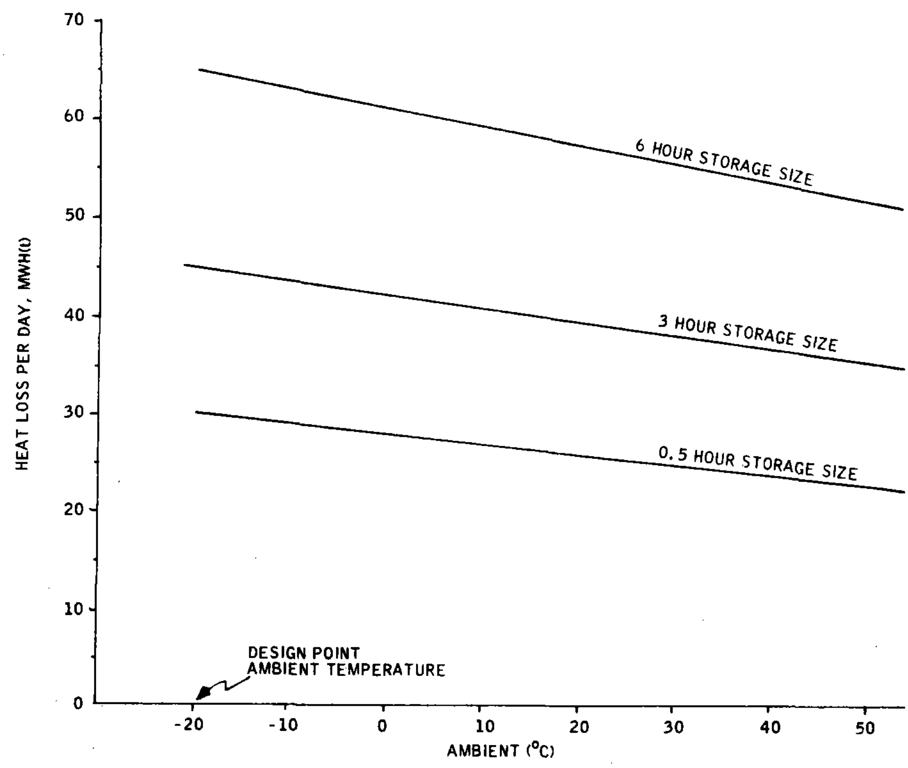

Figure 4-24. Heat Loss for Commercial Plant Storage Subsystem as a Function of Ambient Temperature