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CENTRAL RECEIVER SOLAR THERMAL POWER SYSTEM. PHASE 1. CDRL ITEM 2

Pilot Plant Preliminary Design Report. Volume VII, Pilot Plant Cost and Commercial Plant Cost and Performance

By
Raymon W. Hallet, Jr.
Robert L. Gervais

May 1980
Date Published

Work Performed Under Contract No. EY-76-C-03-1108

McDonnell Douglas Astronautics Company
Huntington Beach, California

U.S. Department of Energy

Solar Energy

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CENTRAL RECEIVER SOLAR THERMAL POWER SYSTEM PHASE 1

CDRL ITEM 2
Pilot Plant
Preliminary Design Report

Volume VII
Pilot Plant Cost and Commercial Plant Cost and Performance

Raymon W. Hallet, Jr. and Robert L. Gervais

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PREFACE

This report is submitted by the McDonnell Douglas Astronautics Company to the Department of Energy under Contract EY-76-C 03-1108 as the final documentation of CDRL Item 2. This Preliminary Design Report summarizes the analyses, design, test, production, planning, and cost efforts performed between 1 July 1975 and 1 May 1977. The report is submitted in seven volumes, as follows:

- Volume I, Executive Overview
- Volume II, System Description and System Analysis
- Volume III, Book 1, Collector Subsystem
  Book 2, Collector Subsystem
- Volume IV, Receiver Subsystem
- Volume V, Thermal Storage Subsystem
- Volume VI, Electrical Power Generation/Master Control Subsystems and Balance of Plant
- Volume VII, Pilot Plant Cost and Commercial Plant Cost and Performance

Specific efforts performed by the members of the MDAC team were as follows:

- McDonnell Douglas Astronautics Company
  Commercial System Summary
  System Integration
  Collector Subsystem Analysis and Design
  Thermal Storage Subsystem Integration
- Rocketdyne Division of Rockwell International
  Receiver Assembly Analysis and Design
  Thermal Storage Unit Analysis and Design
- Stearns-Roger, Inc.
  Tower and Riser/Downcomer Analysis and Design
  Electrical Power Generation Subsystem Analysis and Design
- University of Houston
  Collector Field Optimization
- Sheldahl, Inc.
  Heliostat Reflective Surface Development
- West Associates
  Utility Consultation on Pilot Plant and Commercial System Concepts

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Section 1
INTRODUCTION

This document represents the final submittal of the Pilot Plant Cost and Commercial Plant Cost and Performance Report, CDRL Item 2, Pilot Plant Preliminary Design Report (PDR). The Preliminary Draft Version of this document was submitted in May of 1977. Information contained in the first six volumes of the PDR has been used as a guideline in the derivation of costs and project funding. An exception to this is that an open-loop collector control system has been used as a basis for Commercial Plant Costing. Also, it has been necessary to expand in some areas on the programmatic definition provided in the PDR based on preliminary facilities, manufacturing, development, and test program/operations requirement analysis. Efforts have been made to be responsive to the spirit of cost reporting and supporting descriptions requested by Sandia Laboratories within the scope of effort defined by the Department of Energy.

The PDR reflects the preliminary design which relates to the Central Receiver Solar Thermal Power System Study as indicated in Figure 1-1. Information gained in the last two phases--Subsystem Research Experiments and Preliminary Design--has significantly altered Pilot Plant design and programmatics. For this reason, important changes have occurred in reported costs since the first submittal of this report.

This report contains six sections: (1) the introduction, (2) an overview indicating costs and projected funding, programmatics and groundrules, and the general costing approach, (3) an expansion of programmatics, (4) a section on Pilot Plant costing detail, methodology and rationale, (5) a section on First Commercial Plant costing detail, cost variations, methodology and rationale, and (6) a section on commercial plant performance. Also, the Appendix includes a summary of a conceptual design for a commercial collector manufacturing plant.

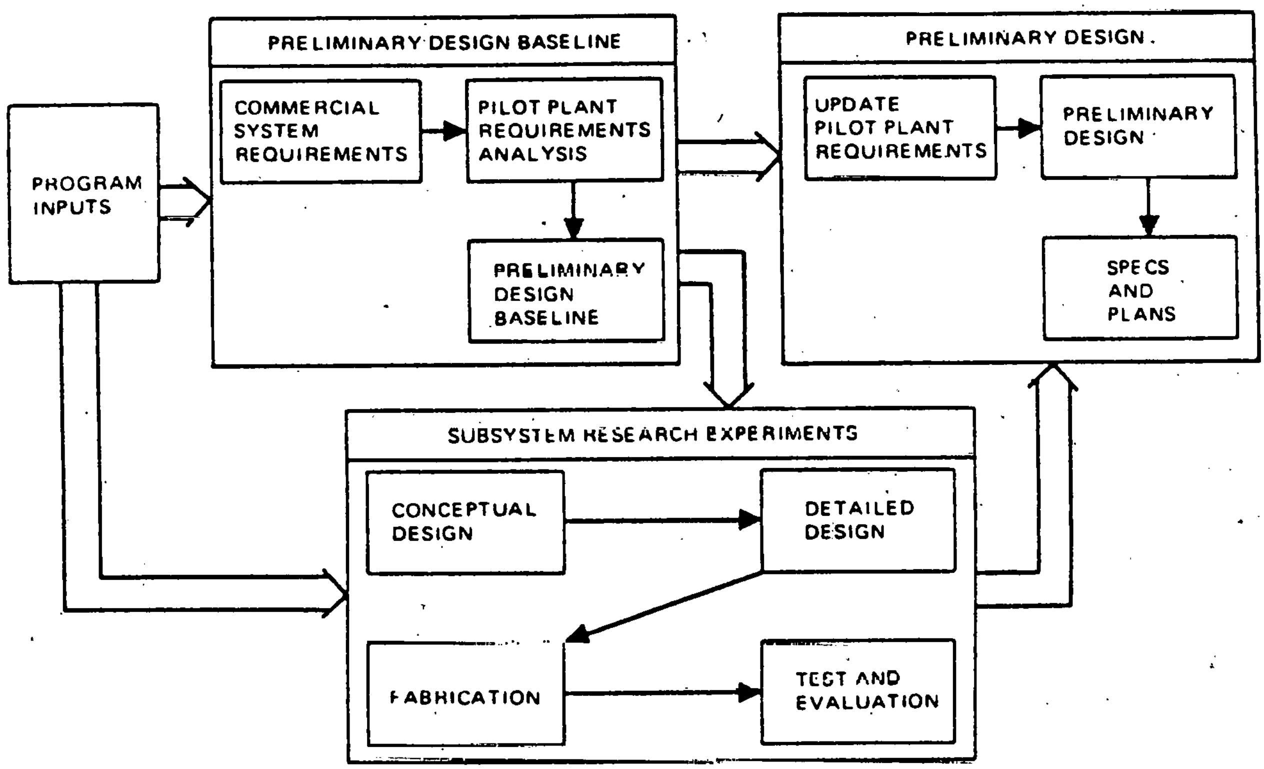


Figure 1-1. Summary Program Network

Section 2
COSTING OVERVIEW

This section contains an overview of projected pilot, first, and Nth commercial plant costs, funding, and supporting descriptions. Following a presentation of steady state costs, Pilot Plant funding for design and development, investment and initial operations is presented. Then, a similar presentation, excluding development cost, is provided for the First Commercial Plant. The discussion also touches on potential variations in Commercial Plant costs and on changes in costs from previous reports. Following this, the underlying programmatics, groundrules, and assumptions are summarized, and the section is concluded with an introduction to the costing approach.

2.1 COSTING RESULTS

Pilot Plant and Commercial Plant costs, as indicated in the Appendix, are based on the technical descriptions and programmatics provided by the May 1977 Pilot Plant Preliminary Design Review (PDR) document, Volumes I through VI. However, the PDR describes a baseline closed-loop collector control system that is costed for the Pilot Plant but not for the Commercial Plant. For Commercial, an open-loop system serves as the cost basis.

Generally, the costs that are presented will indicate a dramatic reduction in dollars in plant investment per net kilowatt of output between the Pilot Plant and Commercial versions of the Central Receiver Concept. Cost reductions are particularly encouraging for the collector subsystem where study results suggest that an eventual cost of less than $\$100/m^2$ in 1977 dollars is almost certain. Under the "right" market, hardware and production scenarios, achievement of nearly one-half of this cost may be within the range of feasibility. The remainder of this subsection provides a summary of these results, starting with the Pilot Plant and then moving into Commercial.

2.1.1 Pilot Plant Costs

The costs projected for Pilot Plant have been reduced almost \$22 million from those indicated in the March 1, 1976 Pilot Plant Cost Report. The earlier projections represented budgetary, "not to exceed," estimates as compared to an expected cost approach used for the latest projections. In addition, certain hardware and system changes have been made since the last report which have allowed a 590-unit or 25% reduction in the number of heliostats required. The impact of these circumstances is reflected in the steady state costs and as spent and committed funding presentations that follow, along with an indication of the most important fiscal groundrules and assumptions.

2.1.1.1 Steady State Costs. Life cycle costs through the first 2 years of pilot plant operation are presented in Figure 2-1. The total cost is $75.4 million, and as expected, the collectors account for the greatest share of total cost at 29%, which is down from 33% in the previous estimates, or $10 million. The next highest costs are the indirects at 15% of the total, and the Receiver at 14%. The latter has gained from 9% shown in the 1976 report. Contingency is now shown as only 8% of the total, representing almost a $10 million reduction from that shown previously. The indirects have changed in content somewhat from the last report in that they no longer include fee which is now buried against each CBS element, and the burden type items are now costed under the Distributables category. However, the indirects now provide for a Construction Manager and a Solar Integrator in addition to the A&E and plant startup, so that these costs have not changed much in total.

Figure 2-2 presents the investment costs only which total to just over $63 million. The collectors are still 29% of the total, which compares to 36% reported previously and reflects the large decrease in cost. This would increase to 35% of the total were the collector's share of spares, handling equipment, and contingency costs allocated directly to the collector. This compares with approximately 50 to 55% of the total projected for the First Commercial Plant where more collectors per megawatt are required to handle a more demanding plant operations scenario.

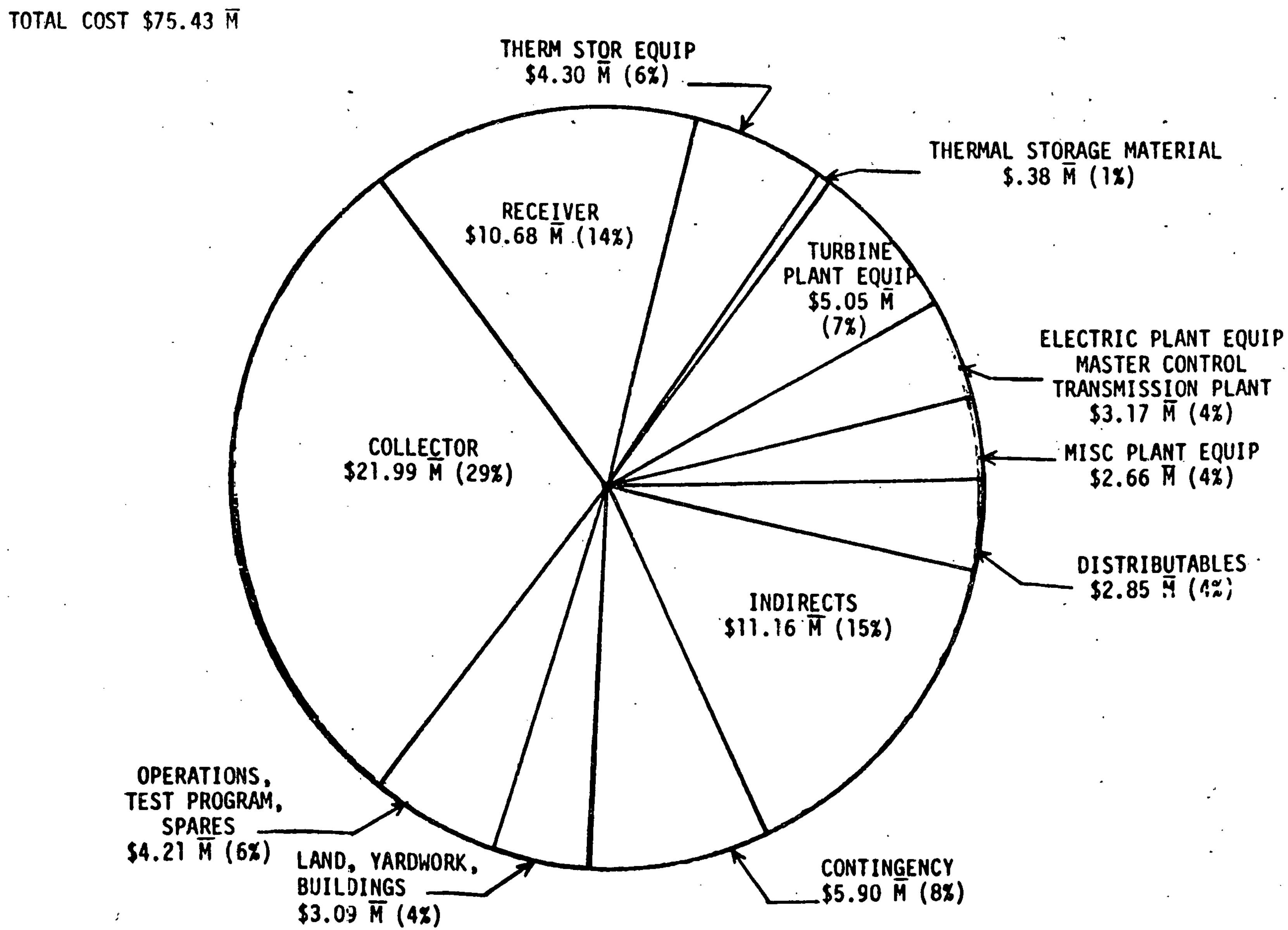


Figure 2-1. Pilot Plant Total Cost

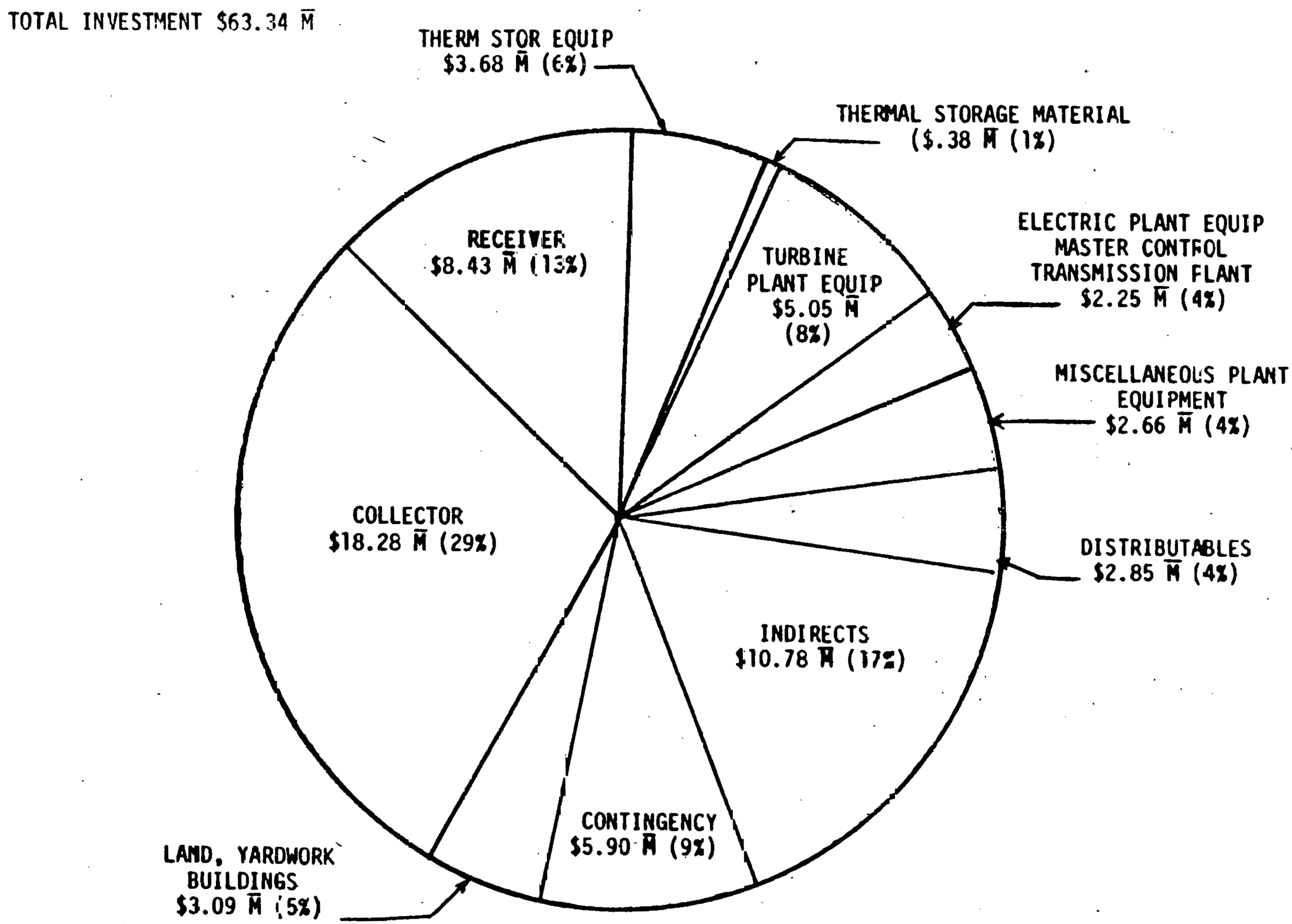


Figure 2-2. Pilot Plant Investment Cost

2.1.1.2 Major Financial Groundrules. The costs presented in Figures 2-1 and 2-2 assume the following major financial groundrules:

1. Cost plus fixed fee contracts.

2. No interest during construction (IDC) on Government contracts.

3. First half 1977 dollars--no escalation.

4. Weighted average contingency totaling 9% applied at individual rates ranging from 5 to 20%.

5. No sales tax on Government contracts.

6. Average 8% fee applied to each CBS line item. Parts and materials include vendor fee. No prime contractor fee on subcontract work is included.

7. Current team members overhead centers. Special rates were not developed.

8. Low side standard team manufacturing support practice. Due to the development nature of the pilot plant, production control, industrial engineering, manufacturing, engineering, and similar support areas are assumed maintained at low standard program levels throughout heliostat production and other production.

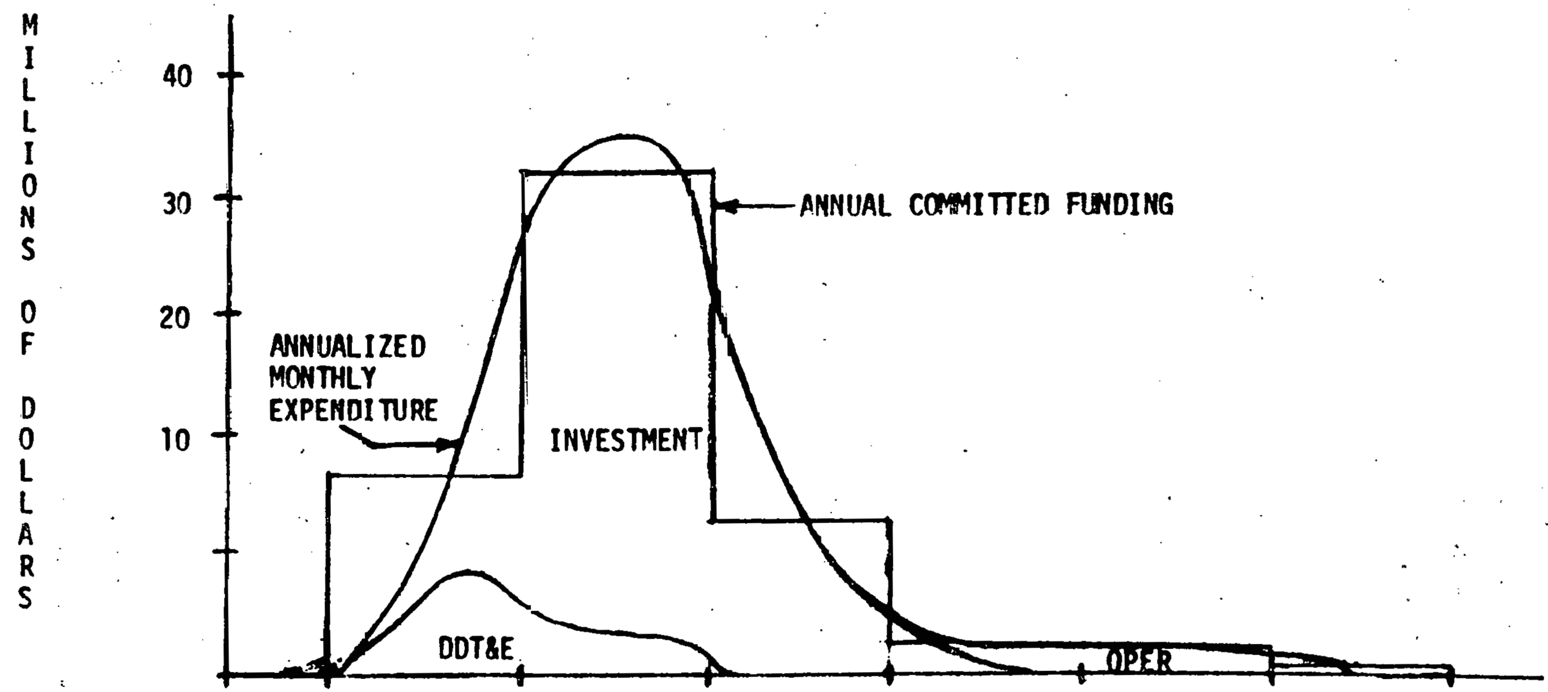
9. Applied contract labor rates include fringes and general contractor overhead.

10. Generally, 89 to 90% cost reduction curve on in-plant fabrication and assembly labor hours. That is, on a 90% curve, the cumulated average cost of labor will tend to diminish each time the cumulated number of heliostats, etc. is doubled.

11. Parts and Material costs directly quoted by vendors for required quantity.

12. Collector costs include a 10% factor for visibility on in-plant labor and material, and 49% on in-plant labor for efficiency, liaison and rework.

2.1.1.3 Pilot Plant Funding. Figure 2-3 shows projected pilot plant funding requirements by government fiscal year. As indicated, the requirements "peak out" in 1979 at $42.5 million. Committed dollars peak in the same year at about the same amount. Comparison with the "as spent" funding indicates a $3.5 million commitment lead in the first year of the program.



GFY	78	79	80	81	82	83
DDT&E	5.2	3.4	.1	.0	.0	.0
INVESTMENT	7.4	39.1	14.9	1.2	.0	.0
OPERATIONS	.0	.0	.0	1.6	2.2	.5
TOTAL AS SPENT	12.6	42.5	14.9	2.8	2.2	.5
TOTAL COMMITTED	16.1	42.0	12.4	2.2	2.2	.5

Figure 2-3. Pilot Plant Funding (1977 Dollars)

The annualized monthly expenditure indicates the degree of expenditure growth or decline. The growth of the projected curve is considerably more relaxed than that projected in 1976. This is due to both the 6-month extension of the IOC and to the lower total projected cost. In viewing this curve, it may be interesting to keep in mind that the first heliostat is installed at the beginning of the third quarter of GFY 1979, and that the tower installation has been completed by that time.

The funded values were determined by distributing projected cost at the major activity level within each non-solar subsystem and by CBS for solar plant equipment over the scheduled period for each phase according to standard funding curves or manloads.

2.1.2 Commercial Plant Costs

The costs projected for the First Commercial Plant indicate a substantial reduction in dollars per kilowatt over the same figure of merit calculated for the Pilot Plant. Most of the reduction is due to scaling benefits of plant sizing with less than one-fifth of the reduction associated with the collectors. The collector savings are the net of increased costs of a higher solar multiple and the economics available with increased production volume. The following summarizes Commercial Plant costs and cost variations, typical funding for the First Commercial Plant, and the major financial groundrules that differ from those applied for the Pilot Plant.

2.1.2.1 Steady State Costs. Investment costs for the First Commercial Plant are shown in Figure 2-4. Here, the collectors are by far the dominate cost accounting for over 50% of the total after the collectors share of spares and miscellaneous plant equipment are added. At 13% of the total, the receiver accounts for an identical share of the cost as it does in the Pilot Plant, and is also the next highest cost item. Turbine plant equipment has increased in importance to 10% of the total while the Indirects have decreased to 8% and thermal storage equipment and material have remained at 9%. However, these percentages are not perfectly comparable to the Pilot Plant's percentages because no contingency is included in the Commercial Plant costs.

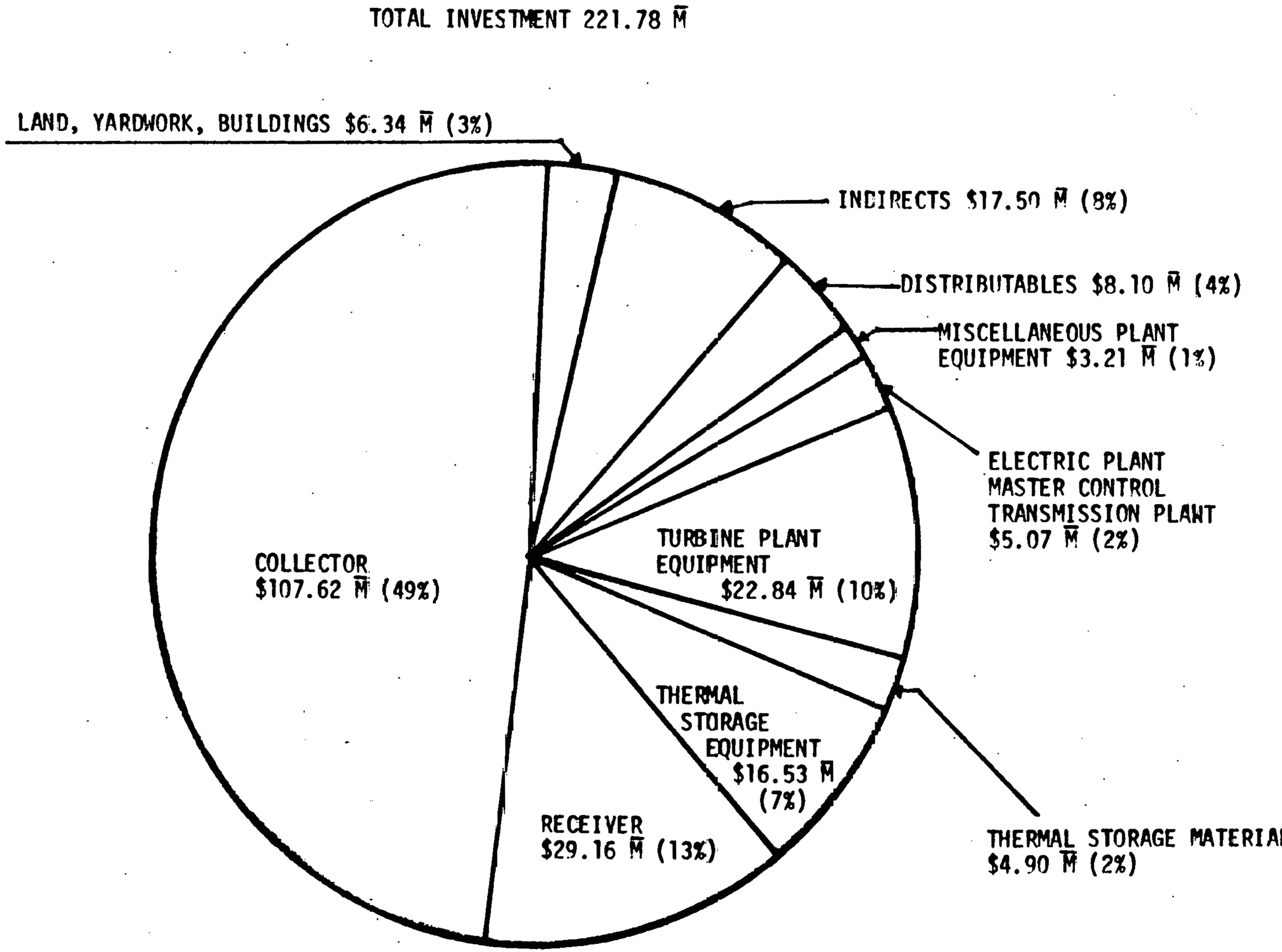


Figure 2-4. First Commercial Investment Cost

Rationale for the exclusion of contingency is based on the belief that these costs represent the expected values, and considering the number of years before the First Commercial Plant is to be built, there may be as much chance that the costs will go down as that they will go up, notwithstanding inflation.

Table 2-1 provides a comparison between Pilot Plant and Commercial Plant costs in terms of dollars per kilowatt for major elements of the system. One interesting feature of the table is that it provides an indication of the scaling benefits of going from a 10-MWe to a 100-MWe plant. This is shown in the third column from the left where the larger the number, the greater the scaling benefit. For all but the collectors, the benefit results from the condition that costs generally do not go up as fast as sizing characteristics when increasing capability or capacity.

The collector reduction is mainly due to economies associated with volume production since the basic heliostat is the same size for both the Pilot and Commercial plants. It is interesting that the collectors account for only 18% of the total reduction, but this would be greater except that the solar multiple is greater for the Commercial Plant than it is for the Pilot Plant. Finally, as indicated in Table 2-1, the projected cost of collectors installed at a rate of 2.5 100-MWe plants per year is estimated at $779/kilowatt or a 57% reduction in cost from Pilot Plant.

The causes of this cost reduction are discussed in detail in Section 5. Generally, they are due to the employment of mostly automated production facilities that are treated as a dedicated burden center. The facilities were conceptually designed to produce 60,000 collectors per year by MDAC and Arthur D. Little Consultants in a manner to reduce not only the labor hours but also the average skill level required. The result has reduced labor to only 28% of the costs, including installation. Although these results are encouraging, $779 per kilowatt by no means represents the lowest potential collector cost that might be achieved by American Industry.

Table 2-1. Dollars per Kilowatt Changes Pilot to First Commercial Plant

Cost element	Investment $/kW First commercial	Investment $/kW Pilot	Pilot ÷ commercial	$/kW reduction
Collector	$1,076*	$1,828	1.7	$ 752
Receiver	292	843	2.9	551
Thermal Storage	214	406	1.9	192
Turbine Plant	228	505	2.2	277
Indirects	175	1,078	6.2	903
Electric Plant, Miscellaneous Plant and Master Control	83	491	5.9	408
Distributables	81	285	3.5	204
Contingency	-	590	-	590
Yard and Buildings	63	309	4.9	246
	$2,212	$6,335	2.9	$4,123

*Cost is $779/kW when 2.5 plants per year are installed.

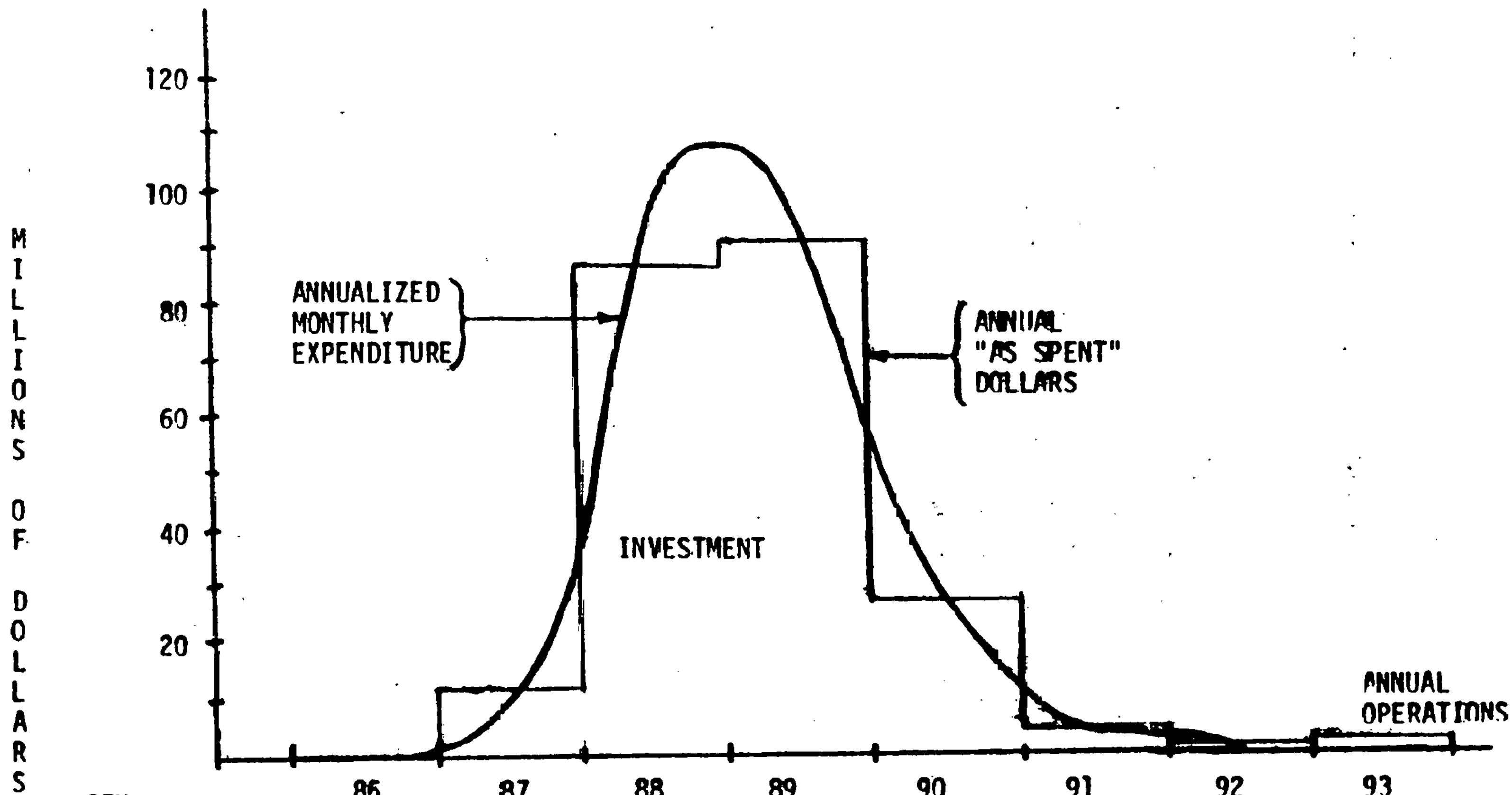
2.1.2.2 Major Financial Groundrules. Groundrules for the costs presented in Figure 2-4 are the same as for Pilot Plant except for the following changes or additions:

1. No IDC by direction.
2. No contingency applied
3. No visibility applied to collector materials or labor
4. No state sales tax applied due to uncertainty of state and potential tax rulings
5. Special collector production overhead center
6. Minimal manufacturing support practice. No analysis except as purchased from the outside.
7. Cost reduction curve of 87% to 90% on in-plant fabrication and assembly labor hours for First Commercial Plant. Materials on a 95% curve as, appropriate, off Pilot Plant material quotes.
8. Nth Commercial labor directly manloaded. Materials assume last unit cost of First Commercial Plant or costed by unit of measure.

2.1.2.3 First Commercial Plant "As Spent" Funding. Figure 2-5 presents an indication of as spent funding requirements for the First Commercial Plant. The annualized monthly expenditure peaks out at about $107 million or a rate of slightly over $9 million/month. The maximum annual outflow is $90 million in 1989. These curves have been derived by funding at the major activity level within each subsystem using standard beta distribution curves.

Cost Variations. Variations in costs associated with different thermal capacities and with variations in annual plant installation rate have been examined from a parametric point of view. Costs have been generated showing behavior where both the solar multiple and the hours of thermal storage capacity are varied. The results are presented in Section 5 (Figure 5-2) and show MDAC's baseline at a solar multiple of 1.7 and 6 hours of storage requiring a $221.3 million investment. Also, indicated is a preliminary estimate of $189 million for a 3-hour storage capacity and a 1.4 solar multiple or a little over $32 million in cost savings.

Cost variation with plant installation frequency has also been considered for variations of two plants installed per year and eight plants installed. Results are graphed in Section 5 (Figure 5-3) and indicate a progression in



GFY	86	87	88	89	90	91	92	93
DDT&E	.0	.0	.0	.0	.0	.0	.0	.0
PRODUCTION	.2	11.5	86.2	90.2	27.7	4.5	1.0	.0
OPERATIONS	.0	.0	.0	.0	.0	.0	.0	3.0
TOTAL	.2	11.5	86.2	90.2	27.7	4.5	1.0	3.0

Figure 2-5. First Commercial Plant Funding

dollars per kilowatt from $1750/year for two plants per year down to about $1400 for eight plants per year. Results are based on cost analyst judgment about the circumstances associated with the two scenarios and the nature of their impact. The costs represent those of the 20th and 80th plants at two and eight per year, respectively, assuming that installations are known by producers in advance to continue for 20 or more years. With this basis, it has been assumed that at two plants per year, BOP costs and the costs of Receiver and Thermal Storage field effort would not be affected much by the rate of two per year because the market may be too dispersed. However, eight plants per year probably imply that several plants each year always will be under construction in the same locality with the same customer, suppliers, and contractors. This could allow a great deal of methods commonality in field installations, if so managed, and also induce significant cost reductions in BOP equipment through competition.

2.2 MAJOR PROGRAM ASSUMPTIONS AND GUIDELINES

2.2.1 Pilot Plant

The major programmatic assumptions and guidelines used in developing the preliminary cost estimates for the pilot plant are as follow:

- Plant Design Selection - October 1977
- Phase 2 ATP--January 15, 1978

  It has been assumed that all of the major hardware contractors, the balance of the plant contractor, and the construction manager for the pilot plant program will be selected by this date.
- The current MDAC team will perform the entire Pilot Plant construction

  Sandia Livermore has furnished a ground rule for the purposes of this estimate which states that it is to be assumed that the Pilot Plant will be constructed entirely by the current Phase 1 contractor teams, rather than subsystems chosen from different contractor teams.

- Detailed Design Phase

  On April 1, 1978 solar subsystem detailed design will commence and by Sandia furnished ground-rule will last no more than 6 months. System requirements and interface definition will commence at ATP and should have progressed sufficiently to define solar subsystem requirements by April 1, 1978. The system requirements analysis and definition activity would continue during the 6-month subsystem detailed design phase. The exception to the above is the collector subsystem whose detail design must be initiated 2 weeks after ATP to accommodate Sandia requested preproduction test.

- Initial Operational Capability on December 31, 1980.

  This date indicates the time at which the integrated system checkout will be completed for the pilot plant. At this time, the program would begin the 2-year test program.

- 2-Year Test Program

  The program guidelines furnished by Sandia included a 2-year operational system test program from January 1, 1981 to December 31, 1982.

- Pilot Plant Located Adjacent to an Existing Operational Facility

  This MDAC assumption provides the benefit of being able to pool resources, such as operations and maintenance personnel, between the Coolwater operational facility and pilot plant, so as to avoid burdening a small pilot plant with all of the requirements associated with being self-sufficient in a remote location.

- Free Land

  By Sandia direction it is assumed that the raw land required for siting the pilot plant will be made available by the utility, at no cost to the program.

- Water Assumed Available at Pilot Plant Boundaries

  The program cost estimates are based upon the premise that there will be no costs for providing a well at the site or transporting water. It is assumed that water is available from the existing Coolwater operating facility and need only be piped to the Pilot Plant for use in the feedwater/steam cycle.

- No Land Rights Costs Included

  The MDAC cost estimate does not include an allocation for acquiring rights-of-way for carrying the electric power from the pilot plant to the utility grid. This approach presumes that the plant output will tie into the same line used to carry output power from the existing facility to the grid.

- Assumed Pilot Plant Site - Barstow, CA

  The Sandia instructions given for the cost estimating included a directive to assume Barstow, California as the site for the pilot plant. The site is actually adjacent to the existing Coolwater facility of Southern California Edison at Daggett, California, East of Barstow.

- Electric Power Substation Costs Included

  The pilot plant cost estimates are based upon the assumption to provide all of the hardware to carry the power out through the high side of the main transformer to the 115-kV distribution grid.

- Minimum Hardware Development

  The pilot plant program schedule, as it is currently defined, is not long enough to allow any substantial development testing of the subsystem components prior to initiation of site activation efforts. Therefore, it is assumed that the program will be using hardware that has been developed and/or is available off-the-shelf, with a minimum of development testing going on during the design effort following program go-ahead.

- Minimum Off-Site Hardware Qualification Tests

  It has been assumed that there will be a minimum of off-site qualification tests for the hardware, especially for the full-size components such as thermal storage heaters, steam generators, receiver panels, etc. For these components, the establishment of facilities and equipment to duplicate the actual operating conditions would basically require the same type of capability as the pilot plant. This would be both a costly and time-consuming program approach, so it has been assumed for the present that these types of tests would be accomplished at the site prior to starting the operational test program in December of 1980. The exception to the above is a Sandia directed preproduction test of a heliostat based on production drawings but fabricated with non-rate tooling.

- Systems Integration Facility for Master Control Development at Huntington Beach

  Another exception to the above paragraph is with respect to the master control efforts. It is currently planned to do the subsystem functional interface simulation work at Huntington Beach prior to integrated system testing at the pilot plant site in order to provide sufficient lead time for developing and checking out the operational software for master control, as well as for simulating field problems in the system hardware/software interfaces. The objective here is to fully define and understand the operating requirements and subsystem to subsystem interface characteristics so as to eliminate the need for on-line software development. This will minimize the time required to install and debug the system hardware and software prior to initiating the operational testing portion of the Phase 2 pilot plant program.

- Collector Subassemblies Will be Fabricated at Huntington Beach, Final Assembly on Site

  This cost estimating effort for the pilot plant program assumes that all of the collector manufacturing operations, such as forming, drilling, machining, glass bonding, and spot welding will be accomplished in existing facilities at the McDonnell Douglas Hungtington Beach location, with the shipment of reflector segments, heliostat pedestal, etc., to the Barstow site, where final assembly of total reflective surfaces, etc. would take place in a building provided by MDAC there. Finished assemblies will then be transported to the field for installation on the foundations. Final assembly of the major electronic equipment, e.g., the field controller, will be accomplished primarily at Huntington Beach, with additional on-site effort, as required, prior to field installation and checkout.

- Receiver Panels Assembled at Canoga Park, Final Receiver Assembly Site

  Rocketdyne currently plans to do all of the tube welding operations for building the receiver panels at Canoga Park. Additionally, the manifold subassemblies will be formed, machined, and welded at existing Rocketdyne facilities in Canoga Park prior to shipping all of the hardware to the pilot plant site, where receiver final assembly and checkout will take place on top of the tower prior to starting the total system checkout.

- SCE Will be Operator During the 2-Year Test Program, MDAC Will be Responsible for Test Planning and Evaluation

  For the purposes of this cost estimating effort, it is assumed that SCE will have the primary responsibility for operating the pilot plant during the 2-year operational test program. MDAC test personnel will be heavily involved in the conduct of the test program during the first year (Research Testing) of the program, and reduced to a sustaining level during the second year. It has been assumed that SCE personnel will do all of the operations and maintenance tasks during this two-year period, with technical support provided by MDAC, Rocketdyne, and Stearns-Roger. Costs for SCE personnel have been included in this cost estimating effort. It is assumed MDAC will have primary responsibility for the preparation of the test plan, monitoring its conduct and evaluating the data.

2.2.2 Commercial Plant

The major programmatic assumptions and guidelines used in developing the preliminary cost estimates for the first and Nth commercial plants are as follows:

- Demonstration Plant Proceeds Commercial Plant

  Per Sandia direction, a 50-100 MWe demonstration plant precedes the construction and operation of the first commercial plant. This means that it has been assumed that all tooling costs, as well as other major nonrecurring costs, will be borne by the demonstration plant.

- First Commercial Plant ATP on July 1, 1986

  Assuming that the demonstration plant meets its objectives of establishing economic viability through at least 1-year on-line operation, the placement of the first commercial plant order, hence ATP, is assumed as July 1, 1986.

- Current MDAC Team Will Perform the Entire Commercial Plant Construction

  It has been assumed for this estimate that the commercial plant will be designed, fabricated, and constructed by the current MDAC team, with each contractor being responsible for the same elements as they are for the pilot plant.

- Commercial Plant Contruction Period

  Construction period encompasses the time from ATP through completion of integrated system checkout, up to Initial Operational Capability. This period is 5-1/2 years for the first commercial plant and 5 years for the Nth commercial plant. The time difference is attributable to differences in production and installation rates for the collector subsystem.

- Solar Plant Commonality

  For the Nth plant, no site specific designs have been assumed.

- No Hardware Development

  The commercial plant schedule does not include hardware development. For the first commercial plant, all hardware development has been assumed to be incorporated during or as a result of the demonstration plant program. Considering the Nth plant, any costs attributable to product improvements have been assumed to be borne by MDAC.

- No Off-Site Hardware Qualification Tests

  All off-site hardware qualification tests are assumed to have been accomplished in the demonstration plant program. Other hardware qualification tests have been assumed to take place at the site during the initial plant startup period prior to Initial Operating Capability date. The exception to the above is the off-line qualification of the master control system using the same approach as used for the pilot plant.

- Commercial Plant Sites - Barstow, California

  The Sandia instructions for the cost estimating include a directive to assume the Barstow, CA, as the region for the commercial plant sites. MDAC has further assumed for the Nth plant that there will be a concentration of solar plants within a radius of 25 miles of Barstow.

- No Land and Right Cost Included

  By inference from the Sandia supplied Cost Breakdown Structure, it has been assumed that the raw land required for siting the commercial plant(s) will be made available by the utility at no cost to the program. By the same inference the MDAC cost estimate does not include an allocation for acquiring rights-of-way for carrying electric power from the commercial plant(s) to the utility grid.

- Water Available at Site(s)

  The program cost estimates are based upon the premise that no costs will be incurred for providing or transporting water to the site.

- Electric Power Substation Costs Included

  The commercial costs estimates are based upon the assumption that the solar plant will provide all the hardware to carry the power through the high side of the main transformer to the distribution grid. Beyond that, no network integration costs are assumed.

- Collector Subassemblies for the First Commercial Plant Will Be Fabricated in Southern California With Final Assembly On Site

  The cost estimating for the first commercial plant assumes that all of the collector manufacturing operations, other than procured components indicated in the make-or-buy plan, will be accomplished at existing facilities in the Southern California area followed by shipment of the subassemblies to the Barstow site. Final assembly would take place in a building provided by MDAC there. Finished assemblies would then be transported to the field for installation. Final assembly of the major electronic equipment will also be accomplished in the Southern California area, with additional on-site effort, as required, prior to field installation and checkout.

- Collector Subassemblies for the Nth Commercial Plant Will Be Fabricated in a Separate Production Facility in Proximity to the Concentration of Solar Plants

  Cost estimates for the Nth commercial plant assumes that all collector manufacturing operations will be accomplished at a dedicated facility near the concentration of solar plants in the Barstow area. Final assembly, similar to that assumed for the pilot and first commercial plants, would take place in a building provided by MDAC at the site. Finished assemblies would then be transported to the field for installation. Costs for this separate - dedicated facility are not included in this estimate and assumed to be borne by MDAC.

  Based on a sales analysis of an assumed MDAC portion heliostat market, the separate production facility was sized to accommodate a steady state heliostat rate volume that corresponds to 60,000 heliostats/year (approximately three 100-MWe plants) which occurs 6 years after placement of the first commercial plant order. As production approaches this steady state rate, decision to build a second plant and/or incorporate vertical integration (collocation of generic material production) must be made. This Nth plant cost estimate does not assume vertical integration.

- Receiver Panels Assembled at Canoga Park, Final Receiver Assembly on Site

  Similar to pilot plant, all receiver panel and manifold production is planned to take place at the Rocketdyne facility in Canoga Park. Subassemblies will then be shipped to the commercial plant site for final assembly and checkout at the top of tower.

- MDAC Team Will Provide Plant Startup Support and Operations and Maintenance Support After Startup

  For the purposes of this cost estimate it is assumed that MDAC will be responsible for the integrated system checkout, a 6-month period, prior to plant Initial Operating Capability. MDAC has included in this cost estimate commercial plant operations and maintenance activities, although it is realized that in practice this will be the responsibility of the utility.

- Commercial Business Practices

  It has been assumed for this cost estimate that the contractor will interface directly with the utilities and hence not incur costs involved with business practices associated with the United States Government.

2.3 COSTING APPROACH

The costs presented in this report reflect a best estimate viewpoint which MDAC believes is in the spirit of the ERDA's intention to gain refined insight about potential pilot and commercial plant funding requirements. This is reflected in the manner of estimating, the amount of overall contingency applied, the cost reduction curves employed, the level of manufacturing support, productivity improvement, and in other areas. Also, although it is difficult to predict design growth, there is just as much chance for eventual design reduction as cost effectiveness studies are continued. Further, costing confidence has been enhanced by the team approach where both Rocketdyne and Stearns-Roger were funded to assist in the exercise, and by the level of detail that was approached in deriving costs.

2.3.1 Costing Methodology

Generally, costs were derived by breaking down the CBS to that level where commonality exists between required materials, parts or tasks and known quantities. Thus, it has been possible to employ experienced estimators in determining fabrication, assembly and installation hours, and to obtain vendor quotes for significant materials and parts. Nonrecurring costs were determined by assessing functional engineering and manufacturing planning tasks, specifically, identifying tooling and facility requirements, and by reducing test hardware needs to equivalent units.

Operations and maintenance costs are based on a preliminary failure rate analysis which also served as a basis for spares philosophy. The FMEAs were used to estimate repair and replacement requirements and manhours.

Also, heliostat cleaning equipment, facilities and timelines were studied in evaluation of cleaning costs. The manhours and equipment for each subsystem were integrated in arriving at a total O&M staff which could be priced. However, technical support of operations as well as systems management are estimated as a level of effort.

Common construction items, "balance of plant" spares, contingency, and fee are estimated using common factors. In the case of construction items, current industry standards have been applied.

2.3.2 Funding Methodology

Funding values were determined by distributing projected cost separately for labor and materials by major activities within the subsystem level (e.g., turbine plant, collector equipment, receiver) over the scheduled period for each phase--D&D, investment, and systems test operations, according to standard funding curves. In addition, for Pilot Plant, solar equipment has been funded at the lowest CBS level. The curves, known as Beta distributions, allow the spread to be skewed, and D&D costs generally have been skewed such that 60% of the cost is expended prior to schedule midpoint. For the most part, investment material has been treated as a normal distribution, and the labor on a 40% curve. Level of effort CBS items have been flat loaded. For committed funding, materials have been generally loaded on a 65% curve, except that special items (e.g., turbine generator) have been loaded on a 80% curve. Also, the collectors were loaded according to standard, MDAC committed funding budgeting procedures.

2.3.3 Cost Breakdown Structure (CBS)

Table 2-2 shows a summary of CBS that was followed in deriving costs. The CBS follows that requested with no exceptions, as MDAC understands the content of each category. Where no costs are shown against a CBS, it is because the costs are covered elsewhere, the category does not apply, or the cost is so small that it has rounded to zero.

Table 2-2. CBS Overview

CBS Number	Cost element
4000	Land and Rights
4100	Yard Work
4103-4180	Buildings
4190	Solar Plant Equipment
4190.1	Collector Equipment
4190.2	Receiver and Tower System
4190.21	Receiver Unit
4190.22	Steam Generator (if in loop)
4190.23-.24	Riser/Downcomer
4190.25-.26	Tower, Platform, Foundation and Site Prep.
4190.27	Design Cost
4190.3	Thermal Storage Equipment
4190.4	Thermal Storage Media
4300	Turbine Plant Equipment
4401	Electric Plant Equipment
4402	Plant Master Control
4500	Miscellaneous Plant Equipment
5309	Transmission Plant (Transformer for Commercial)
7000	Quality Assurance (Special Treatment)
8000	Distributables
8030	Contractor Field Office Personnel and Supplies
8040	Other Construction Items
8100	Indirects (A&E, Construction Management, Solar Integration Control)
8300	Contingency
8500	Escalation (exclude)
8600	Interest During Construction (exclude)
	2-Year Test Program
1000	Operations and Maintenance
2000	Test Program Technical Support
3000	Spares -- beyond startup spares

2.4 SUMMARY

Total pilot plant life cycle cost through 2-year test operations is $75.4 million with peak funding of $42 million in 1979. First Commercial costs have been estimated at $222 million with an eventual potential of $1400/ kilowatt. The programmatics have been defined to identify the major features and thus provide additional background for use in formulating the pilot plant cost estimates. The major programmatic assumptions are consistent with ERDA/Sandia plans, including that the pilot plant will be located adjacent to an existing Daggett facility. Costs were derived in a best estimate manner by MDAC, Rocketdyne and Stearns-Roger using a semi-detail pricing style approach, generally, and a detail approach for collectors. The following section provides further detail on pilot plant programmatics.

Section 3
PROGRAMMATICS

The major program characteristics that have been defined and used in determining the pilot plant and commercial plant cost estimates are presented and briefly described in this section of the documentation. The programmatics for the pilot plant include the definition of the overall pilot plant program requirements, a summary of the major features of each subsystem, the major program milestones, program schedule activities, the manufacturing approach, test program definition, and identification of major program support requirements. Similar data for the commercial plant are presented with major emphasis on commercial plant-pilot plant differences.

3.1 PILOT PLANT PROGRAM

The major goals of the Phase 2 pilot plant program are to demonstrate the technical feasibility and to obtain economic data on a central receiver solar power plant system. The primary goal will be the technical proof-of-principle, although there will also be a great deal of interest in deriving first indications of the operating economics of a solar thermal power plant. The "mission" of the pilot plant program will be to accomplish these goals during the first 2 years of operational life, followed by the generation of electric power on a "business-as-usual" basis by a utility for the remainder of a 30-year plant life, including maintenance.

The basic performance requirements for the pilot plant as stated in the Systems Requirements Specification are as follows:

> "The pilot plant shall be sized to deliver 10 MW net busbar electricity at 2 PM local sun-time on a clear day at winter solstice. The pilot plant shall be sized to allow for all system energy losses, including all thermal storage subsystem energy losses, and still deliver at least 7MWe net busbar power for a period of three hours while operating solely from the storage subsystem."

3.1.1 Pilot Plant System Features

The total system operates with water/steam as the working fluid, and is sized to generate a 10 MW net electrical power to the busbar on winter solstice at 2 PM, as indicated previously. The power generation capability when operating off of thermal storage is also indicated. As a result of the power generation sizing requirement, the land area required is approximately 90 acres. The collector field will require approximately 72 acres with the central exclusion area occupying an additional 2.8 acres, and another 5.2 acres for roads, cooling tower, switch yard, etc. An evaporation pond will require another 10 acres. As was pointed out in the programmatic assumptions and guidelines, the raw land is assumed to be available to the program at no cost, but land improvement associated with the grading, clearing, etc, will be required on the 90-acre parcel.

3.1.1.1 Collector Subsystem. The collector subsystem is comprised of a geometric array of heliostats, which are electronically controlled to continuously reflect direct solar insolation onto an elevated receiver during sunlight hours. The heliostat design incorporates a reflective surface mounted on a tracking support, which positions the reflected beam to a specified accuracy under a range of environmental conditions. The collector subsystem performs additional operational functions such as steering to specified positions for survival, maintenance, and acquisition of the sun. Specific features of the collector subsystem affecting the cost estimates are as follows:

- 1,760 heliostats
- 74 field controllers
- Second-surface mirrors
- Elevation-azimuth drive system
- Separate beam sensor and pedestal

The 1,760 heliostats are pedestal-supported on foundations in the collector field.

Each field controller is used to control 24 heliostats. The field controllers receive command positions from the master control, and they in turn provide closed-loop feedback motor drive commands to control the heliostats for positioning and tracking.

Each reflector panel is a flat structural sandwich. The front face is a 1/8-in. second surface mirror, and the back face is a 0.022-in. galvanized steel sheet. The faces are adhesively bonded to a 2-in. core, made from rigid extruded polystyrene foam (styrofoam). Each of the six panels measures 85 x 114 in. The panel edge is sealed by a polyurethane weatherseal compound.

The drive unit consists of azimuth and elevation drive mechanisms. These drive mechanisms are composed of motors, drive trains, position feedback transducers, reflector support bearings, and structural housings. The azimuth and elevation drive trains are schematically identical and each is essentially a motor with two stages of reduction.

The support structure consists of a main torque tube attached to the drive system and four channel cross beams. Each pair of cross beams supports a group of three reflector panels. Two drive attachment fittings are machined on the surfaces which mate the drive unit and are welded to the torque tube.

A tracking sensor mounted on a separate pedestal is used with each individual heliostat for the purpose of fine-tracking control of the reflected beam direction toward the receiver. It is mounted on a pedestal at the side of the heliostat nearest the receiver so that it receives the reflected beam from some part of the mirror. Its axis is oriented to intersect the aim point on the receiver.

All of the power and data cabling between the collector field and the power house is assumed to have aluminum shielding, and will be installed by direct burial in the ground, sharing common trenches as appropriate.

3.1.1.2. Master Control. The master control for the pilot plant consists of the control and display hardware and the associated software necessary for the overall control and integration of the plant. This overall control includes only those functions involved in startup, operating mode changes, system status determination, shutdown, and emergency safing. Master control allows for three basic operating modes — Automatic, manual, and a combination mode using manual control supported by computer monitoring and alarm. In the automatic mode the pilot plant system is under the control of application software in the central computer. The operator is provided with the capability to monitor the status of the pilot plant and intervene in the execution of the application software. In the manual mode, the operator has the ability to control the system by overriding the application software via discrete hardware controls and displays.

In addition to the basic operating modes, the master control computing capability will be used in a support role to process maintenance data, predict plant performance, process and compile data for reporting plant operations, compile and assemble application software and assemble system software.

3.1.1.3 Receiver Subsystem. The receiver subsystem consists of the receiver unit, the riser/downcomer assembly, the tower, and the supporting control and instrumentation equipment. The functional requirement of the receiver subsystem is to intercept the reflected solar energy from the collector field, and to transport the energy in the form of steam to the turbine generator or thermal storage subsystem for real-time or deferred-power generation. The receiver subsystem also transports conditioned feedwater to the top of the tower to sustain the continuous operation of the subsystem. The major features defined for the receiver subsystem are as follows:

- 24-panel external receiver assembly using Incoloy 800
- 213-ft free-standing steel tower
- Single riser, 4-in. diameter, low carbon steel
- Single downcomer, 6-in. diameter, low chrome-moly steel

The receiver unit is comprised of the following subassembles--panels, flow control, instrumentation and control, and structure. The panel subassembly includes the tubes, insulation, thermal expansion provisions, backup structure, and manifolds. The panels are required to receive water from the flow distribution system at a design inlet pressure and temperature of 13.8 MN/m^2 (2,000 psia) and 211°C (411°F), respectively; and to convert the water to steam at a design outlet pressure and temperature of 10.4 MN/m^2 (1,515 psia) and 349°C (660°F) or 516°C (960°F), respectively, depending upon whether the receiver is putting out derated or rated steam. The panels must absorb the incident radiation at a maximum flux of 0.3 MN/m^2 (0.18 Btu/in^2-sec) efficiently and protect the structure and components within the cylinder defined by the 24 panels. Each of the 24-panel assemblies contains Incoloy 800 tubing with a 12.5 (0.5 in) OD, and a 6.8 mm (0.259 in) ID. Each of the panels contains 70 tubes, which are welded together over the entire length of the panel assembly.

The structural steel tower used in the pilot plant receiver design has a height of 65 m (213 ft) to the receiver support. It is comprised of square cross-section, K-braced frames which are supported on a square concrete footing. The width of the tower at the top is 4.6 m (15 ft) while the base dimension is 12.2 m (40 ft). The square concrete foundation is comprised of a 0.61 m (2 ft) thick mat which is 15.24 m (50 ft) on a side and located 3.9 m (13 ft) below finished grade. Concrete walls and pedestal extend 5.48 m (18 ft) upward from the foundation to meet the steel structure at an elevation 1.52 m (5 ft) above the grade.

The riser design for the pilot plant consists of a nominal 10.16 cm (4 in) diameter pipe with a nominal wall thickness of 1.35 cm (0.531 in), made of ASTM A106B carbon steel. It is designed for a maximum allowable working pressure (ANSI B31.1) of 19.9 MN/m^2 (2,890 psia) at 232°C (450°F) and a flow rate of 16.5 Kg/sec (130,500 lbs/hr).

The downcomer design for the pilot plant consists of a nominal 14.70-cm (6-in) diameter pipe with a nominal wall thickness of 1.82 cm (0.718 in), made of ASTM A335 P22 2-1/4 Cr - 1 Mo alloy. It is designed for a working pressure (ANSI B31.1) of 11.8 MN/m^2 (1,715 psia) at 538°C (1,000°F) and a flow rate of 16.5 kg/sec (130,500 lb/hr).

3.1.1.4 Thermal Storage Subsystem. The thermal storage subsystem "buffers" the electric power generation subsystem from short-term variations in solar insolation and extends the system's generating capacity into periods with low or no insolation. The major features of the thermal storage subsystem definition used for the pilot plant cost estimate are as follows:

- Dual medium (Caloria HT 43 + granite)
- Single thermal storage unit
- Two identical U-tube condensing heat exchangers (thermal storage heaters) in parallel
- Two steam generator modules in parallel
- 103.8 MWHth capacity

The thermal storage subsystem for the 10 MWe pilot plant employs sensible heat storage using dual liquid and solid media for the heat storage in a single tank; that is, storage unit, with the thermocline principle applied to provide high-temperature, extractable energy independent of the total energy stored. The subsystem has three major parts— (1) the central thermal storage unit, mentioned previously; (2) the thermal charging loop; and (3) the heat extraction loop.

The thermal storage unit includes a cylindrical tank, with vertical axis, installed above ground. The tank is 15.25-m (50.0-ft) in diameter by 13.4-m (44.0-ft) high, with a volume of 2,450 m^3 (86,400 ft^3), 646,000 gal. The tank contains 4.53 x 10^6 kg (4,990 ton) of crushed granite rock and coarse silica sand (approximately 2:1 rock: sand by volume) and 525,000 liters (139,000 gal) of Caloria HT 43 heat transfer fluid. The fluid temperature range is from 218 to 302°C (425 to 575°F). The tank is fabricated of ASTM A537 - 70 Grade B structural steel by field-welded construction.

Fluid maintenance for the thermal storage unit is accomplished by filtration to remove suspended solids, distillation of a side stream to remove high boiling compounds, and addition of fresh makeup fluid to replace the material removed.

Ullage maintenance for the thermal storage unit is accomplished by using compressed nitrogen gas stored at 1.20 MN/m^2 (175 psig). The ullage maintenance unit provides tank pressure control, venting, inert gas (nitrogen) control, and volatile vapor recovery and control.

Two thermal storage heaters are used. Each is a U-tube, baffled counter-flow heat exchanger, with a two-pass shell and 464 m^2 (5,000 ft^2) total heat transfer area. The design uses carbon steel for the shell, tubes, and tube sheet.

Two steam generators in parallel are used for the pilot plant TSS design. These are three-stage (series) modules each with separate feedwater pre-heater, boiler, and superheater with 196 m^2 (5,000 ft^2) total heat transfer area per changer. The design uses carbon steel for the shell, tubes, and tube sheet.

3.1.1.5 Electric Power Generation Subsystem. The baseline electric power generation subsystem selected for the pilot plant consists of a nominal 12.5 MWe (gross) single automatic admission tandem compound single-flow turbine-generator using a shell and tube water-cooled condenser for heat rejection. The subsystem will produce 11.2 MWe gross, 10 MWe net electric power at the winter solstice, 2 PM design point, and will produce 12.5 MWe gross, 11.1 MWe net at the summer solstice, 12 PM condition.

Additionally, the subsystem will produce 7.8 MWe gross, 7 MWe net electric power while operating solely from thermal storage. All of the power will be produced at an output voltage of 13,800 and a nominal output frequency of 60 Hz.

The turbine is a single automatic emission tandem compound single-flow non-reheat, condensing machine using four-point extraction for two high-pressure feedwater heaters, a deaerator heater, and a low-pressure feed-water heater. Inlet steam conditions while operating off the receiver are 10.1 MPa (1,465 psia), 510°C (950°F), and while operating off thermal storage they are 2.65 MPa (385 psia), 275°C (525°F). Approximate throttle flows are 14.7 kg/sec (116,500 lb/hr) at 2.5 in Hg absolute for the summer noon condition, and 12.9 kg/sec (102,400 lb/hr) at 2.5 in Hg absolute for the 2 PM, winter solstice design point. Nominal design exhaust conditions for the turbine are 8.46 KPa (2.5 in Hg absolute) and 42.8°C (109°F). Nominal shaft speed for the turbine-generator is 3,600 rpm.

The generator chosen for the pilot plant design requires a rated power output capability of 12.5 MWe, based upon a KVA rating of 16,000 and an 0.85 power factor. The generator is air-cooled, uses oil with pump circulation for bearing lubrication, and features a static excitation system.

The pilot plant condenser design chosen is a shell-and-tube, two-pass water-cooled configuration. The cooling surfaces are 90-10 copper-nickel tubes. Cooling water flow required is 0.725 m^3/s (11,500 gpm). The condensing pressure at which the hardware is designed to operate is 8.46 KPa (2.5 in Hg absolute). Condensing temperature is 42.8°C (109°F). The design water temperature chosen for the condenser was 29.4°C (85°F) inlet and 38.2°C (100.7°F) outlet. The design heat rejection capability of the water-cooled condenser is 90 $\times 10^6$ Btu/hr when operating at the 8.46 KPa (2.5 in Hg absolute) condensing pressure, and while producing 12.5 MWe gross electric power. Air removal is accomplished with a mechanical vacuum pump.

The feedwater heaters consist of one low-pressure heater using stainless steel tubes and a carbon steel shell, one direct contact deaerating heater with stainless steel trays and vent condensing sections and a carbon steel shell, and two high pressure feedwater heaters using carbon steel tubes, carbon shell and drain cooler.

Pilot plant system heat rejection is accomplished through a two-cell, mechanical draft, cross-flow cooling tower which is sized to handle a heat rejection load of 100 GJ/hr (95.0 x 10^6 Btu/hr), going through a 7.8°C (14.0°F) range between 29.4°C (85°F) and 37.2°C (99°F).

The feedwater treatment equipment design includes the use of demineralized makeup water, with the system designed to process approximately 0.15%

of design steam flow during normal operation and a maximum capability of approximately 22% of design steam flow. In-line full-capacity demineralizers are used, with purity levels controller to 20-50 ppb dissolved solids; the pH is maintained at 9.5 tomeet receiver requirements. Treatment chemicals include ammonia for pH control and hydrazine for oxygen scavenging.

The receiver feed pumps take suction from the electric power generation subsystem booster pump and supply feedwater at a controlled pressure to the receiver. Two full-capacity, electric motor-driven, variable-speed receiver feed pumps have been selected to meet this requirement for the pilot plant. The horsepower requirements range from 344 (winter solstice) to 396 horsepower (summer solstice).

3.1.2 Program Milestones

The major milestones used for the cost estimating effort are shown in Figure 3-1. Contract go-aheads for the subsystem contractors, A&E, and solar subsystem integration contractor are assumed to be given by 15 January 1978.

Following the on-site construction and equipment installation activities, checkout of individual subsystems will take place. This type of effort will include acceptance testing of individual hardware elements that had not been acceptance tested prior to arrival on site. At the point in time where the subsystem testing has been accomplished, a major milestone has been identified for initiating checkout of the total system operating as an integrated unit in July 1980.

Following 6 months of integrated system checkout, during which time items such as startup procedures have been developed and the total system and subsystems have been debugged, a major milestone for initiation of a 2-year operational test program has been identified. The December 31, 1980 date represents a 36-month program from ATP to initial operational capability. A 2-year operations test program following the development effort makes the total pilot plant program a 60-month effort.

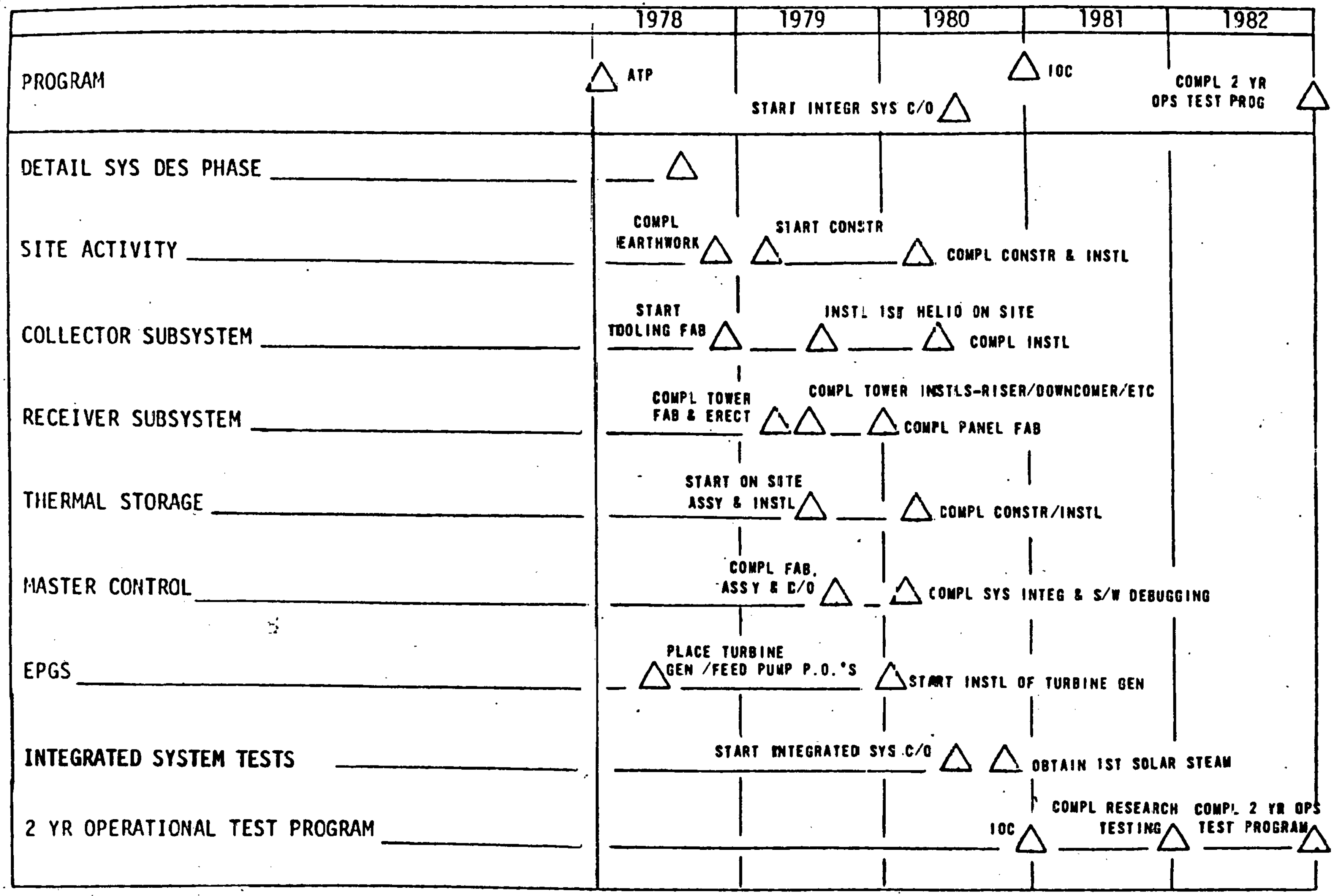


Figure 3-1. Major Pilot Plant Milestones

3.1.3 Program Schedules

The Pilot Plant Program Schedule Summary is shown in Figures 3-2 and 3-3. The schedule activities have been shaped to fit within the major program milestones outlined and discussed in Section 3.1.2.

The A&E design effort, as currently defined, will span a total of 20 months following contract award. Approximately 6 months from ATP, the initial earth-work at the site will commence with the clearing and rough grading of the field. Within 2 weeks following initial earth-work activities, the assembling of temporary buildings tofacilitate construction and pouring of foundations for permanent structures will commence. Installation of initial utilities for use in construction will also be started at that time. All of these activities are critical from a scheduling standpoint since they will pace the timing of subsystem final assembly and installation activities on the site during 1979. A slip of schedule on initial earth-work and construction activities will cascade into program slippage that will be extremely difficult to make up.

For the electric power generation subsystem, the pacing schedule item will be the turbine-generator set. In order to meet the July 1980 initial system checkout milestone, we feel the procurement activities will have to be initiated in January 1978. Allowing 2 months for specification preparation, another month for bid solicitation and vendor response, and a fourth month for proposal evaluation and negotiation, the purchase order should be placed in May 1978. The lead time from placement of the purchase order to hardware delivery on site is approximately 21 months, based upon 2 months for drawing release and 19 months for hardware fabrication and assembly. These time spans have been derived from Stearns-Roger past experience and direct discussions between turbine manufacturers and Stearns-Roger on this particular subject. Following a January 1980 delivery to the site, approximately 5 months are allowed for hardware installation and checkout.

The electrical switchgear and auxiliary equipment will not pose a schedule problem for the program. The receiver feed pump, because of the large size and unique requirements (variable-speed, low flow rate, large

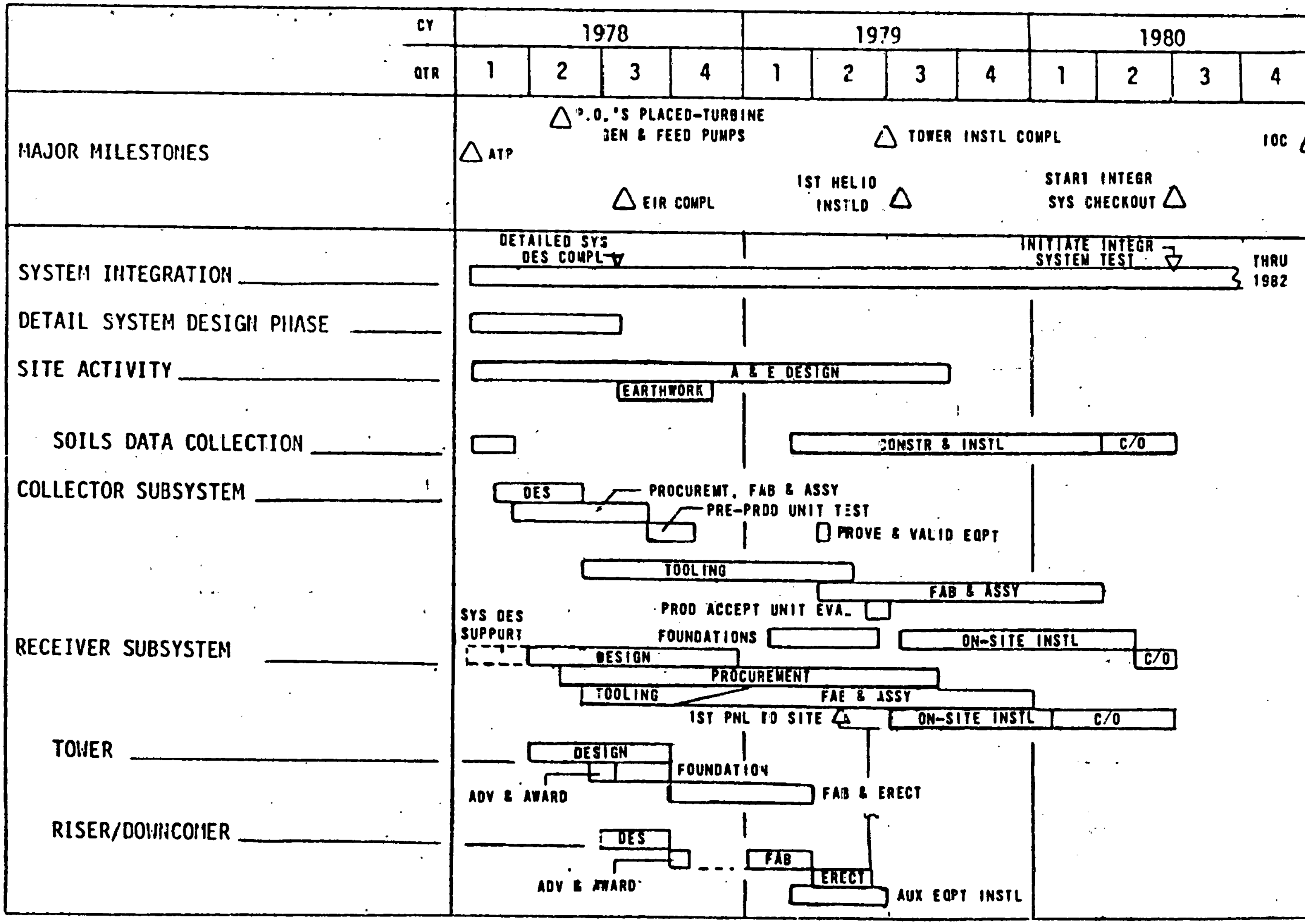


Figure 3-2. Master Program Phasing Schedule - Pilot Plant

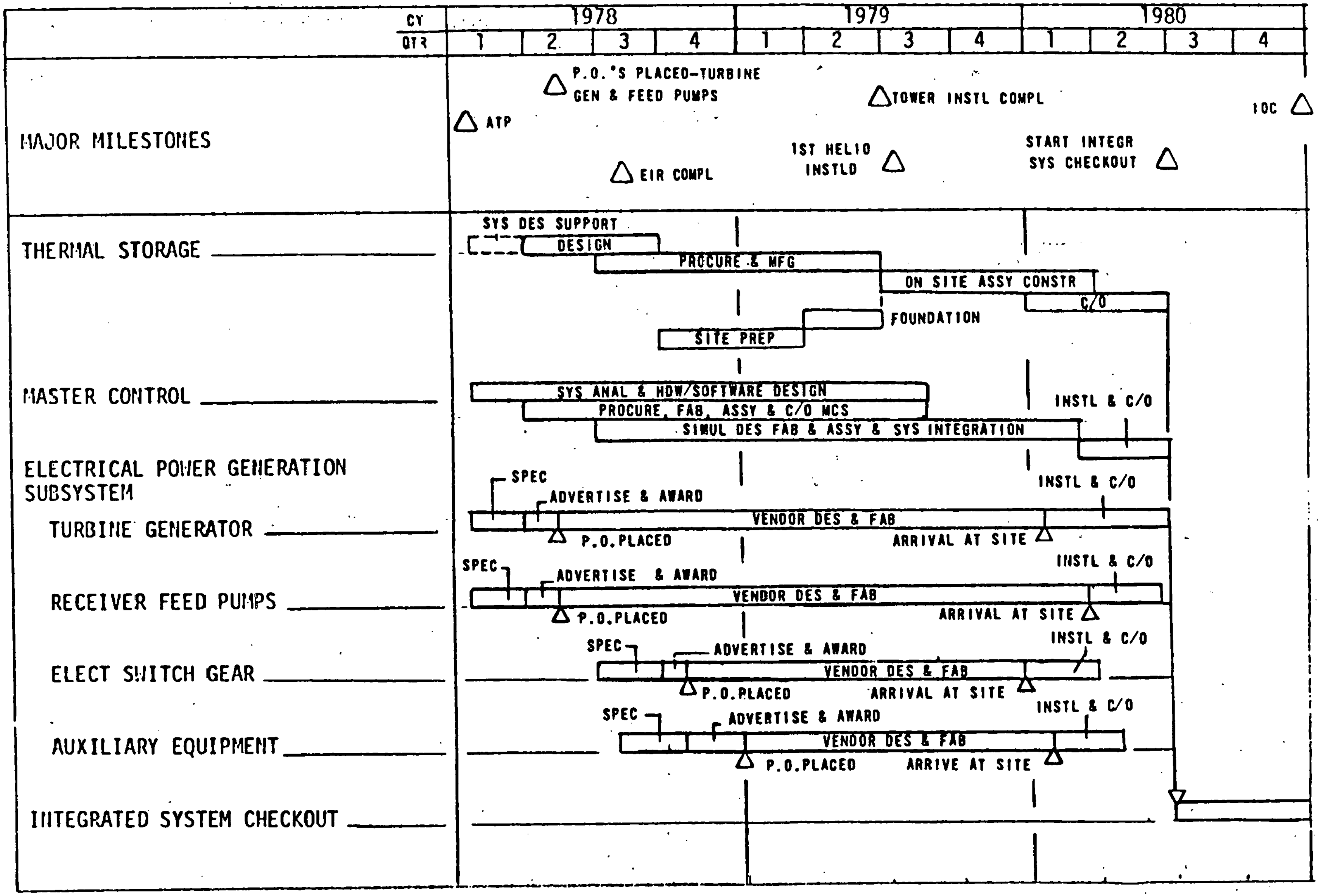


Figure 3-3. Master Program Phasing Schedule - Pilot Plant

developed head), has a nominal lead time of 22months from receipt of purchase order to on site delivery of the hardware. As in the case of the turbine-generator, initiation of procurement activities will have to occur in January 1978 in order to be able to meet the availability requirements on a timely basis.

For the receiver subsystem, completion of the tower construction will be a pacing item in accomplishing all of the subsystem checkout activities prior to July 1980. The steel tower can be fabricated and erected in a total of 6 months, but it cannot be started until the grading has been completed and the tower foundations are formed, poured, and cured.

Fabrication and assembly of the 24 panels for the receiver assembly in 15 months could be a schedule problem, depending upon the amount of elapsed time between completion of the first panel, including testing, and initiation of fabrication activities for the remainder of the panels. Additionally, the schedule for installation and checkout of the receiver on top of the tower is critical. A delay in completion of these activities will delay the initial system checkout effort also, since the receiver is required in order to generate steam for checkout and shake-down operations for other system elements.

At present there are no schedule problems envisioned for the thermal storage subsystem, because all of the purchased parts that have been defined have reasonable lead times, and on-site construction/installation activities should be completed without difficulty.

The schedule for master control shows considerable overlap of hardware/ software design, fabrication, and system integration activities prior to removal of the master control unit from the System Integration Laboratory at Huntington Beach for shipment and installation at the field-site during March 1980. This schedule must be maintained to meet the July 1980 start date for initiating the integrated system tests.

The collector subsystem schedule shown has been constrained to a four month engineering design effort. This has been done to provide early release of the production drawings and timely production of heliostats to avoid excessive production rates and still make all of the hardware on a schedule which will allow on-site installation and checkout of the entire collector field prior to the July 1980 start of integrated system testing.

3.1.4 Manufacturing Considerations

The collector subsystem manufacturing approach has the largest ramifications to program cost because of the quantity and rate of production required. The assumptions used for doing the cost estimating consider that all of the glass bonding, metal forming and machining operations to fabricate heliostat subassemblies are performed at MDAC Huntington Beach. These subassemblies, such as pedestals, reflector panels, and beam sensor poles, would then be shipped to the pilot plant site for final assembly and installation.

All absorber panels of the receiver subsystems will be fabricated at the Rocketdyne Canoga Park facility and then shipped to the pilot plant site for receiver unit final assembly and integration with the tower. All other piping and related components will be delivered directly to the field-site for installation.

The elements of the thermal storage subsystem and the balance of plant hardware will be a combination of purchased units which are installed on site and other elements, such as the thermal storage unit tank, which are fabricated on site; therefore, no off-site manufacturing requirements, such as special tooling, have been included, except as reflected in the prices of the purchased units.

3.1.5 Test Program Definition

The pilot plant test program objectives are listed in Table 3-1.

There will be minimal hardware development testing during the pilot plant program. The principal activities will be connected with software development for master control and other subsysteminterfaces. As the system hardware is installed at the field site, subsystem checkout will be performed to verify specification conformance prior to the initiation of the integrated system checkout.

Table 3-1. Pilot Plant Test Program Objectives

Overall	
•	Demonstrate the viability of the central receiver concept for generation of electric power from solar energy
Specific	
•	Demonstrate reliable operation of all subsystems and the total system
•	Verify compatibility of the energy plant with the balance of plant hardware
•	Demonstrate computer control of central power station operations using solar energy
•	Demonstrate pilot plant operation in each of the defined operating modes
•	Verify the physical and functional interfaces between each of the subsystems
•	Demonstrate the adequacy of pilot plant maintenance concepts

During the time period between 1 July and 31 December 1980, integrated system checkout and initial plant shakedown tests will be performed. Initial plant tests will involve operation of the collector field, receiver, thermal storage, and master control to generate steam and checkout the receiver and thermal storage stability and control, as well as the interface between master control and the three subsystems.

Following successful demonstration of the thermal storage charging and discharging modes of operation, the electrical power generating system (EPGS) will be operated from thermal storage steam to insure the proper operation of the feedwater heaters, turbine, generator, and controls while being provided a constant quality and quantity of steam.

Following successful demonstration of the proper operation of the EPGS hardware, the next step will be to demonstrate the startup, steady-state operation, and shutdown of the EPGS while using steam generated by the receiver directly. The master control interface with the collector field, receiver, and EPGS will also be exercised at this time. In all cases where the EPGS is being operated, it is envisioned that it is connected to the electrical network, such that all electrical power output will be utilized.

The objectives of the two-year operational test program, as currently envisioned, will be to demonstrate the technical proof-of-concept for the Central Receiver Solar Thermal Power System, to gather data on operating concepts and maintenance requirements, and to derive some indicators as to the economic viability of the concept. During this period, the system will be operated in the research test mode for 1 year and the power production mode for 1 year. The system will be started up, operated with receiver steam to generate power and charge thermal storage, and operated from thermal storage on a daily basis throughout the seasons, with the output power being integrated into a utility network. The 2-year time period will allow the system to be operated through two sets of seasons, thus providing opportunities to encounter all of the variations in the incident flux that would occur over the course of a year, including passing clouds, overcast days, sun showers, high winds, etc. Critical maintenance data will also be derived. Additionally, there will be two indicators on the quantities of annual power that could be derived from a solar plant of this size. Southern California Edison operating personnel will also have become sufficiently familiar with all of the system and subsystem characteristics during the 2-year test program to be able to take over the plant operation totally upon completion of the test program and operate it on a "business-as-usual" basis for the remainder of its plant life.

3.1.6 Program Support Requirements

As a result of the analysis made to date of the pilot plant test and operations program, a preliminary listing of support requirements, in terms of hardware and facilities, has been defined. This list is, of course, incomplete at this stage of the program and primarily consists of those items having an impact on the program costs.

For the collector subsystem, two complete test units plus extra reflective surfaces, motors, and drives will be required for the qualification and acceptance test programs. Installation and checkout equipment will include such items as handling fixtures and slings, workstands, leveling fixtures, wrenches, voltmeters, ohmmeters, forklift, pickup truck, mobile cranc, communication sets, inclinometers, theodelites, mobile test set, and refector washing equipment.

For the receiver, thermal storage, and electrical power generation subsystems, support hardware will include portable test sets associated installation and checkout equipment such as handling fixtures and slings, workstands, meters, cranes, etc.

A facility for master control hardware and software development, integrations, and checkout at MDAC Huntington Beach will be required.

3.2 COMMERCIAL PLANT PROGRAM

The overall design guidelines for the commercial plant are (1) the system shall be centered around established water-steam turbine equipment and (2) the system shall derive its power for turbine operation exclusively from collected solar energy. These guidelines rule out the design of a hybrid system in which a solar receiver and a fossil-fueled boiler are operated in a parallel or series-parallel configuration. As a result, a thermal storage subsystem must be included in the design to absorb the operational transients in available power and provide extended generating capacity during periods when the Sun is not available.

Specific performance requirements for the MDAC commercial system are as follows:

Design Point Power Level	
From Receiver	100 MWe Net
From Thermal Storage	70 MWe Net
Solar Multiple	1.7
Hours of Storage	6
Plant Availability (Exclusive of sunshine)	90%
Operational Lifetime (With normal maintenance)	30 years

3.2.1 Commercial Plant System Features

The total system operates with water/steam as the working fluid, and is sized to generate 100 MW net electrical power to the busbar as stated previously. The power generation capability when operating off of thermal storage is also as shown above. As a result of the power generation sizing requirement, the total fenced land area requirement is approximately 950 acres.

3.2.1.1 Collector Subsystem. The features of the collector subsystems for the commercial plant are the same as those for the pilot plant with the exception of the quantity of heliostats and field controllers required. These numbers for the commercial plant are:

Heliostats	23,414
Field Controllers	976

3.2.1.2 Master Control. Master control architecture for the pilot plant is modular in design thus permitting growth to meet the expanded 100 MWe commercial plant requirements. Operational characteristics and features remain the same.

3.2.1.3 Receiver Subsystem. The major features defined for the commercial receiver subsystem are as follows:

- 24-panel external receiver assembly using Incoloy 800
- 794-ft concrete tower
- Single riser, 12-in. diameter, low carbon steel
- Single downcomer, 18-in. diameter, low chrome - moly steel

The receiver panels are required to receive water from the flow distribution systems at a design inlet pressure and temperature of 15.5 MN/m^2 (2,200 psia) and 218°C (425°F) and to convert the water to steam at a design outlet pressure and temperature of 11.1 MPa (1,615 psia) and 368°C (694°F) or 516°C (960°F). The panels must absorb the incident radiation at a maximum flux of 0.85 MW/m^2 (0.50 (Btu/in^2-sec) efficiently and protect the structure and components within the cylinder defined by the 24 panels. Each of the 24 panel assemblies contains Incoloy 800 tubing with a 12.5 mm (0.5 in) OD and a 6.8 mm (0.269 in) ID. Each of the panels contains 170 tubes which are welded together over the entire length of the panel assembly.

The concrete tower proposed for the commercial plant receiver design has a height of 242 m (794 ft) to the receiver support. It is comprised of minimum 4,000-psi concrete, reinforced and supported on an annular concrete foundation. The width of the tower at the top is 15.32 m (50.25 ft) while the base dimension where it connects to the foundation is 45.72 m (150 ft). The annular concrete foundation is comprised of a 3.81 m (12.5 ft) thick mat which has a maximum diameter of 30.96 m (200 ft), with an inner diameter of 30.49 m (100 ft). The top of the foundation is located 4.88 m (16 ft) below finished grade.

The riser design for the pilot plant consists of a nominal 30.48 cm (12 in) diameter schedule 160 pipe with a nominal wall thickness of 3.33 cm (1.312 in), made of ASTM A106C carbon steel. It is designed for a working pressure (ANSI B31.1) of 22.55 MPa (3,270 psia) at 232°C (450°F) and a flow rate of 211.2 kg/sec (1.673×10^6 lb/hr).

The downcomer design for the pilot plant consists of a nominal 45.72 cm (18 in) diameter schedule 160 pipe with a nominal wall thickness of 3.57 cm (1.781 in), made of ASTM A335 P22 2-1/4 Cr - 1 Mo alloy. It is designed for a working pressure (ANSI B31.1) of 12.24 MPa (1,775 psia) at 537.8°C (1,000°F) and a flow rate of 211.2 kg/sec (1.673×10^6 lb/hr).

3.2.1.4 Thermal Storage Subsystem. The major features of the thermal storage subsystem definition used for the commercial plant cost estimate are:

- Dual medium (Caloria HT 43 + granite)
- Four thermal storage units
- Five identical U-tube heat exchangers (thermal storage heaters)
- Five steam generator modules in parallel
- 1,857 MWHth capacity

The thermal storage tanks are 27.6 m (90.5 ft) in diameter by 18.3 m (60 ft) high, with a volume of 10,900 m^3 (386,000 ft^3, 2,890,000 gal). The tank contains 20.3×10^6 kg (22,300 ton) of crushed granite rock and coarse silica sand (approximately 2:1 rock: sand by volume) and 2.2×10^6 liters

(583,000 gal) of Caloria HT 43 heat transfer fluid. The fluid temperature range is from 232 to 316°C (450 to 600°F). The tank is fabricated of ASTM A537-70 Grade B structural steel by field-welded construction.

Fluid maintenance for the thermal storage unit is accomplished by filtration to remove suspended solids, distillation of a side stream to remove high boiling compounds, and addition of fresh makeup fluid to replace the material removed.

Ullage maintenance for the thermal storage units is accomplished by using compressed nitrogen gas stored at 1.20 MN/m^2 (175 psig). The ullage maintenance unit provides tank pressure control, venting, inert gas (nitrogen) control, and volatile vapor recovery and control.

Five thermal storage heaters are used. Each is a U-tube, baffled counterflow heat exchanger, with a two-pass shell and 1,672 m^2 (18,000 ft^2) total heat transfer area. The design uses carbon steel for the shell, tubes, and tube sheet.

Five steam generators are used in parallel for the current commercial plant TSS design. These are three-stage (series modules) each with separate feedwater preheater, boiler and superheater with 435 m^2 (4,684 ft^2) total heat transfer area. The design uses carbon steel for the shell, tubes, and tube sheet.

3.2.1.5 Electric Power Generation Subsystem. The baseline electric power generation subsystem selected for the commercial plant consists of a nominal 112 MWe (gross) single automatic admission tandem compound, double flow turbine using a shell-and-tube, water-cooled condenser, coupled with wet cooling towers for heat rejection. The subsystem will produce 112 MWe gross, 100 MWe net electric power at equinox noon. Additionally, the subsystem will produce 76.1 MWe gross, 70 MWe net electric power while operating solely from thermal storage. All of the power will be produced at an output voltage of 13,800 and a nominal output frequency of 60 Hz.

The turbine is a single automatic admission, tandem compound double flow condensing machine using five-point extraction for three high-pressure feedwater heaters, a deaerator heater, and a low-pressure feedwater heater. Inlet steam conditions while operating off the receiver are 10.1 MPa (1,465 psia), 510°C (950°F). Approximate throttle flows are 121.1 kg/sec (959,000 lb/hr) at 2.5 in Hg absolute for the summer noon condition, and 114.3 kg/sec (905,600 lb/hr) at 2.5 in Hg absolute for the nighttime operation. Nominal design exhaust conditions for the turbine are 8.46 KPa (2.5 in Hg absolute) and 43°C (109°F). Nominal shaft speed for the turbine-generator is 3,600 rpm.

The generator chosen for the commercial design has a nominal power output capability of 112 MWe, based upon a KVA rating of 130,000 and a 0.90 power factor. The generator is hydrogen-cooled, uses oil with pump circulation for bearing lubrication, and features a static excitation system.

The commercial plant condenser design chosen is a shell and tube, two-pass design. The cooling surfaces are 90-10 copper-nickel tubes. Cooling water flow rate required is 7.1 m^3/sec (112,100 gpm). The condensing pressure at which the hardware is designed to operate is 8.46 kPa (2.5 in Hg absolute). Condensing temperature is 43°C (109°F). The design cooling water temperature chosen for the condenser was 31.1°C (88°F) inlet and 40°C (102°F) outlet. The design heat rejection capability of the water-cooled condenser is 785 x 10^6 Btu/hr when operating at the 8.46 kPa (2.5 in Hg absolute) condensing pressure, and while producing 112 MWe gross electric power. Air removal is accomplished with a mechanical vacuum pump.

The feedwater heaters consist of one low-pressure heater using stainless steel tubes and a carbon steel shell, one direct contact deaerating heater with stainless steel trays and vent condensing sections and a carbon steel shell, and three high-pressure feedwater heaters using carbon steel tubes and shell.

The feedwater treatment equipment design includes the use of demineralized makeup water, with the system designed to process approximately 0.15%

of design steam flow during normal operation and a maximum capability of approximately 3% of design steam flow. In-line full-capacity polishing demineralizers are used, with purity levels controlled to 20-50 ppb dissolved solids; the pH is maintained at 9.5 to meet receiver requirements. Treatment chemicals include ammonia for pH control and hydrazine for oxygen scavenging.

Three half-capacity, electric-motor-drive, variable-speed receiver feed pumps have been selected to supply feedwater at a controlled pressure to the receiver.

3.2.2 Program Data

Master program phasing schedule for the first commercial plant is presented in Figures 3-4 and 3-5. Based on a commercial plant program ATP of July 1986, program milestones are as follows:

System Design Complete - January 1987
First Heliostat Installed - July 1988
Initial Plant Startup - July 1991
Commercial Plant IOC - January 1992

Due to the similarity in the design and performance concepts of the pilot plant and commercial plant hardware and software, overall manufacturing, test, and support approaches are the same for the two programs. These approaches, in essence, require the performance of all major assembly, installation, checkout, and test activities at the field site.

Of the components of the Central Receiver Solar Energy System, the heliostats present the greatest opportunity for cost reduction through the application of mass production methods. Other elements, such as the receiver and master control, require a lesser quantity of hardware and will not require high rate production techniques.

The commercial manufacturing plant for the heliostats will require an area 900 by 500 ft, providing 450,000 ft^2 of manufacturing and storage area. Eight separate sections are located within this area as follows:

- Support component fabrication area

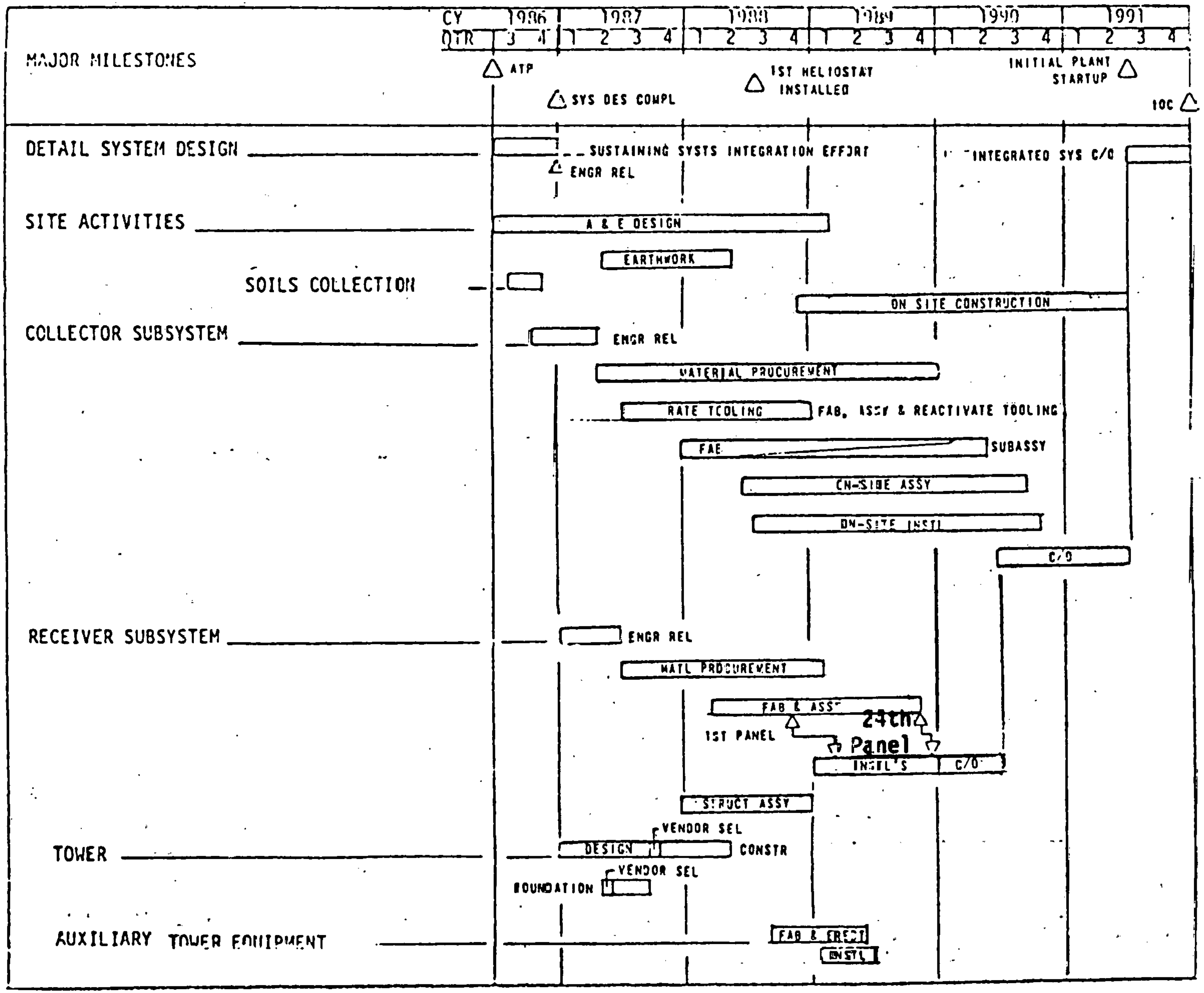


Figure 3-4. Master Program Phasing Schedule - First Commercial Plant

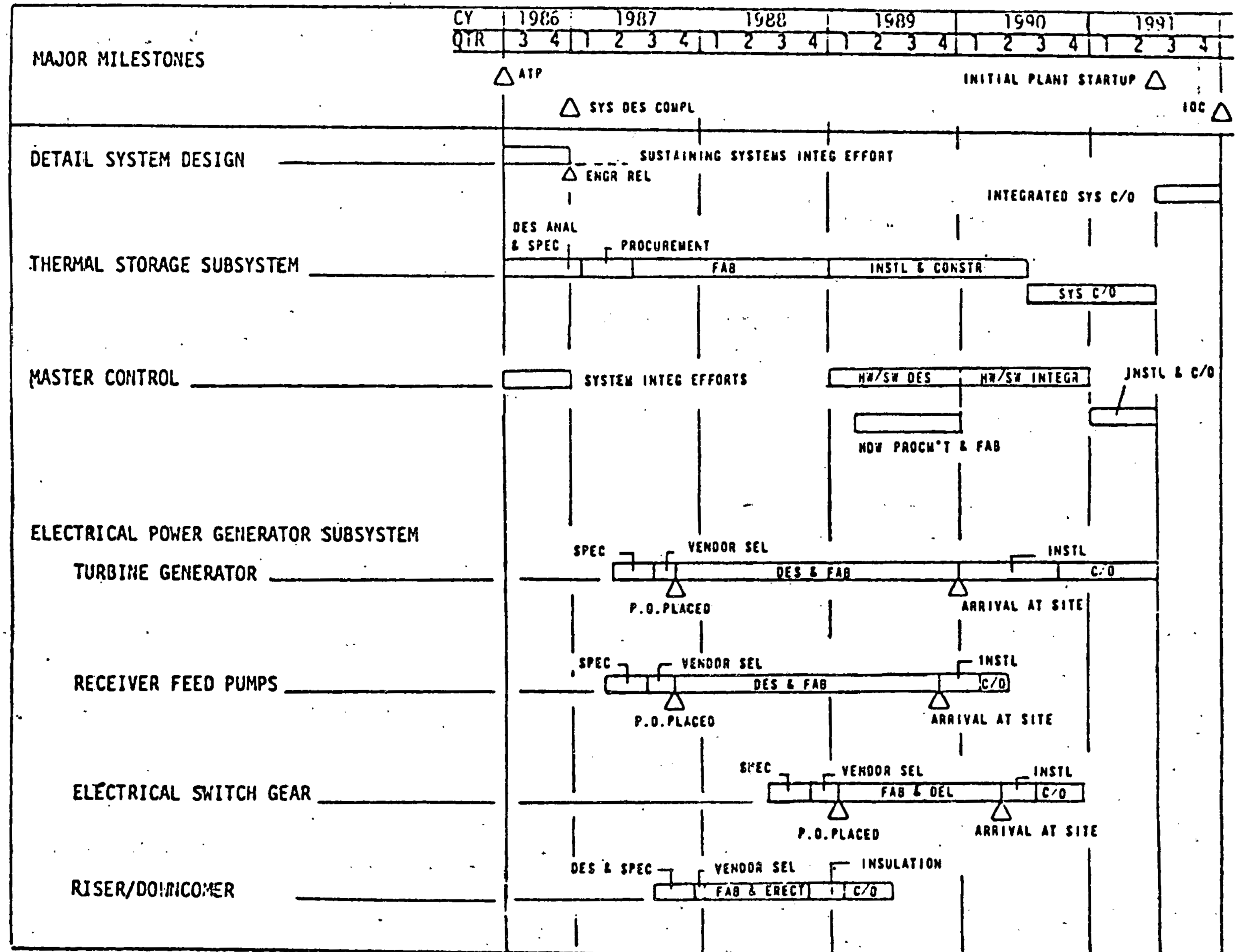


Figure 3-5. Master Program Phasing Schedule - First Commercial Plant

- Finishing process line
- Support component assembly and shipping area
- Reflective assembly area
- Component machining area
- Drive assembly area
- Electrical assembly and test area
- Storage and rework area

The overall plant is sized for a steady-state capacity of 60,000 heliostats per year. It is designed to simultaneously supply a minimum of four site assembly plants. Each site plant measures 240 by 320 ft or a total of 76,800 ft^2. The nominal assembly capacity of each site plant is 60 heliostat units per day. These plants will be located adjacent to the installation site to reduce the final transport requirements for the fully assembled heliostats.

Section 4

PILOT PLANT COSTING DETAIL, METHODOLOGY AND RATIONALE

This section presents additional detail about Pilot Plant costs and funding along with specific methodology and rationale. The section is organized by CBS or CBS groupings beginning with Total Pilot Plant costs. Each subsection indicates the scope of work, contains a cost breakdown, semi-annual "as-spent" and commitment funding and schedule plots, and a description that indicates the basis of costing, including a brief technical description. Due to the large dollar value of the collector equipment, a more detailed scope of work is provided for that subsystem.

4.1 TOTAL CENTRAL RECEIVER PILOT PLANT COSTS (DP1000)

This element includes all elements that comprise a central receiver power plant. It includes all subsystems that directly make the power plant operable including turbine plant equipment, electric plant equipment, miscellaneous plant equipment, collector equipment, receiver equipment, thermal storage equipment and thermal storage materials. Also included are land, structures and facilities, spare parts, contingency, distributables and indirect costs. The costs charged to this element are to provide for the labor, material and equipment required to design, fabricate, deliver, assemble, install, align, activate checkout, and support acceptance and two years systems operations testing, as appropriate, for all of the subsystems listed above. Also included is preparation of all installation, maintenance, and operating instructions.

4.1.1 Cost Summary

Summary Pilot Plant costs are shown in Table 4-1. The Solar Plant Equipment are, by far, the largest costs and include the costs of the Collector, Receiver and Tower, Thermal Storage Equipment, and the Thermal Storage Medium. Quality Assurance costs are allocated within the other costs. Distributable costs cover only those areas in support of the Balance of Plant except that initial Solar Plant Equipment spares are included. Burden type costs for the Solar Plant Equipment are covered in the individual contractor's overhead rates. Also, no state sales tax has been included in

Table 4-1. Total Pilot Plant Costs

SOLAR ELEC PILOT PLANT 10.10.11. DATE: 77/06/25.

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
1000	OPER. & MAINT.	0.00	.07	1.98	2.05	2.05
2000	TEST PROG TECH SU	0.00	.00	1.52	1.52	1.52
3000	SPARE PARTS	0.00	.35	.29	.64	.64
4000	LAND-LAND RIGHTS	.00	0.00	0.00	0.00	.00
4100	YARD WORK	.00	.58	.07	.65	.65
4103	TURBINE BLDG.	0.00	.68	.51	1.19	1.19
4105	ADMIN. BLDG.	0.00	.25	.19	.43	.43
4106	CIR.-SER.WATER P.	0.00	.00	.00	.01	.01
4108	WAREHOUSE	0.00	.31	.23	.54	.54
4141	MAINTENANCE BLDG.	0.00	.03	.02	.06	.06
4142	WATER TREAT.EQ.BL	0.00	.05	.04	.08	.08
4143	SEWAGE TREATMENT	0.00	.00	0.00	.00	.00
4170	THERMAL STORAGE S	0.00	.13	0.00	.13	.13
4180	CONTROL BLDG.	0.00	.00	0.00	.00	.00
4190	SOLAR PLANT EQ.	6.57	15.72	15.05	30.76	37.34
4300	TURBINE PLANT EQ.	.00	4.45	.50	5.05	5.05
4401	ELECT.PLANT EQ.	.00	.72	.34	1.06	1.06
4402	PLANT MASTER CTR	.92	.68	.51	1.19	2.11
4500	MISC. PLANT EQ.	.00	1.61	1.05	2.66	2.66
5309	TRANSMISSION PLAN	0.00	.00	0.00	.00	.00
8000	DISTRIBUTABLES	0.00	.74	2.11	2.85	2.85
8100	INDIRECTS	.38	.00	10.78	10.78	11.16
8300	CONTINGENCY	.87	4.32	2.72	5.04	5.91
	GRAND TOTAL	3.74	28.59	38.10	66.70	70.44

the costs due to uncertainty about how the plant would be taxed. Indirects include costs for construction management, the A&E, a Solar Integrator, and plant startup, and cover these activities, as appropriate, for the entire plant.

4.1.2 Pilot Plant Funding

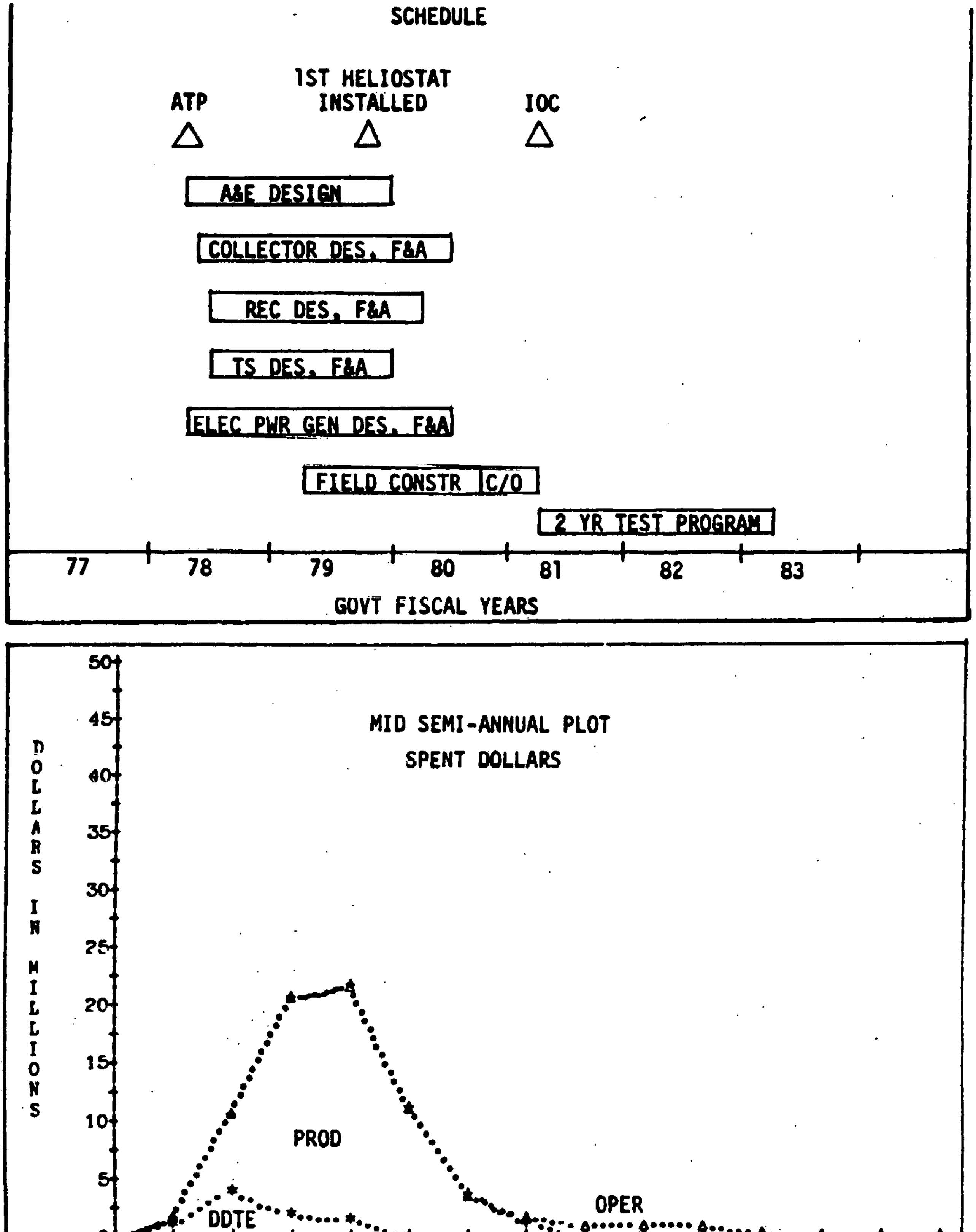
Typical funding that may be required for a Pilot Plant on an as-spent basis is shown in Figure 4-1. The funding is shown on a semiannual basis on a Government Fiscal Year (October 1 to September 30). Also, Figure 4-2 shows committed funding. In these plots and all following funding plots, plot points are at mid-period (i.e., June 30 and December 31) and represent the total funding required over a 6-month period. Also, where relatively small numbers are spread over extended periods, a significant rounding loss may occur at lower WBS levels. However, the loss is only on output so that such losses do not accumulate in the total funding curves.

The semiannual plots provide a better picture of funding buildup. Figure 4-1 shows "spent" funding buildup to a peak in the last half of 1979 at $21.9 million as compared to a $22.4 million peak in the first half on a committed basis. Commitments are $5.3 million greater than expenditure during the first year and one-half mainly due to commitments on the turbine generator, feed pumps, certain special materials and other heavy equipment.

The relatively low spending and commitments in the first half of 1978 reflect that this is mainly a period of design and drawings refinement, site analysis, systems analysis, specification definition, and manufacturing planning. No major equipment purchase orders are placed in this period, and except for the turbine generator, receiver feed pumps, master control and receiver Incoloy 800 tubing, procurement does not build up much until the last quarter of 1978.

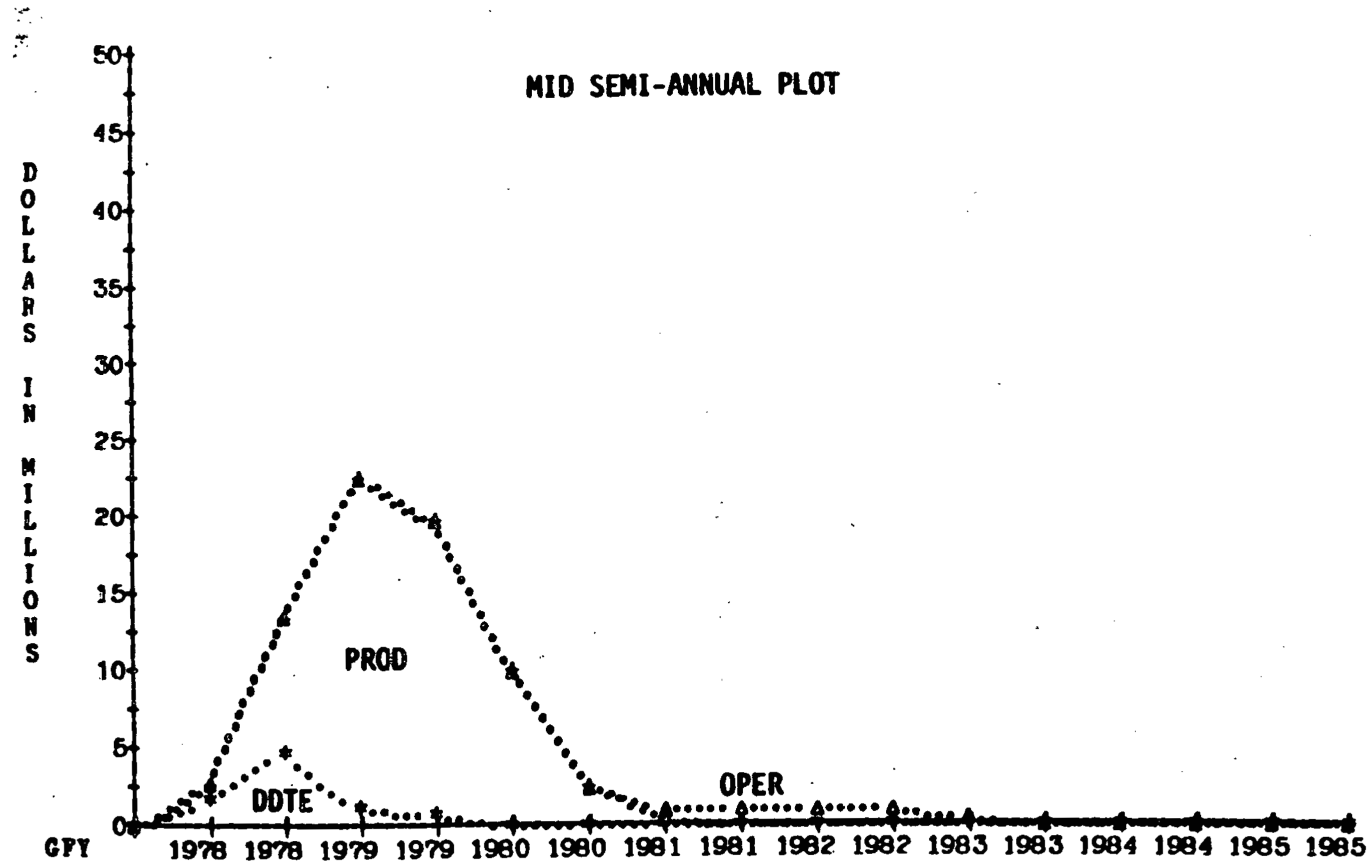
4.1.3 Costing Methodology

Costing for each CBS element has been accomplished by the contractor having the technical responsibility for the element. Thus, the methodology varies somewhat between each subsystem, but is probably the most appropriate for costing each area, also. Generally, individual parts or materials have been costed based on vendor quotes or on experience or catalogs if the



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT·E	1·3	3·9	2·0	1·4	·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
PROD	·5	6·9	18·6	20·5	11·1	3·8	1·2	0·0	0·0	0·0	0·0	0·0	0·0	0·0
OPER	0·0	0·0	0·0	0·0	0·0	0·0	·5	1·1	1·1	1·1	·5	0·0	0·0	0·0
TOTAL	1·8	10·8	20·6	21·9	11·1	3·8	1·7	1·1	1·1	1·1	·5	0·0	0·0	0·0

Figure 4-1. Total Pilot Summary Chart



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT.E	1.7	4.8	1.3	.9	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	.9	8.8	21.1	18.8	9.9	2.5	.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	.5	1.1	1.1	1.1	.5	0.0	0.0	0.0	0.0	0.0
TOTAL	2.6	13.5	22.4	19.6	9.9	2.5	1.1	1.1	1.1	1.1	.5	0.0	0.0	0.0	0.0	0.0

Figure 4-2. Total Pilot Committed Dollars

material is a "frequent" buy item. Labor is costed by various methods ranging from internal judgments to standard costing or historical factoring to resource load costing. Details are presented in each subsection and detail cost sheets have been coded in the following manner for solar equipment.

Source of Estimate	Code
Subcontractor Proposal	M
Vendor Quote	V
Algorithm or CCR	A
In-house Estimate	I
Historically Based Factor	H
Catalog or Experienced Price	C

4.2 LAND AND YARD WORK (4000 AND 4100)

This element includes items such as land purchase and land rights, clearing and rough grading cost, and land improvements and preparation (e.g., survey, grading drainage). Not included in this element are the costs for preparing the site for subsystem elements, which are generically allocated (e.g., earthwork for collector foundations), surveys and other engineering work, procurement effort, and construction direction. These elements are included under the effort in Indirect (8100). Maintenance costs are included under System Test Operations (1000). The costs are to provide for all materials and equipment included within this CBS element as well as the locally subcontracted effort necessary to transport, fabricate, assemble, install, and checkout materials and equipment at the Pilot Plant site.

4.2.1 Land Rights and Yard Work Costs and Technical Characteristics

The total costs estimated by Stearns-Roger are as follows:

Title	Non-recurring (million)	Recurring (million) Material	Labor	Total	Total NR&R
Land and land rights	$0.00	$0.00	$0.00	$0.00	$0.00
Yard work	0.00	0.58	0.07	0.65	0.65
Total (4000)	$0.00	$0.58	$0.07	$0.65	$0.65

Land cost is not indicated because it will be furnished by Southern California Edison at no charge to the program. A list of the elements included under yardwork, as well as Technical Characteristics and Preparation, is provided in Table 4-2 and additional cost detail is provided in Table 4-3.

4.2.2 Land and Yard Work Schedule, Funding and Important Drivers

Figure 4-3 shows the schedule and funding. This element starts 31 months prior to IOC and is completed within 13 months. Essentially, funding commences in 1978 and continues through 1979 with the peak in the first half of 1979. Committed dollars are shown in Figure 4-4.

4.2.3 Land and Yard Work Costing Methodology

Costing is based on Stearns-Roger experience with "yardwork" for power plants of this size and utilizes current industrial equipment, material, and labor costs reflecting the Barstow area location for the Pilot Plant. The basis for the cost estimate is a somewhat expanded equipment and technical characteristics list similar to Table 4-2, which in essence defines the scope of work. Materials and equipment items are priced, and fabrication and installation is estimated from the scope.

4.3 BUILDINGS (4100)

This element includes all structures and facilities required at the Pilot Plant site including turbine generator buildings, maintenance buildings, administration buildings, and any other permanent structures and facilities associated with providing power. Not included in this element are surveys, design and other engineering work, procurement effort, and construction direction which are normally included under the A&E effort within Indirect (8100). The costs are to provide for site preparation and for all materials and equipment, as well as for the subcontracted effort necessary to transport, fabricate, assemble, install, and checkout materials and equipment at the Pilot Plant site.

Table 4-2. Technical Description Land and Yard Work

- Land Improvement and Preparation

  135 fenced acres

  Rough grade and clear

  Land drainage - 11,900 LF Ditching and 12-24 in culverts

  Sanitary sewer drainage piping - 1,500 LF 12 ft Concrete Pipe, 1,100 LF 6 in Cast Iron Pipe

  Water Supply Line - 2,500 LF 6 in Sched. 40 pipe (Cost under 4,500.229)

  Sidewalks - 500 LF Concrete Walkway

  Surface Parking Areas - 400 SY - 6 in base with 2 in bituminous cover

  Fencing - 10,800 LF

  Landscaping

  Fire Protection - 750 LF 8 in pipc (Cost under 4,500.229) 5 hydrants and valves and fittings

  Yard Lighting - 50 Road Fixtures - 50 Yard Fixtures

  Roads - 16,670 SY - 12 in base with 2 in bituminous cover

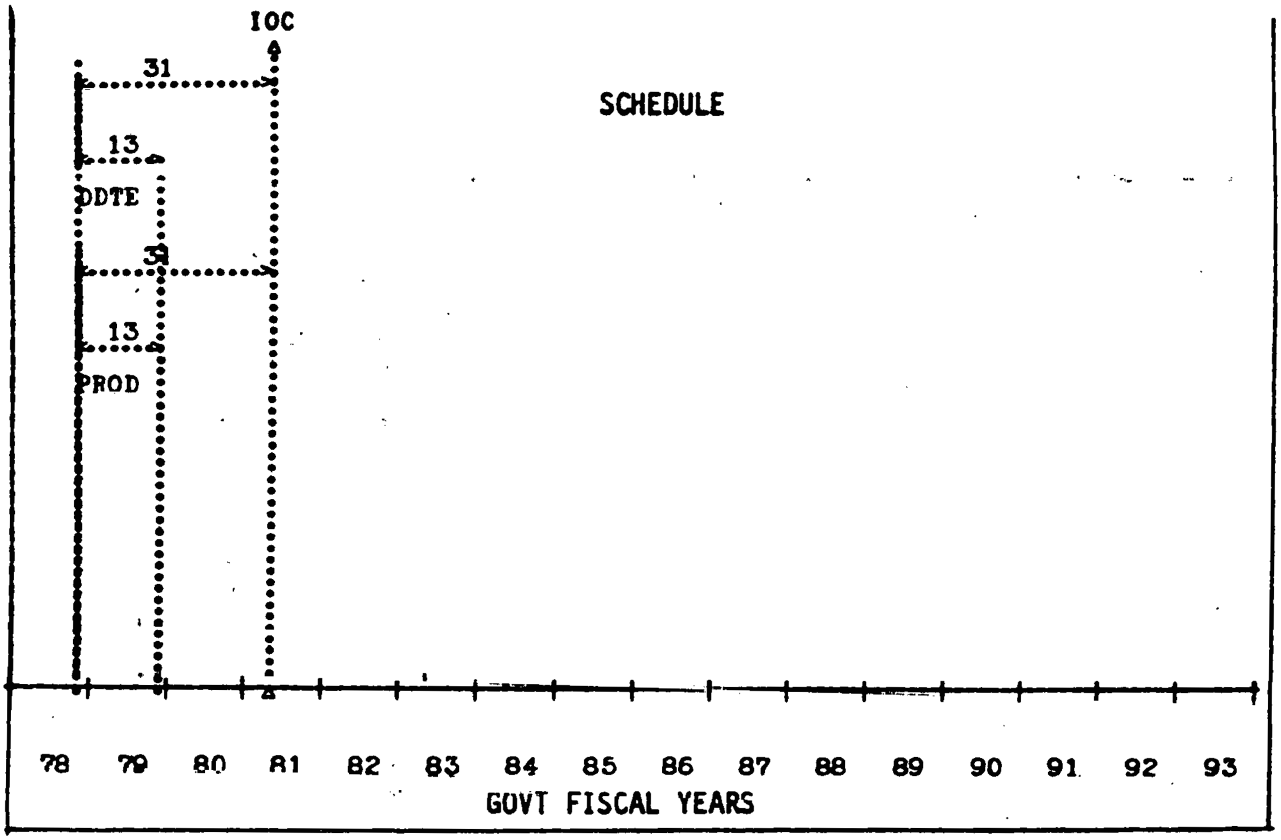
Table 4-3. Land and Yardwork Cost Detail

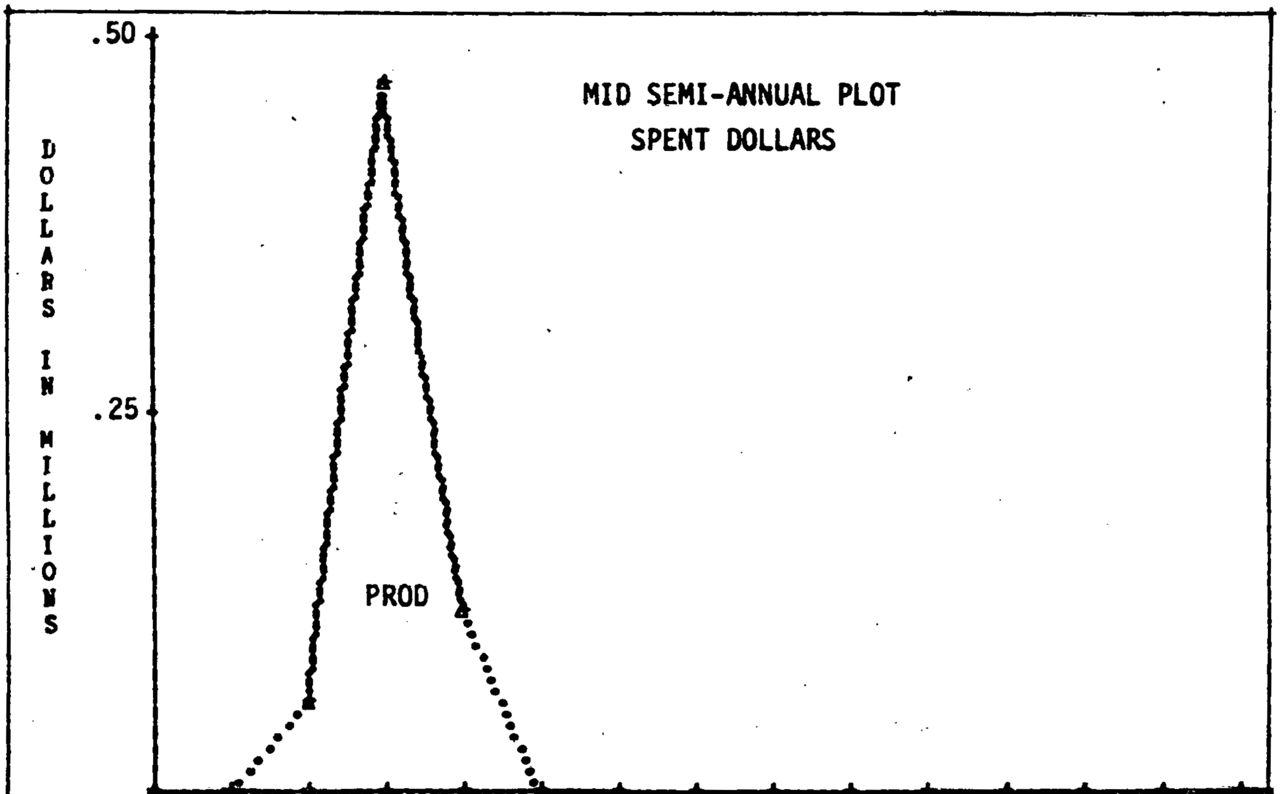
PILOT--40*41 WBS SERIES 12,50,29, DATE: 77/05/26,

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
4000,1	LAND - PRIV ACQ,	,00	0,00	0,00	0,00	,00
4000	SUBTOTAL	,00	0,00	0,00	0,00	,00
4100,1	GRADING,GEN,EXC,	0,00	,37 H	0,00	,37	,37
4100,2	ROADWAY,FERC,-LI	0,00	,17 H	0,00	,17	,17
4100,3	SANITARY SEWER SY	0,00	,04 H	,07 H	,11	,11
4100,4	YARD DRAIN,-STORM	0,00	,01 H	0,00	,01	,01
4100,5	WATERFRONT IMPRV,	0,00	,00	0,00	,00	,00
100,6	ROADS CONST TO CO	0,00	,00	0,00	,00	,00
4100,7	RAILWAY ACCESS	0,00	,00	0,00	,00	,00
4100,8	WATERWAY ACCESS F	0,00	,00	0,00	,00	,00
4100,9	AIR ACCESS FAC,	0,00	,00	0,00	,00	,00
4100	SUBTOTAL	,00	,58	,07	,65	,66

PILOT--40*41 WBS SERIES 12,50,29, DATE: 77/05/26,

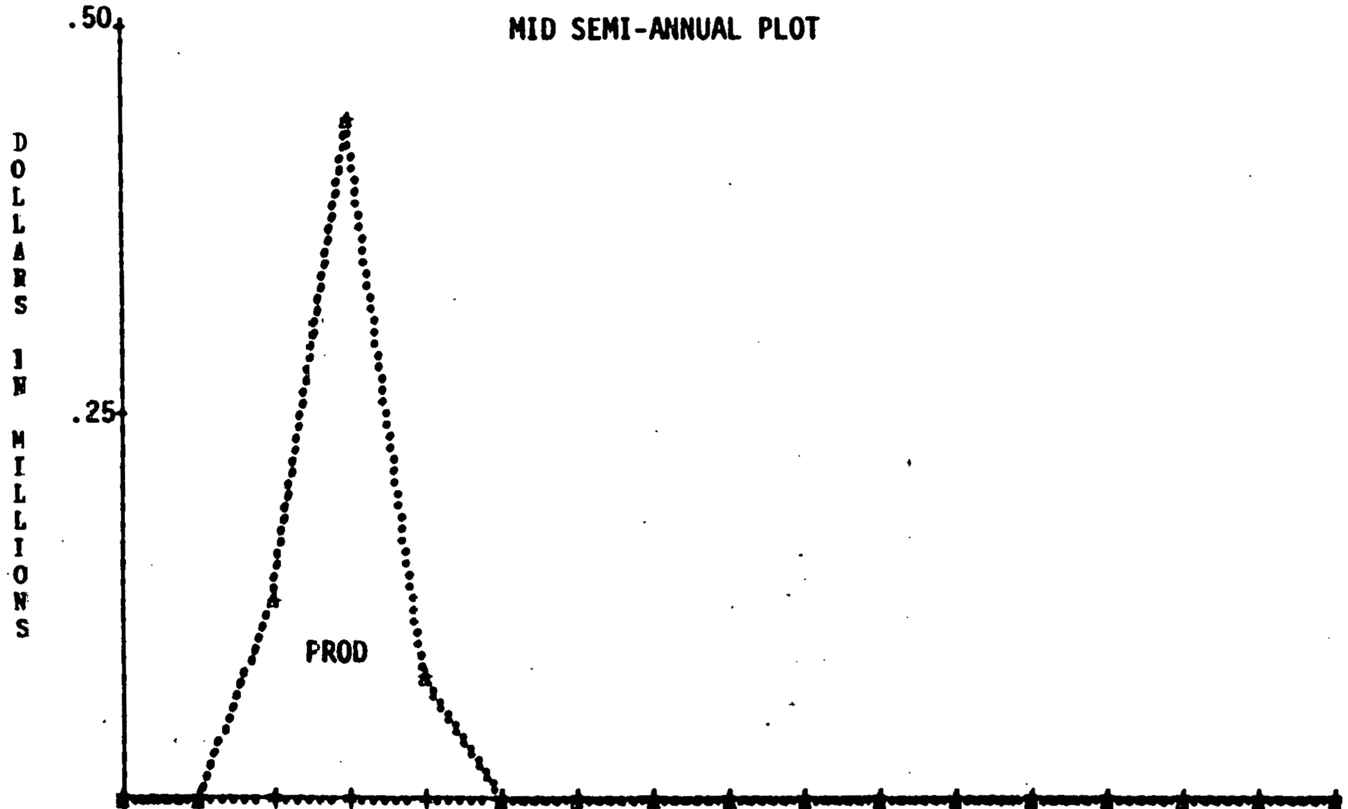
WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
4000,11	LAND - SURVEYS	,00	0,00	0,00	0,00	,00
4000,12	EASEMENTS - R,O,W	,00	0,00	0,00	0,00	,00
4000,13	CLEARING LAND	,00	0,00	0,00	0,00	,00
4000,1	SUBTOTAL	,00	0,00	0,00	0,00	,00
4100,21	ROADS	0,00	,05 H	0,00	,05	,05
4100,22	SIDEWALKS	0,00	,00 H	0,00	,00	,00
4100,23	PARKING	0,00	,00 H	0,00	,00	,00
4100,24	RET WALL,BRIDGES	0,00	,01 H	0,00	,01	,01
4100,25	FENCES-GATEWAYS	0,00	,10 H	0,00	,10	,10
4100,26	YARD LIGHTING	0,00	,00	0,00	,00	,00
4100,2	SUBTOTAL	0,00	,17	0,00	,17	,17





GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT•E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	.1	.5	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	.1	.5	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 4-3. Land, Rights, and Yardwork Summary Chart



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT•E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	.1	.4	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	.1	.4	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 4-4. Land, Rights, and Yardwork Committed Dollars

4.3.1 Buildings Costs and Technical Characteristics

Costs estimated by Stearns-Roger are as follows:

Title	Non-recurring (million)	Recurring (million) Material	Labor	Total	Total NR&R
Turbine building	$0.00	$0.68	$0.51	$1.19	$1.19
Admin bld	0.00	0.25	0.19	0.43	0.43
Cir & ser water PH	0.00	0.00	0.00	0.01	0.01
Warehouse	0.00	0.31	0.23	0.54	0.54
Maintenance bld	0.00	0.03	0.02	0.06	0.06
Water treat eq bld	0.00	0.05	0.04	0.08	0.08
Sewage treatment	0.00	0.00	0.00	0.00	0.00
Thermal storage	0.00	0.13	0.00	0.13	0.13
Control bld	0.00	0.00	0.00	0.00	0.00
Total (4100)	$0.00	$1.45	$0.99	$2.44	$2.44

A more detailed description of these facilities is given in Table 4-4 including the square footage for each facility. Additional cost detail is provided in Table 4-5.

4.3.2 Buildings Schedule, Funding and Important Drivers

Committed funding and schedule is indicated in Figure 4-5. Construction starts 24 months prior to IOC and must be completed within a 14-month period. Funding occurs primarily in 1979, peaking at $2.2 million in the second half of the year on an as-spent basis, as shown in Figure 4-6. Table 4-6 provides a funding breakdown by individual building.

4.3.3 Buildings Costing Methodology

Costing is based on Stearns-Roger experience with structures for power plants of this size and utilizes current industry experience concerning dollars per square foot applicable in the desert southwest for each of the various types of buildings required. Building costs are developed from the list of buildings, which indicates type and square footage. Other major construction accounts (i.e., earthwork, concrete, and painting) are estimated and prorated to the buildings based on many previous power plant cost relationships for units of this size.

Table 4-4. Technical Description Buildings

Administration/Technical Building

35 x 60 x 22 ft metal siding, two story, insulated heated and air conditioned. Two story - 4,200 ft^2.

Turbine-Generator Building

100 x 60 x 46 ft metal siding, two main stories, insulated, heated and air-cooled (evaporative coolers). Control room and computer room air conditioned. Two story - 12,000 ft^2.

Maintenance/Assembly/Warehouse Building

95 x 60 x 20 ft metal siding, single story, high bay assembly area, area, insulated, heated and air-cooled (evaporative coolers). One story - 5,700 ft^2.

This CBS item includes the following structures:

1. Diesel-Generator Building 15 x 30 ft. One story - 450 ft^2. (existing facility).
2. Water Treatment Building 30 x 35 x 15 ft. One story - 1,050 ft^2.
3. Clarifier Clearwell Enclosure 60 x 30 x 8 ft. Cover - 1,800 ft^2.

Table 4-5. Buildings Cost Detail (Page 1 of 2)

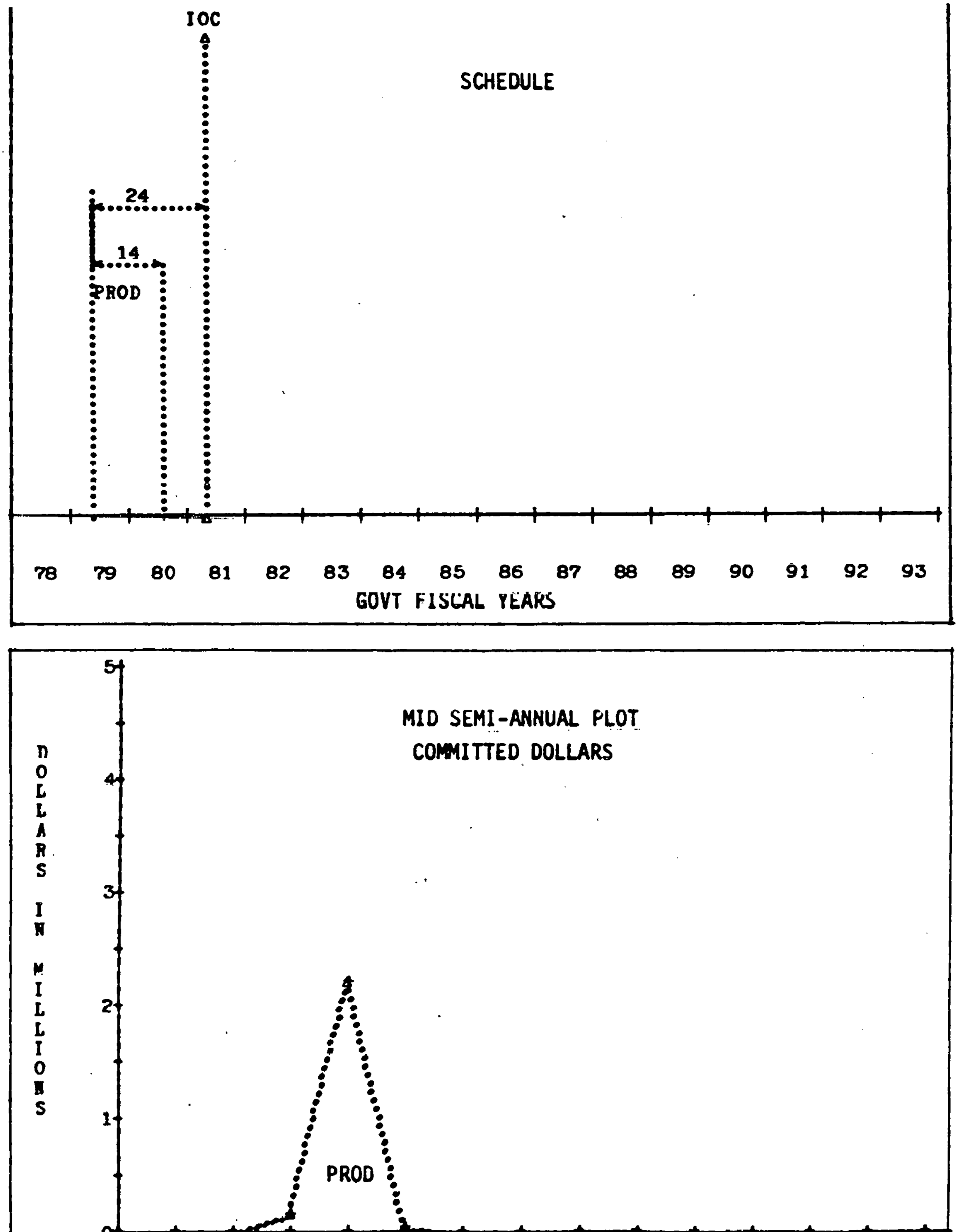
WBS 50 SERIES PILOT PLANT 16.09.47. DATE: 77/05/23.

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
4103.1	SUBSTRUCTURE	0.00	.14	.21	.36	.36
4103.2	SUPERSTRUCTURE	0.00	.20	.13	.33	.33
4103.4	BUILDING MECH.	0.00	.19	.05	.24	.24
4103.5	LTNG+BLD.SER PWR	0.00	.14	.10	.24	.24
4103.9	PAINTING	0.00	.00	.02	.02	.02
4103	SUBTOTAL	0.00	.68	.51	1.19	1.19
4105.1	SUBSTRUCTURE	0.00	.05	.08	.13	.13
4105.2	SUPERSTRUCTURE	0.00	.07	.05	.12	.12
4105.4	BLDG MECHH.SYS.	0.00	.07	.02	.09	.09
4105.5	ELECTRICAL	0.00	.05	.04	.09	.09
4105.6	PAINTING	0.00	.00	.01	.01	.01
4105	SUBTOTAL	0.00	.25	.19	.43	.43
4106.1	SUBSTRUCTURE	0.00	.00	.00	.00	.00
4106.2	SUPERSTRUCTURE	0.00	.00	.00	.00	.00
4106.4	BLDG.MECH.SYS.	0.00	.00	.00	.00	.00
4106.5	ELECTRICAL	0.00	.00	.00	.00	.00
4106.6	PAINTING	0.00	.00	.00	.00	.00
4106	SUBTOTAL	0.00	.00	.00	.01	.01
4108.1	SUBSTRUCTURE	0.00	.07	.10	.16	.16
4108.2	SUPERSTRUCTURE	0.00	.09	.06	.15	.15
4108.4	BLDG.MECH.SYS.	0.00	.09	.02	.11	.11
4108.5	ELECTRICAL	0.00	.07	.04	.11	.11
4108.6	PAINTING	0.00	.00	.01	.01	.01
4108	SUBTOTAL	0.00	.31	.23	.54	.54
4141.1	SUPERSTRUCTURE	0.00	.01	.01	.02	.02
4141.2	SUPERSTRUCTURE	0.00	.01	.01	.02	.02
4141.4	BLDG.MECH.SYS.	0.00	.01	.00	.01	.01
4141.5	ELECTRICAL	0.00	.01	.00	.01	.01
4141.6	PAINTING	0.00	.00	.00	.00	.00
4141	SUBTOTAL	0.00	.03	.02	.06	.06

Table 4-5. Buildings Cost Detail (Page 2 of 2)

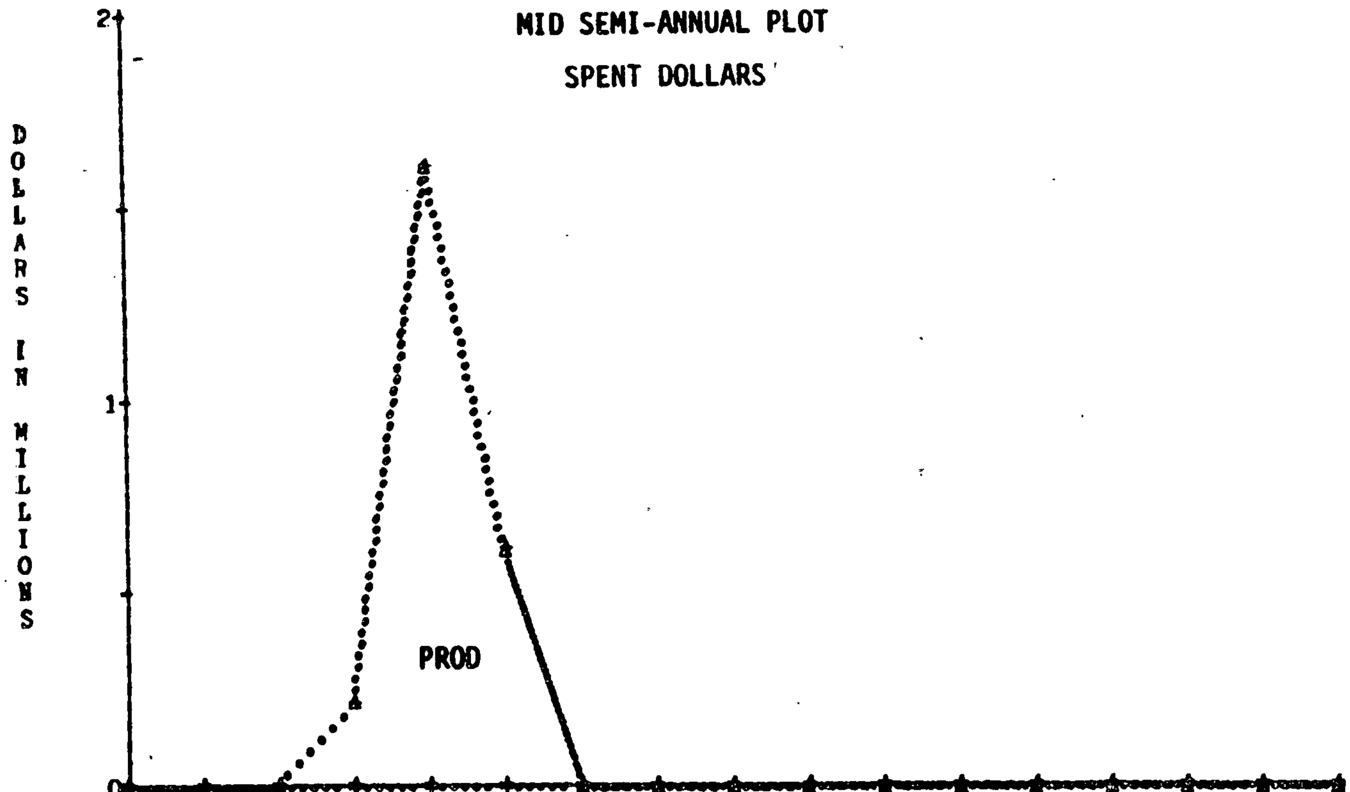
WBS 50 SERJES PILOT PLANT 16,09,47, DATE: 77/05/23.

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	RECURRING (MIL) LABOR	RECURRING (MIL) TOTAL	TOTAL NR+R
4142.1	SUBSTRUCTURE	0.00	.01 H	.02 H	.03	.03
4142.2	SUPERSTRUCTURE	0.00	.01 H	.01 H	.02	.02
4142.4	BLDG. MECH.SYS.	0.00	.01 H	.00 H	.02	.02
4142.5	ELECTRICAL	0.00	.01 H	.01 H	.02	.02
4142.6	PAINTING	0.00	.0C H	.00 H	.00	.00
4142	SUBTOTAL	0.00	.05	.04	.08	.08
4143.1	SUBSTRUCTURE	0.00	.0C	0.00	.00	.00
4143.2	SUPERSTRUCTURE	0.00	.0C	0.00	.00	.00
4143.4	BUILDING MECH.SYS	0.00	.0C	0.00	.00	.00
4143.5	ELECTRICAL	0.00	.0C	0.00	.00	.00
4143.6	PAINTING	0.00	.0C	0.00	.00	.00
4143	SUBTOTAL	0.00	.0C	0.00	.00	.00
4170.1	SUBSTRUCTURE	0.00	.0C	0.00	.00	.00
4170.2	SUPERSTRUCTURE	0.00	.01 I	0.00	.01	.01
4170.4	BLDG. MECH. SYS.	0.00	.0C	0.00	.00	.00
4170.5	ELECTRICAL	0.00	.12 I	0.00	.12	.12
4170.6	PAINTING	0.00	.0C	0.00	.00	.0C
4170	SUBTOTAL	0.00	.13	0.00	.13	.13
4180.1	SUBSTRUCTURE	0.00	.0C	0.00	.00	.0C
4180.2	SUPERSTRUCTURE	0.00	.0C	0.00	.00	.00
4180.4	BLDG.MECH.SYS.	0.00	.0C	0.00	.00	.00
4180.5	ELECTRICAL	0.00	.0C	0.00	.00	.0C
4180.6	PAINTING	0.00	.0C	0.00	.00	.00
4180	SUBTOTAL	0.00	.0C	0.00	.00	.00



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT·E	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
PROD	0·0	0·0	·2	2·2	·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
OPER	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
TOTAL	0·0	0·0	·2	2·2	·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0

Figure 4-5. Buildings Summary Chart



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT•E	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	0•0	0•0	•2	1•6	•6	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	0•0	0•0	•2	1•6	•6	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0

Figure 4-6. Buildings Spent Dollars

Table 4-6. Detail Funding by Building ($ Millions)

Title	1978	1979	1979	1980	1980
Turbine bld	0.00	0.08	1.08	0.03	0.00
Admin bld	0.00	0.01	0.42	0.00	0.00
Cir ser water pump house	0.00	0.00	0.01	0.00	0.00
Warehouse	0.00	0.00	0.00	0.54	0.00
Maintenance bld	0.00	0.00	0.00	0.06	0.00
Water treat eq bld	0.00	0.00	0.08	0.00	0.00
Sewage treatment bld	0.00	0.00	0.00	0.00	0.00
Thermal storage	0.00	0.01	0.12	0.00	0.00
Control bld	0.00	0.00	0.00	0.00	0.00
Grand total	0.00	0.10	1.71	0.63	0.00

4.4 COLLECTOR EQUIPMENT

This element includes all items related to the central receiver heliostats and field controllers which include reflective surfaces, backing and support structure, foundations and site preparations, drive units, control sensors and wiring, insulation, protective enclosures, and lightning protection. Also included are field controllers, heliostat controllers, control sensors and all heliostat field communications and power wiring.

Costs are to provide for the labor and material required to design, fabricate, deliver, assemble, install, align, calibrate and checkout and support acceptance test. The field preparations, including foundation excavations and wire trenching, are included in the cost as well as the initial two years of systems test operations for 1,760 heliostats and 74 field controllers. Maintenance and operating instructions costs are also included.

4.4.1 Scope of Work Detail

Additional detail on the scope of work is included below:

Engineering

Nonrecurring

1. Perform design and analyses and prepare detail design drawings for the heliostat, field control equipment, maintenance, installation and alignment equipment.

2. Prepare design drawings for heliostat foundation, including plot plan.
3. Provide design requirements and analysis for power and control wiring.
4. Provide collector system power requirements.
5. Design electrical production test equipment for factory checkout of manufactured components.
6. Provide technical support to Logistic Support during technical documentation preparation and validation.
7. Prepare and validate operating instructions and troubleshooting guides.
8. Design containers and provide packaging drawings for the shipment of the heliostat array and control system components, maintenance and installation equipment and alignment equipment to the Pilot Plant site.
9. Prepare transportation plan which will provide transport methods and the technical requirements for the handling, transportation and storage of the heliostat array, and control system program materials during manufacturing, installation and test activities.
10. Provide test support and determine test procedures and plans.

Recurring

1. Provide technical management for this program.
2. Provide sustaining engineering support to resolve fabrication, assembly, or installation problems.
3. Provide test support of inhouse subsystem testing.
4. Provide technical support of heliostat assembly, system installation (including focusing calibration and checkout), and direction of MDAC tests at the test site.
5. Provide assistance, as required, during acceptance testing.
6. Provide systems test operations support.

Engineering Labs

Nonrecurring

1. Utilizing the first two completely assembled heliostats, accomplish in-plant testing to verify control electronics and heliostat function.

Planning

Nonrecurring

1. Prepare and release fabrication and assembly planning paper for those parts/assemblies which are not common to Subsystem Research Experiment (SRE) hardware.
2. Prepare and release tool orders for parts/assemblies, including those which are common to SRE.

Recurring

1. Provide liaison planning support to manufacturing.
2. Accomplish repeat release of fabrication and assembly planning paper.

Industrial Engineering

Recurring

1. Provide analyses of details, subassemblies, and assemblies to establish equipment loads, need dates and alternate production methods.

Tooling

Nonrecurring

1. Design and fabricate tooling.
2. Assist in prove and complete of tools.

Recurring

1. Provide tool liaison support to manufacturing.

Manufacturing

Nonrecurring

1. Manufacture electrical production test equipment.
2. Manufacture heliostat, field controller and ancillary test hardware.

Recurring

1. Fabricate and subassemble components of the heliostat in accordance with planning paper and schedules.
2. Fabricate and assemble the field controller in accordance with planning paper and schedules.
3. Provide direct supervision over contract hires at the test site.

Quality Assurance

Recurring

1. Perform necessary inspection and test to assure hardware conformance for both make and buy hardware.
2. Provide inspection coverage at the installation site to assure conformance to drawings and specifications.
3. Perform necessary inspection of calibrations of special "out-of-spec" monitoring equipment.

MSK (Contract Hires)

1. Perform assembly of heliostats, heliostat installation, heliostat array controller installation, focusing, alignment, and system checkout in accordance with MDAC supervision direction.
2. Perform excavations, trenching and other site preparation in accordance with MDAC supervision directions.

Logistics Support

Nonrecurring

1. Prepare and validate installation Site Activation Kit Work Order (SAKWO) and maintenance instructions.
2. Develop and prepare a maintenance plan to cover scheduled and corrective maintenance requirements.
3. Plan, develop and implement a Site Activation Material Availability Control (SAMAC) function to support installation and test activities at site.

Recurring

1. Provide sustaining SAMAC effort to support installation and checkout activities.
2. Provide sustaining engineering to resolve support problems.
3. Provide management of the on-site system installation activities, to include site activation planning and coordination with the customer.

Facilities

Nonrecurring

1. Prepare facility criteria drawings, calculations, and specifications and update as necessary to reflect production requirements.
2. Develop cost estimates and finalize facilities packages.
3. Direct facility construction projects, including modifications and rearrangements to existing plant area to accommodate dedicated production functions.
4. Direct and control all rearrangements necessary to accommodate this project at the MDAC plant in Huntington Beach, California.
5. Procure and ensure timely delivery of identified support equipment required at the pilot plant site.

4.4.2 Collector Equipment Costs

McDonnell Douglas Astronautics Company, with assistance from Stearns-Roger, has estimated costs as follows:

Title	Non-recurring (million)	Recurring (million) Material	Labor	Total	Total NR&R
Reflective unit	$1.02	$3.83	$1.59	$5.42	$6.44
Drive unit	0.38	4.09	1.72	5.81	6.19
Sensor/cal eq	0.13	0.78	0.25	1.03	1.15
Contr/inst eq	0.09	0.51	1.31	1.82	1.91
Foundation and site prep	0.01	0.71	0.00	0.71	0.72
Des eng tst and pln	1.83	0.43	1.18	1.61	3.44
Packing cont and trans	0.05	0.00	0.02	0.02	0.06
Field assy inst and c/o	0.21	0.11	1.76	1.87	2.08
Lightning protect	0.00	0.00	0.00	0.00	0.00
Total	$3.71	$10.45	$7.82	$18.28	$21.99

Additional cost detail is provided in Table 4-7. Table 4-8 provides a brief technical description.

An analysis of the cost impact of an open-loop collector subsystem for Pilot Plant was made. The analysis indicated a cost increment decrease of $600,000. The decrease is the net difference between the addition of 35 more heliostats to the field, which is then offset by the elimination of the sensor, sensor pole and foundation, tracking mirror and sensor wiring from the field.

4.4.3 Pilot Plant Collector Equipment Funding

Collector funding and schedule are shown in Figure 4-7. Figure 4-8 shows committed dollars. The D&D effort starts 35 months prior to IOC and runs for 14 months while production starts 32 months prior to IOC and ends 3 months prior to IOC. However, the last 6 months of production are mainly for acceptance test and final hardware integration. System test operations start at IOC and run for 24 months. The peak funding for the collector equipment occurs during GFY 1979.

Table 4-7. Collector Cost Detail (Page 1 of 3)

6001 WBS SERIES PILOT PLANT 16.45.17. DATE: 77/05/23.

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
4190.111	REFLECTIVE SURFAC	.96 I	1.37 V	1.49 I	2.85	3.81
4190.112	MIRROR BACKING ST	.05 I	1.51 V	.10 I	1.61	1.66
4190.113	HELIOSTAT SUPT.	.02 I	.95 V	.00 I	.95	.97
4190.11	SUBTOTAL	1.02	3.83	1.59	5.42	6.44
4190.121	AZMUTH IL MIRROR	.19 V,I	1.28 V	.81 I	2.06	2.26
4190.122	ELEVATION DR.	.17 V,I	1.20 V	.73 I	1.93	2.11
4190.123	MOTOR	.00 I	.81 V	.00 I	.81	.82
4190.124	POSITION EMIT,IND	.01 I	.44 I,V	.13 I	.57	.58
4190.125	EMERGENCY PWR,SUP	0.00	.00 V	0.00 I	.00	.00
4190.126	POWER DISTR,EQ.	.00 I	.36 V,M	.05 I	.41	.42
4190.12	SUBTOTAL	.38	4.09	1.72	5.81	6.19
4190.131	SENSOR UNIT	.08 I	.06 I,V	.17 I	.23	.31
4190.132	SENSOR TOWER	.04 I	.64 I,V	.00 I	.64	.68
4190.134	WIRING BTWN HELIO	.00 I	.07 V	.08 I	.16	.16
4190.13	SUBTOTAL	.13	.78	.25	1.03	1.16
4190.141	HELIO.CONTROLLER	.06 I	.19 I,C,V	.97 I	1.16	1.22
4190.142	FIELD CTR.+ELEC.	.01 I	.07 I,C,V	.04 I	.11	.12
4190.143	SIG.DISTRIB.EQ.+M	.02 I	.25 V,I	.30 I	.55	.57
4190.14	SUBTOTAL	.09	.51	1.31	1.82	1.91
4190.151	FOUNDATION(HEL+SE	.00 I	.65 M(S,I)	0.00	.65	.66
4190.152	SITE PREP.	0.00	.06 M	0.00	.06	.06
4190.15	SUBTOTAL	.01	.71	0.00	.71	.72

Table 4-7. Collector Cost Detail (Page 2 of 3)

6001 WBS SERIES PILOT PLANT 16,45,17, DATE: 77/05/23,

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
4190,161	DESIGN COST	1,09 I	,00	,09 I	,09	1,18
4190,162	SUST,ENG,SUPPORT	,58 I	,01 I	1,03 I	1,04	1,62
4190,163	PRE-PROD UNIT	,16 I	0,00	0,00	0,00	,16
4190,164	SITE PLANT ACTIV	0,00	,41 V,C	,07 I	,48	,48
4190,16	SUBTOTAL	1,83	,43	1,18	1,61	3,44
4190,171	CONTAINERS FOR SH	,05 I	0,00	,01 I	,01	,06
4190,172	TRANSPORTATION	0,00	0,00	,01 I	,01	,01
4190,17	SUBTOTAL	,05	,00	,02	,02	,06
4190,181	HELIOSTAT + CTR,E	,21 I	,10 I	1,53 I,M	1,63	1,85
4190,182	SENSOR/CAL,EQ,	,00 I	,00	,23 I	,23	,23
4190,18	SUBTOTAL	,21	,11	1,76	1,87	2,08

Table 4-7. Collector Cost Detail (Page 3 of 3)

6001 WBS SERIES PILOT PLANT 16,42,17, DATE: 77/05/23,

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
4190,1611	REFLECTIVE UNIT	,13 I	0,00	0,00	0,00	,13
4190,1612	DRIVE UNIT	,15 I	0,00	,04 I	,04	,19
4190,1613	SENSOR/CAL, EQ,	,19 I	0,00	0,00	0,00	,19
4190,1614	CONTROL EQ,+SOFTW	,62 I	,00	,05 I	,05	,66
4190,1615	FOUNDATION + SITE	,00 I	0,00	0,00	0,00	,00
4190,161	SUBTOTAL	1,09	,00	,09	,09	1,18
4190,1811	FIELD ASSY	,21 I	,03 I	,55 I	,65	,86
4190,1812	INST, + C/O	0,00	,02 I	,98 I,M	1,00	1,00
4190,181	SUBTOTAL	,21	,10	1,53	1,65	1,85
4190,1821	FIELD ASSY	0,00	0,00	,00	,00	,00
4190,1822	INST, + C/O	0,00	0,00	,21 I	,21	,21
4190,1823	CALIBRATION	0,00	,00 I	,02 I	,02	,02
4190,182	SUBTOTAL	,00	,00	,23	,23	,23
2-24-77	REVIS	3,71	10,45	7,82	18,28	21,99

Table 4-8. Technical Description Collector Subsystem (Page 1 of 2)

Reflector - 6 sandwiched panels composed of float glass, polystyrene and sheet steel, then connected to the mirror backing structure.	
Reflective Surface	1,226.5 lb
• Reflective Surface Area	408 ft^2
• Second Surface Mirror	0.125 in
• Polystyrene Rigid Foam Core	2 in
• Galvanized Sheet Steel 26 gage	0.020 in
• Tracking Mirror	38.9 lb
Mirror Backing Structure	1,108.3 lb
• Crossbeams 11 gage Channels	215.50 in-14 in depth
• Torque Tube	206.25 in-10.75-in OD
• Drive Attachment Fitting	Low carbon steel
Heliostat Support Structure	508.5 lb
• Pedestal	108 in - 20 in dia
Drive - consist of an orbidrive in the elevation and azimuth axis	
Azimuth/Elevation Drive Actuators	
• Drive Ratio	
• • Input Drive	45:1
• • Output Drive	961:1
• Final Drive Ratio	43,245:1
Actuator Motor	
• Power	42 frame, 230 VAC 3 Ø, 4 pde, 60 Hz
• Horsepower Rating	18.6 (1/4)
Power Distribution Equipment and Wiring	240 V 60 Hz
Position Indicators - a Sensor (encoder) on the Drive Output -4 bit. Incremental encoder on motor - 1 bit.	
Sensor	
Sensor Unit - 5 element silicon detectors	
Sensor Tower - Two-part Steel Tube Length (212 to 312 in)	

Table 4-8. Technical Description Collector Subsystem (Page 2 of 2)

Control/Instrumentation Equipment

Heliostat controller

- Digital microprocessor
- Drive motor controller
- Communication interface

Field controller

- 1 per 24 heliostats
- High-speed digital microprocessor
- Master control interface
- Heliostat control interface
- Command calculation and formating

Signal distribution equipment and wiring

- Digital data bus
- Interface master/field/heliostat controllers

Foundation

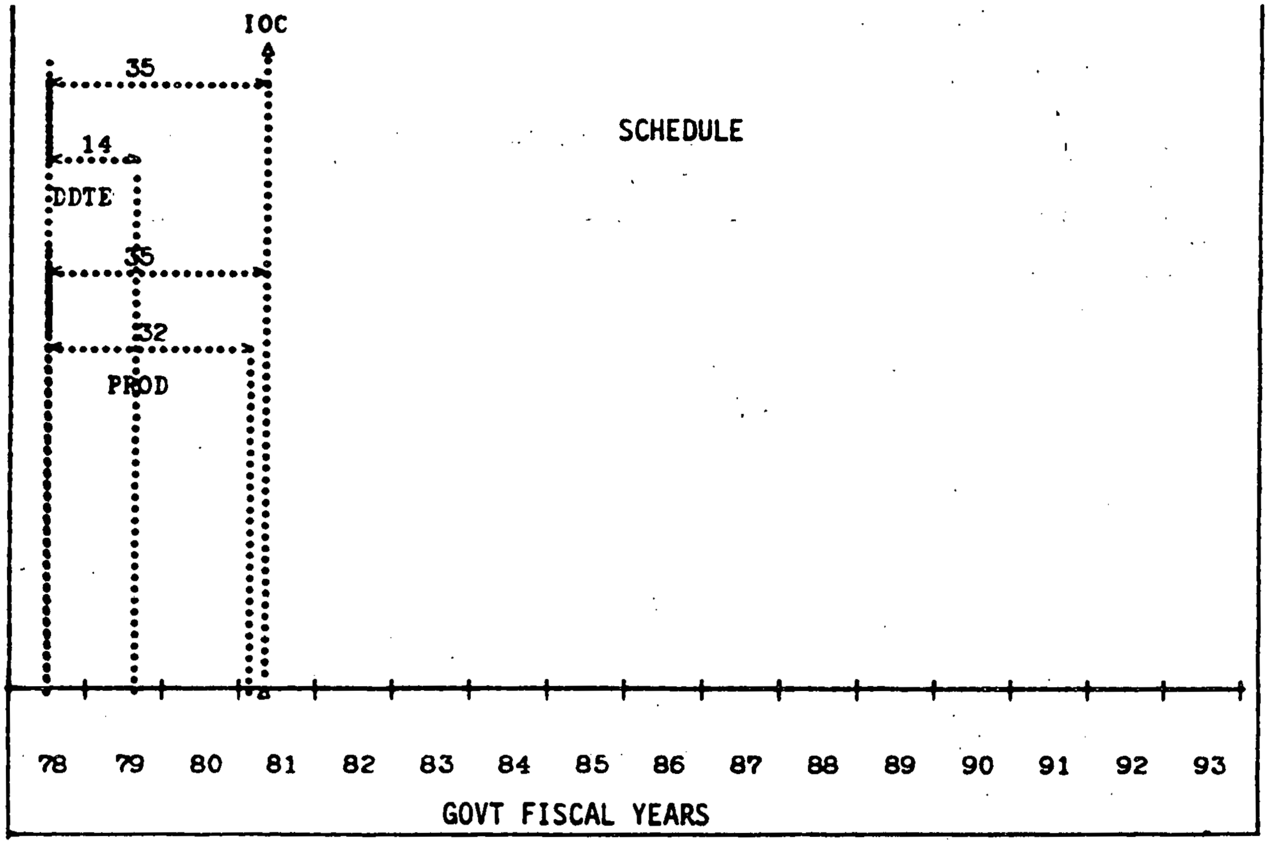
Reinforced precast concrete - 2.4 cu yd

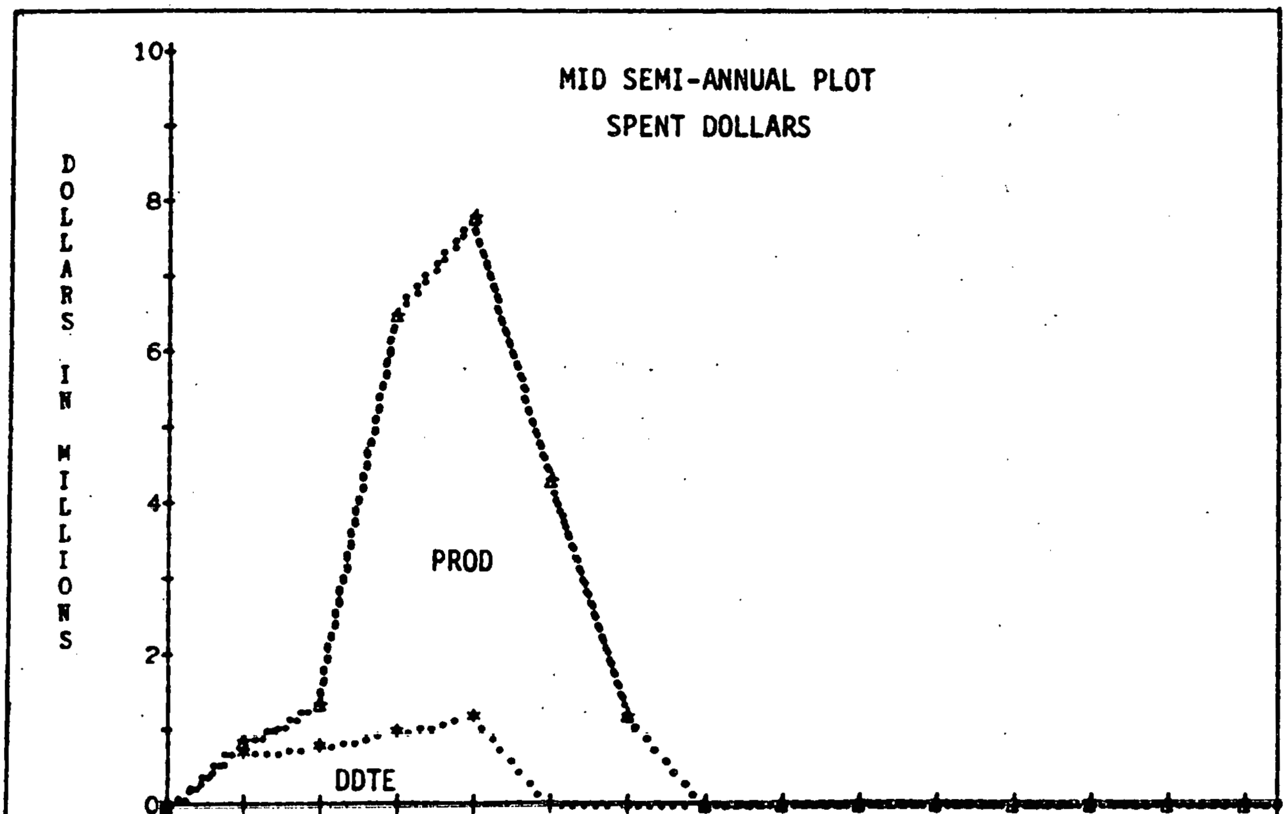
Weight of structure - 9,750.0 lb

Packing Containers

Mirror panels - 12 per container - 40 reusable required

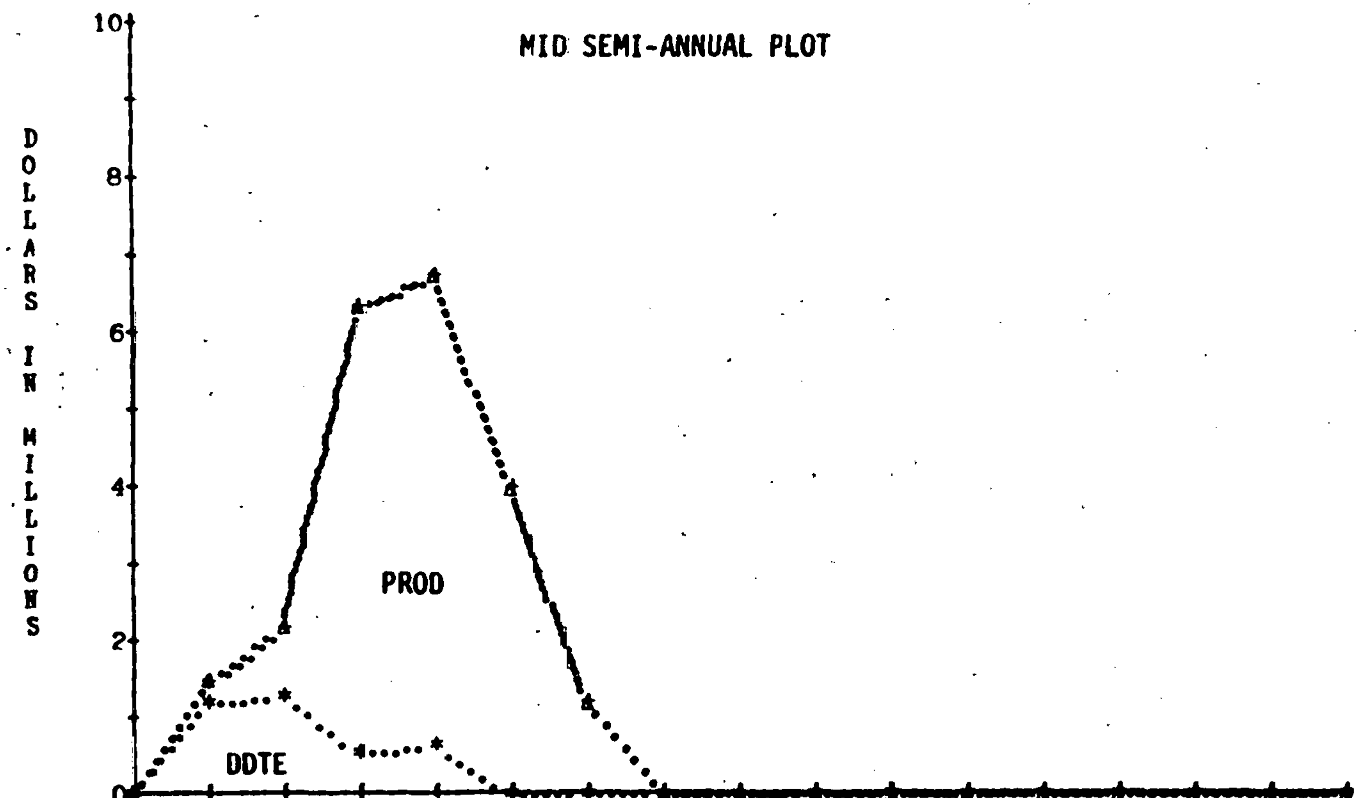
Drive unit - 1 per pallet - 250 reusable required





GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT•E	•7	•8	1•0	1•2	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	•1	•6	5•5	6•6	4•3	1•2	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	•8	1•4	6•5	7•8	4•3	1•2	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0

Figure 4-7. Collector Equipment Summary Chart



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT•E	1•2	1•3	•5	•6	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	•3	•9	5•3	6•1	4•0	1•2	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	1•5	2•2	6•4	6•7	4•0	1•2	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0

Figure 4-8. Collector Equipment Committed Dollars

4.4.4 Cost Methodology

The collector equipment cost estimates reflect the major program assumptions and guidelines given in Section 2.2.1 of Volume VII, and the Scope of Work Detail given in Section 4.4.1 of this volume.

Volume III, Collector Subsystem, provides the comprehensive data base from which the major program assumptions and guidelines, and the scope of work detail were developed. Section 4, Pilot Plant Collector Definition, and Section 5, Pilot Plant Plans and Schedules, of Volume III are the principal data base.

Costing of the Pilot Plant collector equipment was accomplished by using the McDonnell Douglas Astronautics Company normal estimating and pricing practices which are applied to develop firm business cost proposals. These practices generally employ the expertise of the functional organization of the company and the expertise of other segments of the industry which are involved in solar energy development. Figure 4-9 provides an example of the MDAC estimating practices used to develop labor hour estimates for manufacturing.

The specific costing methodology employed in any program phase for the collector subsystem is described by major MDAC functional element. This conforms to the accounting practices which normally govern the cost data base from which estimates are derived. General function descriptions are provided as follows.

Engineering Functions - These functions consists of Development Engineering, Engineering Laboratories and Logistics. Estimates for these functions are derived from Statements of Work, Schedules and Program Plans.

Operations Functions - These functions consist of manufacturing, planning, tooling and quality assurance. Estimates for these functions are derived from Statements of Work, Schedules and Program Plans. Estimates for the collector equipment were more specifically derived from detailed engineering designs and detailed manufacturing flow plans.

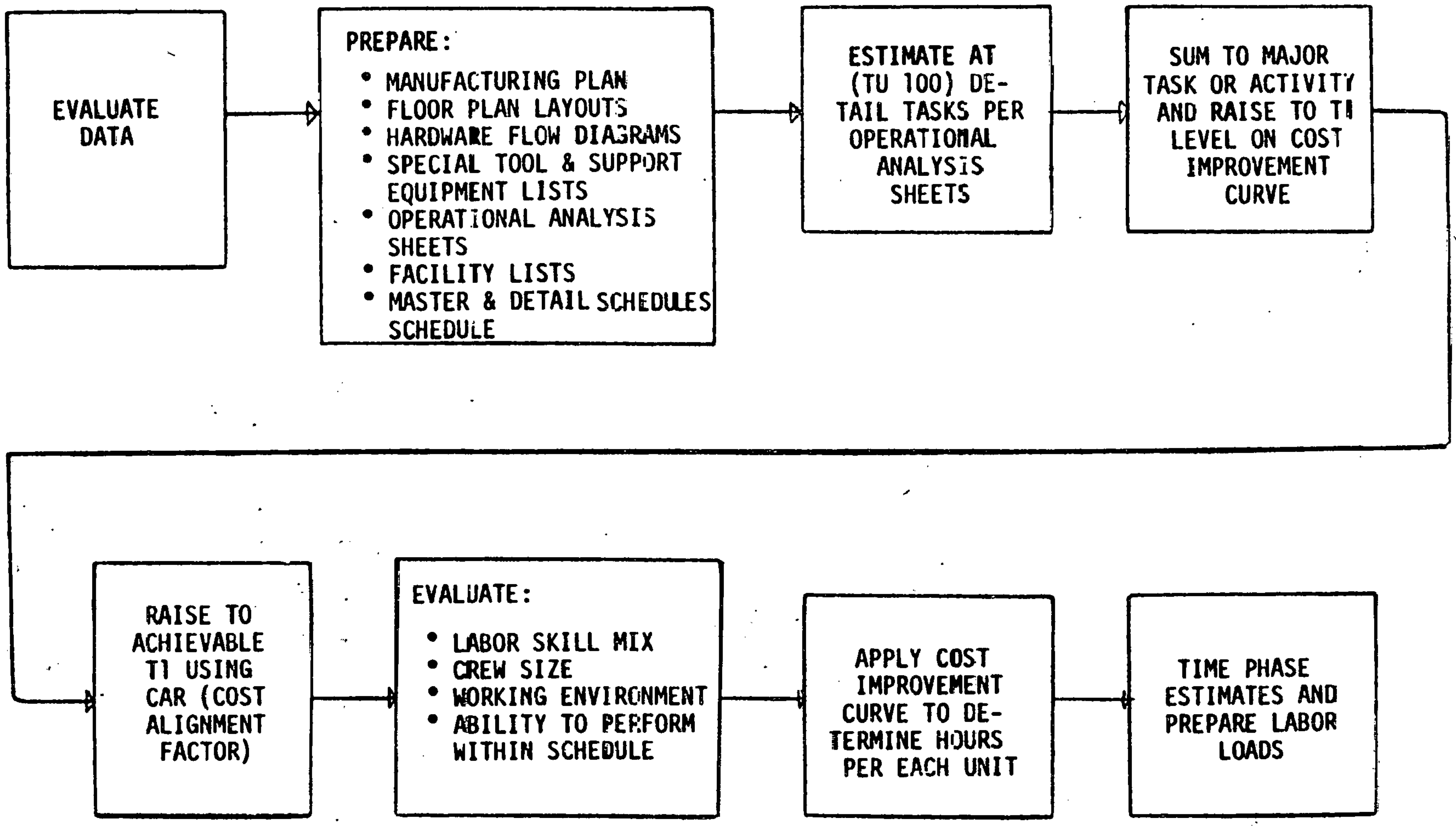


Figure 4-9. Detail Labor Hour Estimating Methodology

Procurement - Procurement includes raw materials purchased parts, purchased equipment and subcontracts. These costs are typically derived from supplier quotations in response to specific requests, supplier price catalogs and historical cost data from MDAC records.

Detail descriptions of the functional elements and the specific estimating methods are described under the functional element subheadings below.

Cost Methodology - Labor and Material

Manufacturing

The manufacturing hardware and assembly estimates were derived for the Pilot Plant by utilizing the detail estimating method as depicted on Figure 4-9. These first unit estimates were projected down a 89% cost reduction curve for a quantity of 1,760 heliostats and 74 field controllers. The installation and site activation cost is based on an assessment of all of the activities and tasks to be performed, as well as the skills required to accomplish the work package, by experienced estimators. The manhours for these skills were calculated based on the schedule requirements. The labor rates experienced in the site area for the skills required were applied to the manhours and these appear in the costs as contract labor.

Tooling

The tooling function is responsible for design, fabrication and maintenance of tools through the life of the program. The tooling estimator has at his disposal all the information available for the manufacturing and material estimators. The tool estimating basic data manual is the basis for the tooling estimates. This manual is a compilation of actual tool cost history. This cost history is considered to be raw estimates so are factored by an approved division-wide bid factor to provide a realistic attainable tooling estimate.

The tooling sustenance has been estimated by use of a division factor of 6.4% of manufacturing. This factor was derived from actual cost relationships.

Planning and Quality Assurance

These functions have been estimated by use of a factor applied to the manufacturing manhour estimates. The factors used are based on previous program cost history. The Quality Assurance also includes direct estimates based on the number of men required to accomplish receiving inspection and testing procedures.

Production Support

Industrial Engineering and the activities of the personnel who establish the budgets for Manufacturing, Planning, Tooling and Quality Assurance charge into an account which is allocated against the labor hour base developed by those groups. Since this effort is allocated, it is estimated by a factor. The factor is derived from the actual cost relationships.

Material

Material estimates are primarily based on quotation received from vendors and current raw material prices. The first unit values were established and then projected down a 95% cost reduction curve for 1,760 heliostats and 74 field controllers.

Engineering and Logistics

The Engineering and Logistics efforts were estimated by manloading each of the cost breakdown structure tasks. The estimates include program management, development design, and sustaining engineering effort.

4.5 RECEIVER AND TOWER SYSTEM (4190.2)

This element comprises all items related to the receiver including the tower and platform, receiver unit, riser piping, downcomer piping, insulation and foundation and site preparation. Costs are to provide for the labor and material required to design, fabricate, deliver, assemble, install, checkout and activate, and support acceptance test and the initial two years of system test operations for one receiver and tower equipment set, including test hardware and preparation of all installation, maintenance and operating instructions.

4.5.1 Receiver and Tower Equipment Costs and Technical Characteristics

Costs have been estimated by Rocketdyne Division of Rockwell International and Stearns-Roger to be as follows:

Title	Non-recurring (million)	Recurring (million) Material	Labor	Total	Total NR&R
Receiver unit	$0.00	$1.86	$5.75	$7.61	$7.61
Steam generator	0.00	0.00	0.00	0.00	0.00
Riser and horiz pipe	0.00	0.02	0.05	0.07	0.07
Downcomer and horiz	0.00	0.04	0.08	0.12	0.12
Tower and platform	0.00	0.27	0.15	0.42	0.42
Foundation and site	0.00	0.05	0.16	0.21	0.21
Des eng test and pln	2.24	0.00	0.00	0.00	2.24
Total (4190.2)	$2.24	$2.24	$6.19	$8.43	$10.67

Additional cost detail is provided in Table 4-9, and Table 4-10 provides a technical description of the costed items.

4.5.2 Receiver and Tower Equipment Schedule, Funding and Important Drivers

Receiver schedule and funding information is shown on Figure 4-10. Design and development starts 36 months prior to IOC and continues for 21 months while production starts 34 months prior to IOC and ends at IOC. However, the last six months of production is mainly for acceptance test and final hardware integration. Systems test operations start at IOC and continue for 24 months. This schedule results in funding that peaks at $3.8 million in the second half of 1979. Figure 4-11 indicates the spread of committed dollars.

The 36-month design, fabrication, and construction period is based on utilizing components and systems specifications from the existing preliminary design. At the beginning of the program, it is expected that requirements will be frozen and that component and subsystems specifications can be released to manufacturing and vendors where appropriate and that quotations can be received in the first 4 months. The only exception to this is for the

Table 4-9. Receiver and Tower System Cost Detail (Page 1 of 3)

6002 WBS SERIES PILOT PLANT 17.17.58. DATE: 77/05/23.

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
4190.211	ABSORBER UNIT	.00	.88 V	4.72 I	5.60	5.60
4190.212	PIPING	0.00	.48 V	.32 I	.80	.80
4190.213	SUP,STR,PLATFORMS	0.00	.15 I	.01 I	.16	.16
4190.214	INST. + CTR.	0.00	.27 I	.05 I	.32	.32
4190.215	PACKING + TRANS.	0.00	.02 I	.10 I	.11	.11
4190.216	FIELD ERECTION+IN	0.00	.06 I,H	.54 I,H	.60	.60
4190.21	SUBTOTAL	.00	1.86	5.75	7.61	7.61
4190.231	FROM TUR,GEN,BLDG	0.00	.02 C,H	.03 I	.04	.04
4190.232	FROM THERMAL STOR	0.00	.01 C,H	.02 I	.03	.03
4190.23	SUBTOTAL	0.00	.02	.05	.07	.07
4190.241	TO TURBINE GEN,BL	0.00	.03 C,H	.07 I	.10	.10
4190.242	TO THERMAL STORAG	0.00	.01 C,H	.01 I	.03	.03
4190.24	SUBTOTAL	0.00	.04	.08	.12	.12
4190.251	TOWER	0.00	.14 C	.10 I	.24	.24
4190.252	PLATFORM	0.00	.03 C	.04 I	.07	.07
4190.253	ELEVATOR+OTHER AC	0.00	.08 H,C	0.00	.08	.08
4190.254	LIGHTING	0.00	.01 H	0.00	.01	.01
4190.255	LIGHTNING	0.00	.01 H	0.00	.01	.01
4190.25	SUBTOTAL	0.00	.27	.15	.42	.42
4190.261	FOUNDATION	0.00	.04 C,H	.15 I	.19	.19
4190.262	EXCAVATION	0.00	.01 H	.01 I	.02	.02
4190.26	SUBTOTAL	0.00	.05	.16	.21	.21

Table 4-9. Receiver and Tower System Cost Detail (Page 2 of 3)

6002 WBS SERIES PILOT PLANT 17,1/,58, DATE: 77/05/23,

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
4190,2111	ABSORBER	0,00	,87 V	4,70 I	5,57	5,57
4190,2112	DRUM	0,00	,00 V	0,00	,00	,00
4190,2113	DOORS,HOUSING,LIN	0,00	,01 V	,02 I	,03	,03
4190,211	SUBTOTAL	,00	,88	4,72	5,60	5,60
4190,2311	PIPING	0,00	,01 C	,02 I	,03	,03
4190,2312	HANGERS,VAL,,PIPE	0,00	,00 C	,00 I	,00	,00
4190,2313	INSULATION	0,00	,01 C,H	0,00	,01	,01
4190,231	SUBTOTAL	0,00	,02	,03	,04	,04
4190,2321	PIPING	0,00	,01 C	,02 I	,03	,03
4190,2322	HANGARS,VAL,PIP S	0,00	,00 C	,00 I	,00	,00
4190,2323	INSULATION	0,00	,00 H	0,00	,00	,00
4190,232	SUBTOTAL	0,00	,01	,02	,03	,03
4190,2411	PIPING	0,00	,02 C	,06 I	,08	,08
4190,2412	HANGERS,VAL,PIPE	0,00	,00 C	,01 I	,01	,01
4190,2413	INSULATION	0,00	,01 H	0,00	,01	,01
4190,241	SUBTOTAL	0,00	,03	,07	,10	,10
4190,2421	PIPING	0,00	,00 C	,01 I	,01	,01
4190,2422	HANGERS,VAL,,PIPE	0,00	,00 C	,00 I	,00	,00
4190,2423	INSULATION	0,00	,01 H	0,00	,01	,01
4190,242	SUBTOTAL	0,00	,01	,01	,03	,03
2-24-77	REVIS	2,24	2,24	6,19	8,43	10,67

Table 4-9. Receiver and Tower System Cost Detail (Page 3 of 3)

6002 WBS SERIES PILOT PLANT		17,17,58,			DATE:	77/05/23,
WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
4190,271	TOWER + FOUNDATIO	,09 J	0,00	0,00	0,00	,09
4190,272	RECEIVER	2,12 I	0,00	0,00	0,00	2,12
4190,273	RISER,DOWNCOMER+H	,03 I	0,00	0,00	0,00	,03
4190,27	SUBTOTAL	2,24	0,00	0,00	0,00	2,24

Table 4-10. Technical Description Receiver and Tower Equipment (Page 1 of 2)

Receiver Unit Assembly	
Diameter	23 ft
Height	62 ft
No. Absorber Panels	24
Exposed Surface	2,963 ft^2
Absorber Panel	
Height	41 ft
Width	3.3 ft
Weight	3,000 lb
No. of tubes	70
Tube OD	0.5 in
Tube ID	0.269 in
Tube Material	Incoloy 800
Surface Coating	Pyromark
Insulation	Blown, Closed Pore FG
Thermal Expansion	Sliding Channels
Absorptivity, Min.	0.9
Peak Heat Flux, MW/m^2	0.3
Outlet Temperature, °C(°F)	516/349 (960/660)
Inlet Temperature, °C(°F)	218/104 (425/220)
Outlet Press MN/m^2 (psia)	10.4 (1,500)
Inlet Press MN/m^2 (psia)	13.8 (2,000)
Riser Piping	
Pipe	ASTM A106B carbon steel, 4-in dia, schedule 160
Supports	Variable spring, constant, and rigid pipe guides

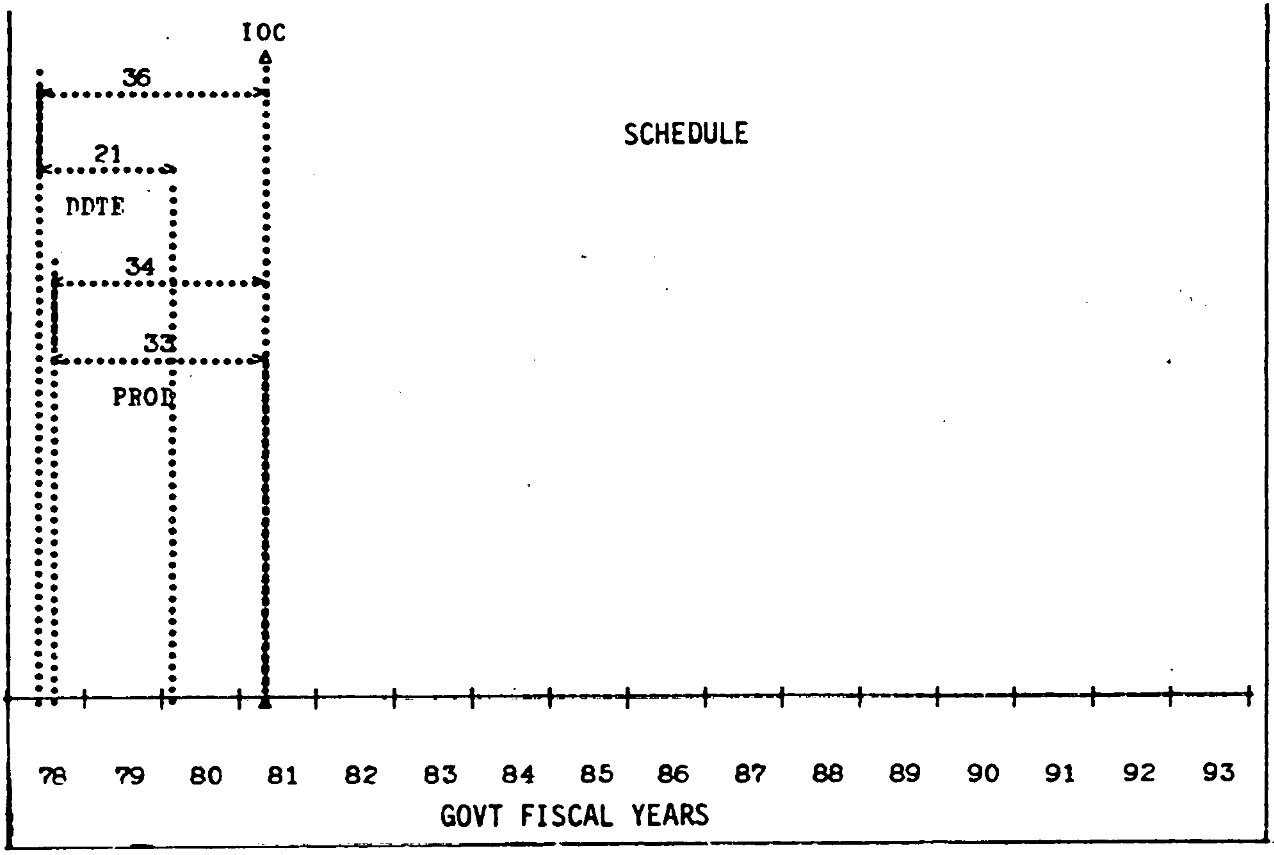
Table 4-10. Technical Description Receiver and Tower Equipment (Page 2 of 2)

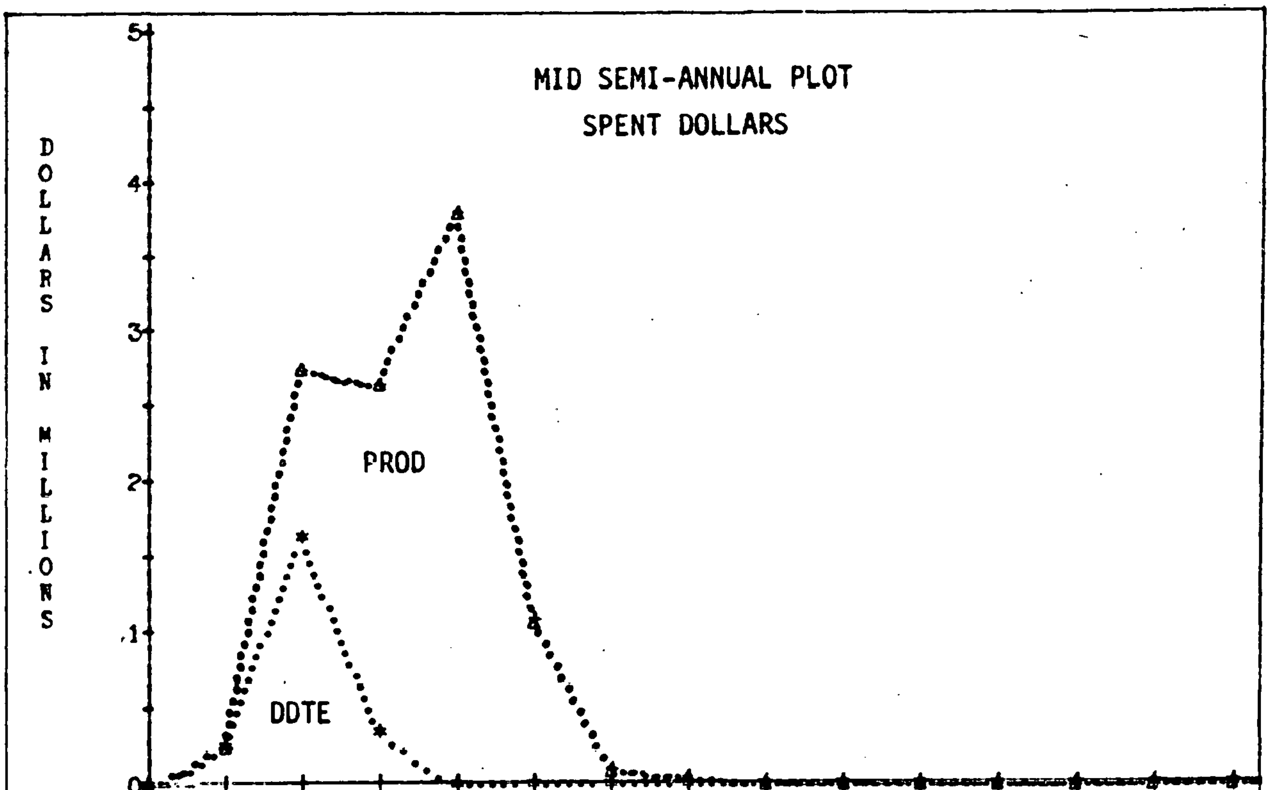
Downcomer Piping	
Pipe	ASTM A335P22 chrome moly, 6 in dia, schedule 160
Supports	Variable spring, constant and rigid
	Rigid pipe guides
Insulation	
Riser	2.5 in t
Downcomer	5 in t
Tower and Platform	
Tower	130 tons steel
Elevator	208 ft
Caged ladder	208 ft
Platforms	Steel grating and handrail
Aircraft lights	Strobe
Foundation and Site Preparation	
Earthwork	2,800 cubic yards Total
Foundation	470 cubic yards slab, 260 cubic yards walls
	400 cubic yards concrete, 30 tons rebar

Incoloy 800 tubing that is used to fabricate the absorber. In this particular case, release to the vendor is required within 2 months after contract go-ahead.

4.5.3 Receiver and Tower Equipment Costing Methodology

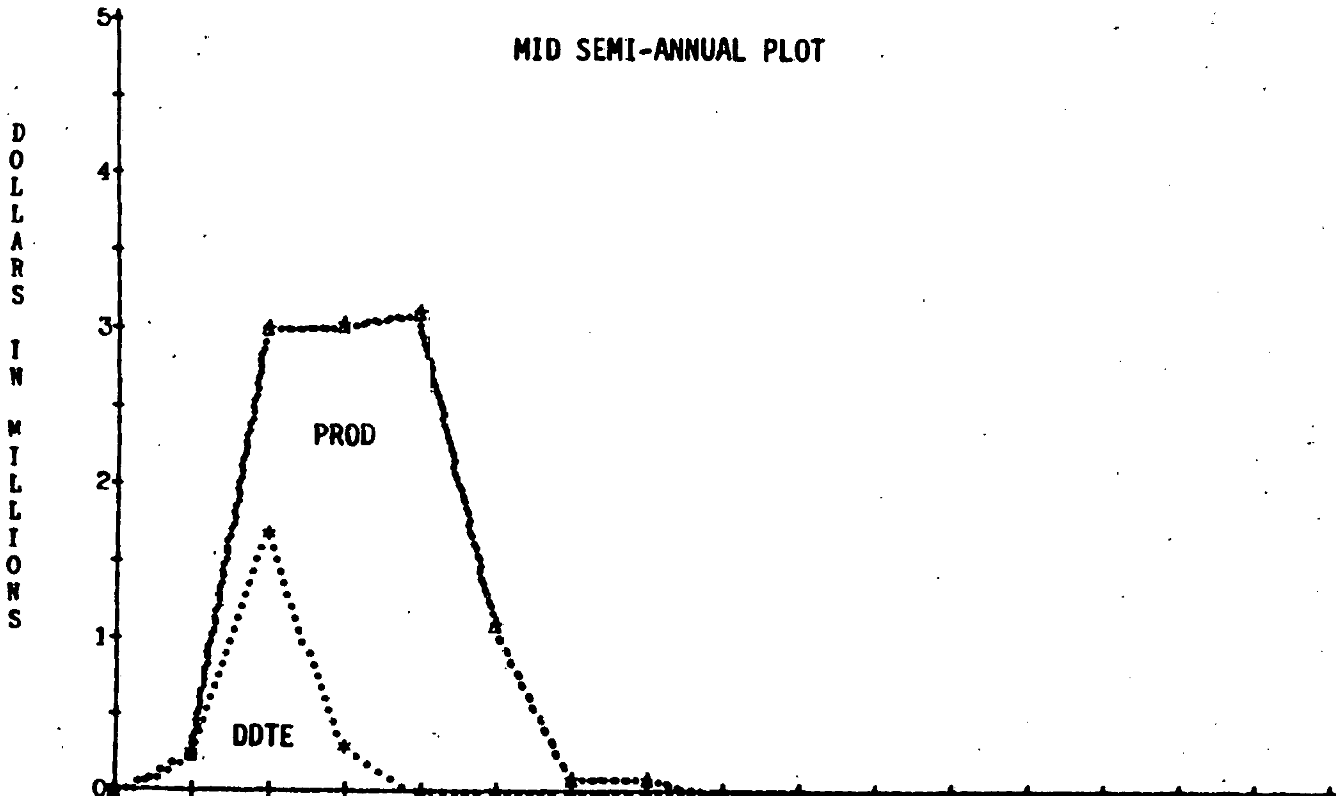
The costing methodology incorporates the approach used by the Rocketdyne Division of Rockwell International for the receiver unit along with the approach used by Stearns-Roger for the tower, riser and downcomer piping, and foundation.





GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT•E	.3	1.6	.4	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	1.1	2.3	3.8	1.1	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	.3	2.8	2.7	3.8	1.1	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 4-10. Receiver and Tower System Summary Chart



GFY	1978	1978	1979	1979	1980	1980	1931	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT·E	.3	1.7	.3	.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	1.3	2.7	3.1	1.1	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	.3	3.0	3.0	3.1	1.1	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 4-11. Receiver and Tower System Committed Dollars

4.5.3.1 Overall Procedure. Costing of the receiver unit is based on Rocketdyne experience concerning the design, manufacture, and test of the SRE and Engineering and Manufacturing Department expertise on similar tasks. Estimates used 1977 equipment, material, and labor costs reflecting appropriate fabrication, assembly, and installation at the SCE Coolwater Station in Barstow, California. Estimates were made from detailed equipment, parts, and materials lists, quotations from established vendors and up-to-date catalog prices. All engineering costs associated with the design and development of the receiver were made by cognizant management personnel in the Rocketdyne Engineering Department. The estimates were based on design tasks for similar equipment. In general, most estimates were based on experience on the SRE program and also based on experience on similar structural jobs. All labor costs reflect current wage rates at Rocketdyne for appropriate cost centers, which are in agreement with rate levels approved by the United States Government. In-field costs for construction are based on today's prevailing rates in the Barstow area.

Costing of the tower, riser and downcomer piping, and foundation is based on Stearns-Roger experience in the construction and installation of piping networks, concrete foundations, and structural steel work. Estimates were generally based on historical factors such as composite values per cubic yard for concrete and earthwork and a percentage of the piping system for riser/downcomer support structures. Field labor costs for construction reflect today's prevailing rates in the Barstow area.

4.5.3.2 Sources of Estimates. All valves, controls, and components which are to be purchased were based either on vendor quotes or on catalog price lists. Raw material, primarily Incoloy 800 tubing, was based on quotes from Huntington Alloy, Inc., the only supplier of Incoloy 800 in the United States. Manufacturing costs were based very strongly on experience with SRE and on Manufacturing Department knowledge of learning curves with which they are able to estimate reduction in costs for a given product as the production level increases. Construction costs for the receiver structure, as well as mounting the absorber panels on the structure, were based on estimates provided by Rocketdyne's Facilities and Industrial Engineering Department. They utilized the 1976 edition of Process Plant Construction Estimating Standards published by Richardson Engineering Services, Inc., and the Estimators Piping Manhour Manual published by Page and Nation.

4.5.3.3 Driving Assumptions/Scenarios. Fabrication costs for absorber panels reflect the application of a high-speed seam welding technique developed during SRE panel fabrication. This technique is ten times faster than previous practice and received the ASME code stamp in October 1976. Also, it is important to emphasize that estimates have been heavily influenced by "cleansed" SRE prototype hardware actuals. A late review by Rocketdyne of this procedure has indicated that a substantial downward revision of cost of something more than $500,000 may be justified. This is not reflected in the costs that are shown.

4.6 THERMAL STORAGE EQUIPMENT (4190.3)

The thermal storage equipment element includes the heat storage equipment portion of the central receiver plant including the thermal storage unit, heat exchangers, instrumentation and control units, foundation and site preparation, and associated piping, valves, and pumps. Costs are to provide for the labor and material required to design, fabricate, deliver, assemble, install, checkout and activate and support acceptance test and the initial 2 years of systems test operations for one thermal storage equipment set and associated materials. Also included as any test hardware and preparation of installation, maintenance, and operating instructions.

4.6.1 Thermal Storage Equipment Costs and Technical Characteristics

Costs have been estimated by Rocketdyne Division of Rockwell International and McDonnell Douglas Astronautics Company as follows:

Title	Non-recurring (million)	Recurring (million) Material	Labor	Total	Total NR&R
Thermal stor unit	$0.00	$0.94	$0.00	$0.94	$0.94
Circulation eq	0.00	0.37	0.16	0.52	0.52
Heat exchangers	0.00	0.65	0.21	0.86	0.86
Instr and control	0.00	0.39	0.00	0.39	0.39
Foundation and site	0.00	0.29	0.00	0.29	0.29
Des eng test and pln	0.63	0.00	0.67	0.67	1.30
Total (4190.3)	$0.63	$2.64	$1.04	$3.68	$4.30

Additional cost detail is provided in Table 4-11, and Table 4-12 is a brief technical description of the costed items.

4.6.2 Thermal Storage Equipment Schedule, Funding, and Important Drivers

The funding and schedule for this element is provided in Figure 4-12, which indicates that D&D funding starts 36 months prior to IOC and is essentially completed after 11 months. Purchase of major cost long-lead items is initiated 27 months prior to IOC. Installation of all equipment piping commences 21 months prior to IOC and is completed 12 months prior to IOC. Filling of the thermal storage unit with rock and heat transfer fluid is completed 9 months prior to IOC which phases into checkout of the thermal storage subsystem scheduled for completion 6 months prior to IOC. During the remaining 6-month portion, the thermal storage subsystem will be activated and tested with the other major subsystems. The tank construction and system installation phase beginning on 1 July 1979 includes in-house engineering as well as field engineering to coordinate and supervise the field installation.

Table 4-11. Thermal Storage Equipment Cost Detail

6003 WBS SERIES PILOT PLANT 17,29,30, DATE: 77/05/23,

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
4190,311	STORAGE TANKS-HEA	0,00	,79 M	0,00	,79	,79
4190,312	INSULATION	0,00	,09 H	0,00	,09	,09
4190,313	VLLAGE MAINT EQ	0,00	,04 C	0,00	,04	,04
4190,314	FLUID MAINT EQ	0,00	,03 V	0,00	,03	,03
4190,31	SUBTOTAL	0,00	,94	0,00	,94	,94
4190,321	PIPING-SUPT STAND	0,00	,17 H	0,00	,17	,17
4190,322	VALVES	0,00	,08 V	0,00	,08	,08
4190,323	PUMPS	0,00	,07 V	0,00	,07	,07
4190,324	INSULATION	0,00	,03 H	0,00	,03	,03
4190,325	STEAM DRUMS	0,00	,01 C	0,00	,01	,01
4190,326	WATER/STEAM PIPIN	0,00	,01 H	,01 H	,02	,02
4190,327	FIELD ERECTION-IN	0,00	,00	,15 H	,15	,15
4190,32	SUBTOTAL	0,00	,37	,16	,52	,52
4190,331	DESUPERHEATERS	0,00	,01 C	0,00	,01	,01
4190,332	STEAM GEN HEAT EX	0,00	,31 V,A,H	,21 A,H	,52	,52
4190,333	THERMAL STORAGE H	0,00	,27 M	0,00	,27	,27
4190,334	INSULATION	0,00	,05 H	0,00	,05	,05
4190,335	SUPPORT STR	0,00	,01 H	0,00	,01	,01
4190,33	SUBTOTAL	0,00	,65	,21	,86	,86
4190,351	TANK FOUNDATIONS	0,00	,01 I	0,00	,01	,01
4190,353,1	DIKES OR EMERG CO	0,00	,23 I	0,00	,23	,23
4190,354	SITE PREP	0,00	,01 I	0,00	,01	,01
4190,355	SAFETY PROT EQ,	0,00	,03 I	0,00	,03	,03
4190,352	OTHER FOUNDATIONS	0,00	,01 I	0,00	,01	,01
4190,35	SUBTOTAL	0,00	,29	0,00	,29	,29

Table 4-12. Technical Description Thermal Storage Equipment (Page 1 of 2)

Assembly	Description
Thermal storage	Single cylindrical tank, axis vertical, installed above ground, 15.2 m (50.0 ft) diameter by 13.4 m (44.0 ft) high; 2,450 m^3 (86,400 ft^3, 646,000 gal) volume; contains 4.53 x 10^6 kg (4,990 ton) of granite rock and coarse silica sand (approximately 2:1 rock:sand by volume) and 525,000 liters (139,000 gal) of Caloria HT43 heat transfer fluid. Fluid temperature range: 218 to 302°C (425 to 575°F). Fabricated of ASTM A537-70 Grade B structural steel by field-welded construction.
Ullage maintenance unit	Storage and control of ullage gas with compressed gas storage at 1.20 MPa (175 psia); tank pressure control, venting, inert gas (nitrogen) control, volatile vapor recovery and control
Fluid maintenance unit	Full-flow, continuous filtration with dual 80-mesh filters upstream of pump; periodic distillation with vacuum distillation unit in side-stream to remove polymerized materials; periodic fluid makeup
Desuperheater	Direct contact mixing chamber with water injected through multiple atomizing nozzles into superheated steam; single unit; three nozzles.
Thermal storage heater	Two identical exchangers in parallel; each is TEMA type DFU, with removable U-tube bundle, 2 shell passes, 6 tube passes; steam/water on tube side; 464 m^2 (5,000 ft^2) heat transfer area per exchanger; carbon steel
Steam generator	Three-stage (series) modules each with separate feedwater preheater, boiler, and superheater; 2 modules in parallel; steam/water on shell side; carbon steel: Preheater is straight tube, floating head, counterflow exchanger with 196 m^2 (2,106 ft^2) heat transfer area per exchanger Boiler is horizontal U-tube kettle boiler with 791 m^2 (8513 ft^2) heat transfer area per exchanger Superheater is horizontal U-tube, crossflow exchanger with 84 m^2 (904 ft^2) heat transfer area per exchanger

Table 4-12. Technical Description Thermal Storage Equipment (Page 2 of 2)

Assembly	Description
Fluid charging loop pump	Two identical pumps in parallel; centrifugal, high-temperature type, with dual-speed electric motors; each pump has flow of 64 kg/s(141 lb/s), and 0.060 MWe (80 hp)*motor input at maximum charging rate (15 MWt)
Fluid extraction loop pump	Two identical pumps in parallel; centrifugal, high temperature type, with single-speed electric motors; each pump has flow of 70 kg/s(155 lb/s), and 0.052 MWe (70 hp)*motor input at maximum extraction rate (16.1 MWt)

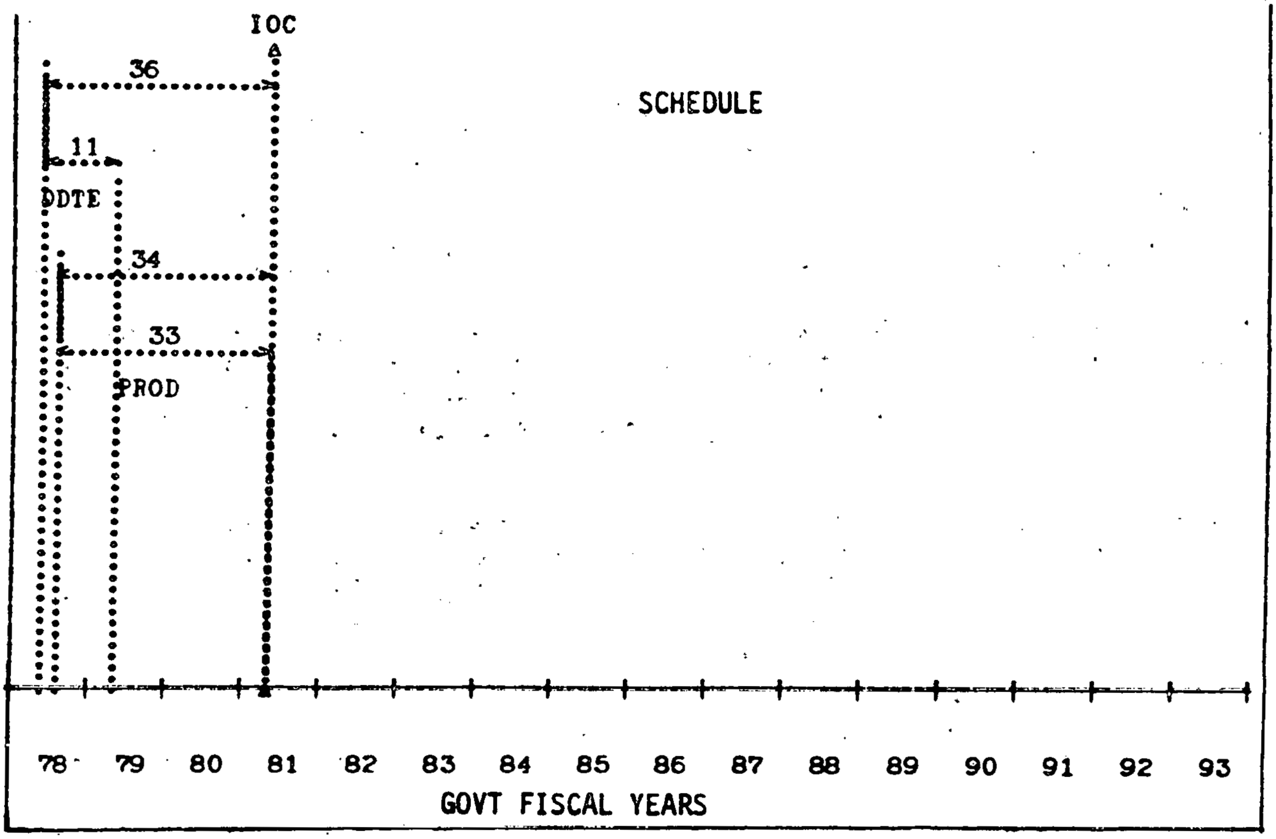
*Required input power; not full motor capacity

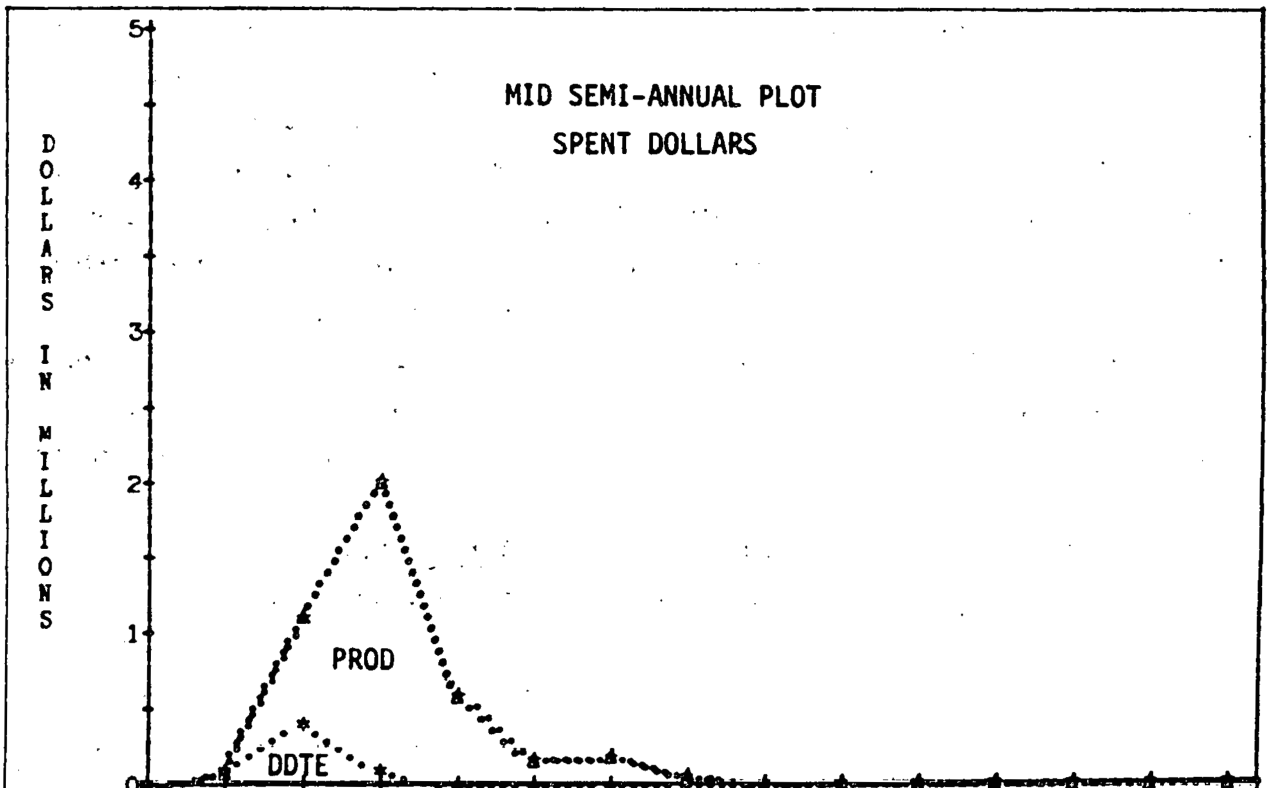
Engineering checkout commences 1 January 1980 and lasts for 1 year with cost primarily incurred by field operating personnel. Technical support of system tests operations is included for the 2-year operation phase beginning at IOC. Engineering effort has been man loaded for each development issue or task based on experience with similar field erection subcontracts. Peak funding is in the first half of 1979 at $2.0 million. Important drivers on a schedule are the lead times required for the material and installation of the thermal storage unit tank in the installation of the piping and control systems. The schedule is based on the fact that site construction and installation of all equipment cannot begin until the earth work is completed at the end of the second quarter of 1979. Figure 4-13 indicates committed funding.

4.6.3 Thermal Storage Equipment Costing Methodology

The costing methodology incorporates the approach used by the Rocketdyne Division of Rockwell International for all elements other than the steam generator portion of the heat exchangers, along with the approach used by McDonnell Douglas Astronautics Company for the steam generator heat exchangers.

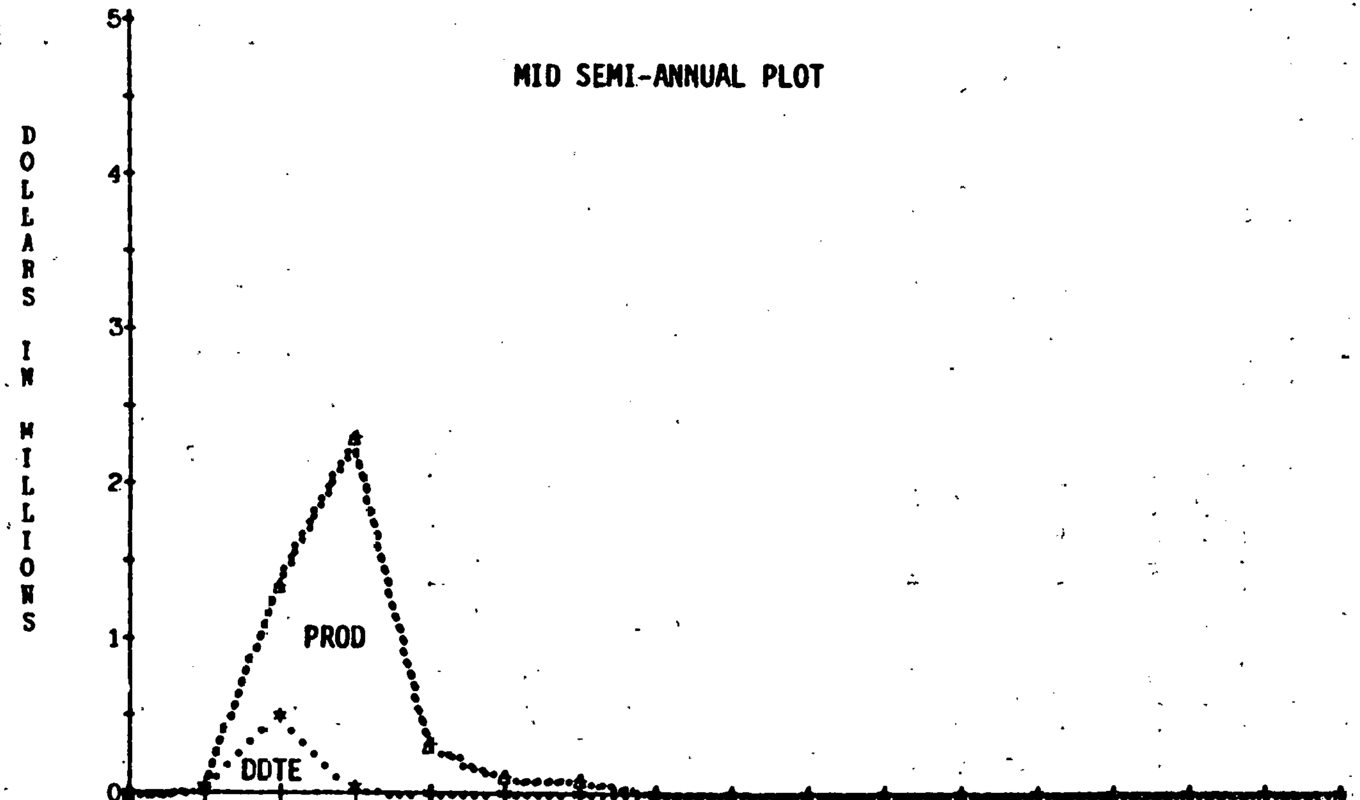
4.6.3.1 Overall Procedure. Costing is based on Rocketdyne Division experience concerning the design, manufacture, and testing of the subsystem research experiments and the facility engineering department experience on





GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT•E	•1	•4	•1	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	0•0	•7	1•9	•6	•2	•2	•1	0•0	0•0	0•0	0•0	0•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	•1	1•1	2•0	•6	•2	•2	•1	0•0	0•0	0•0	0•0	0•0	0•0	0•0

Figure 4-12. Thermal Storage Equipment Summary Chart



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT•E	•1	•5	•1	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	0•0	•9	2•2	•3	•1	•1	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	•1	1•4	2•3	•3	•1	•1	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0

Figure 4-13. Thermal Storage Equipment Committed Dollars

similar construction projects. Estimates used 1977 industrial equipment material and labor costs reflecting appropriate fabrication, assembly, and installation at the SCE Coolwater Station at Barstow. Estimates were made from a detailed equipment, parts and materials list, quotations from established vendors and up-do-date catalog prices. Engineering costs were based on current wage rates at Rocketdyne for appropriate cost centers which are in agreement with costs in the power plant construction industry. Costs reflect appropriate A&D burden and fee factors. Construction costs are based upon today's prevailing rates in the Barstow area.

Fabrication costs of the steam generator heat exchangers are based on a cost estimating relationship derived from current vendor quotes for several sizes and an earlier estimating manual curve. Appropriate indirect and field labor factors were applied to these costs based on historical experience.

4.6.3.2 Sources of Estimates. Rocketdyne's Facility Engineering Department utilized the 1976 addition of "Process Plant Construction Estimating Standards" published by Richardson Engineering Services, Inc., "Estimators Piping Manhour Manual" published by Page and Nation, and the "Electrical Tradebook" published by Biddle Trade Publishing Company, for electrical and mechanical costing installation detail. CBS category 4190.36 "Design Costs" contains nonrecurring design engineering and vendor coordination up to the initiation of construction on 1 July 1979, and recurring construction coordination and all checkout activities up to IOC.

Vendors were contacted for estimates on the fabrication of the thermal storage heater and steam generator heat exchangers, thermal storage, principal control valves, fluid circulation pumps, and the desuperheater. Heat exchanger price quotations were obtained from Southerwestern Engineering, Thermxchanger Co., Wiegmann and Rose, Industrial Fabricating Company and Yuba Heat Transfer Corp. Thermal storage tank quotations were obtained from Pittsburg Des Moines Co. and Pacific Fabricators. The FMU filter and distillation units were priced from vendors supplying identical or similar components. Hand valve, relief valve, check valve, transducer and miscellaneous fluid component prices were obtained from current catalogs. Electronic controllers switching, and signal conditioning subassembly units were based on costs of a similar control and instrumentation system built 3 years ago and updated with appropriate cost escalation.

4.6.3.3 Driving Assumptions/Scenarios. The 36-month design, fabrication and construction period is based on utilizing the component and system specification from the existing preliminary design Phase I contract. At the beginning of the program it is expected that requirements will be frozen and that component and subsystem specifications can be written and released for vendor review and quotations within the first 4 months at the completion of the preliminary design review. From this point it will take approximately 4 months before vendors and suppliers can be under contract. Components and subsystems that require detailed design work by vendors will contain a review period prior to initiation of vendor fabrication or installation. Site installation and construction cannot begin before 1 July 1979, which will be the point at which earth work as well as the tower construction is completed. It is expected that tank erection and all major component and piping installation as well as controls integration will be completed during the 6-month interval of the latter half of 1979. During the first quarter of 1980, the thermal storage unit will be filled with the rock/sand storage medium as well as the heat transfer fluid. System checkout will occur during the second quarter of 1980 and include operation of all components in a cold flow mode and with heat applied whenever steam is available from the receiver. Testing of the thermal storage subsystem in concert with other major subsystems in the central receiver plant will occur during the second half of 1980. It is expected that whenever steam is available during the integrated testing period, bed conditioning of the thermal storage unit will occur. It is planned that the system will be completely functionally operational and checked through all operating modes by December 1980 at the beginning of IOC.

4.7 THERMAL STORAGE MATERIAL (4190.4)

This element includes the organic and inorganic heat storage materials. Costs provide the labor and material required to procure the materials and install the storage material in the thermal storage subsystem.

4.7.1 Thermal Storage Material Costs and Technical Characteristics

Costs provided by the Rocketdyne Division of Rockwell International are shown below.

Title	Non-recurring (million)	Recurring (million) Material	Labor	Total	Total NR&R
Inorganic material	$0.00	$0.06	$0.00	$0.06	$0.06
Organic material	0.00	0.19	0.00	0.19	0.19
Delivery	0.00	0.04	0.00	0.04	0.04
Handling at site	0.00	0.09	0.00	0.09	0.09
Subtotal	$0.00	$0.38	$0.00	$0.38	$0.38

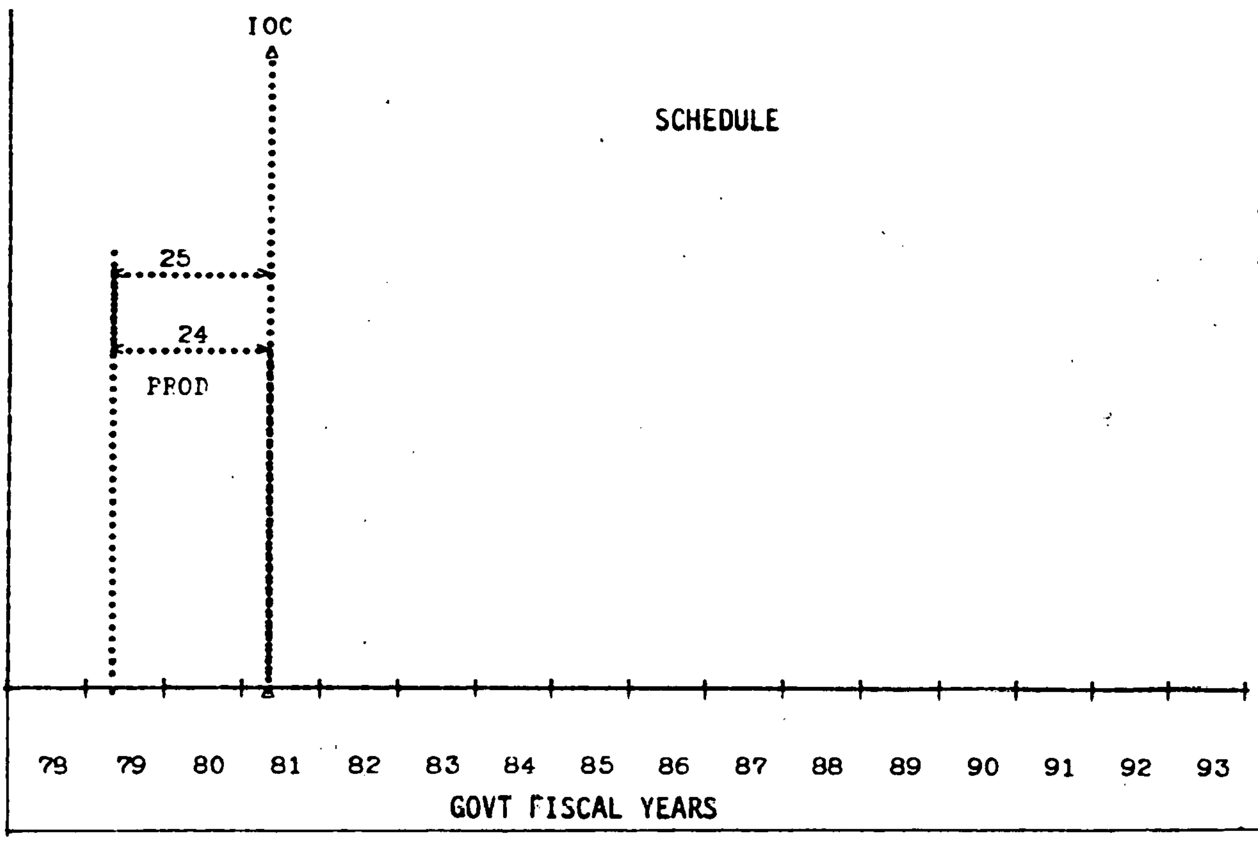
These costs cover 525 m^3 (139,000 gal) of Caloria HT-43, and 4.530 x 10^6 kg (4,990 tons) of graded river gravel and sand approximately 2 to 1 ratio of rock sand by volume. The river gravel is nominally 25 mm (1 in) size, and the sand is a coarse silica grade nominally 1.5 mm (1/16 in) in size. The Caloria HT-43 is a readily available product of the Exxon Corporation and has been proved successful meeting the thermal storage subsystem requirements of the pilot plant in the SRE systems tests.

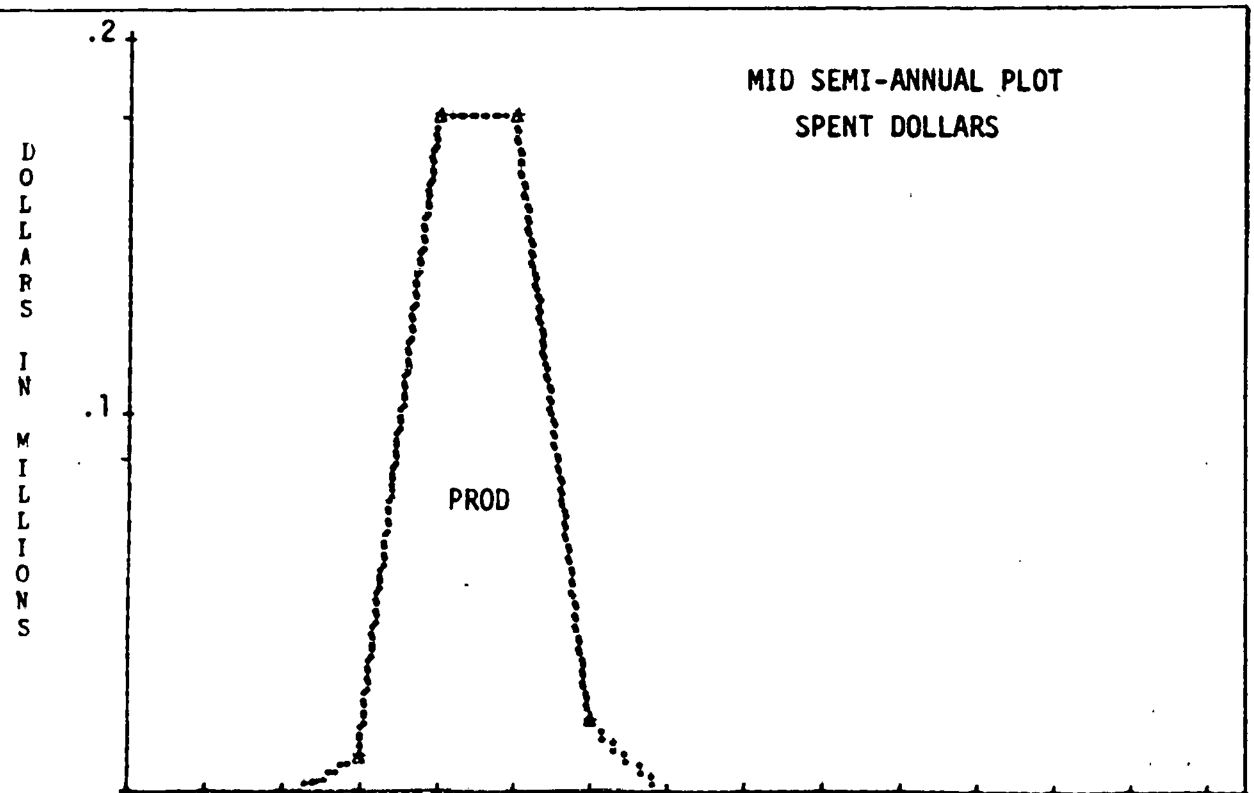
4.7.2 Thermal Storage Material Schedule, Funding and Important Drivers

The funding indicated in Figure 4-14 shows cost peaking in the first half of 1980 during the period of filling the thermal storage unit with the rock and heat transfer fluid. Procurement and installation starts 25 months prior to IOC and continues for 24 months. Lead times are not critical for any items involved. Committed dollars are funded in Figure 4-15.

4.7.3 Thermal Storage Material Costing Methodology

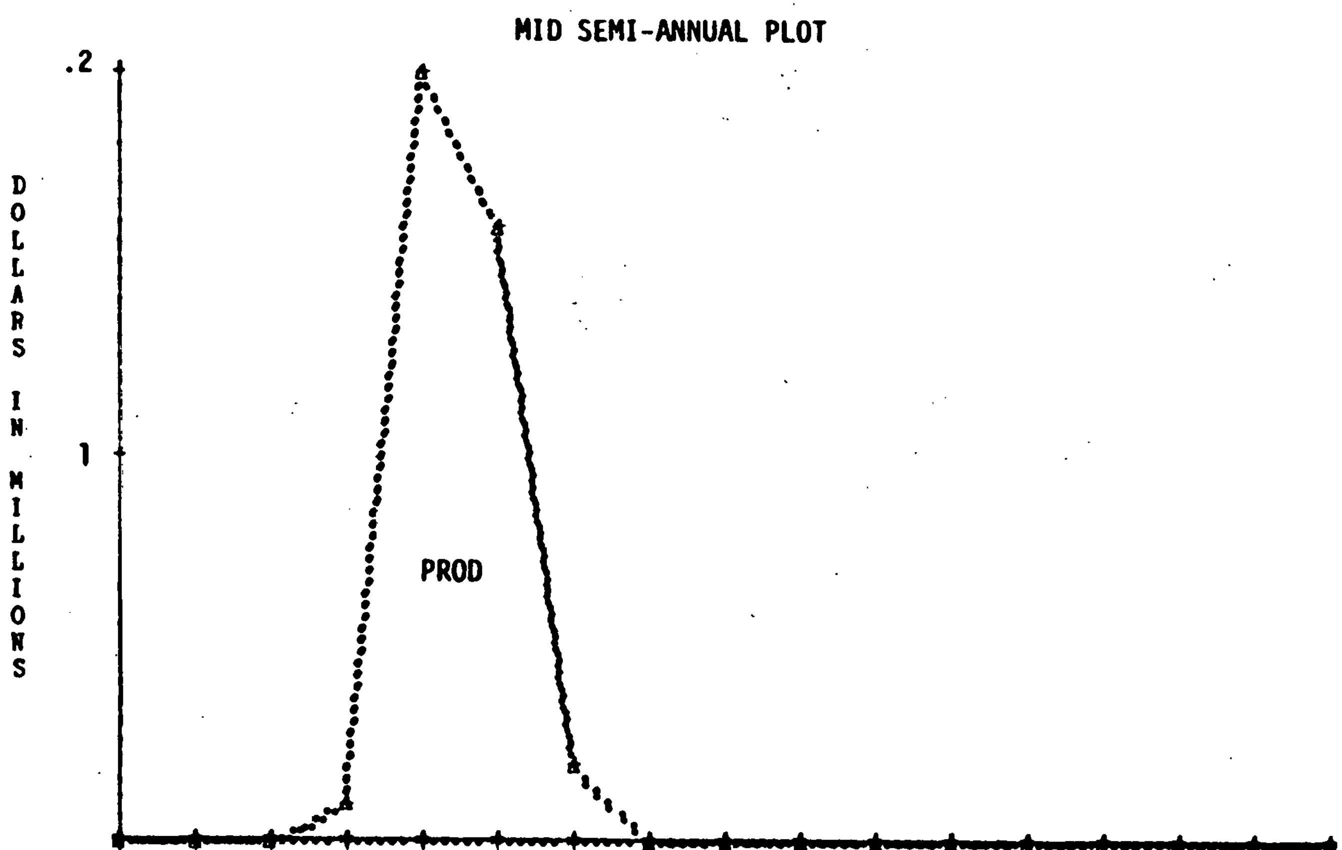
The costing approach used by the Rocketdyne Division of Rockwell International is described in the following paragraphs.





GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT•E	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	0•0	0•0	•0	•2	•2	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	0•0	0•0	•0	•2	•2	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0

Figure 4-14. Thermal Storage Material Summary Chart



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT•E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	0.0	.0	.2	.2	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	.0	.2	.2	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 4-15. Thermal Storage Material Committed Dollars

4.7.3.1 Overall Procedure. Costs for the storage medium were established by contacting suppliers of the required material.

4.7.3.2 Sources of Estimates. The source of cost for the Caloria HT-43 was the supplier Exxon Corporation, which quoted a price of $0.86 per gallon at Houston. The Caloria HT-43 has been in production for several years and is available for delivery in large quantities from its Houston facility. The cost of the rock and sand is based upon local supply within 50 miles of the pilot plant site and is based upon a $3 per ton quarry price for rock plus $12 per ton quarry price of the sand.

4.7.3.3 Driving Assumption/Scenarios. The use of the Caloria HT-43 plus rock is based upon economics derived from prior analysis and tests during the SRE program. These studies and tests showed that use of this combination results in a most economic storage of thermal energy for the desired temperatures, is readily available in large quantities, and can be scaled and utilized in a wide range of sizes with the best potential for lasting 30 years with a minimum of maintenance.

4.8 TURBINE PLANT EQUIPMENT (4300)

This element includes the turbine generator, supply and exhaust headers, condensing equipment, cooling equipment, water circulating equipment, water treatment equipment, instrumentation and controls, and connective piping and insulation. No included in this element are surveys, design and other engineering work, procurement effort, and construction direction which are normally included under the indirect effort (8100). Costs are to provide for site preparation, all material and equipment, and for the subcontracted labor and services necessary to transport, fabricate, assemble, install, and checkout materials and equipment at the Pilot Plant site.

4.8.1 Turbine Plant Equipment Costs and Technical Characteristics

The costs shown below have been estimated by Stearns-Roger:

Title	Non-recurring (million)	Recurring (million			Total NR&R
		Material	Labor	Total	
Turbine generator	$0.00	$2.39	$0.16	$2.55	$2.55
Heat rejection sys	0.00	0.90	0.08	0.97	0.97
Condensing sys	0.00	0.23	0.11	0.33	0.33
Feed heating sys	0.00	0.84	0.22	1.05	1.05
Water cir/treat eq	0.00	0.11	0.04	0.14	0.14
Total (4300)	$0.00	$4.45	$0.60	$5.05	$5.05

Table 4-13 provides detailed cost; this equipment is described in Table 4-14.

4.8.2 Turbine Plant Equipment Schedule, Funding and Important Drivers

Figure 4-16 shows Turbine Plant Equipment funding and schedule. This element starts 35 months prior to IOC and continues for 28 months. Peak funding of $1.8 million occurs in 1979. Figure 4-17 shows the estimated committed cost. These results reflect heavy front loading covering the turbine generator and receiver feed pumps.

4.8.3 Turbine Plant Equipment Costing Methodology

Costing is based on Stearns-Roger experience with power plants of this size and utilizes current industrial equipment, material, and labor costs reflecting the Barstow area location for the pilot plant. Estimates were made from the equipment list which defines the scope of work. Quotes were obtained or catalogs consulted for equipment and materials and site fabrication, assembly, and installation hours and dollars estimated based on experience and desert southwest labor rates. From these costs, the costs of the other major construction accounts (i.e., earthwork, concrete, piping, painting, and insulation) are prorated based on many previous power plant cost relationships for units of this size. Costs of instrumentation and control were estimated separately using typical equipment prices and experience on installation.

Table 4-13. Turbine Plant Equipment Cost Detail (Page 1 of 4)

65 WBS SERIES PILOT PLANT 17.43.49. DATE: 77/05/23.

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR-R
4300.11	TURBINE GEN.-ACCE	0.00	2.34 V,C	.09 I	2.44	2.44
4300.12	FOUNDATIONS	.00	.04	.06	.10	.10
4300.13	STANDBY EXCITERS	0.00	.00	0.00	.00	.00
4300.14	LUBRICATING SYS.	.00	.01	.01	.02	.02
4300.15	GAS SYSTEM	.00	.00	0.00	.00	.00
4300.16	REHEATERS	0.00	.00	0.00	.00	.00
4300.17	WEATHERPROOF HOUS	0.00	.00	0.00	.00	.00
4300.1	SUBTOTAL	.00	2.39	.16	2.55	2.55
4300.21	HEAT REJECT. EQ.	0.00	.33 C	0.00	.33	.33
4300.22	INSTALLATION COST	0.00	.00 C,H	.06 I	.06	.06
4300.23	EXHAUST DUCT	0.00	.10 C,H	.02 I	.12	.12
4300.24	EVAPORATION POND	0.00	.46 H	0.00	.46	.46
4300.2	SUBTOTAL	0.00	.90	.08	.97	.97
4300.31	CONDENSATE SYS.	.00	.23	.11	.33	.33
4300.32	TURBINE BYPASS SY	.00	.00	0.00	.00	.00
4300.3	SUBTOTAL	.00	.23	.11	.33	.33
4300.41	REGENERATIVE HEAT	0.00	.09	.02	.11	.11
4300.42	PUMPS	0.00	.72	.18	.90	.90
4300.43	PIPING + TANKS	0.00	.03	.02	.04	.04
4300.4	SUBTOTAL	0.00	.84	.22	1.05	1.05
4300.51	MAKE-UP TREAT.SYS	0.00	.06	.02	.08	.08
4300.52	CHEM.TREAT.-CONVR	0.00	.05	.02	.07	.07
4300.5	SUBTOTAL	0.00	.11	.04	.14	.14

Table 4-13. Turbine Plant Equipment Cost Detail (Page 2 of 4)

65 WBS SERIES PILOT PLANT 17,41,49, DATE: 77/05/23,

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
4300,121	CONCRETE	0,00	,04	,06	,10	,10
4300,122	STRUCTURAL STEEL	0,00	,00	0,00	,00	,00
4300,12	SUBTOTAL	,00	,04	,06	,10	,10
4300,141	LUB OIL COND,EQ,	0,00	,01	,00	,01	,01
4300,142	STORAGE TANKS	0,00	,00	,00	,00	,00
4300,143	FIRE PROTECT, EQ,	0,00	,00	0,00	,00	,00
4300,14	SUBTOTAL	,00	,01	,01	,02	,02
4300,151	HYDROGEN	0,00	,00	0,00	,00	,00
4300,152	CARBON DIOXIDE	0,00	,00	0,00	,00	,00
4300,15	SUBTOTAL	,00	,00	0,00	,00	,00
4300,311	PUMPS,DRIVES-CONT	0,00	,09	,00	,09	,09
4300,312	COND,STRG,TANKS	0,00	,09	,04	,14	,14
4300,313	PIPING,VALVES-FTS	0,00	,00	,00	,00	,00
4300,314	INSULATION	0,00	,03	0,00	,03	,03
4300,315	FOUNDSATIONS,SUP,	0,00	,01	,06	,07	,07
4300,31	SUBTOTAL	,00	,22	,11	,33	,33
4300,321	ACTUATING VALVES	0,00	,00	0,00	,00	,00
4300,322	PRESS,RED,ASSY,	0,00	,00	0,00	,00	,00
4300,323	PIPING MAN,-FIT,	0,00	,00	0,00	,00	,00
4300,324	DESUPERNATING SYS	0,00	,00	0,00	,00	,00
4300,325	INSULATION	0,00	,00	0,00	,00	,00
4300,326	HANGERS,FOUND,ETC	0,00	,00	0,00	,00	,00
4300,32	SUBTOTAL	,00	,00	0,00	,00	,00

Table 4-13. Turbine Plant Equipment Cost Detail (Page 3 of 4)

65 WBS SERIES PILOT PLANT 17.41.49. DATE: 79/05/23.

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR-R
4300.411	CLOSED HEATERS	0.00	.09 C	.01 I	.09	.09
4300.412	OPEN HEATERS	0.00	.00 H	0.00	.00	.00
4300.413	INSULATION	0.00	.00 H	0.00	.00	.00
4300.414	FOUNDATION,SUP,ET	0.00	.00 C	.01 H	.01	.01
4300.41	SUBTOTAL	0.00	.09	.02	.11	.11
4300.421	MAIN FEED PUMPS	0.00	.62 C	.04 I	.66	.66
4300.422	AUXILIARY	0.00	.06 C	.00 I	.07	.07
4300.423	DRAINS,PUMPS-DR.	0.00	.01 C	.00 I	.01	.01
4300.424	INSULATION	0.00	.03 C	.14 I	.17	.17
4300.425	FOUNDATIONS,SUP,E	0.00	.00 C	0.00	.00	.00
4300.42	SUBTOTAL	0.00	.72	.18	.90	.90
4300.431	FEED PIPING	0.00	.00	0.00	.00	.00
4300.432	DRAINS - COOLERS	0.00	.00	0.00	.00	.00
4300.433	DRAINS - FLASK TA	0.00	.00	0.00	.00	.00
4300.434	EXTRAC.,DRAIN,ETC	0.00	.00	0.00	.00	.00
4300.435	INSULATION	0.00	.00	0.00	.00	.00
4300.436	HANGERS,SUP,-INS.	0.00	.00	0.00	.00	.00
4300.43	SUBTOTAL	0.00	.03	.02	.04	.04
4300.511	EVAPORATOR SYS.	0.00	.00	0.00	.00	.00
4300.512	ION EXCHANGE SYS.	0.00	.00	0.00	.00	.00
4300.513	FILTER - SEP.SYS.	0.00	.00	0.00	.00	.00
4300.514	PUMPS - DRIVES	0.00	.00	0.00	.00	.00
4300.515	PIPES,VALVES - FI	0.00	.00	0.00	.00	.00
4300.516	STORAGE TANKS	0.00	.00	0.00	.00	.00
4300.517	HANGERS,FOUND.,ET	0.00	.00	0.00	.00	.00
4300.51	SUBTOTAL	0.00	.06	.02	.08	.08

Table 4-13. Turbine Plant Equipment Cost Detail (Page 4 of 4)

65 WBS SERIES PILOT PLANT 17.41.49. DATE: 77/05/23.

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR-R
4300.521	CHEM. STORAGE	0.00	.0C	0.00	.00	.00
4300.522	CON.DEM.-FILTER S	0.00	.0C	0.00	.00	.00
4300.523	CON.-DEM.STORED S	0.00	.0C	0.00	.00	.00
4300.524	RESIN STORAGE	0.00	.0C	0.00	.00	.00
4300.525	BOILER BLOWDOWN	0.00	.0C	0.00	.00	.00
4300.526	PUMPS - DRIVES	0.00	.0C	0.00	.00	.00
4300.527	PIPING,VALVES + F	0.00	.0C	0.00	.00	.00
4300.528	INSULATION	0.00	.0C	0.00	.00	.00
4300.529	HANGERS,FOUND.,SU	0.00	.0C	0.00	.00	.00
4300.52	SUBTOTAL	0.00	.05	.02	.07	.07

Table 4-14. Technical Description Turbine Plant Equipment
(Page 1 of 2)

TURBINE GENERATOR

12,500 kW, 1,465 psig - 950°F, single automatic admission, tandem compound single flow condensing. Also included is:

- Lube oil filter and pump set - 10 gpm
- Lube oil filter
- Lube oil purifier - 10 gpm, centrifuge separator
- Lube oil transfer pump - 50 gpm, gear type
- Condenser hot well pumps - 450 gpm, 230 TDH, horizontal inst. 50 hp
- Condenser vacuum pumps - 7.5 SCFM, 1 in HGA, mech. vac.
- Lube oil storage tank - 4,000 gal, 2 compartment
- Turbine gland seal drain tank - 3 ft dia, 6 ft height
- Turbine drains tank - 3 ft dia, 5 ft height
- 350 kW diesel generator set
- Equipment foundations (cost under 4,103.1)

TURBINE SUPPLY AND EXHAUST HEADERS

Main stream line from receiver (excluding downcomer piping on tower) to turbine.

CONDENSER/COOLING EQUIPMENT

Shell and tube, water-cooled condenser, with 12,000 ft^2 cooling surface

FEEDWATER EQUIPMENT

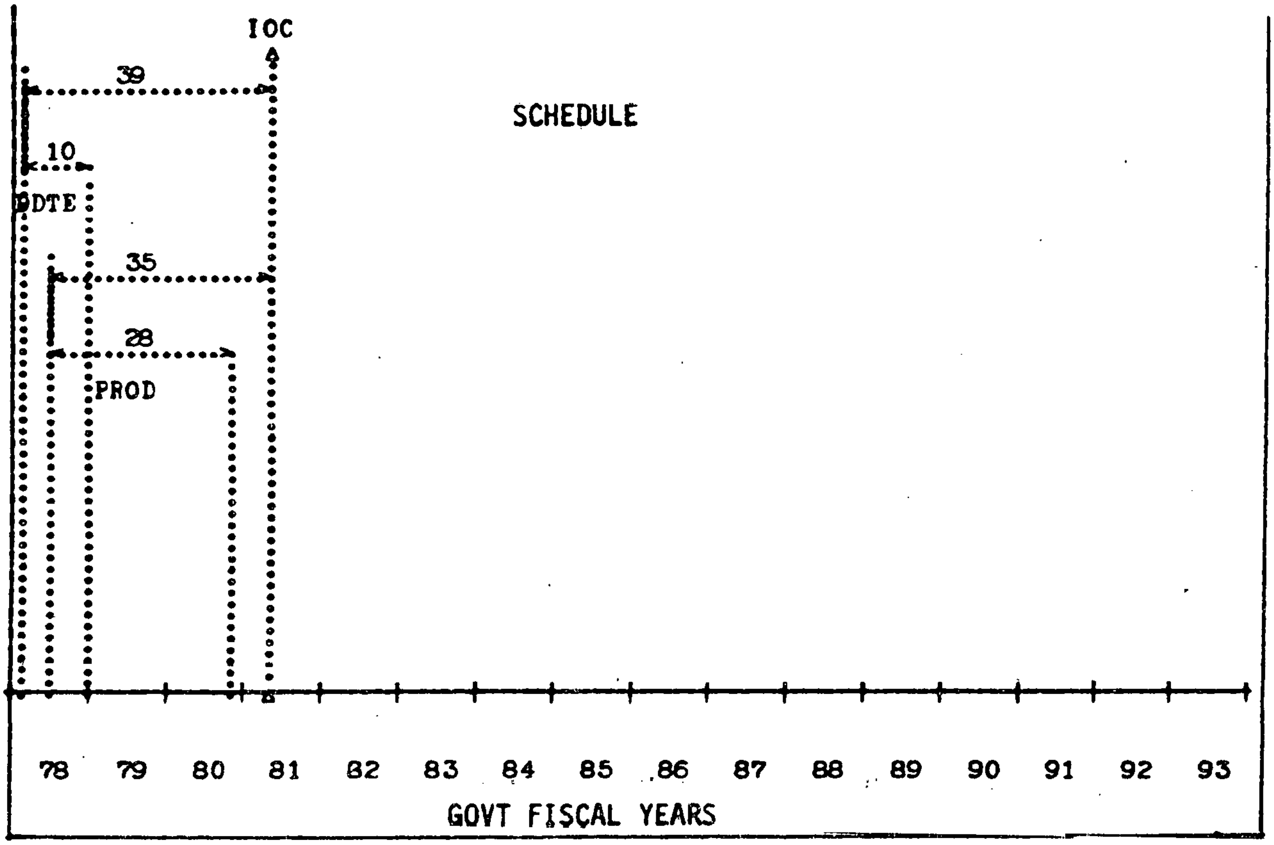
- Condensate transfer pumps - 200 gpm, horizontal inst.
- Receiver feedwater pumps - 3,465 RPM, 600 hp
- Booster pumps - 575 gpm, 250 hp 4 stage
- Condensate storage tanks - 2 - 50,000 gal
- Flash tank - 3 ft dia, 6 ft height str. shell
- Low pressure feedwater heater - stainless steel
- High pressure feedwater heater - carbon steel
- Deaerating heater

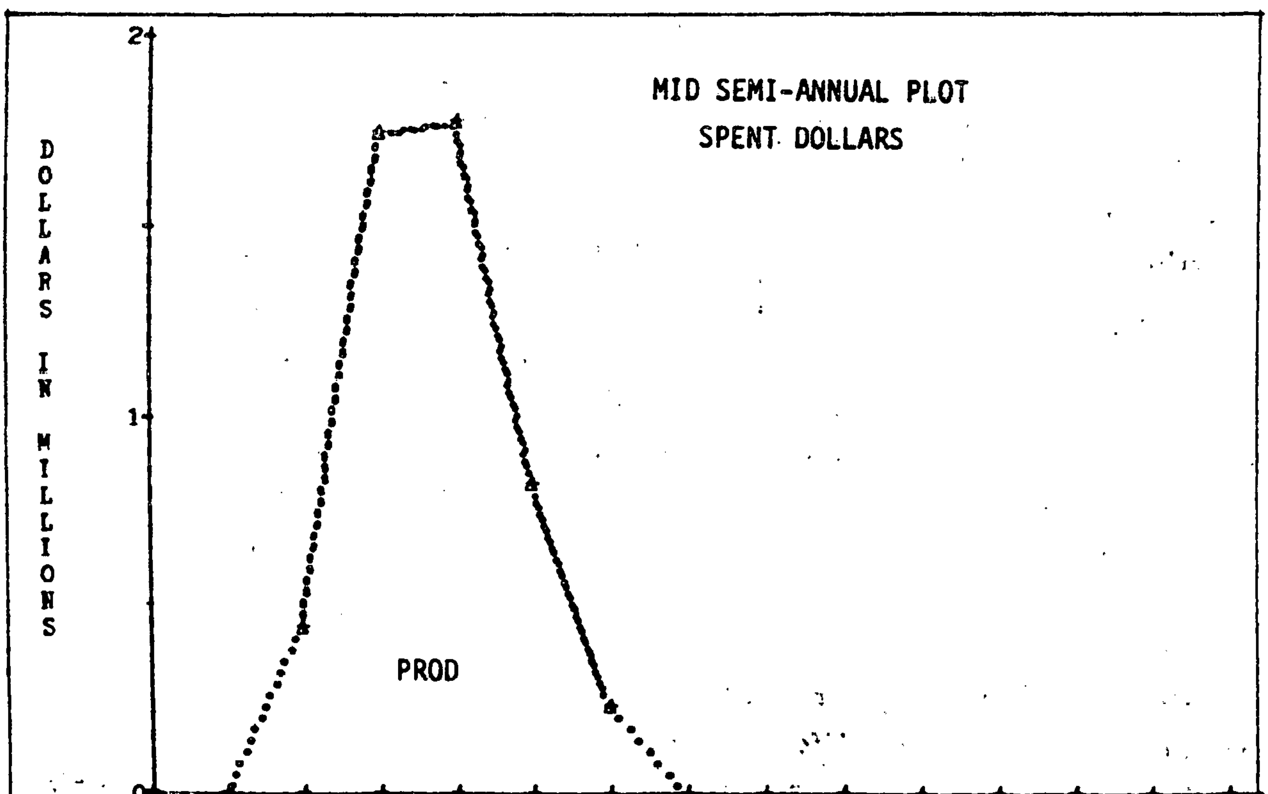
Table 4-14. Technical Description Turbine Plant Equipment
(Page 2 of 2)

WATER CIRCULATING/TREATMENT EQUIPMENT	
	Demineralizer caustic feed pump
	Demineralizer acid feed pump (2)
	Demineralizer caustic storage tank - 6,000 gal
	Demineralizer acid storage tank - 6,000 gal
	Makeup demineralizer sand filters
	Feedwater chemical feed tanks and pumps
	Makeup demineralizers - 50 gpm
	In-line demineralizers - 450 gpm
	Raw water clarifier
INSTRUMENTATION AND CONTROL	
	Minicomputer, digital and analog controls, control panels and miscellaneous instruments and controls.
PIPING	
	Piping systems required in the turbine-generator subsystem other than headers.
THERMAL INSULATION	
	Thermal insulation and lagging required for the Turbine-Generator Subsystem Piping Systems and equipment.

4.9 ELECTRIC PLANT EQUIPMENT (4401)

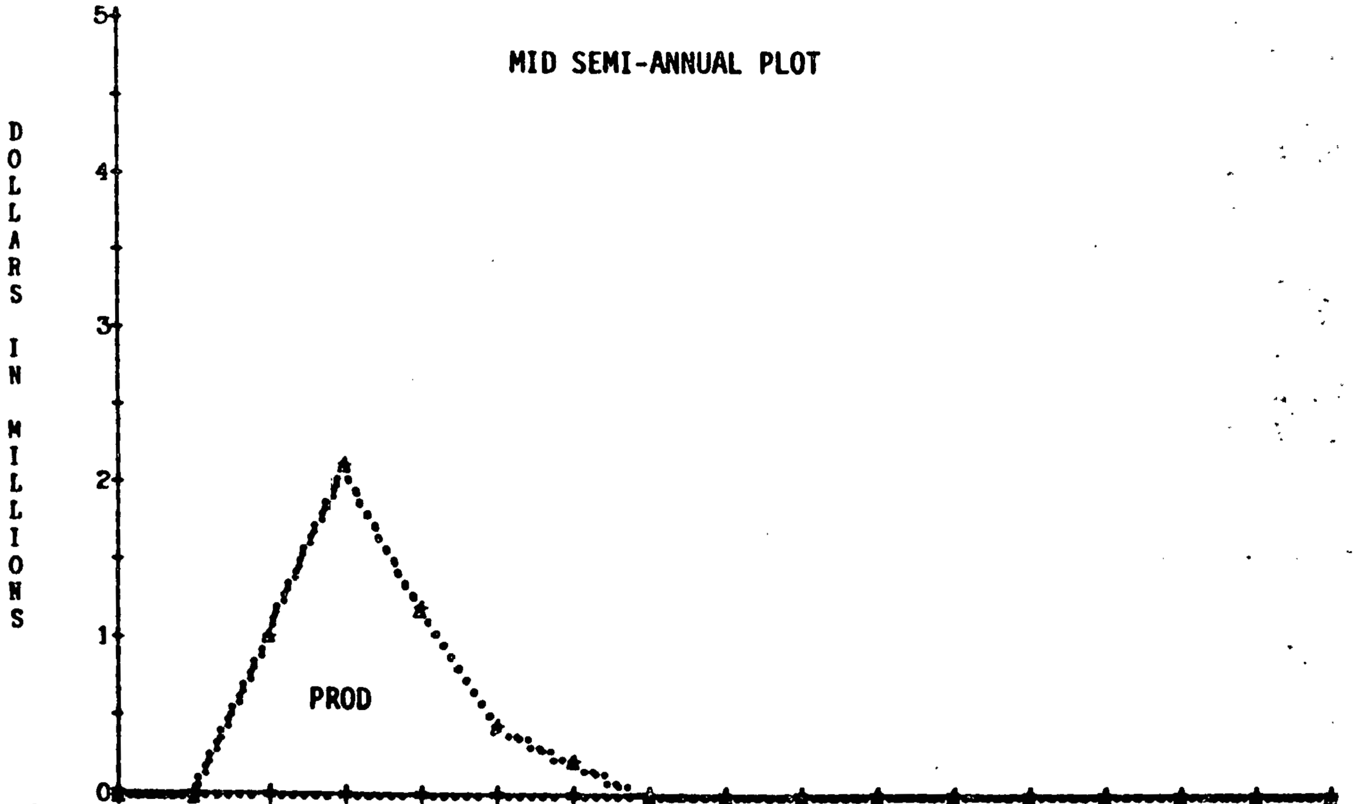
This element includes power conditioning, station service equipment switchboards, power and control wiring, power distribution, protective equipment and instrumentation, controls and communications. Not included in this element are surveys, design and other engineering work, procurement activities and site construction direction which are normally included under the A&E effort (8100). Costs are to provide for site preparation, for all material and equipment, and for the subcontracted labor and services necessary to transport, fabricate, assemble, install, and checkout materials and equipment at the Pilot Plant site.





GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT.E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	.5	1.8	1.8	.8	.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	.5	1.8	1.8	.8	.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 4-16. Turbine Plant Equipment Summary Chart



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT•E	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	•0	1•0	2•1	1•2	•5	•2	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	•0	1•0	2•1	1•2	•5	•2	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0

Figure 4-17. Turbine Plant Equipment Committed Dollars

4.9.1 Electric Plant Equipment Costs and Technical Characteristics

Stearns-Roger has estimated costs as follows:

Title	Non-recurring (million)	Recurring (million) Material	Labor	Total	Total NR&R
Switchgear	$0.00	$0.24	$0.05	$0.29	$0.29
St service eq	0.00	0.31	0.06	0.37	0.37
Switchboards	0.00	0.00	0.00	0.00	0.00
Protective eq	0.00	0.03	0.04	0.07	0.07
Elec str & wir ctnr	0.00	0.05	0.04	0.09	0.09
Power wiring	0.00	0.09	0.15	0.24	0.24
Total (4401)	$0.00	$0.72	$0.34	$1.06	$1.06

Table 4-15 provides detail cost and Table 4-16 shows a description of the equipment.

4.9.2 Electric Plant Equipment Schedule, Funding and Important Drivers

Electric plant equipment schedule and funding are shown in Figure 4-18. The schedule shows activity starting 31 months prior to IOC and continuing for 17 months. Funding peaks in the second half of 1979 at $600,000.

Figure 4-19 shows the estimated committed cost.

4.9.3 Electric Plant Equipment Costing Methodology

Costing is based on Stearns-Roger experience with power plants of this size and utilized current industrial equipment, material, and labor costs reflecting the proposed Barstow area plant location. Estimates were made from the equipment list which defines the scope of work. Quotes were obtained or catalogs consulted for equipment and materials and site fabrication, assembly, and installation hours and dollars estimated based on experience and desert southwest labor rates. From these costs, the costs of the other construction accounts (i.e., earthwork, concrete, painting, electric structures and containers, wiring, and instrumentation) are prorated based on many previous power plant cost relationships for units of this size.

Table 4-15. Electric Plant Equipment Cost Detail (Page 1 of 3)

66 WBS SERIES PILOT PLANT 17,49,28, DATE: 77/05/23,

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	RECURRING (MIL) LABOR	RECURRING (MIL) TOTAL	TOTAL NR-R
4401,11	GENERATOR CIRCUIT	,00	,11	,02	,13	,13
4401,12	STATION SERVICE	,00	,13	,03	,16	,16
4401,1	SUBTOTAL	,00	,24	,05	,29	,29
4401,21	ST,SER,- ST,UP TA	,00	,16	,04	,21	,21
4401,22	LOW VOL,UNIT SUB,	0,00	,01	,00	,01	,01
4401,23	AUXILIARY PRW,SOU	0,00	,13	,02	,15	,15
4401,2	SUBTOTAL	,00	,31	,06	,37	,37
4401,41	GENERAL ST,GR,SYS	0,00	,03	,04	,07	,07
4401,42	FIRE PROTECT,EQ,	0,00	,00	0,00	,00	,00
4401,4	SUBTOTAL	0,00	,03	,04	,07	,07
4401,51	CONCRETE TUN,FOR	0,00	,01	,00	,01	,01
4401,52	CABLE TRANS-SUPPT	0,00	,04	,04	,08	,08
4401,53	CONDUIT	0,00	,00	0,00	,00	,00
4401,54	OTHER STRUCTURES	0,00	,00	0,00	,00	,00
4401,5	SUBTOTAL	0,00	,05	,04	,09	,09
4401,61	GENERATOR CIR,WIR	0,00	,00	0,00	,00	,00
4401,62	ST,SER,POWER WIRI	0,00	,09	,15	,24	,24
4401,6	SUBTOTAL	0,00	,09	,15	,24	,24

Table 4-15. Electric Plant Equipment Cost Detail (Page 2 of 3)

66 WBS SERIES PILOT PLANT 17.49.26. DATE: 77/05/23.

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
4401.111	GENERATOR SWITCHG	0.00	.03 C,H	.00 I	.03	.03
4401.112	GEN.NEUT.GR.EQ.	0.00	.00	0.00	.00	.00
4401.113	GEN. CURRENT	0.00	.01 C,H	.00 I	.01	.01
4401.114	GEN.SURGE ARRESTO	0.00	.07 C,H	.01 I	.08	.08
4401.115	EXC. SWITCHGEAR	0.00	.01 C,H	.00 I	.02	.02
4401.116	SPECIAL SCREENS,E	0.00	.00	0.00	.00	.00
4401.11	SUBTOTAL	.00	.11	.02	.13	.13
4401.121	STATION SWITCHGEA	0.00	.12 C,H	.03 I	.15	.15
4401.122	STATIONMOTOR	0.00	.01 C,H	.00 I	.02	.02
4401.123	SYS.NEUTRAL GR.DE	0.00	.00	0.00	.00	.00
101.124	SEP.MOUNT.ST.SER.	0.00	.00	0.00	.00	.00
4401.125	SPECIAL SCREENS,E	0.00	.00	0.00	.00	.00
4401.12	SUBTOTAL	.00	.13	.03	.16	.16
4401.211	ST.SER.TRANSFORME	0.00	.13 C,H	.02 I	.15	.15
4401.212	ST. STARTUP TRANS	0.00	.05 C,H	.00 I	.05	.05
4401.213	FOUNDATIONS,ETC.	0.00	.01 C,H	.01 I	.02	.02
4401.214	VOLTAGE REG. EQ.	0.00	.00	0.00	.00	.00
4401.215	INSUL.OIL STORAGE	0.00	.00	0.00	.00	.00
4401.21	SUBTOTAL	.00	.16	.04	.21	.21
4401.221	UNIT SUBST.-TRANS	0.00	.00 C,H	.00 I	.01	.01
4401.222	SPEC.SCRNS,.BASES	0.00	.00	0.00	.00	.00
4401.22	SUBTOTAL	0.00	.01	.00	.01	.01
4401.231	BATTERY SYS.	0.00	.02 C,H	.01 I	.02	.02
4401.232	AUXILIARY GTN.	0.00	.11 C,H	.02 I	.13	.13
4401.233	MOTOR GEN,SET	0.00	.00	0.00	.00	.00
01.23	SUBTOTAL	0.00	.13	.02	.15	.15

Table 4-15. Electric Plant Equipment Cost Detail (Page 3 of 3)

66 WBS SERIES PILOT PLANT 17,49,28, DATE: 77/05/23,

WBS	TITLE	NON-REQUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR-R
4401,411	GROUND COND,-CONN	0,00	,03 C,H	,04 I	,07	,07
4401,412	GROUND WELLS,MATS	0,00	,00	0,00	,00	,00
4401,41	SUBTOTAL	0,00	,03	,04	,07	,07
4401,621	ALL POWER CABUS-R	0,00	,09	,15	,24	,24
4401,62	SUBTOTAL	0,00	,09	,15	,24	,24

66 WBS SERIES PILOT PLANT 17,49,28, DATE: 77/05/23,

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR-R
4401,2321	DIESEL ENGINE/GEN	0,00	,11 C,H	,02 H	,13	,13
4401,2322	GAS TURBINE/GEN,	0,00	,00	0,00	,00	,00
4401,2323	STEAM TURBINE/GEN	0,00	,00	0,00	,00	,00
4401,232	SUBTOTAL	0,00	,11	,02	,13	,13
2-24-77	REVIS	,00	,72	,34	1,06	1,06

66 WBS SERIES PILOT PLANT 17,49,28, DATE: 77/05/23,

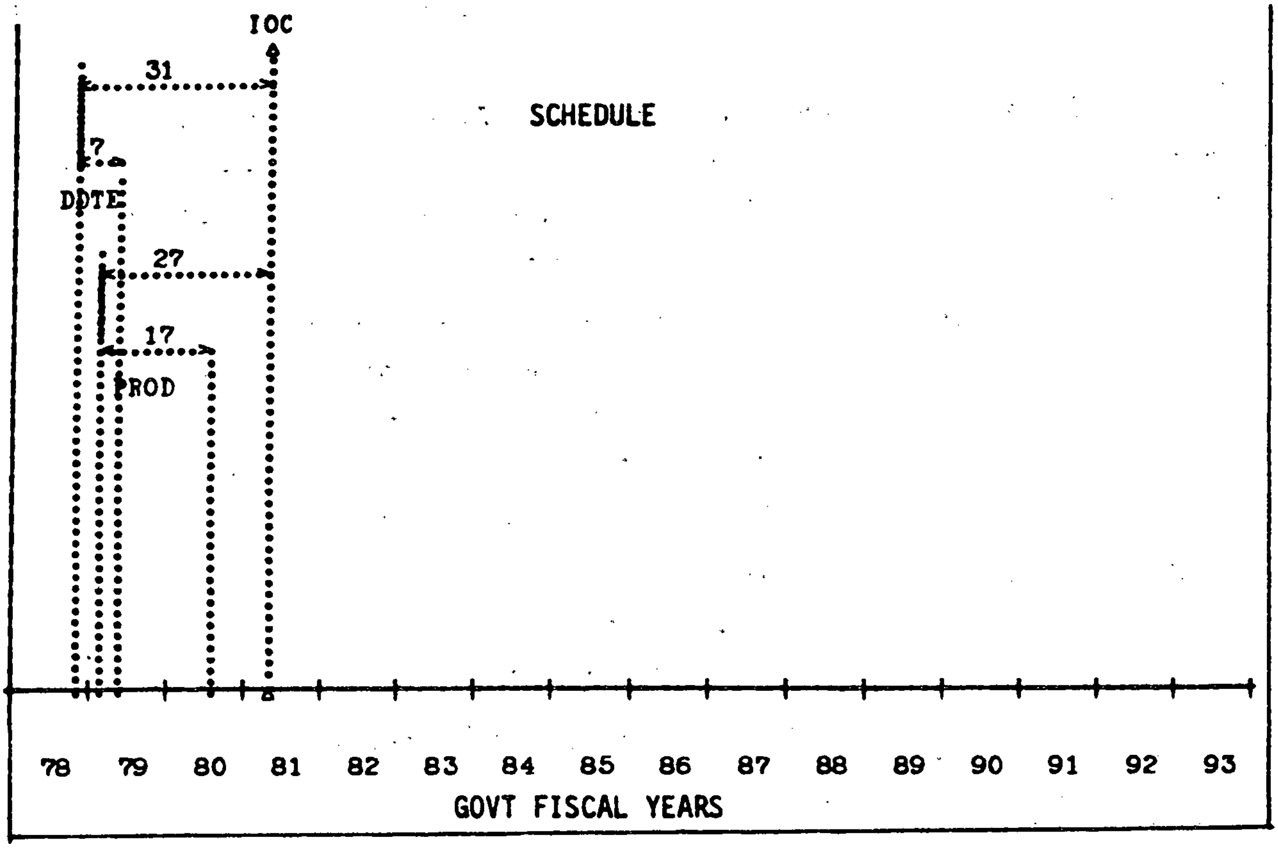
WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR-R
4401,2321	DIESEL ENGINE/GEN	0,00	,11 C,H	,02 H	,13	,13
4401,2322	GAS TURBINE/GEN,	0,00	,00	0,00	,00	,00
4401,2323	STEAM TURBINE/GEN	0,00	,00	0,00	,00	,00
4401,232	SUBTOTAL	0,00	,11	,02	,13	,13
2-24-77	REVIS	,00	,72	,34	1,06	1,06

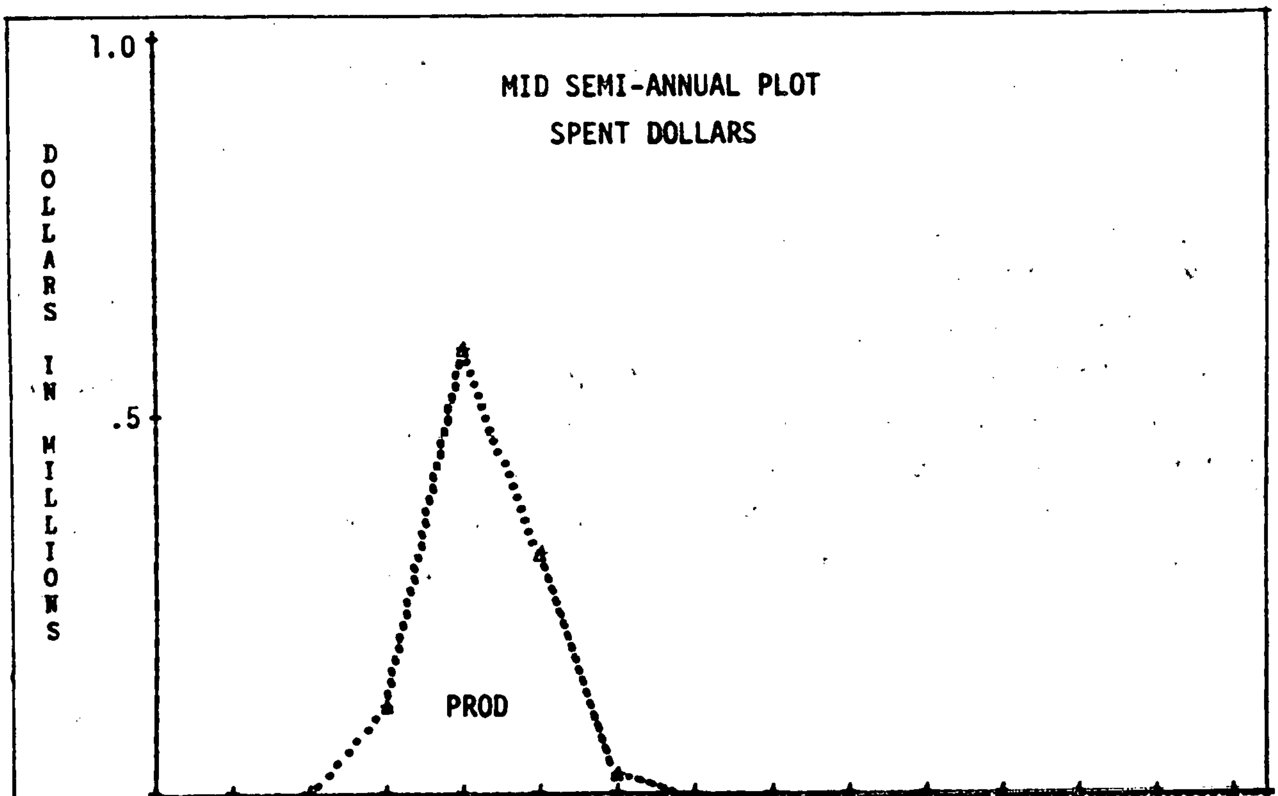
Table 4-16. Technical Description Electric Plant Equipment

Switchgear	480 V switchgear and motor controls, distribution panels - 480 V and 120/208 V
Station service equipment equipment	Main power transformer 115-13.2 kV Auxiliary power transformer 13,200/480 V 480-120/208 V transformers Oil-fired steam generator Station battery and battery charger
Protective equipment	Generator circuit breaker cubicle Generator surge protection cubicle Generator ground cubicle
Electrical structures and wiring containers	Cable trays, duct banks, manholes
Power and control wiring	Wiring and conduit for power plant
Instrumentation, master control and communications	Instrumentation, wiring, in plant communication

4.10 MASTER CONTROL (4402)

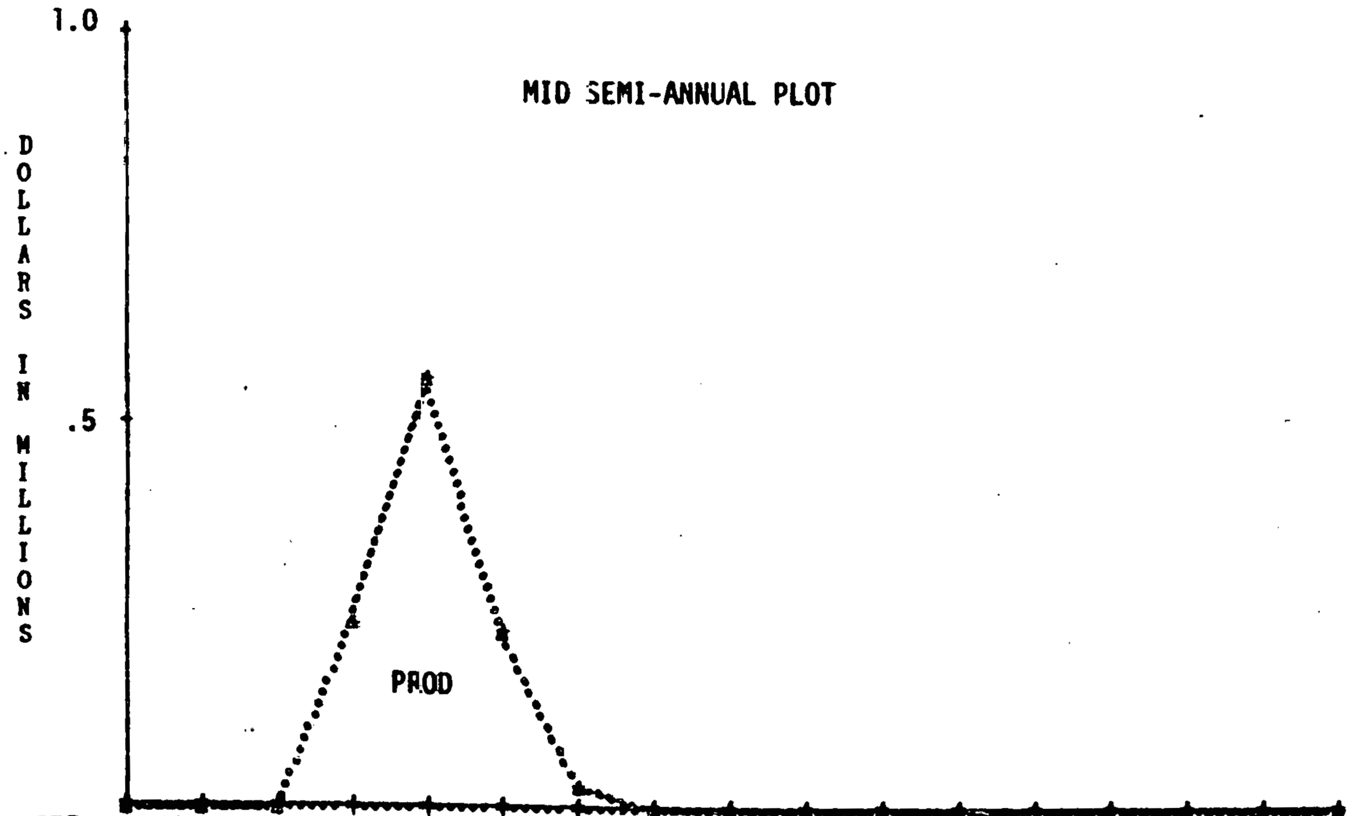
This element includes integration and software, computers and peripheral equipment, manual controls and displays, signal interface unit, computer interface unit, and communications wiring. Costs are to provide for the labor and material required to design, fabricate, assemble, deliver, install, checkout, and both activate and support acceptance test and the initial 2 years of operations for one master control set, including preparation of installation, maintenance, and operating instructions.





GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT•E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	0.0	.1	.6	.3	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	.1	.6	.3	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 4-18. Electric Plant Equipment Summary Chart



CFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT•E	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	0•0	0•0	•2	•6	•2	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	0•0	0•0	•2	•6	•2	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0

Figure 4-19. Electric Plant Equipment Committed Dollars

4.10.1 Master Control Costs and Technical Characteristics

Costs estimated by MDAC are presented as follows:

Title	Non-recurring (million)	Recurring (million) Material	Labor	Total	Total NR&R
Computer	$0.00	$0.03	$0.00	$0.03	$0.03
Peripheral eq	0.00	0.03	0.00	0.03	0.03
Ctr panel & board	0.00	0.03	0.00	0.03	0.03
Inter eq sig & comp	0.00	0.25	0.00	0.25	0.25
Software D&D	0.22	0.00	0.00	0.00	0.22
Software/hdwr test	0.14	0.00	0.00	0.00	0.14
Hardware design	0.52	0.00	0.33	0.33	0.85
Control wiring	0.02	0.24	0.10	0.34	0.36
Sp test pr instr	0.03	0.00	0.00	0.00	0.03
Fld install & c/o	0.00	0.00	0.17	0.17	0.17
Total (4402)	$0.92	$0.58	$0.61	$1.19	$2.11

In addition, Figure 4-20 provides a schematic upon which these costs are based.

4.10.2 Master Control Schedule, Funding and Important Drivers

Schedule and funding for this subsystem are shown in Figure 4-21. The D&D begins 37 months prior to IOC and continues for 27 months while production extends from 34 months prior to IOC for 28 months including support of systems integration activities that begin in the last quarter of fiscal year 1979 and extend for 8 months through the second quarter of fiscal year 1980. Figure 4-22 shows the estimated committed cost.

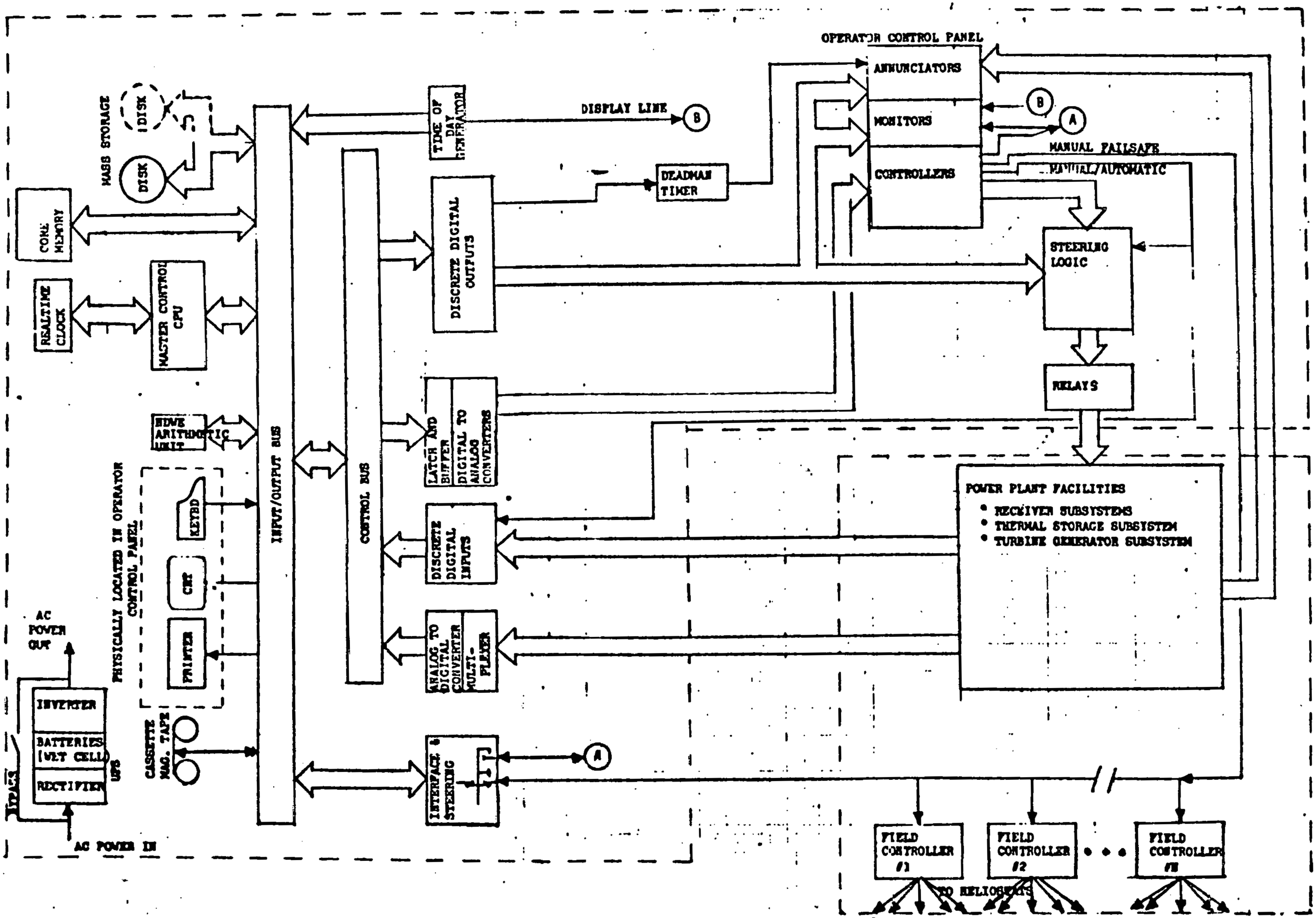
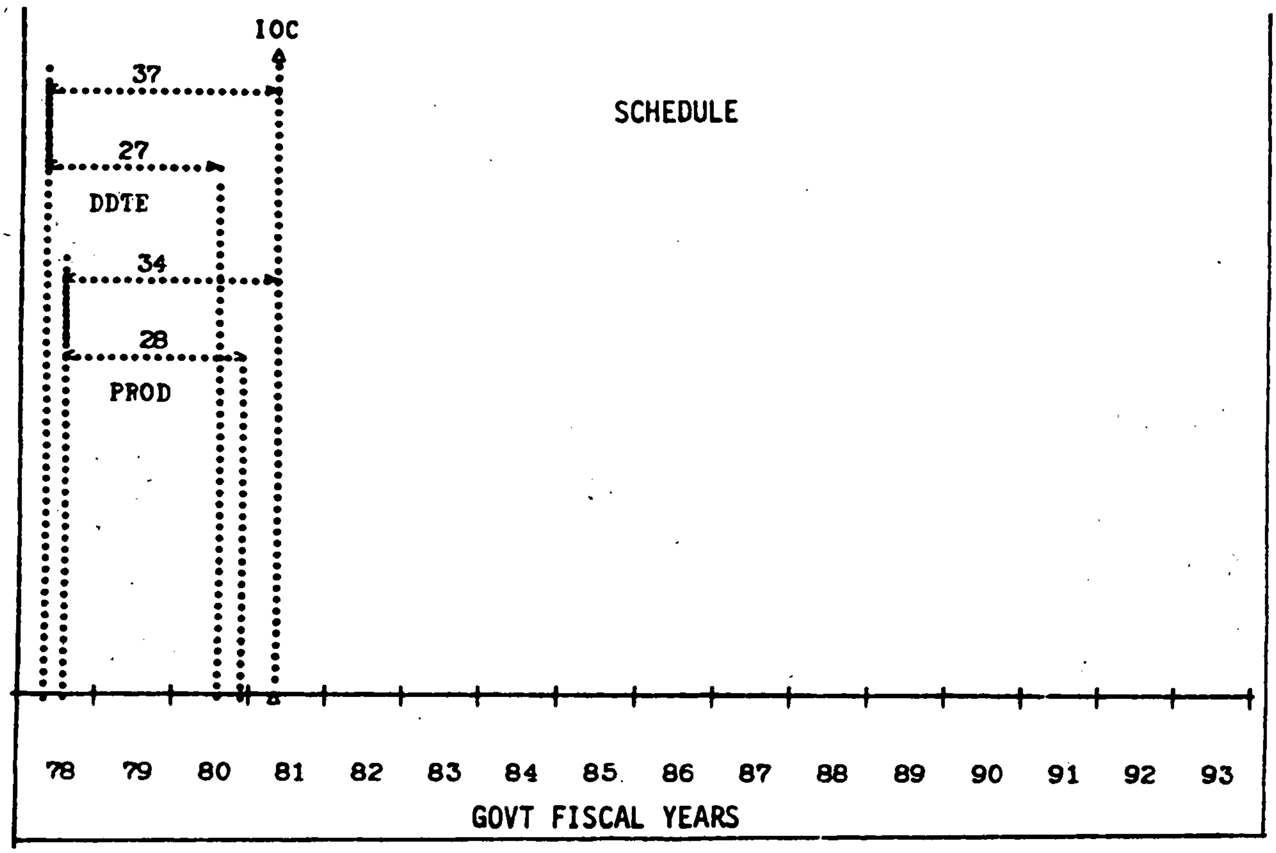
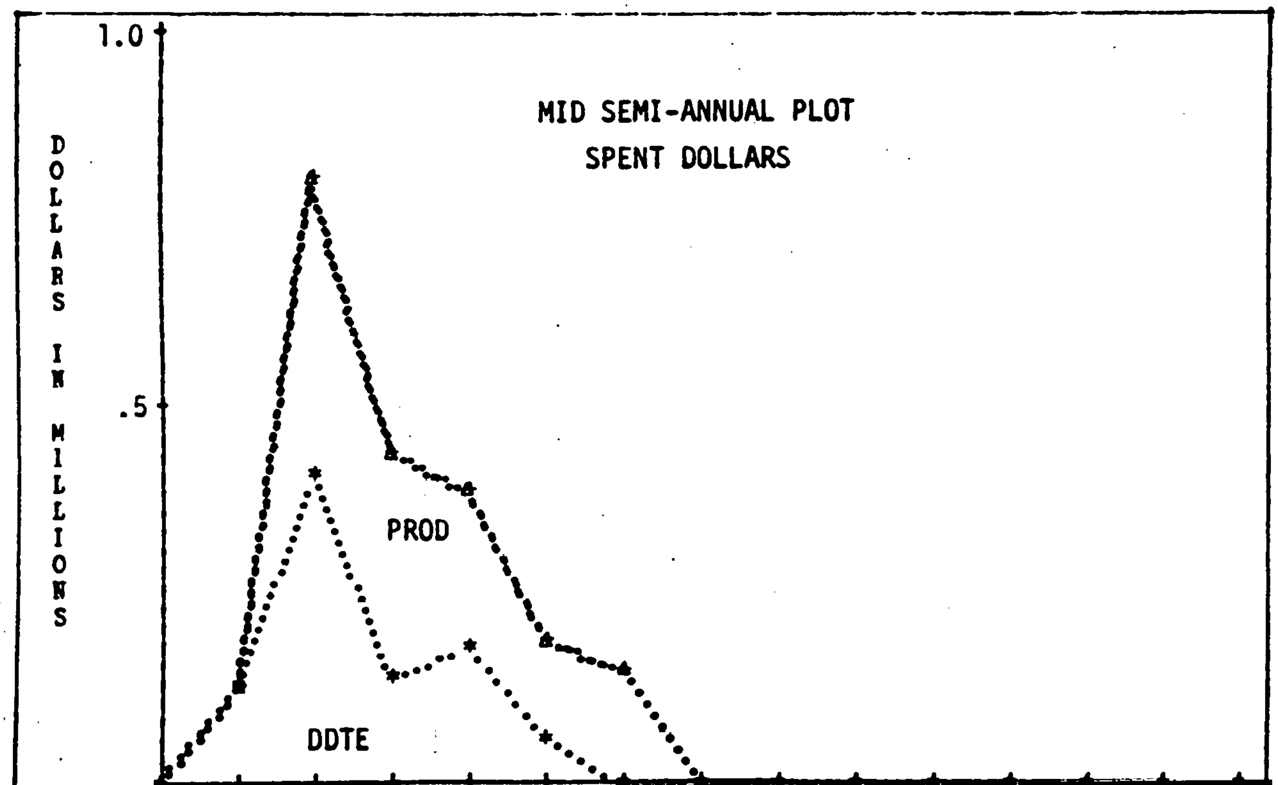


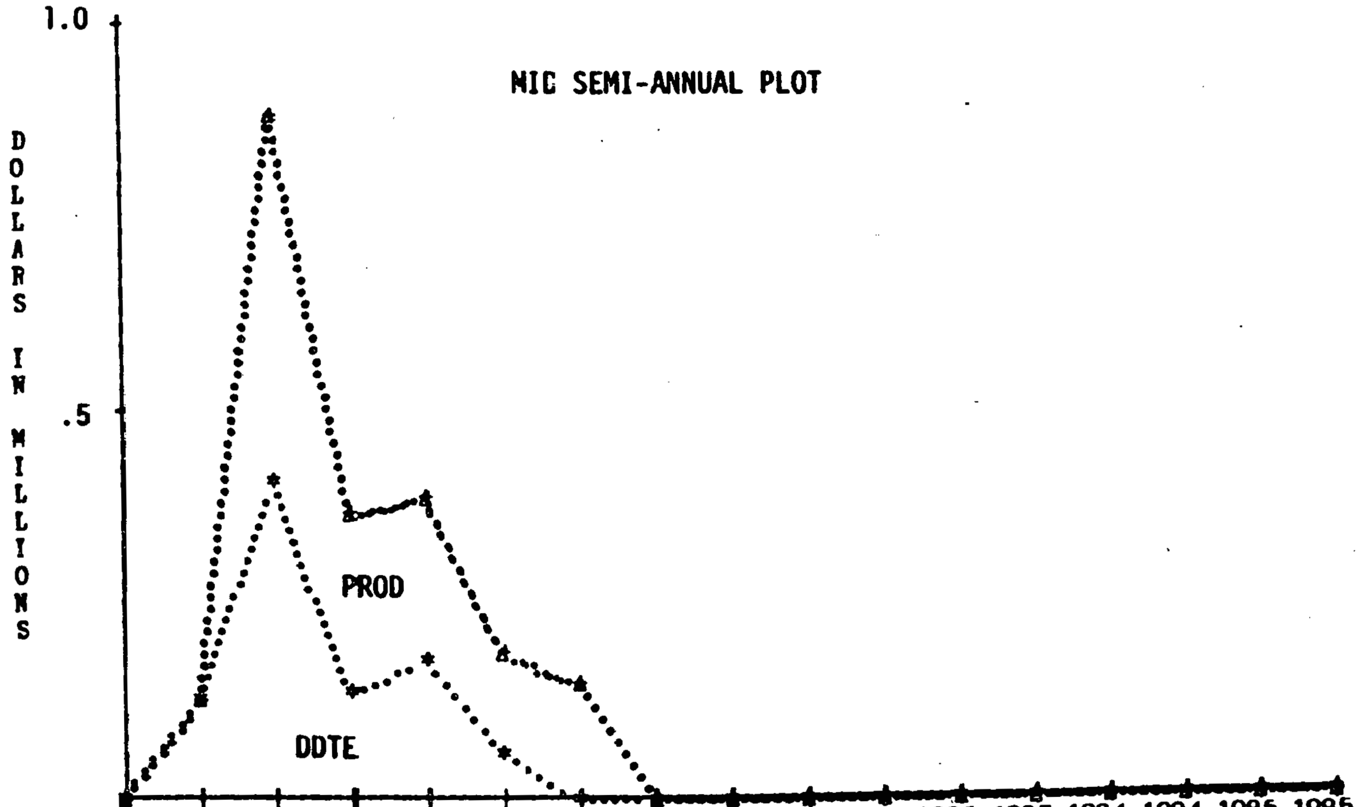
Figure 4-20. Pilot Plant Master Control Architecture





GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT·E	·1	·4	·1	·2	·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
PROD	0·0	·4	·3	·2	·1	·2	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
OPER	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
TOTAL	·1	·8	·4	·4	·2	·2	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0

Figure 4-21. Plant Master Control Summary Chart



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT·E	.1	.4	.1	.2	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	.5	.2	.2	.1	.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	.1	.9	.4	.4	.2	.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 4-22. Plant Master Control Committed Dollars

4.10.3 Master Control Costing Methodology

Costs are based on MDAC experience in electronics systems. Specifically, estimates were derived from 1977 quoted prices for Digital Equipment Corporation equipment and MDAC experience for associated material and labor costs reflecting appropriate fabrication, assembly, and installation locations that were determined from an equipment list derived from the schematic shown in Figure 4-20. This list, along with some preliminary data handling rates, was employed in a search for equipment and associated costs.

The integration/software CBS category was generally estimated based on engineering experience. Design and development costs, which include manufacturing support and planning and engineering design and test, were estimated by man-loading functional tasks at the subsystem level while engineering software specialist judgment was applied to estimate total man-hours that would be required for software and integration in the investment phase.

4.11 MISCELLANEOUS PLANT EQUIPMENT (4500)

This element includes the field communications, transportation and handling equipment, furnishing and fixtures and other maintenance and service equipment. Not included in this element are surveys, design and other engineering work, procurement activities and site construction direction which are included under the Indirect effort or under other subsystem elements. Costs are to provide for site preparation, for all material and equipment, and for the labor and services necessary to transport, fabricate, assemble, install, and checkout materials and equipment at the plant site.

4.11.1 Miscellaneous Plant Equipment Costs and Technical Characteristics

Costs have been estimated by Stearns-Roger, MDAC, and Rocketdyne as follows:

Title	Non-recurring (million)	Recurring (million) Material	Labor	Total	Total NR&R
Trans & lifting eq	$0.00	$0.60	$0.86	$1.46	$1.46
Air & water ser eq	0.00	0.80	0.19	0.98	0.98
Communications eq	0.00	0.00	0.00	0.00	0.00
Furnishings & fix	0.00	0.22	0.00	0.22	0.22
Total (4500)	$0.00	$1.61	$1.05	$2.66	$2.66

Table 4-17 provides detail cost and Table 4-18 provides a description of the equipment.

4.11.2 Miscellaneous Plant Equipment Schedule, Funding and Important Drivers

Miscellaneous plant schedule and funding are shown in Figure 4-23. As indicated, the effort starts 25 months prior to IOC and continues for 18 months. Funding peaks at $1.3 million in the first half of 1980. Figure 4-24 shows the estimated committed cost.

4.11.3 Miscellaneous Plant Equipment Costing Methodology

Costing is based on Stearns-Roger experience concerning equipment for power plants of this size and on MDAC and Rocketdyne experience in estimating the additional equipment related to the nonconventional portion of the plant. Estimators used 1977 industrial equipment, material, and labor costs reflecting appropriate fabrication, assembly and installation locations. Estimates were made from the equipment list which defines the scope of work. Quotes were obtained or catalogs consulted for equipment and materials relating to the conventional portion of the plant.

Special equipment costs related to the nonconventional portions of the plant were mainly estimated from design concepts. Based on preliminary

Table 4-17. Miscellaneous Plant Equipment Cost Detail (Page 1 of 2)

68 SERIES WBS PILOT PLANT 17,57,23, DATE: 79/05/23,

WBS	TITLE	NON-RECUR (MIL)	------RECURRING (MIL) MATERIAL	LABOR	TOTAL------	TOTAL NR-R
4500,11	CRANES,HOISTS,ETC	,00	,37	,01	,39	,39
4500,12	RAILWAY EQ,	0,00	,00	0,00	,00	,00
4500,13	ROADWAY EQ,	0,00	,00	0,00	,00	,00
4500,14	WATERCRAFT	0,00	,00	0,00	,00	,00
4500,15	VEHICLE MAINT, EQ	0,00	,00	0,00	,00	,00
4500,16	RECEIVER EQ,	,00	,03	,33	,36	,36
4500,17	COLLECTOR EQ,	0,00	,20	,51	,71	,71
4500,18	THERMAL ST, EQ,	0,00	,00	,00	,00	,00
4500,1	SUBTOTAL	,00	,60	,86	1,46	1,46
4500,21	AIR SYSTEM	0,00	,10	,02	,12	,12
4500,22	WATER SYSTEM	0,00	,70	,17	,87	,87
4500,2	SUBTOTAL	0,00	,80	,19	,98	,98
4500,31	LOCAL COM,SYS,	0,00	,00	0,00	,00	,00
4500,32	SIGNAL SYSTEM	0,00	,00	0,00	,00	,00
4500,3	SUBTOTAL	0,00	,00	0,00	,00	,00
4500,41	SAFETY EQ,	0,00	,02	0,00	,02	,02
4500,42	SHOP LAB - TEST E	0,00	,18	0,00	,18	,18
4500,43	OFFICE EQ,-FURN,	0,00	,01	0,00	,01	,01
4500,44	ENVIRN,MONITOR EQ	0,00	,00	0,00	,00	,00
4500,45	DINING FACILITIES	0,00	,00	0,00	,00	,00
4500,46	CLEANING EQ,	0,00	,00	0,00	,00	,00
4500,4	SUBTOTAL	0,00	,22	0,00	,22	,22

Table 4-17. Miscellaneous Plant Equipment Cost Detail (Page 2 of 2)

68 SERIES WBS PILOT PLANT 17,57,25, DATE: 79/05/23,

WBS	TITLE	NON-RECUR (MIL)	------RECURRING (MIL)------ MATERIAL	LABOR	TOTAL	TOTAL NR+R
4500,111	TURBINE BLDG,CRAN	,00	,09 V,H	,00 I	,09	,09
4500,112	OTHER CRANES,HOIS	,00	,29 I	,01 I	,30	,30
4500,11	SUBTOTAL	,00	,37	,01	,39	,39
4500,211	COMPRESSED AIR	0,00	,10 C	,02 I	,12	,12
4500,212	SUBATMOSPHERIC AI	0,00	,00	0,00	,00	,00
4500,21	SUBTOTAL	0,00	,10	,02	,12	,12
4500,221	WATER SUPPLY PUMP	0,00	,13 C	,00 I	,14	,14
4500,222	FIRE PUMPS,DRIVES	0,00	,02 C	,00 I	,03	,03
4500,223	WATER COND,SYS,	0,00	,24 C	,01 I	,24	,24
4500,224	STRG TANKS/RESERV	0,00	,02 C,H	,00 I	,03	,03
4500,225	STATION SER,PUMPS	0,00	,00 C	,00 I	,00	,00
4500,226	DOMESTIC WATER TR	0,00	,00 C	,00 I	,01	,01
4500,227	DOMESTIC WATER PU	0,00	,02 C	,00 I	,02	,02
4500,228	WATER HEATING EQ,	0,00	,03 C	,00 I	,03	,03
4500,229	WATER DIS,SYSTEM	0,00	,23 C	,15 I	,38	,38
4500,22	SUBTOTAL	0,00	,70	,17	,87	,87
4500,412	PORTABLE FORE EXT	0,00	,02 C	0,00	,02	,02
4500,41	SUBTOTAL	0,00	,02	0,00	,02	,02

Table 4-18. Technical Description Miscellaneous Plant Equipment (Page 1 of 2)

Communications	
	Public address, signal lights, radio equipment
Transportation and handling	
	Turbine room crane
	Miscellaneous lifting equipment
	Receiver panel ship and handling fixture
	Reflector sling
	Seg. transporter truck
	Special field installation and maintenance rig
	Shipping containers - various
	Segment lifting device
Furnishing and fixtures	
	Lab equipment
Environmental control	
	10 acre, lined evaporation pond
Other equipment	
	Bearing cooling water pumps (2)
	Potable water pumps (2)
	Sump pumps
	Fire pumps (electric motor and diesel engine-driven) - 1,500 gpm, 200 hp
	Jockey pump (fire header pressure maintenance) - 50 gpm
	Bearing cooling water head tank (1)
	Potable water storage tank (1) - 6,000 gal
	Service air compressor - 350 SCFM, 100 psig
	Instrument air compressors (2) - 250 SCFM, 100 psig
	Potable water filter
	Instrument air dryer

Table 4-18. Technical Description Miscellaneous Plant Equipment (Page 2 of 2)

Potable water chlorinator
Sewage treatment plant - 3,000 gpd, aeration unit
Bearing cooling water heat exchanger
Service air receiver
Instrument air receiver
Oil skimmer
Ionization facility
Heliostat maintenance override unit
Receiver tube flush equipment
Heliostat cleaning vehicle - 5,000 gal
Receiver scaffold
Miscellaneous ropes, cables, spanners, platforms, safety gear, drills, etc.

drawings, detail estimates were made using quotes, catalogs and manufacturing estimating judgment, using detail estimating procedures.

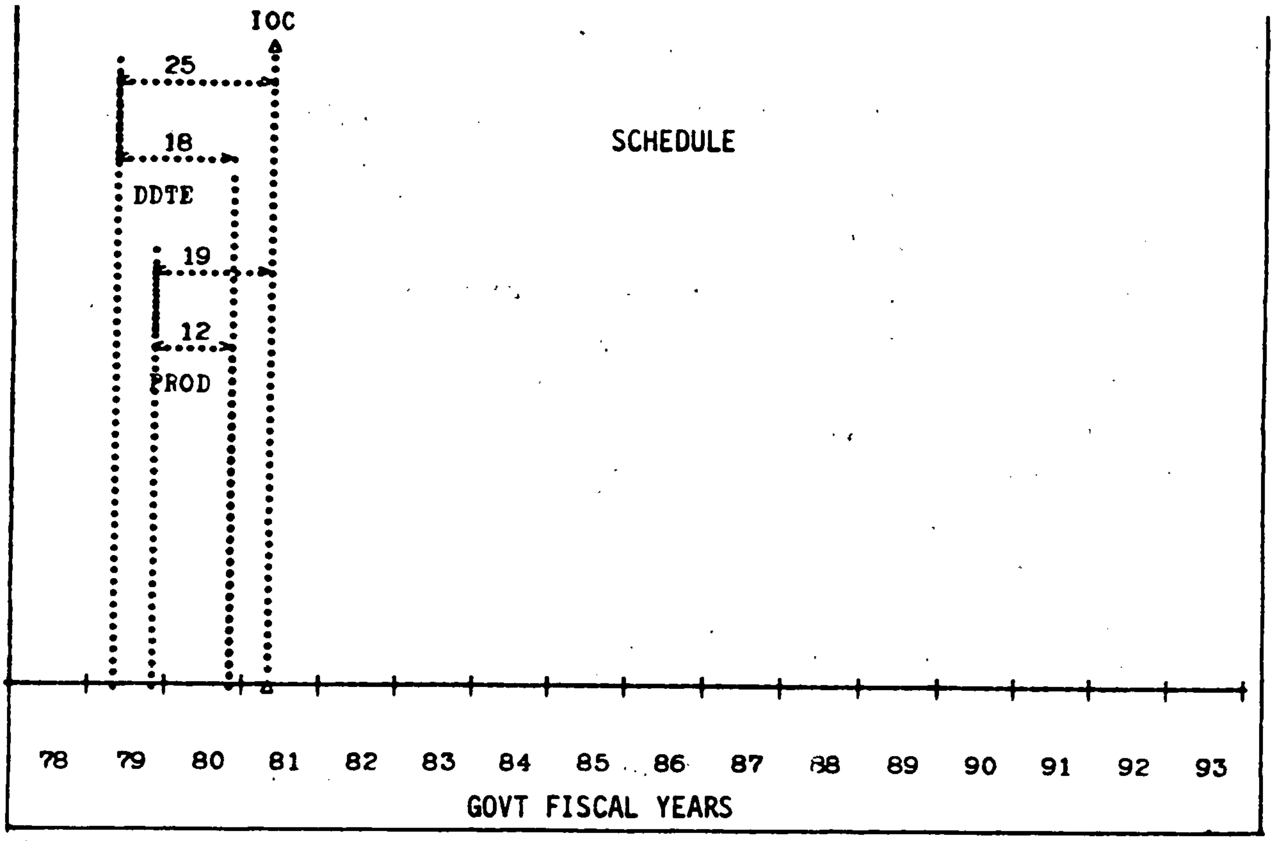
4.12 QUALITY ASSURANCE AT THE INSTALLATION SITE (7000)

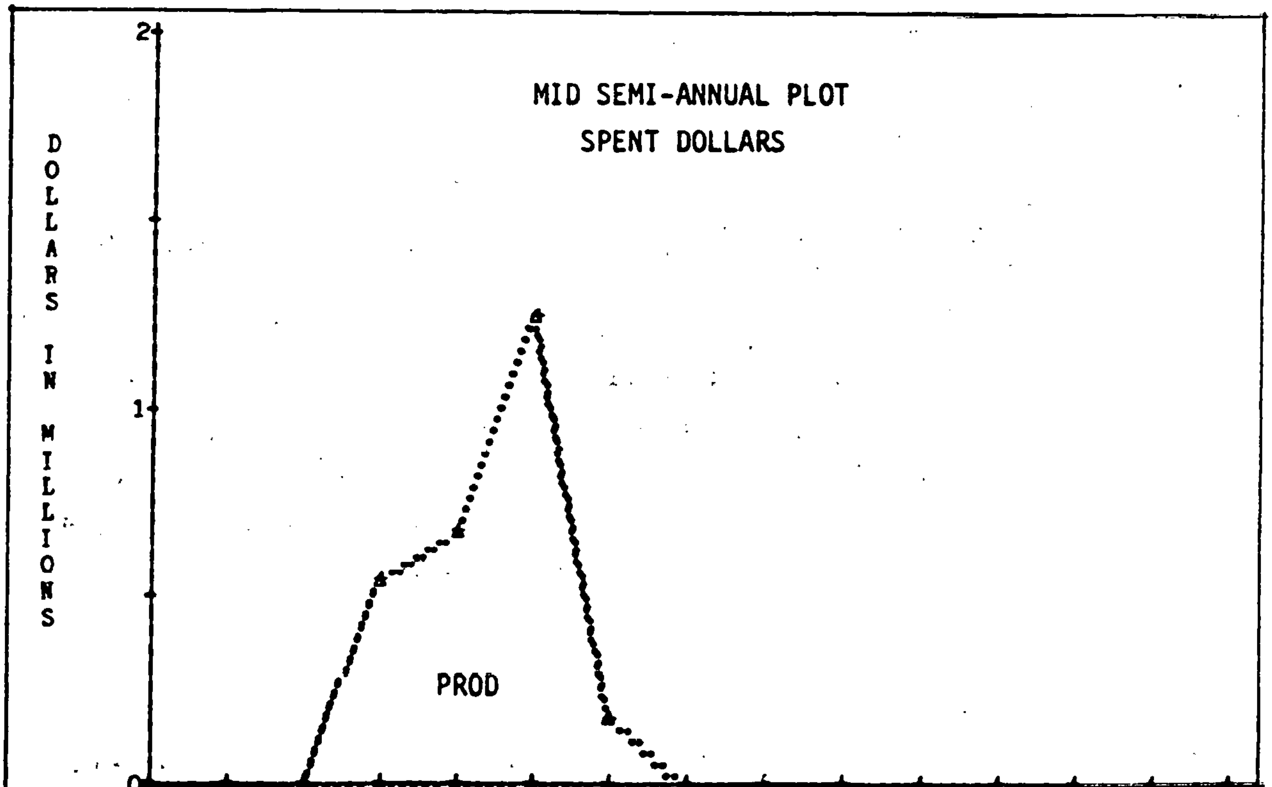
No quality assurance costs are indicated because the effort involved is distributed within other CBS costs. Stearns-Roger estimates that Quality Assurance at the construction site generally amounts to 1% of the direct construction labor or 2% of the engineering. Quality is mainly assured before the hardware reaches the site and may amount to anywhere from 5 to 20% depending on the hardware and the "hardness" of tooling. Of course, final quality is assured through the considerable amount of subsystems and system checkout and startup effort that has been costed in other CBS elements.

4.13 DISTRIBUTABLES (8000)

This element includes construction facilities, construction equipment, construction service, training, and other costs.

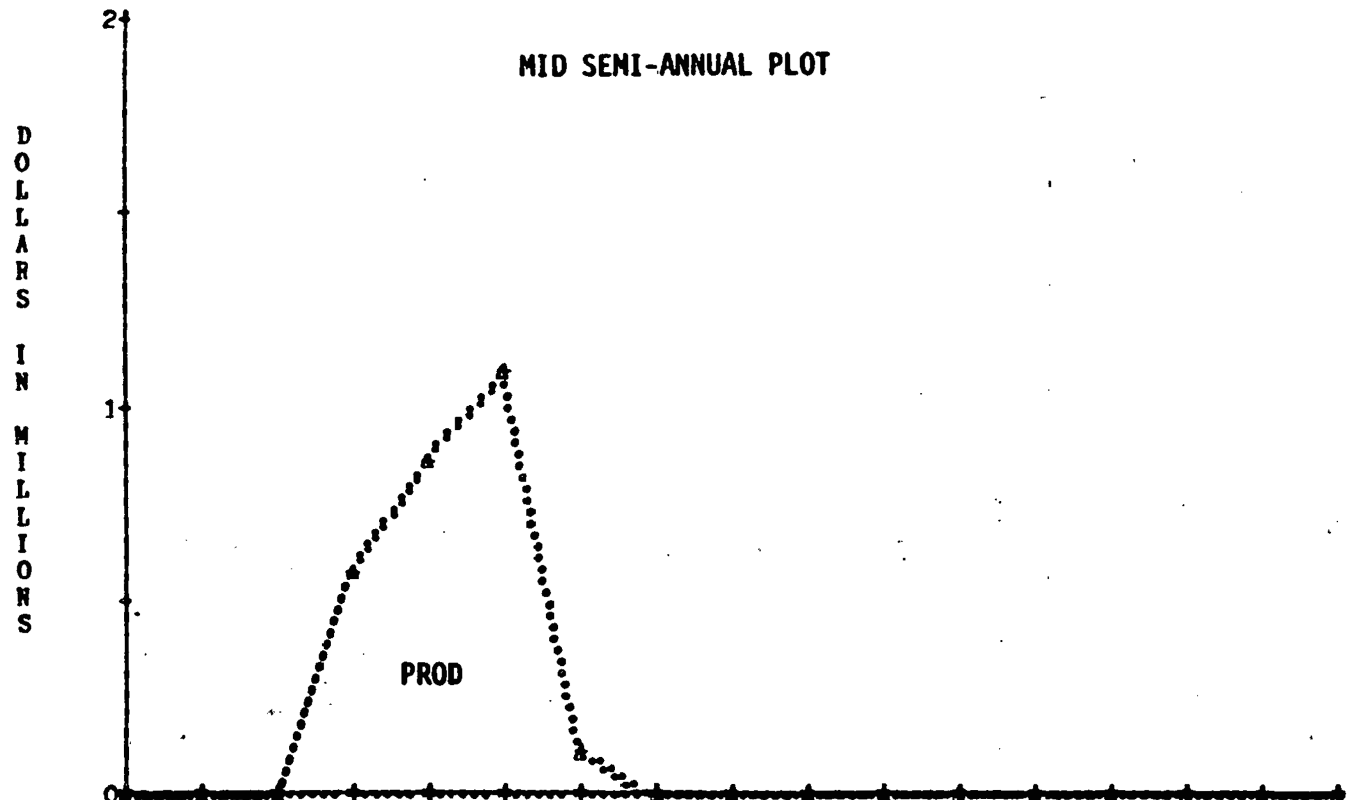
The costs charged to this element are to provide for the labor, material and equipment required to support construction, activation and checkout.





GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT•E	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	0•0	0•0	•6	•7	1•3	•2	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	0•0	0•0	•6	•7	1•3	•2	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0

Figure 4-23. Miscellaneous Plant Equipment Summary Chart



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT.E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	0.0	.6	.9	1.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	.6	.9	1.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 4-24. Miscellaneous Plant Equipment Committed Dollars

4.13.1 Distributable Cost

Costs of this element, as estimated by Stearns-Roger and MDAC, are as follows:

Title	Non-recurring (million)	Recurring (million) Material	Labor	Total	Total NR&R
Contractor F.O.	$0.00	$0.00	$0.36	$0.36	$0.36
Other constr item	0.00	0.74	1.75	2.49	2.49
Total	$0.00	$0.74	$2.11	$2.85	$2.85

Table 4-19 provides detailed cost and Table 4-20 provides a more detailed description of these costs. Several distributable costs are not shown according to the CBS because of difficulty in reallocating the effort or because they do not apply. These areas include 8040.2, "Insurance, Construction Equipment, and Autos," which is covered under 8040.4, "Construction Equipment," 8040.33, "Electricity and Water," which is covered under 8040.32, "Buildings and Structures," and 8040.51, "Purchased Utilities," which is covered under 8040.32, also. Also, 8040.57, "Operation and Maintenance of Construction Facilities and Equipment," is generally covered under other CBS elements. 8040.7, "Payroll Taxes" is included in labor rates and 8040.8, "Foreign Duties and Taxes," does not apply. No cost is shown for "Aggregate Plant" or "Concrete Batch Plant," since these costs are covered in the costs of the materials.

4.13.2 Distributable Cost Funding

The schedule and funding for this element are shown on Figure 4-25. The effort starts 35 months prior to IOC and continues for 28 months. Figure 4-26 shows the estimated committed distributables. Generally, the funding parallels the site construction of the balance of the plant. Distributables for construction that starts earlier are allocated against the individual subsystems.

Table 4-19. Distributables Cost Detail

80 WBS SERIES PILOT PLANT 18.05.12. DATE: 77/05/23.

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
8040.1	INSUR.INJ. + DAMA	0.00	0.00	.29	.29	.29
8040.2	INSUR.CONSTR.EQ.+	0.00	0.00	.00	.00	.00
8040.3	TEMPORARY CONST.	0.00	0.00	.24	.24	.24
8040.4	CONSTRUCTION EQ.	0.00	0.00	.66	.66	.66
8040.5	CONSTRUCTION SER.	0.00	.10	.47	.57	.57
8040.6	SPARE PARTS	0.00	.63	.09	.73	.73
8040.7	FED.+STATE TAXES	0.00	.00	.00	.00	.00
8040.8	FOREIGN DUTIES+TA	0.00	.00	.00	.00	.00
40	SUBTOTAL	0.00	.74	1.75	2.49	2.49
8040.31	SITE ACCESS+IMPR.	0.00	0.00	.02	.02	.02
8040.32	BUILDINGS+STRUCTS	0.00	0.00	.19	.19	.19
8040.33	ELEC. + WATER	0.00	0.00	.00	.00	.00
8040.34	COMMUNCATIONS EQ.	0.00	0.00	.03	.03	.03
8040.35	AGGREGATE PLANT	0.00	0.00	.00	.00	.00
8040.36	CONCRETE BATCH PL	0.00	0.00	.00	.00	.00
8040.3	SUBTOTAL	0.00	0.00	.24	.24	.24
8040.52	SEC.WATCHMEN+GUAR	0.00	0.00	.16	.16	.16
8040.53	ED +TESTING PRG F	0.00	.10	.15	.25	.25
8040.54	MTR.REC.+STORAGE	0.00	0.00	.12	.12	.12
8040.55	I+T OF CONSTR.MTR	0.00	0.00	.02	.02	.02
8040.56	SITE CLEANUP	0.00	0.00	.02	.02	.02
8040.57	O+M OF CONSTR.FAC	0.00	0.00	.00	.00	.00
8040.58	SNOW REMOVAL	0.00	0.00	.00	.00	.00
8040.5	SUBTOTAL	0.00	.10	.47	.57	.57
8040.61	TURBINE PLT.EQ.	0.00	.01	0.00	.01	.01
8040.62	ELEC.PLANT EQ.	0.00	.01	0.00	.01	.01
8040.63	COLLECTOR PLT. EQ	0.00	.11	.09	.20	.20
8040.64	RECEIVER EQ.	0.00	.42	0.00	.42	.42
8040.65	THERMAL STR.EQ.	0.00	.08	0.00	.08	.08
8040.6	SUBTOTAL	0.00	.63	.09	.73	.73

Table 4-20. Distributables

Construction Facilities

Included in this CBS item are:

1. Temporary buildings
2. Temporary earthwork and foundations
3. Temporary piping and electrical
4. Plant cleanup
5. Temporary utilities

Construction Equipment

Included in this CBS item are:

1. Contractor's construction equipment
2. Small tools
3. Gas and oil
4. Construction equipment maintenance

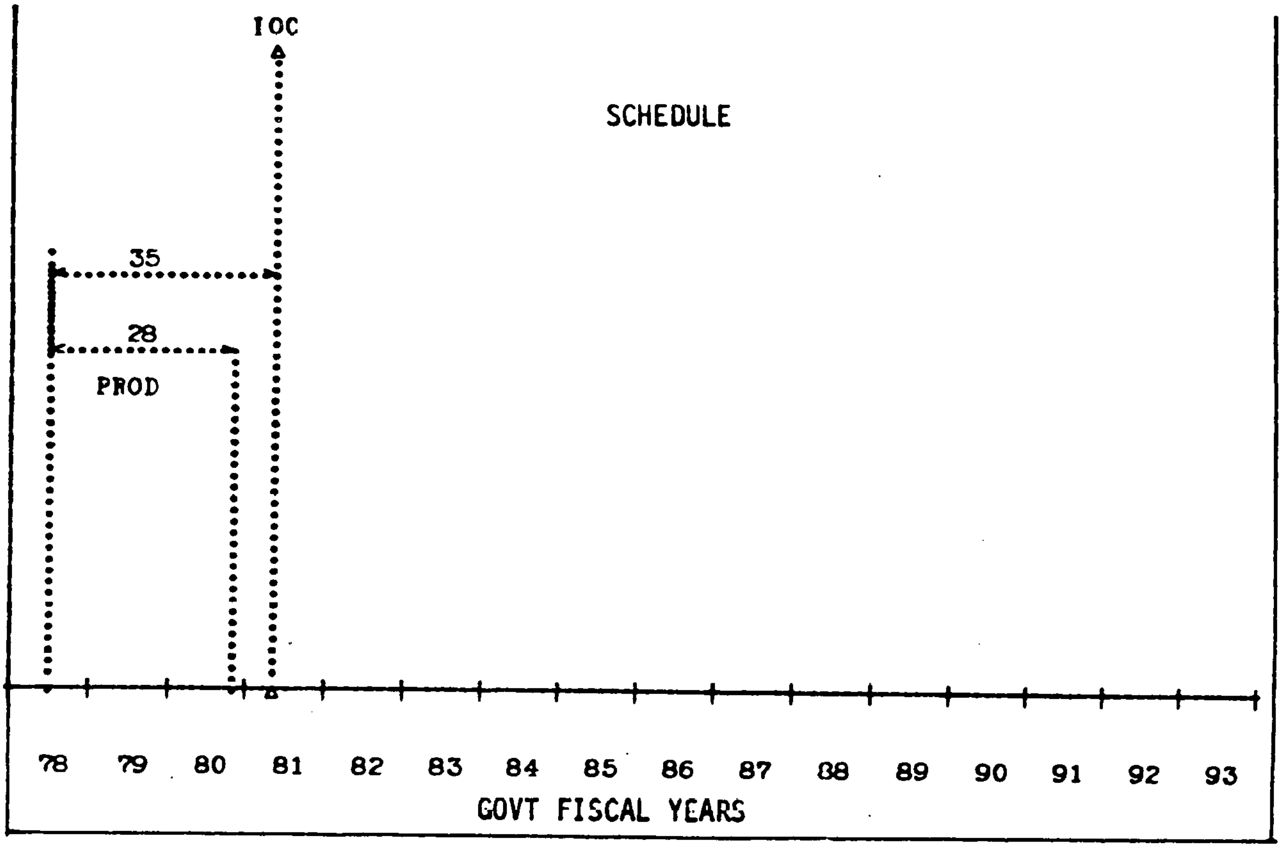
Construction Services

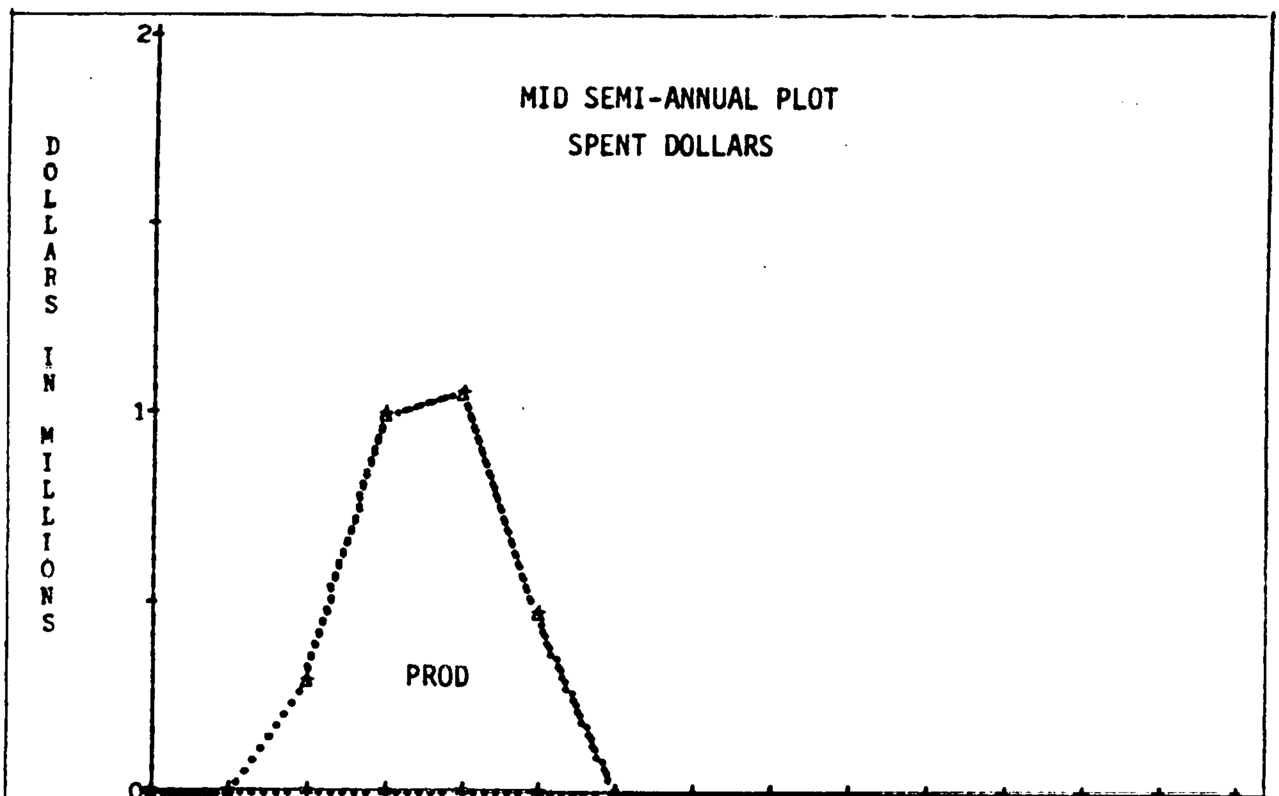
Included in this CBS item are:

1. Constructor's field supervision and accounting
2. Field engineer
3. Security
4. Material receiving and warehousing
5. Safety and first aid personnel
6. Telephone and telegraph
7. Field office supplies and equipment
8. All-risk insurance
9. Payroll taxes and insurance
10. Permits
11. General expendable supplies
12. Safety equipment and supplies
13. Purchased utilities
14. Operator training

Spare Parts

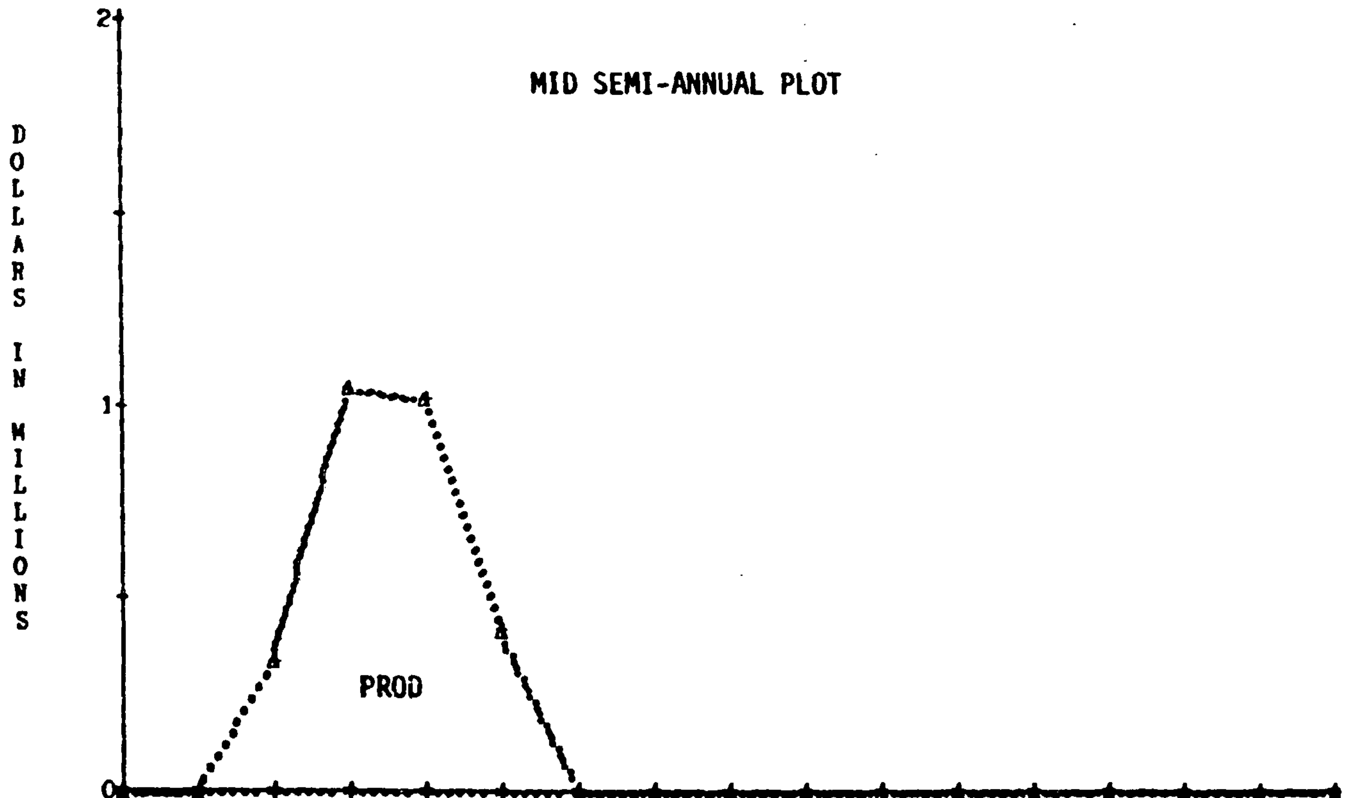
This item includes initial investment spares for all subsystems.





GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT•E	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	0•0	•3	1•0	1•1	•5	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	0•0	•3	1•0	1•1	•5	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0

Figure 4-25. Distributables Summary Chart



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT•E	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	0•0	•3	1•1	1•0	•4	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	0•0	•3	1•1	1•0	•4	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0

Figure 4-26. Distributables Committed Dollars

4.13.3 Cost Methodology

Costing is based on Stearns-Roger experience concerning these costs for power plants of this size and utilizing current industrial equipment, material and labor costs reflecting the Barstow area for the pilot plant as well as MDAC experience on development projects. Cost analysis of recent conventional plants has been made to determine appropriate experience factors and the results applied to the direct field cost to estimate construction facilities, equipment and services costs, and training. In addition, preliminary training requirements for the nonconventional elements were evaluated and costed based on estimator judgment.

Spares were estimated based on Stearns-Roger experience on plants of similar size for the conventional portion of the pilot plant and on preliminary failure rate data for the unconventional portion of the plant. Spares requirements for the latter type of equipment were determined for each important potential failure item and the resulting quantity extended by unit costs determined in costing the equipment subsystems in order to obtain a cost figure. Spares cost for the conventional equipment were determined using experience factors applied to hardware cost.

4.14 INDIRECT COST (8100)

This element includes A&E services, construction manager, solar integration contractor, startup, and other costs.

The costs charged to this element are to provide for the labor required to design, specify, contract, support construction, manage, train for, activation and checkout.

4.14.1 Indirect Costs

Costs of this element as estimated by Stearns-Roger and MDAC are as follows:

Title	Non-recurring (million)	Recurring (million) Material	Labor	Total	Total NR&R
A&E services	$0.00	$0.00	$1.23	$1.23	$1.23
Construction mgmt	0.38	0.00	3.00	3.00	3.38
Solar subsys int	0.00	0.00	5.20	5.20	5.20
Engr & des of S. S.	0.00	0.00	0.00	0.00	0.00
Master contr des	0.00	0.00	0.00	0.00	0.00
Plant startup & C/O	0.00	0.00	1.36	1.36	1.36
Total	$0.38	$0.00	$10.78	$10.78	$11.16

Table 4-21 shows detailed cost and Table 4-22 provides a more detailed description of these costs.

4.14.2 Indirect Cost Funding

The schedule and funding for this element are shown on Figure 4-27. The D&D and production shows the estimated committed costs, see Figure 4-28.

4.14.3 Cost Methodology

Costing is based on Stearns-Roger experience concerning indirect costs for power plants of this size as well as MDAC experience on development projects. Cost analysis of recent conventional plants has been made to determine appropriate experience factors and results applied for A&E, and construction management costs. Solar integration contractor and startup cost have been manloaded. Engineering cost other than A&E for overall plant design and layout for balance of plant are included against the individual subsystem.

Table 4-21. Indirects Cost Detail

81 SERIES WBS PILOT PLANT 18.19.29. DATE: 79/05/23.

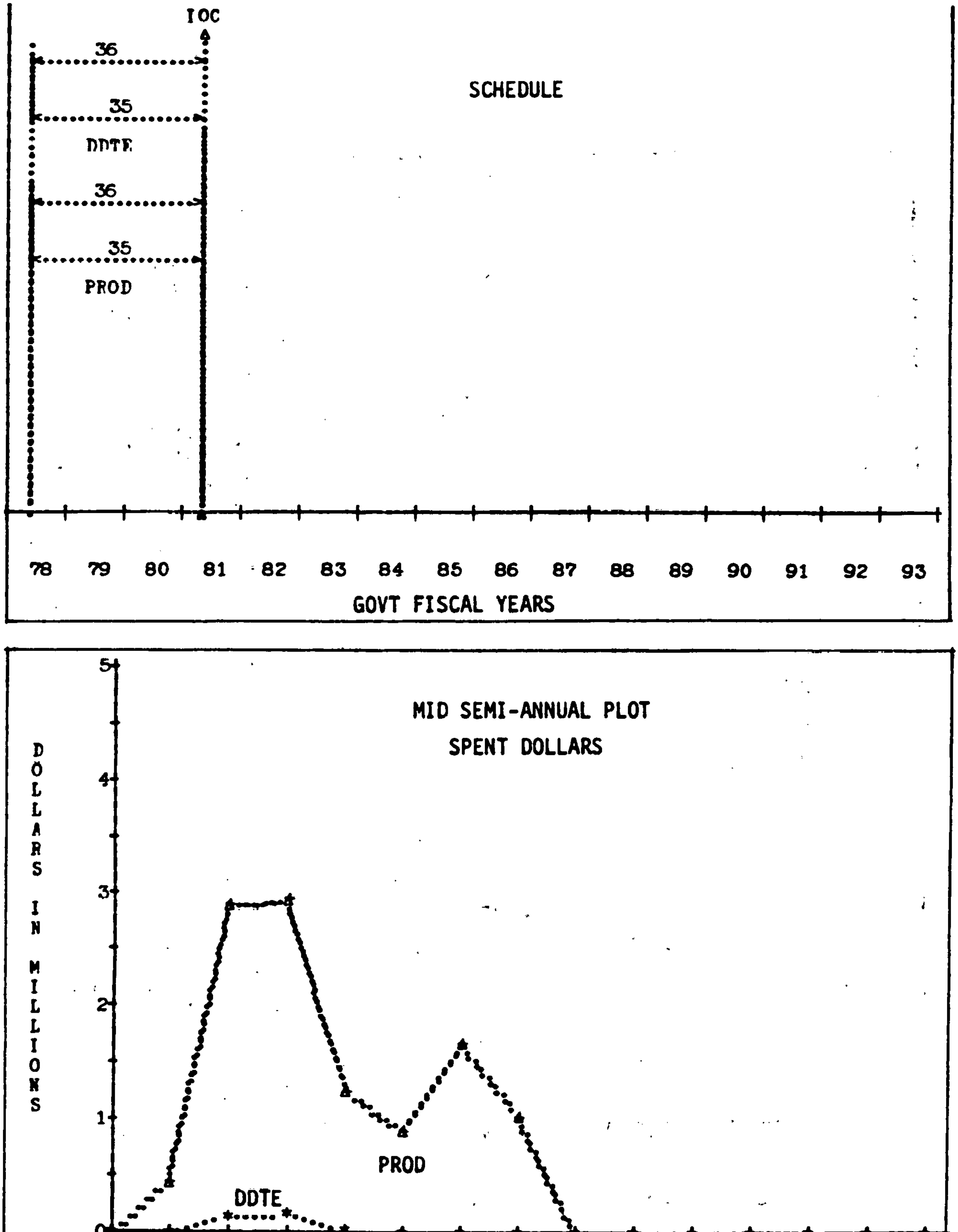
WBS	TITLE	NON-RECUR (MIL)	------RECURRING (MIL)------ MATERIAL	LABOR	TOTAL	TOTAL NR+R
8100.11	PRELIM.DESIGN SER	0.00	.0C	.38	.38	.38
8100.12	DETAILED DES. SER	0.00	.0C	.85	.85	.85
8100.13	ENGR. SUPPORT	0.00	.0C	0.00	.00	.00
8100.1	SUBTOTAL	0.00	.0C	1.23	1.23	1.23
8100.21	C.M. SUP.DURING D	.38	0.0C	0.00	0.00	.38
8100.22	C.M. DURING CONST	0.00	0.0C	3.00	3.00	3.00
8100.2	SUBTOTAL	.38	.0C	3.00	3.00	3.38
8100.41	COLLECTORS	.00	0.0C	0.00	0.00	.00
8100.42	RECEIVERS	.00	0.0C	0.00	0.00	.00
8100.43	STORAGE	.00	0.0C	0.00	0.00	.00
8100.4	SUBTOTAL	.00	0.0C	0.00	0.00	.00
8100.51	SOFTWARE DESIGN	.00	0.0C	0.00	0.00	.00
8100.52	HARDWARE DESIGN	.00	0.0C	0.00	0.00	.00
8100.53	SOFTWARE/HDWR.DES	.00	0.0C	0.00	0.00	.00
8100.5	SUBTOTAL	.00	0.0C	0.00	0.00	.00

Table 4-22. Indirect Cost Descriptions

Architect and Engineering Services Included in this CBS item are engineering management, preliminary and design service, specifications and procurement of materials and equipment, and system management.
Plant Startup These CBS items includes initial plant startup.
Construction Management These CBS items include: 1. Site management 2. Contracts administration 3. Engineering interpretation 4. Source inspection (materials and manufactured item) 5. Quality Assurance (of on-site construction) 6. Labor relations 7. Safety inspection 8. Scheduling (and up dating) 9. Accounting (computer, cost control, cost trend forecasting, etc.) 10. Material accountability and control 11. As-built drawings

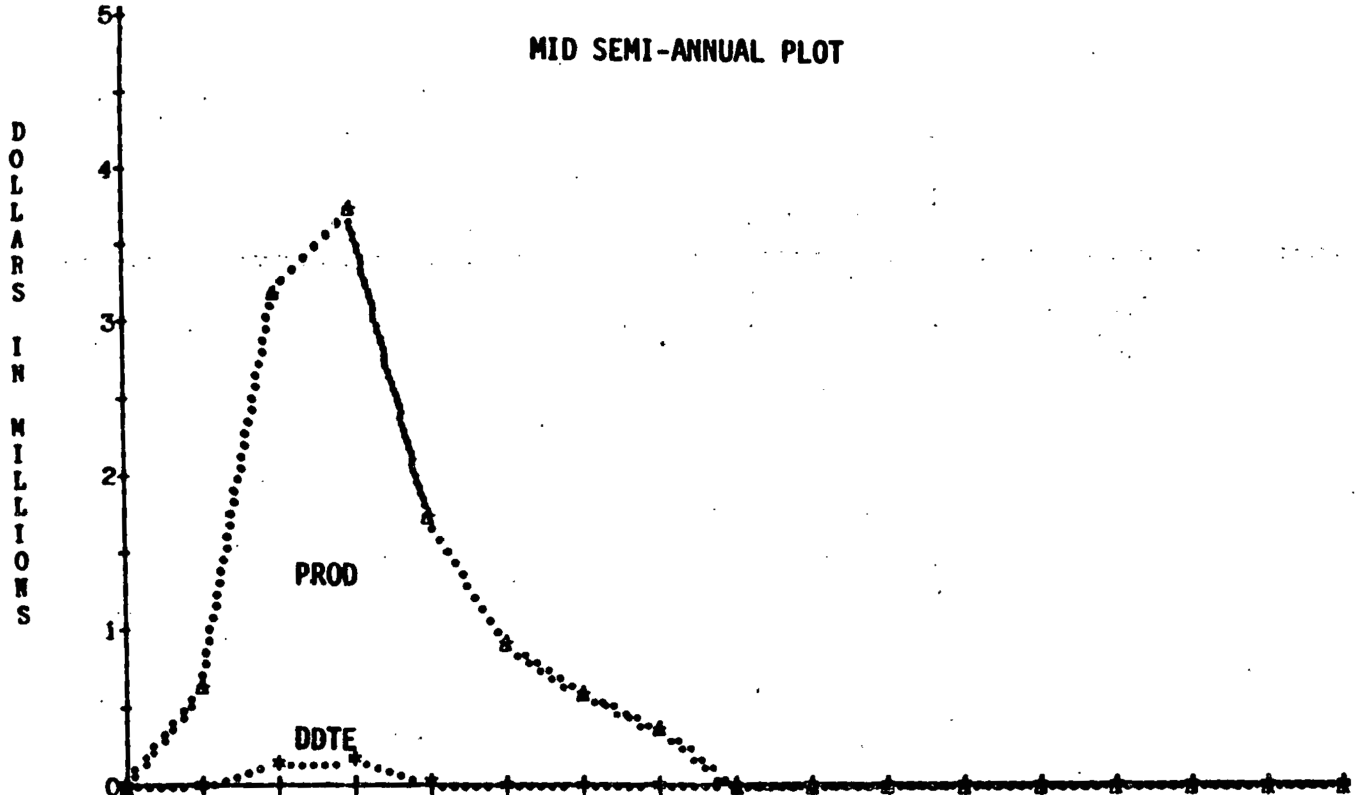
4.15 CONTINGENCY (DP4100)

This element provides for additional costs arising from incomplete definition, schedule uncertainty, fabrication, assembly and installation problems and similar situations. Costs are to allow for the potential impact of such circumstances.



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT.E	.0	.2	.2	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	.5	2.8	2.8	1.2	.9	1.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	.5	2.9	3.0	1.3	.9	1.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 4-27. Indirects Summary Chart



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT·E	.0	.2	.2	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	.6	3.1	3.6	1.7	.9	.6	.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	.7	3.2	3.8	1.8	.9	.6	.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 4-28. Indirects Committed Dollars

4.15.1 Contingency Cost

Contingency has been included as follows:

Title	Non-recurring (million)	Recurring (million) Material	Labor	Total	Total NR&R
Solar plant eq	$0.66	$1.57	$1.50	$3.08	$3.73
Elec pwr gen eq	0.00	0.48	0.14	0.61	0.61
Master control	0.18	0.12	0.12	0.24	0.42
Land yard	0.00	0.03	0.00	0.03	0.03
Dist indr & other	0.03	0.05	0.90	0.95	0.98
Buildings	0.00	0.07	0.05	0.12	0.12
Total	$0.87	$2.32	$2.72	$5.04	$5.90

4.15.2 Contingency Funding

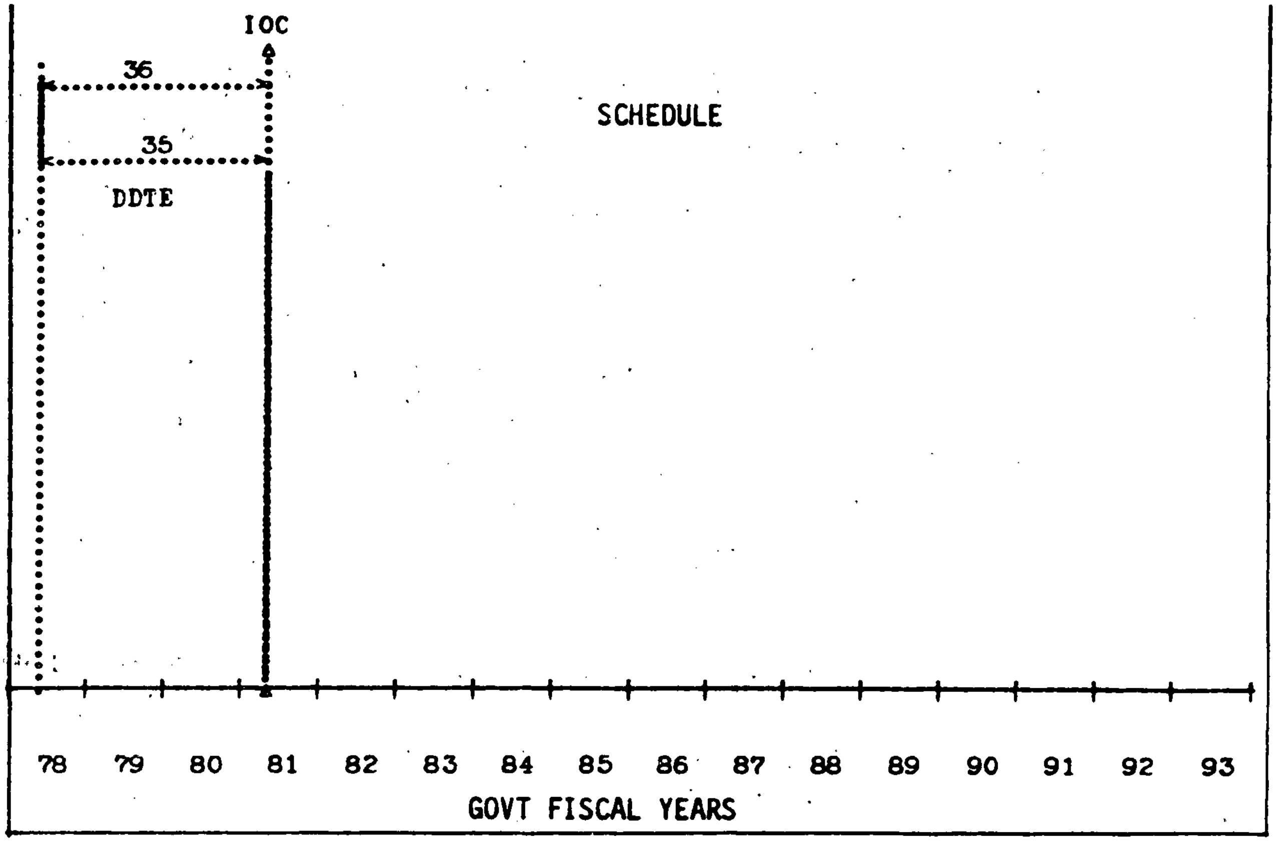
Contingency as shown in Figure 4-29 has been spread by phase in general proportion to the funding in each phase. Funding peaks at $2.0 million in the second half of 1979. Figure 4-30 shows the estimated committed cost.

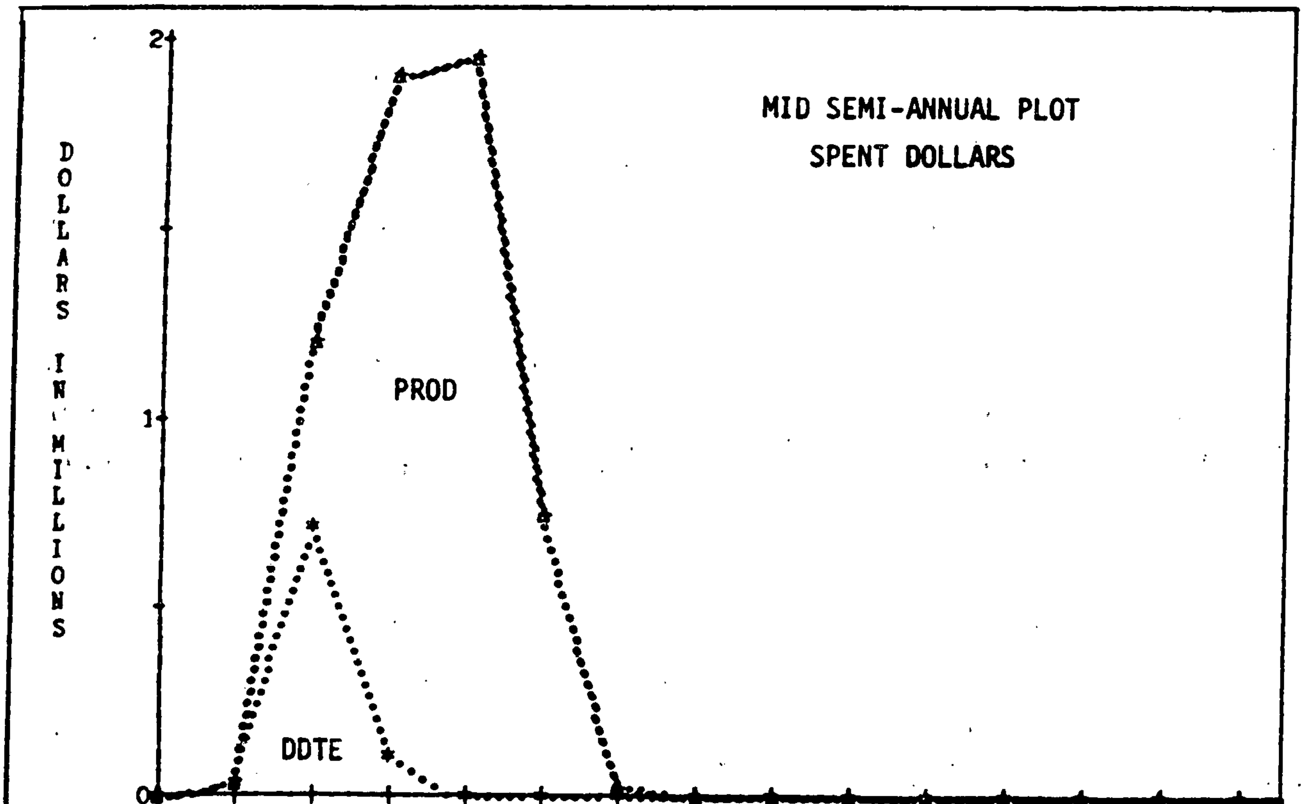
4.15.3 Cost Methodology

Contingency costs have been applied with the following percentages:

Element	Applied Contingency
Solar Plant	10%
EPG	7%
Indirect and Distributable	7%
Land and Yard	5%
Buildings	5%
Master Control	20%
Weighted Ave	9%
Operations	0%

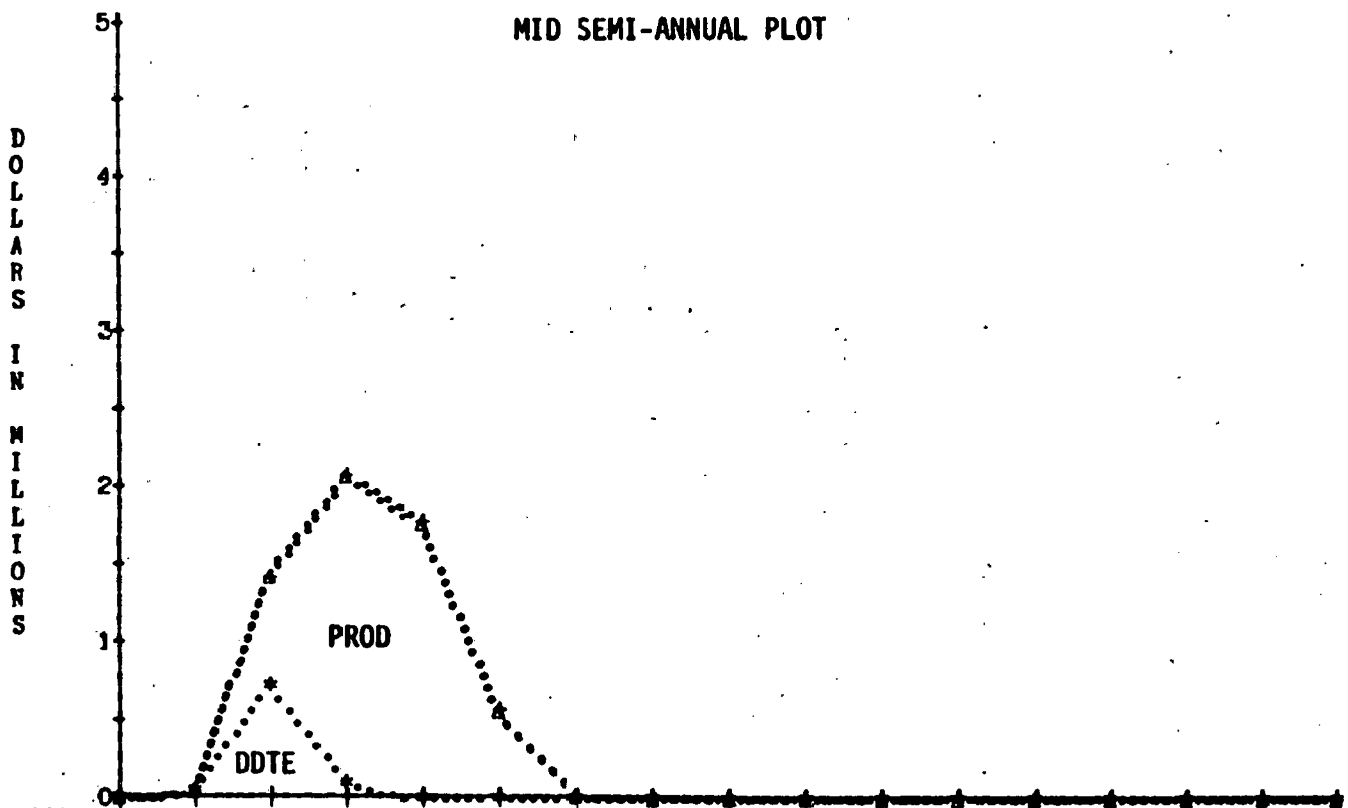
No contingency was applied for operations because it was estimated on a staffing basis.





GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT•E	•0	•7	•1	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	0•0	•5	1•8	2•0	•8	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	•0	1•2	1•9	2•0	•8	•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0

Figure 4-29. Contingency Summary Chart



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984	1985	1985
DDT•E	.0	.7	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	.7	2.0	1.8	.6	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	.0	1.4	2.1	1.8	.6	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 4-30. Contingency Committed Dollars

The actual factors applied are based on judgment of the relative risk involved in each subsystem using 10% for the solar plant equipment as the baseline.

4.16 TWO-YEAR TEST PROGRAM (1000, 2000, AND 3000)

This element includes the effort necessary to operate and maintain the systems and subsystems during the two year test phase including testing, evaluation, technical support, operations and maintenance and follow-on spares.

4.16.1 Test Program Cost

Costs for the systems test operation have been estimated by Rocketdyne, Stearns-Roger, and MDAC as follows:

Title	Non-recurring (million)	Recurring (million) Material	Labor	Total	Total NR&R
Oper and maint	$0.00	$0.07	$1.98	$2.05	$2.05
Test prog tech su	0.00	0.00	1.52	1.52	1.52
Spare parts	0.00	0.35	0.29	0.64	0.64
Total	$0.00	$0.42	$3.79	$4.21	$4.21
EPG and MC	$0.00	$0.01	$0.00	$0.01	$0.01
Collector	0.00	0.20	0.29	0.50	0.50
Receiver	0.00	0.07	0.00	0.07	0.07
Therm stor	0.00	0.06	0.00	0.06	0.06
Total spares	$0.00	$0.65	$0.29	$0.64	$0.64

Typical staffing is shown in Table 4-23 and is based on advice provided by Southern California Edison and an analysis of special maintenance requirements by MDAC logistics and supported by the subcontractors.

4.16.2 System Test Operation Funding

Funding for this phase of the program has been level loaded starting at IOC and continuing for 24 months. The level of funding is $1.05 million per semiannual period, as shown in Figure 4-31.

Table 4-23. Technical Description Test Operations Manload

Personnel	5 Days	7 Days
Pilot Plant Senior Operator		3
Assistant Operator		1
Plant Engineer		1
Electrical Technician		4
Mechanical Technician		2
Optical Technician		1
Structural/Mechanical Technician		3
Electromechanical Technician	1	
Mechanical/Electrical Technician	1	
Heavy Equipment Operator	1	
Rigger	1	
Cleaner	4	
	8	16
5-Day Personnel 8	8	
7-Day Personnel 16 x 7/5 =	22	
Total 5-Day Basis	30	

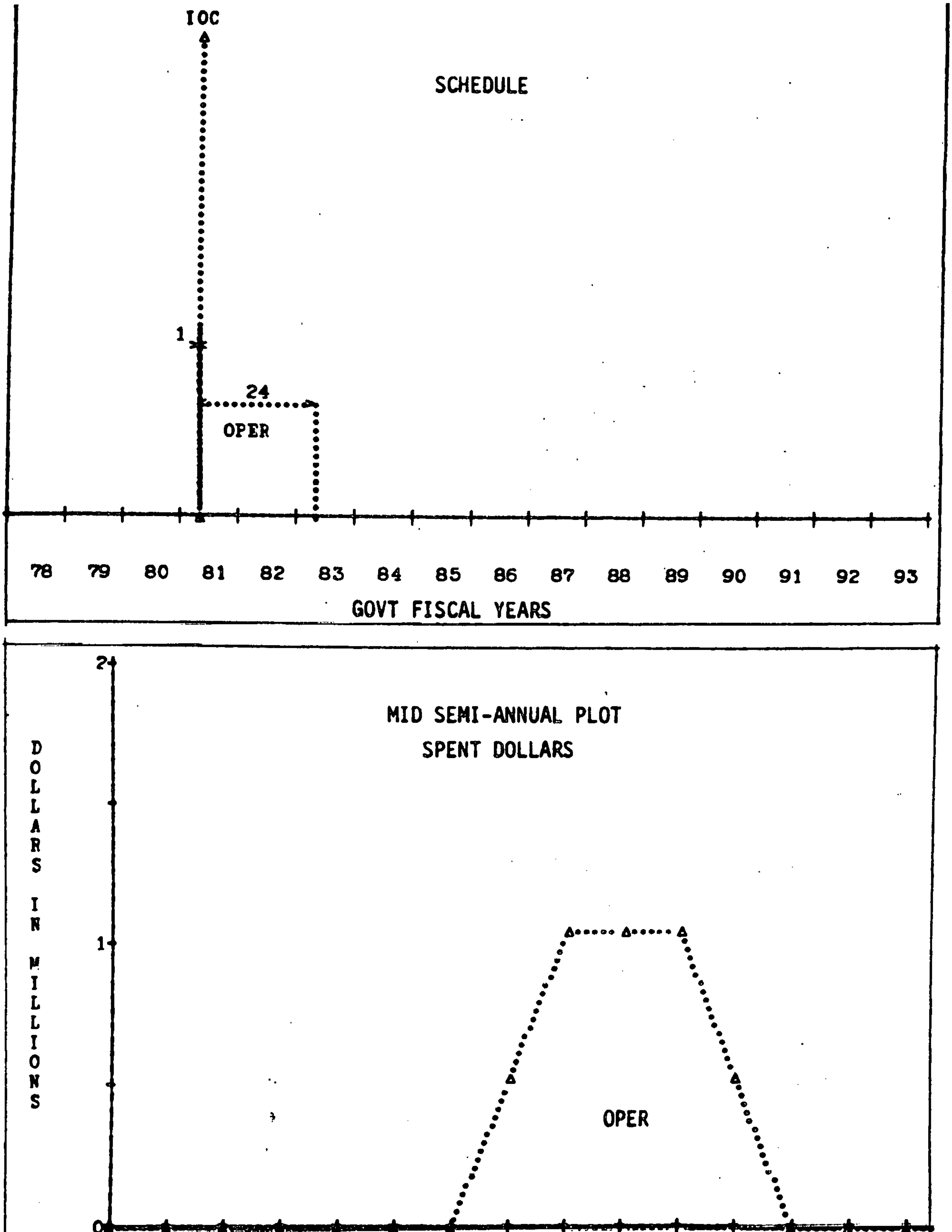
Master Control Maintenance - Service Contract

Consumables - Washing Solution

Support - Covered in Labor Rates

4.16.3 Cost Methodology

Costing is based on utility experience on conventional plants and on preliminary failure rate data and FMEAs for the unconventional portion of the plant as well as MDAC experience in timelining operational activities. For unconventional equipment maintenance requirements, failure rates were employed to estimate the number of plant-wide failures per year for each important potential failure item. Estimates of the average time required to locate the failure, to remove and replace the item and return have been extended by the failures per year to arrive at expected hours per year. Also, preventive maintenance hours per item have been estimated by



GFY	1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
DDT•E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	.5	1.1	1.1	1.1	.5	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	.5	1.1	1.1	1.1	.5	0.0	0.0	0.0

Figure 4-31. Two-Year Test Program Summary Chart

Effectiveness Engineering considering failure rates and FMEAs and conventional plant experience on boiler tube. A similar basis was used to estimate repair cost for replaced and repairable parts.

Heliostat cleaning cost has been another area of interest and has been estimated by defining required equipment and manpower to operate the equipment and timelining the effort, assuming use of the resources and a particular cleaning frequency. The results may be directly converted to annual labor, material equipment, and facilities cost.

The results of the above analysis for each subsystem have been compiled and integrated with the functional manning estimate for a conventional plant to determine plant staffing requirements. In addition, an allowance for contract labor support to handle minor nonrecurring modifications and construction problems during the initial phase has been included as a percentage of O&M and other test operations phase costs.

Spares were estimated based on Stearns-Roger experience on plants of similar size for the conventional portion of the Pilot Plant and on preliminary failure rate data for the unconventional portion of the plant. Spares requirements for the latter type of equipment were determined for each important potential failure item and the resulting quantity extended by unit costs determined in costing the equipment subsystems in order to obtain a cost figure. Spares cost for the conventional equipment were determined using experience factors applied to hardware cost.

The Master Control Maintenance contract is based on published quotes for monthly maintenance on each item of equipment. Additional costs for this item prior to the operations phase are included in the Master Control Investment costs. Washing solution costs are based on vendor quotes.

Section 5
COMMERCIAL PLANT
COSTING DETAIL, METHODOLOGY AND RATIONALE

This section presents additional detail about costs and funding, along with specific methodology and rationale for a 100 MWe First Commercial Central Receiver Solar Electric Plant. Also discussed are possible cost variations with plant thermal capacities and production volume. The section is organized by CBS or CBS groupings, beginning with total plant costs and variations. Each subsection indicates the scope of work, contains a cost breakdown, semi-annual funding and schedule plots, and a description that indicates the basis of costing, including a brief technical description. Due to the large dollar value of the collector equipment, a more detailed scope of work is provided for that subsystem.

5.1 TOTAL FIRST COMMERCIAL PLANT COST AND COST VARIATIONS

Although preliminary, commercial plant costs are of considerable interest because they provide an indication of the eventual economics of the Central Receiver Concept. This subsection presents the costs in total and indicates how they may vary with change in solar multiple and thermal storage capacity. Possible cost reductions with increases in plant installation frequency is briefly covered, also.

5.1.1 Total Central Receiver First Commercial Plant Costs and Funding

This element includes all elements that comprise a central receiver power plant. It includes all subsystems that directly make the power plant operable, including turbine plant equipment, electric plant equipment, miscellaneous plant equipment, collector equipment, receiver equipment, thermal storage equipment and thermal storage materials. Also included are land, structures and facilities, spare parts, distributables, and indirect costs. The costs charged to this element are to provide for the labor, material and equipment required to fabricate, deliver, assemble, install, align, activate checkout, and provide 1 year of systems operations for all of the subsystems listed above.

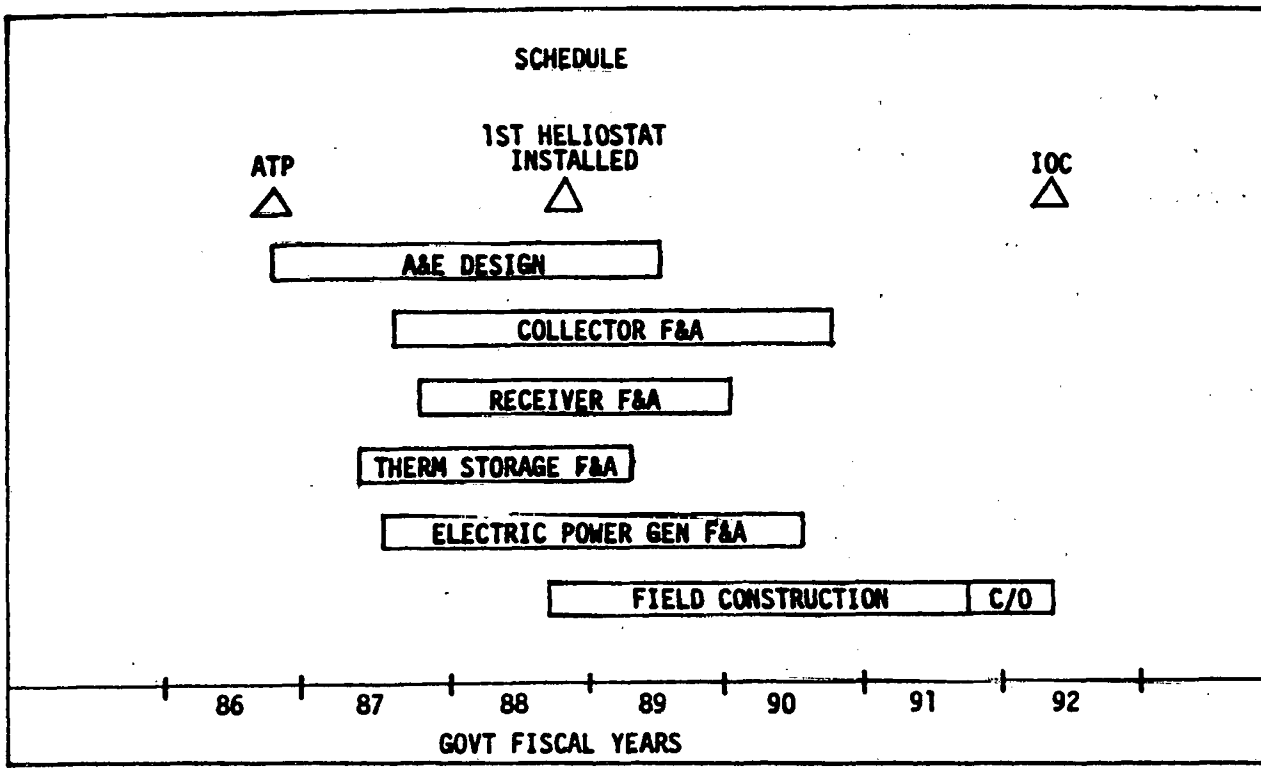
5.1.1.1 First Commercial Cost Breakdown. First commercial plant costs are shown in Table 5-1. In this presentation, operations include no technical support costs and represent a typical year's cost. The solar plant equipment are, by far, the largest costs and include the costs of the collector, receiver and tower, thermal storage equipment, and the thermal storage medium. Quality Assurance costs are allocated within the other costs. Distributable costs cover only those areas in support of the Balance of Plant except that initial solar plant equipment spares are included. Burden type costs for the Solar Plant Equipment are covered in the individual contractor's overhead rates. Also, no state sales tax has been included in the costs due to uncertainty about the tax rate, if any, and how the plant would be taxed. Indirects included costs for construction management, the A&E, a solar integrator, and plant startup and cover these activities, as appropriate, for the entire plant.

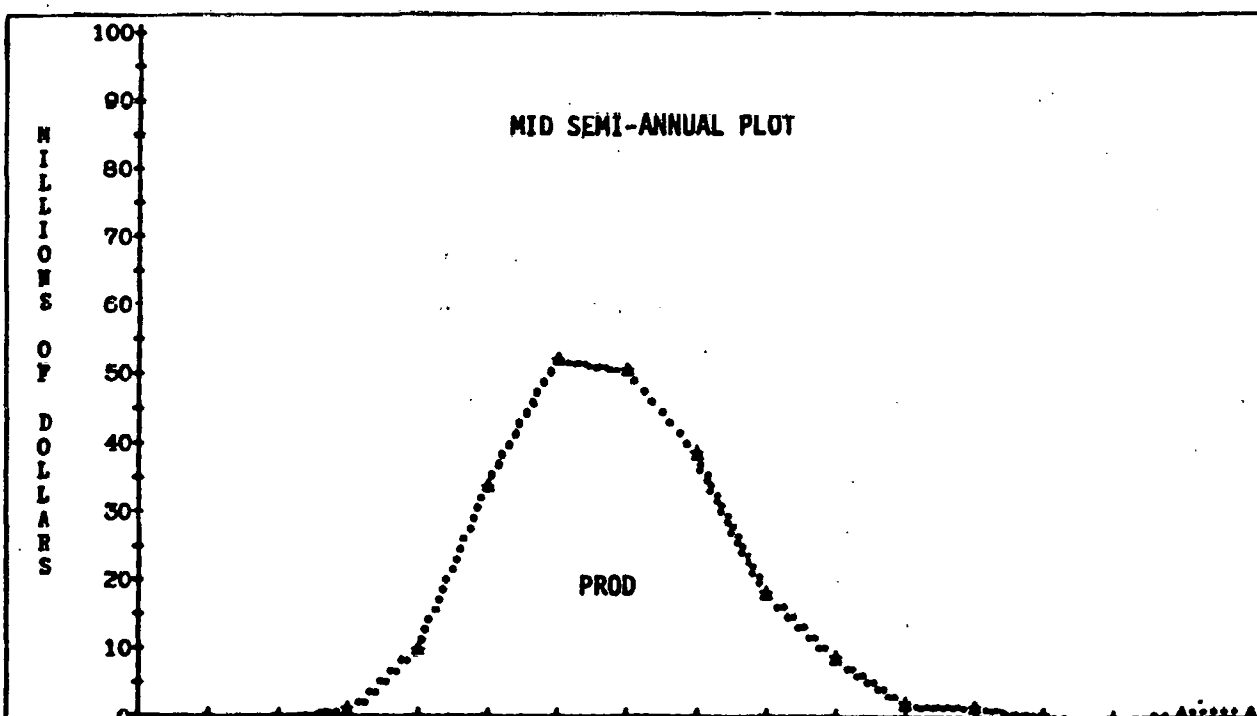
5.1.1.2 Typical First Commercial Funding. Typical funding that may be required for a first commercial plant on an as-spent basis are shown in Figure 5-1. The funding is shown on a semiannual basis on a government fiscal year (October 1 to September 30). In this plot and all following funding plots, plot points are at mid-period (i.e., June 30 and December 31) and represent the total funding required over a 6-month period. Also, where relatively small numbers are spread over extended periods, a significant rounding loss may occur at lower CBS levels. However, the loss is only on output so that such losses do not accumulate in the total funding curves. The semiannual plots provide a better picture of funding buildup. Figure 5-1 shows a buildup to peak funding in the last half of 1988 under a 5-1/2-year schedule. The peak occurs about when the first heliostat is installed. The minor funding requirements in 1991 and 1992 cover subsystem and system checkout and the funds shown in 1993 represent typical annual operation and maintenance costs.

Table 5-1. First Commercial Investment

FIRST COMM ALL BUT 10-30 07.47.02. DATE: 77/05/26.

WBS	TITLE	NON-RECUR (MIL)	------RECURRING (MIL)------ MATERIAL	LABOR	TOTAL	TOTAL NR&R
4000	LAND&LAND RIGHTS	0.00	.00	0.00	.00	.00
4100	YARD WORK	0.00	1.50	.03	1.53	1.53
4103	TURBINE BLDG.	0.00	1.30	.86	2.16	2.16
4105	ADMIN.BLDG.	0.00	.66	.44	1.10	1.10
4106	CIR.&SER.WATERP.H	0.00	.00	.00	.01	.01
4108	WAREHOUSE	0.00	.52	.35	.86	.86
4141	MAINTENANCE BLDG.	0.00	.00	0.00	.00	.00
4142	WATER TREAT.EQ.BL	0.00	.19	.13	.32	.32
4143	SEWAGE TREATMT BL	0.00	.00	0.00	.00	.00
4170	THERMAL STORAGE S	0.00	.32	0.00	.32	.32
4180	CONTROL BLDG.	0.00	.00	0.00	.00	.00
4144	AUX GEN BLDG.	0.00	.04	0.00	.04	.04
4190	SOLAR PLANT EQ.	.00	111.83	46.38	158.22	158.22
4300	TURBINE PLANT EQ.	0.00	20.76	2.09	22.84	22.84
4401	ELEC. PLANT EQ	0.00	2.02	1.25	3.27	3.27
4402	PLANT MASTER CTR.	0.00	1.24	.54	1.78	1.78
4500	MISC. PLANT EQ.	0.00	2.87	.35	3.21	3.21
5309	TRANSMISSION PLAN	0.00	.01	.01	.02	.02
7000	QUALITY ASSURANCE	0.00	.00	0.00	.00	.00
8000	DISTRIBUTABLES	0.00	2.91	5.19	8.10	8.10
8100	INDIRECTS	0.00	0.00	17.50	17.50	17.50
8300	CONTINGENCY	.00	.00	.00	.00	.00
	GRAND TOTAL	.00	146.17	75.11	221.28	221.28
	ANNUAL OPER & SPARES	0.00	.93	2.06	2.99	2.99





GFY	1986	1986	1987	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992	1992	1993	1993
DDT•E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	.2	1.5	10.0	33.9	52.3	51.0	39.2	18.7	9.0	2.7	1.8	1.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.5
TOTAL	0.0	.2	1.5	10.0	33.9	52.3	51.0	39.2	18.7	9.0	2.7	1.8	1.0	0.0	1.5	1.5

Figure 5-1. Total Commercial Summary Chart

5.1.1.3 Costing Methodology. Costing for each CBS element has been accomplished by the contractor having the technical responsibility for the element. Thus, the methodology varies somewhat between subsystems, but is probably the most appropriate for costing each area. Generally, individual parts or materials have been costed based on vendor quotes or on experience or catalogs if the material is a "frequent" buy item. Labor is costed by various methods ranging from internal judgments to standards costing or historical factoring to resource load costing. Details are presented in each subsection and detail cost sheets have been coded in the following manner for solar equipment:

Source of Estimates	Code
Subcontractor Proposal	M
Vendor Quote	V
Algorithm or CER	A
In-House Estimates	I
Historical Based Factor	H
Catalog or Experienced Price	C

5.1.2 Cost Versus Thermal Capacity

Figure 5-2 presents parametric first commercial plant costs as a function of variation in hours of storage from 0.5 to 6 and solar multiples of 1, 2, and 3. Costs are for capital investment only, and do not include annual operations and maintenance or replacement spares. The base point for this analysis is the baseline MDAC design for 6 hours of storage and a solar multiple of 1.7 which is estimated to cost $221.3 million. An alternate design for 3 hours of storage and a solar multiple of 1.4 would lower this cost to $189 million.

The methodology used to calculate these parametric cost curves involved a determination of which items would remain constant regardless of plant size and which items would vary with plant size changes. It was determined that land and buildings, balance of plant, distributables, and about one-fourth of indirects would remain constant. The remaining items — collector,

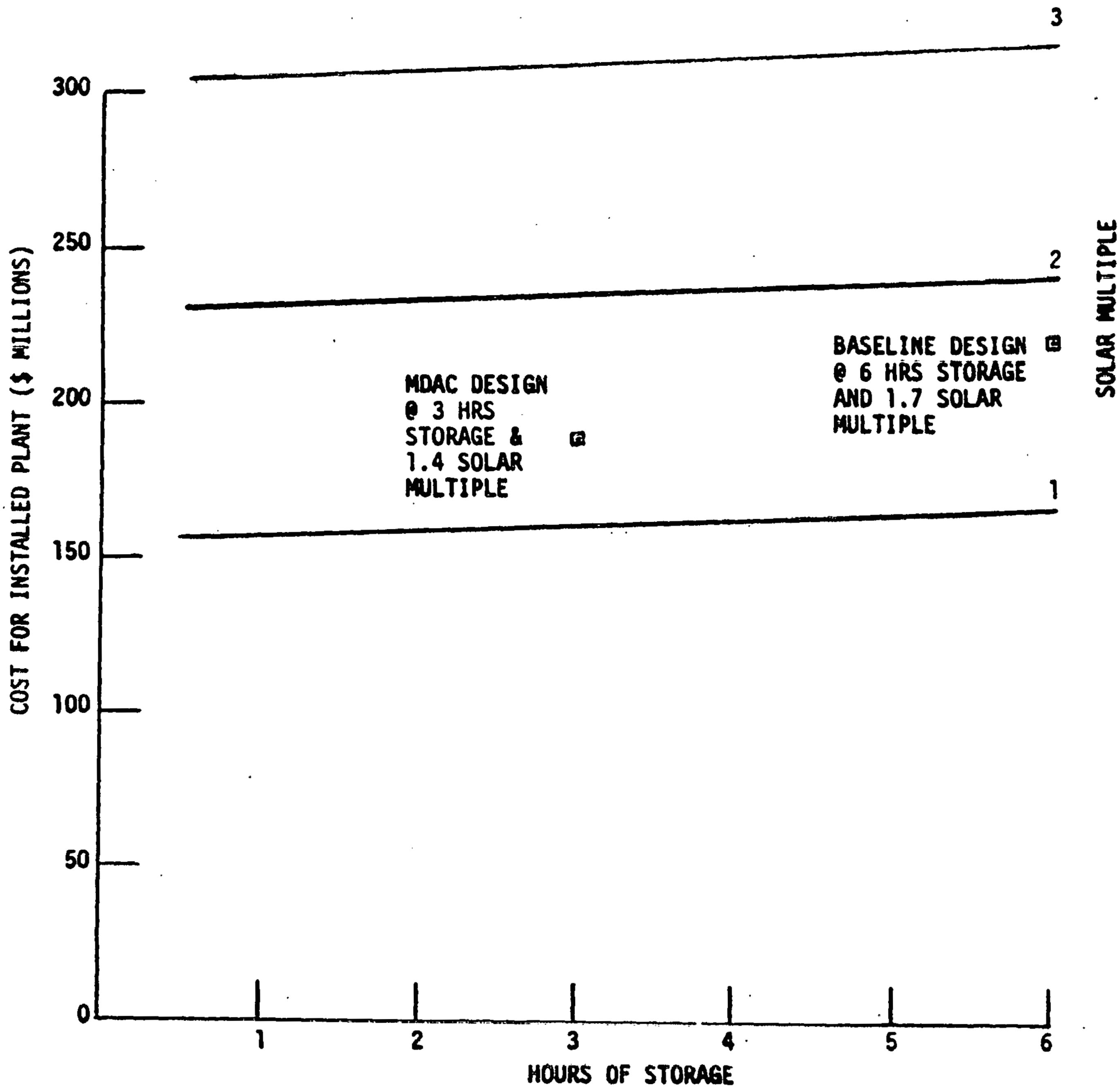


Figure 5-2. Parametric First Commercial Plant Costs

receiver, tower, and thermal storage, were varied as a function of their primary design characteristics with the balance of indirects assumed to vary in proportion to the subtotal of all other plant costs. Collector costs were estimated as a function of number of heliostats on a cost reduction curve receiver costs as a function of surface area, tower costs as a function of tower height, and thermal storage costs as a function of equipment size and quantities of storage materials.

5.1.3 Cost Variation With Plant Installation Frequency

The results of a cursory analysis, as requested, of the impact of commercial plant installation frequencies is shown in Figure 5-3. The analysis suggests that a $1,400 per kilowatt investment cost is possible under the right set of circumstances. These circumstances presume that the most probable way the higher installation frequencies will occur is where the same utilities and/or general localities always have a number of installations constantly in progress at the same time. This could lead to balance of plant (BOP) installation commonality, provide incentive to major BOP equipment suppliers to reduce prices, allow general contractors to develop cost saving installation capital, and lead to significant reduction in solar equipment costs over first commercial.

Costs were generated by extending first commercial cost to two additional data points — one for two plants per year and one for eight plants per year. Two plants per year is a good early base point because it appears to be about the point where installation rates may start to become significant to receiver and BOP costs, although the frequency of installation still may not be great enough to have an impact on BOP costs. On the other hand, eight plants per year allow assumption of a considerable amount of vertical integration for collectors, and the volume is probably great enough to greatly encourage special techniques/equipment leading to site effort cost reductions for BOP as well as receiver, tower, and thermal storage. Also, special construction management techniques might be developed to reduce construction time and the costs of management and startup.

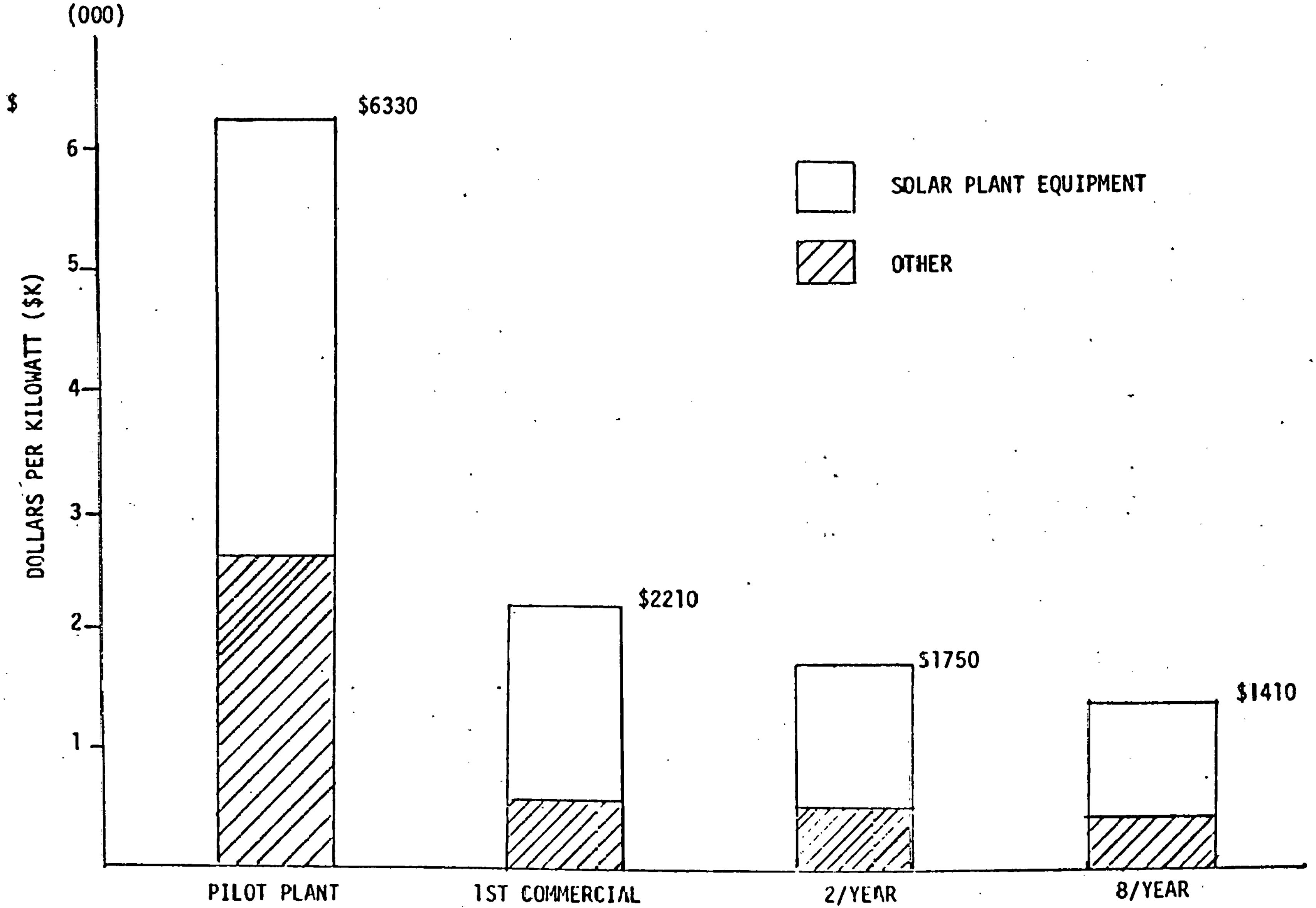


Figure 5-3. Commercial Plant Cost Reduction Potential

Based on these justifications, Nth plant collector and receiver cost backup has been examined for areas of potential reduction due to hardware simplification, vertical integration impacts, or production and installation improvements. Receiver, tower and thermal storage equipment costs also were taken further down a cost reduction curve, as were BOP costs, to the unit cost of the 20th and 80th plants which represents the midpoints of 20-year production for 2 and 8 plants per year. A shallow 95% cost reduction curve has been applied to BOP and thermal storage, while the receiver and collectors were extended on a 90% slope. Slopes were applied assuming the baseline costs reflect prior equivalent production/learning, as appropriate. Indirect costs were cut 69% for 8 plants per year and 35% for 2 plant per year.

5.2 LAND, LAND RIGHTS, AND YARDWORK (4000 AND 4100)

This element includes items such as land purchase and land rights, clearing and rough grading cost, and land improvements and preparation (e.g., survey and grading drainage). Not included in this element are the costs for preparing the site for subsystem elements, which are generically allocated (e.g., earthwork for collector foundations), surveys and other engineering work, procurement effort, and construction direction are included under the effort in Indirect (8100). Maintenance costs are included under System Operations (1000). The costs are to provide for all materials and equipment included within this CBS element as well as the locally subcontracted effort necessary to transport, fabricate, assemble, install and checkout materials and equipment at the first commercial plant site.

5.2.1 Land and Yardwork Costs

The total costs estimated by Stearns-Roger are as follows:

	Recurring (million)		
Title	Material	Labor	Total
Land and Land Rights	$0.00	$0.00	$0.00
Yardwork	1.50	0.03	1.53
Total (4000 and 4100)	$1.50	$0.03	$1.53

Land cost is not indicated because it is assumed, as directed, that land would be furnished by the potential user at no charge to the program. A list of the elements included under land improvements and preparation, as well as technical characteristics and preparation, is provided in Table 5-2.

5.2.2 Funding

Figure 5-4 shows the schedule and funding. This element starts 58 months prior to IOC and is completed within 13 months. Essentially, all funding occurs in 1987 and 1988 with the peak in the first half of 1988.

5.2.3 Costing Methodology

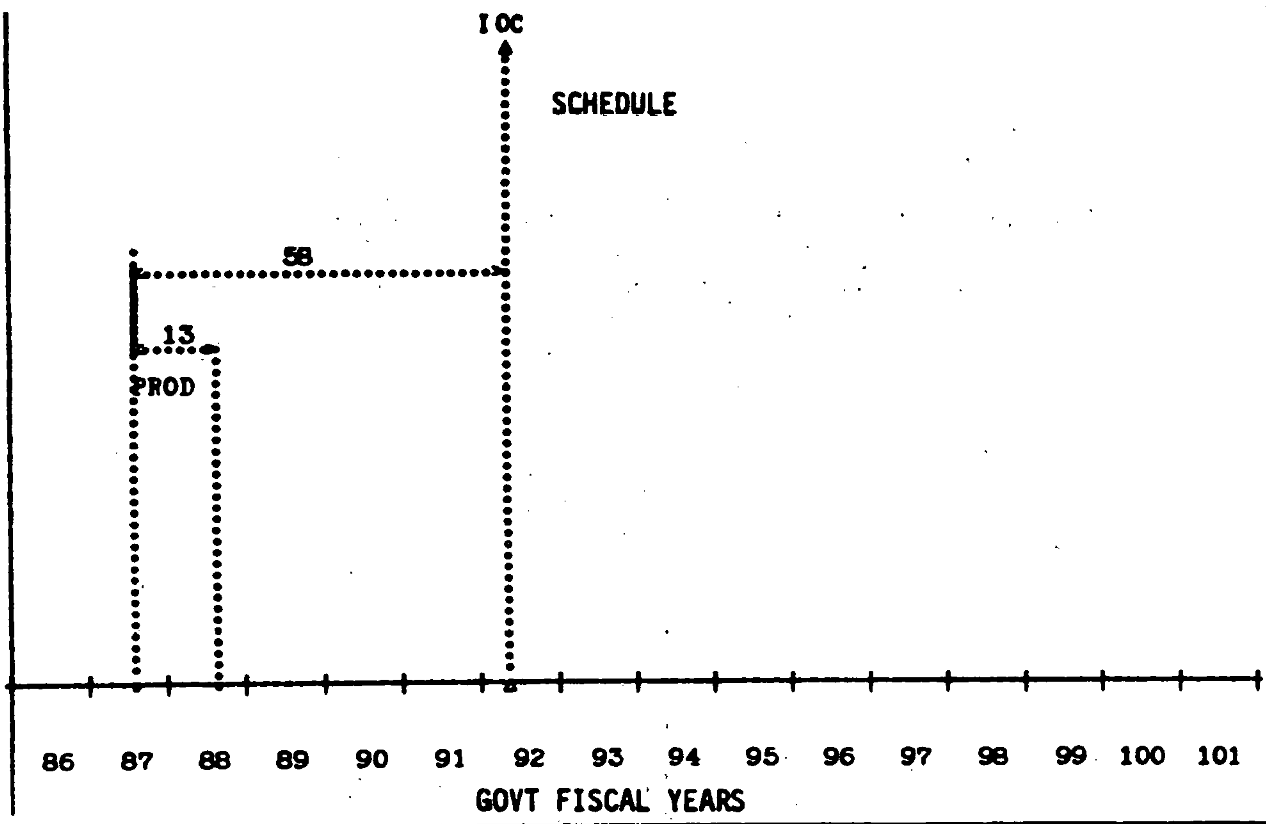
Costing is based on Stearns-Roger experience with "yardwork" for power plants of this size and utilizes current industrial equipment, material and labor costs reflecting the Barstow area plant. The basis for the costs estimate is a somewhat expanded equipment and technical characteristics list similar to Table 5-2, which in essence defines the scope of work. Materials and equipment items are priced and fabrication and installation estimated from the scope.

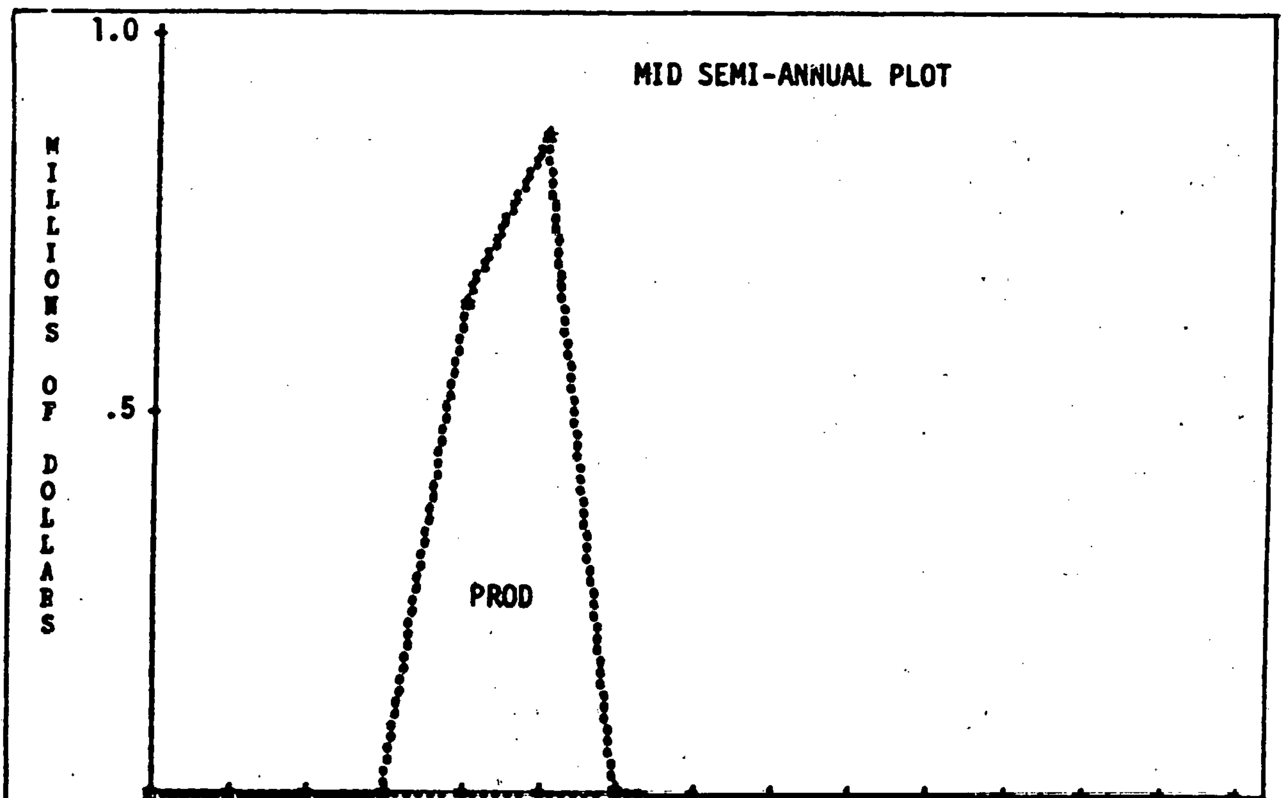
5.3 BUILDINGS (4103 THROUGH 4180)

This element includes all structures and facilities required at the first commercial plant site including turbine generator buildings, maintenance, administration buildings, and any other permanent structures and facilities associated with providing power. Not included in this element are surveys, design and other engineering work; procurement effort and construction direction which are normally included under the effort within Indirect (8100). The costs are to provide for site preparation and for all materials and equipment as well as for the subcontracted effort necessary to transport, fabricate, assemble, install and checkout materials and equipment at the commercial plant site.

Table 5-2. Technical Description Land Preparation

Land Improvement and Preparation
1450 fenced acres
Rough grade and clear
Land drainage — 37,000 linear ft ditching, 35 to 24 in culverts
Sanitary sewer drainage piping — 3,500 linear ft 24 in concrete pipe, 1150 linear ft 10 in cast iron pipe
Water supply line — 4,500 linear ft 12 in sched 40 pipes (cost under 4500.229)
Sidewalks and curbs — 1,750 linear fit cement walkways
Surface parking areas — 1,100 sq yd — 6 in base/2 in bituminous cover
Fencing — 35,000 linear ft
Landscaping
Fire protection — 1,000 linear ft 8 in pipe
Seven hydrants and valves and fittings
Yard lighting — 150 road fixtures — 270 yard fixtures
Roads — 47,800 sq yd — 12 in base with 2 in bituminous cover





GFY	1986	1986	1987	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992	1992
DDT•E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	0.0	0.0	.7	.9	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	.7	.9	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 5-4. Land, Rights, and Yardwork Summary Chart

5.3.1 Building Costs

Stearns-Roger has estimated structures costs as shown below:

Title	Recurring (million) Material	Labor	Total
Turbine bldg	$1.30	$0.86	$2.16
Admin bldg	0.66	0.44	1.10
Cir and ser water ph	0.00	0.00	0.01
Warehouse	0.52	0.35	0.86
Maintenance bldg	0.00	0.00	0.00
Water treat equip bldg	0.19	0.13	0.32
Sewage treat bldg	0.00	0.00	0.00
Thermal storage	0.32	0.00	0.32
Control bldg	0.00	0.00	0.00
Aux gen bldg	0.04	0.00	0.04
Total	$3.03	$1.78	$4.81

There is no sewage treatment building and the control building is actually part of the administration building. A more detailed description of these facilities is given in Table 5-3, including the square footage for each facility.

5.3.2 Buildings Funding

Funding and schedule for all buildings is indicated in Figure 5-5. Construction starts 39 months prior to IOC and must be completed within a 17-month period. The funding peaks at $2.3 million in the last half of 1989. Detail funding by building is provided in Table 5-4.

5.3.3 Costing Methodology

Costing is based on Stearns-Roger experience with structures for power plants of this size and utilizes current industry experience concerning dollars per square foot applicable in the desert southwest for each of various types of buildings required. Building costs are developed from the list of buildings, which indicates type and square footage. Other major construction accounts (i.e., earthwork, concrete, and painting) are estimated and prorated to the buildings based on many previous power plant cost relationships for units of this size.

Table 5-3. Technical Description Buildings

Administration/Technical Building

60 x 90 x 22 ft metal siding, two stories, insulated heated and air conditioned. Two stories – 10,800 sq ft

Turbine-Generator Building

85 x 150 x 80 ft metal siding, two main stories, insulated, heated and air-cooled (evaporative coolers). Control room and computer room air conditioned. Two stores – 25,500 sq ft

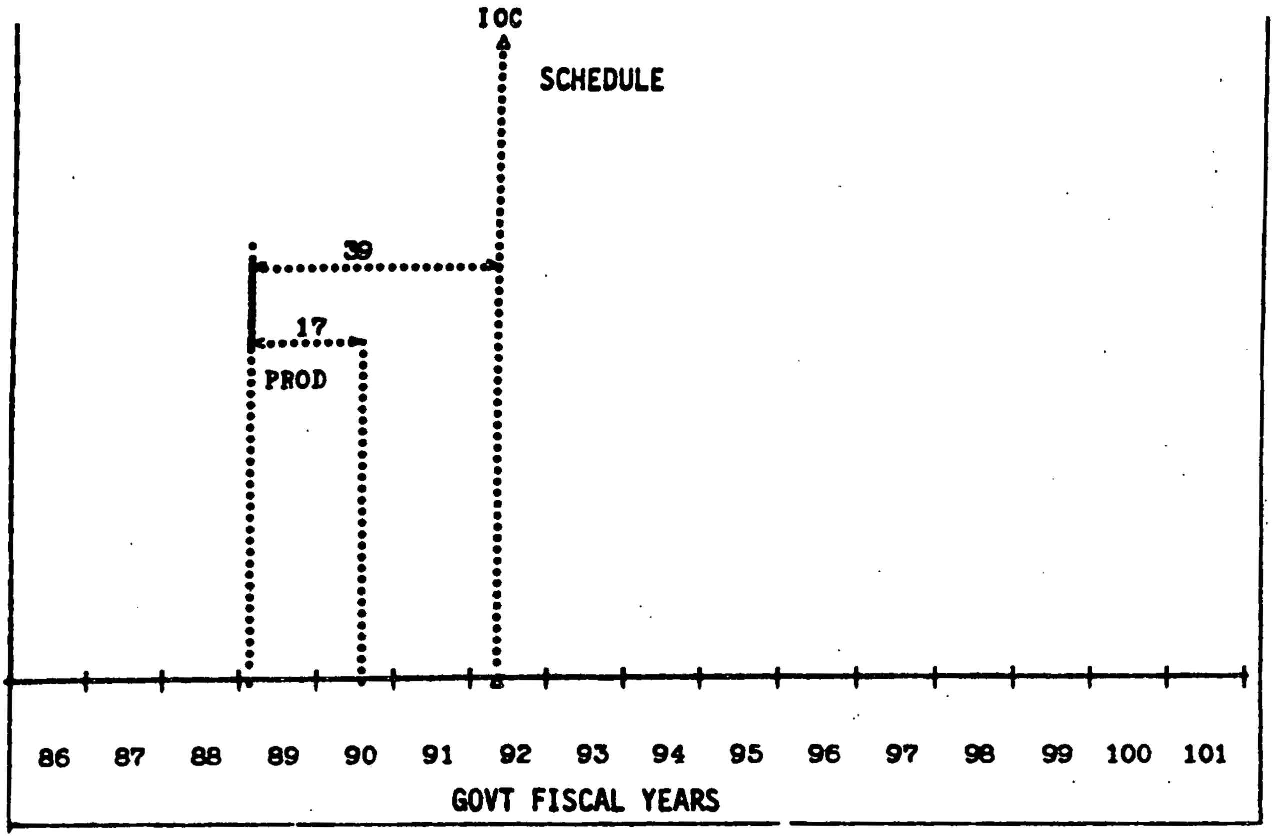
Maintenance/Assembly/Warehouse Building

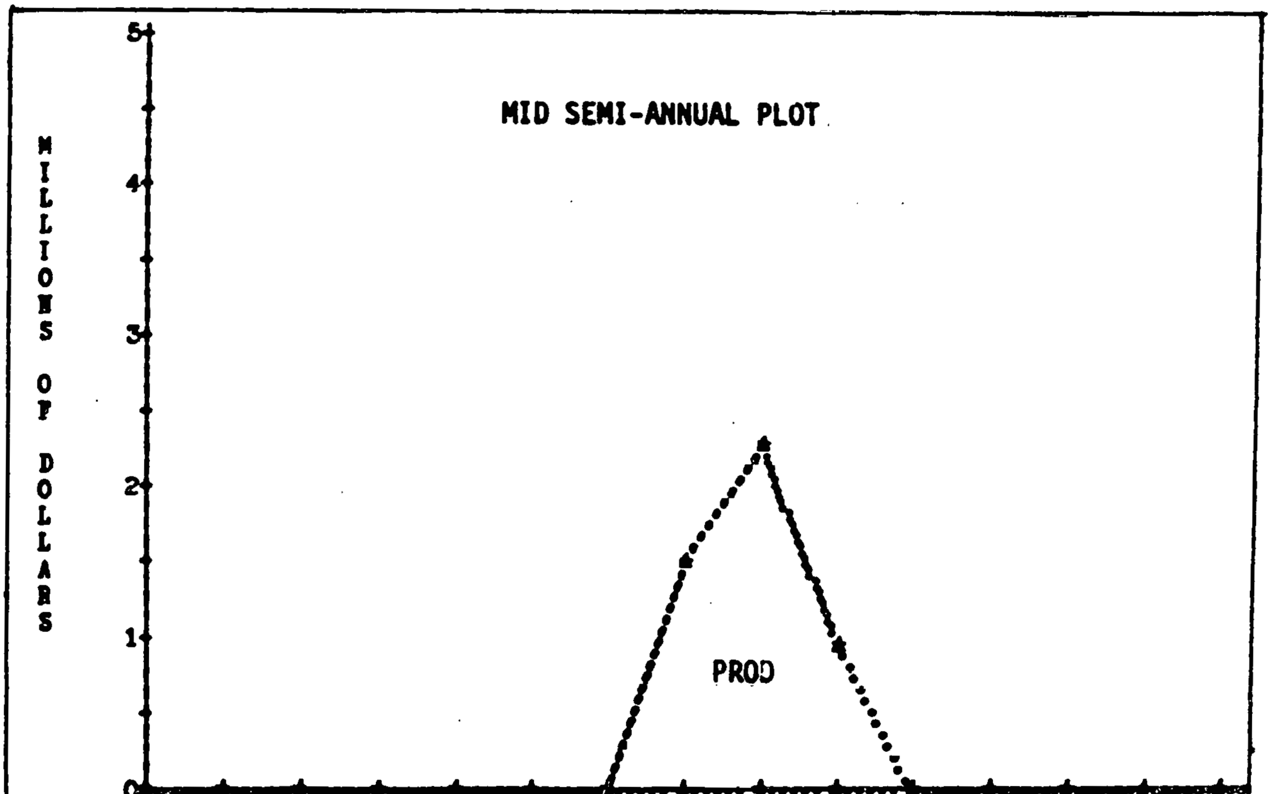
90 x 150 x 20 ft metal siding, single story, high bay assembly area, insulated, heated and air-cooled (evaporative coolers). One store – 13,500 sq ft

Other Facilities and Site Improvements

This CBS item includes the following structures:

1. Diesel-generator building 30 x 45 ft. One story – 1,350 sq ft
2. Water treatment building 50 x 60 x 25 ft. One story – 3,000 sq ft
3. Clarifier clearwell enclosure 30 x 70 x 8 ft. One story – 2,100 sq ft
4. Thermal storage shed 23 x 43 ft. One story – 989 sq ft





GFY	1986	1986	1987	1987	1988	1988	1989	1939	1990	1990	1991	1991	1992	1992
DDT•E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.3	1.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.3	1.0	0.0	0.0	0.0	0.0	0.0

Figure 5-5. Buildings Summary Chart

Table 5-4. Detail Funding by Building ($ Millions)

Title	1988	1989	1989	1990	1990	1991
Turbine building	0.00	0.92	1.24	0.00	0.00	0.00
Admin building	0.00	0.59	0.51	0.00	0.00	0.00
Cir ser water pump house	0.00	0.00	0.01	0.00	0.00	0.00
Warehouse	0.00	0.00	0.25	0.62	0.00	0.00
Maintenance building	0.00	0.00	0.00	0.00	0.00	0.00
Water treat eq building	0.00	0.02	0.30	0.00	0.00	0.00
Sewage treatment building	0.00	0.00	0.00	0.00	0.00	0.00
Thermal storage shed	0.00	0.00	0.00	0.32	0.00	0.00
Control building	0.00	0.00	0.00	0.00	0.00	0.00
Aux gen building	0.00	0.00	0.00	0.04	0.00	0.00
Grand Total	0.00	1.53	2.31	0.98	0.00	0.00

5.4 COLLECTOR EQUIPMENT (4190.1)

This element includes all items related to the central receiver heliostats and controllers and includes reflective surfaces, backing and support structures, foundations and site preparations, drive units, protective enclosures, packing containers, and lightning protection. Also included are field controllers, heliostat controllers, control sensors and all heliostat field communications and power wiring. Costs are to provide for the labor and material required to fabricate, deliver, assemble, field preparation, including foundation excavations, and wire trenching, install, align, calibrate, and checkout 23,414 heliostats, 976 field processors/controllers, and 22,448 heliostat controllers.

5.4.1 Scope of Work Detail

Additional detail on the scope of work is included below:

Production Support

1. Provide liaison planning support to manufacturing.
2. Accomplish repreat release of fabrication and assembly planning paper.

Industrial Engineering

1. Provide sustaining analyses of details, subassemblies, and assemblies to establish equipment loads, need dates and alternate production methods.

Tooling

1. Provide tool liaison support to manufacturing.
2. Assure continued production to specification tooling conformance.

Manufacturing

1. Fabricate and subassemble components of the heliostat in accordance with planning paper and schedules.
2. Fabricate and assemble the field processors and heliostat controllers in accordance with planning paper and schedules.
3. Provide direct supervision over contract hires at the installation site.

Quality Assurance

1. Perform necessary inspection and test to assure hardware conformance.
2. Provide inspection coverage at the installation site to assure conformance to drawings and specifications.
3. Perform necessary inspection/calibration of special "out-of-spec" monitoring equipment.

MSK (Contract Hires)

1. Perform assembly of the heliostats, heliostat installation, heliostat array controller installation, focusing, alignment, and system checkout in accordance with MDAC supervision direction.
2. Perform excavation, trenching, and other site preparation in accordance with MDAC supervision direction.

Logistics Support

1. Provide sustaining Site Activation Material Availability Control (SAMAC) effort to support installation and checkout activities.
2. Provide sustaining engineering to resolve support problems.
3. Provide management of the on-site system installation activities, to include site activation planning and coordination with the customer.

Facilities

1. Update, as necessary, facility criteria drawings, calculations, and specifications to reflect production requirements.
2. Develop cost estimates and finalize facilities packages for site plant moves.
3. Direct site plant construction projects and any modifications and rearrangements to existing plant areas for cost reduction purposes.
4. Procure and ensure timely delivery of identified support equipment required at the installation site.

5.4.2 Collector Equipment Costs

McDonnell Douglas Astronautics Company with assistance from Stearns-Roger and A. D. Little has estimated costs as follows:

	First Commercial			
Title	Material	Labor	Total	Nth Plant
Reflective unit	$28.47	$4.49	$32.96	$19.44
Drive unit	41.01	3.73	44.74	30.17
Sensor/cal equip	0.10	0.00	0.10	0.10
Control/inst equip	4.69	0.34	5.03	3.93
Foundation and site prep	7.73	0.00	7.73	7.73
Design eng tst and plan	0.00	1.74	1.74	1.74
Pack cont and trans	0.24	0.52	0.77	0.76
Field assy inst and c/o	0.93	13.64	14.56	14.07
Lightning protection	0.00	0.00	0.00	0.00
Total (4190.1)	$83.16	$24.46	$107.62	$77.94

The costs shown are for an open-loop control system. The Nth plant represents a production rate of 60,000 heliostats per year installed at a rate of approximately 15,600 heliostats per year. Although the factory rate is almost nine times and the installation rate two times that for the first commercial plant, the full cost reduction potential is probably significantly greater than that represented, for reasons to be discussed later. Additional cost detail is provided in Table 5-5, and Table 5-6 provides a brief technical description.

5.4.3 First Commercial Collector Equipment Funding

Representative first commercial plant collector funding and schedule are shown in Figure 5-6. Procurement and production effort starts 56 months prior to IOC and runs to 6 months prior to IOC. Checkout starts 18 months prior to IOC and runs 12 months so that there is some overlap with on-site assembly and installation. As spent funding peaks at $32 million in the last half of 1988, it remains at basically that level in the first half of 1989 and then tapers off in the last half. Peak requirements occur somewhat over 2 years after procurement starts.

5.4.4 Cost Methodology

Costing is based on McDonnell Douglas Astronautics Company experience concerning the design, manufacture, and testing of structural-mechanical,

Table 5-5. Collector Cost Detail (Page 1 of 2)

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R	TOTAL NTH
4190.111	REFLECTIVE SURFAC	0.00	10.52 I,V	3.01 I	13.53 I	13.53	9.36
4190.112	MIRROR BACKING ST	0.00	11.45 I,V	.57 I	12.02	12.02	7.11
4190.113	HELIOSTAT SUPP	0.00	6.51 I,V	.91 I	7.42	7.42	2.99
4190.114	PROTECTIVE ENCL.	0.00	.00	0.00	.00	.00	.01
4190.11	SUBTOTAL	0.00	28.47	4.49	32.96	32.96	1[illegible].4[illegible]
4190.121	AZIMUTH MIRROR DR	0.00	13.47 I,V	1.58 I	15.05	15.05	7.72
4190.122	ELEVATION DR.	0.00	12.60 I,V	1.62 I	14.22	14.22	8.08
4190.123	MOTOR	0.00	7.26 I,V	.03 I	7.29	7.29	6.83
4190.124	POSITION LIMIT IN	0.00	4.21 I,V	.39 I	4.60	4.60	4.21
4190.125	EMER.PWR.SUP.	0.00	.00 V	0.00	.00	.00	.01
4190.126	POWER DISTR.EQ.	0.00	3.47 V,M	.11 I	3.58	3.58	3.37
4190.12	SUBTOTAL	0.00	41.01	3.73	44.74	44.74	30.17
4190.131	SENSOR UNIT	0.00	.00	.00	.00	.00	.01
4190.132	SENSOR TOWER	0.00	.00	.00	.00	.00	.01
4190.133	CALIBRATION EQ.	0.00	.10 I	0.00	.10	.10	.11
4190.134	WIRING BTWN HE-SB	0.00	.00	.00	.00	.00	.01
4190.13	SUBTOTAL	0.00	.10	.00	.10	.10	.11
4190.141	HELIOST CONTROLLE	0.00	1.73 I,C,V	.23 I	1.96	1.96	1.56
4190.142	FIELD CTR/ELEC	0.00	.70 I,C,V	.05 I	.74	.74	.16
4190.143	SIGNAL DIST.EQ.+M	0.00	2.26 I,V	.07 I	2.33	2.33	2.26
4190.14	SUBTOTAL	0.00	4.69	.34	5.03	5.03	3.98

Table 5-5. Collector Cost Detail (Page 2 of 2)

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	RECURRING (MIL) LABOR	RECURRING (MIL) TOTAL	TOTAL NR+R	
4190,151	FNDTN (HELIO-SEN)	0,00	6,95 M(C,I)	0,00	6,95	6,95	6,96
4190,152	SITE PREPARATION	0,00	,77 M	0,00	,77	,77	,77
4190,15	SUBTOTAL	0,00	7,73	0,00	7,73	7,73	7,73
4190,161	DESIGN COST	,00	0,00	0,00	0,00	,00	,00
4190,162	SUST,ENGR,SUPPORT	0,00	0,00	,00	,00	,00	,00
4190,164	SITE PLANT ACTIV	0,00	0,00	1,74 I	1,74	1,74	1,78 I
4190,16	SUBTOTAL	,00	0,00	1,74	1,74	1,74	1,78
4190,181	HELIOSTAT-CTR EQ,	0,00	,92 V,I	12,28 I,M	13,20	13,20	12,82 I,M
4190,182	SENSOR/CAL, EQ,	0,00	,00	1,36 I	1,36	1,36	1,25 I
4190,18	SUBTOTAL	0,00	,92	13,64	14,56	14,56	14,07

Table 5-6. Technical Description Collector Subsystem (Page 1 of 2)

Reflector — 6 sandwiched panels composed of float glass, polystyrene and sheet steel, then connected to the mirror backing structure	
Reflective surfaces	1,187.5 lbs
• Reflective surface area	400 ft^2
• Second surface mirror	0.125 in
• Polystyrene rigid foam core	2 in
• Galvanized sheet steel (26 gage)	0.020 in
Mirror backing structure	1,108.3 lb
• Cross beams — 11-gage channels	215.50 in — 14 in deep
• Torque tube	206.25 in — 10.75 in dia
• Drive attachment fitting	Low carbon steel
Heliostat support structure	508.5 lb
• Pedestal	108 in — 20 in dia
Drive — Consists of an orbidrive elevation and azimuth/axis	
Azimuth/elevation drive actuators	
• Drive ratio	
• Input drive	45:1
• Output drive	961:1
• Final drive ratio	43,245:1
Actuator motor	42 frame, 230 VAC, 3-phase, 4 pole, 60 Hz
• Power	
• Horsepower rating	18.6 (1/4)
Power distribution equipment and wiring	240 V 60 Hz

Table 5-6. Technical Description Collector Subsystem (Page 2 of 2)

Position indicators

- A sensor (encoder) on the drive output - 4 bit
- Incremental encoder on drive input (motor) - 1 bit

Control/instrumentation equipment

Heliostat controller

- Digital microprocessor
- Drive motor controller
- Communication interface

Field controller

- 1 per 24 heliostats
- High speed digital microprocessor
- Master control interface
- Heliostat control interface
- Command calculation and formatting

Signal distribution equipment and wiring

- Digital data bus
- Interface master/field/heliostat controllers

Foundation

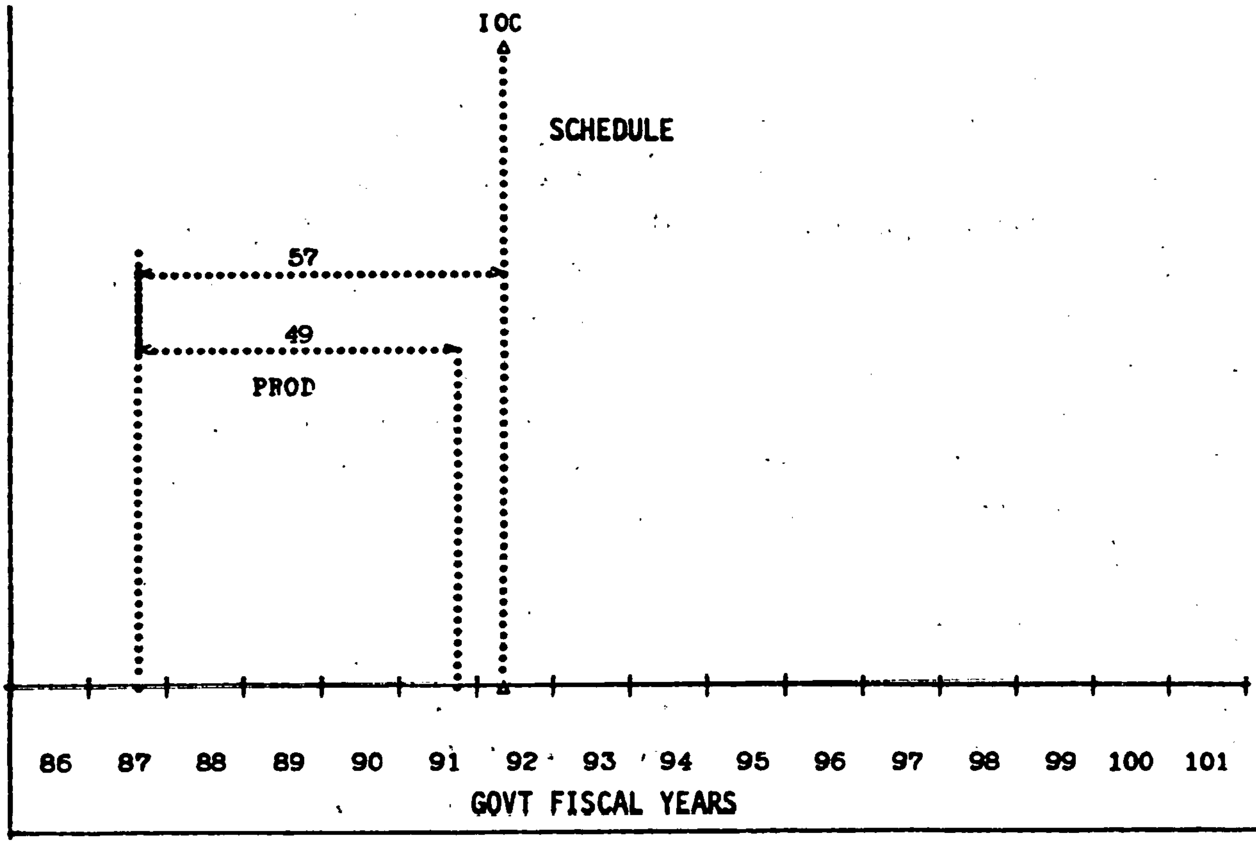
Reinforced precast concrete — 2.4 cu yd

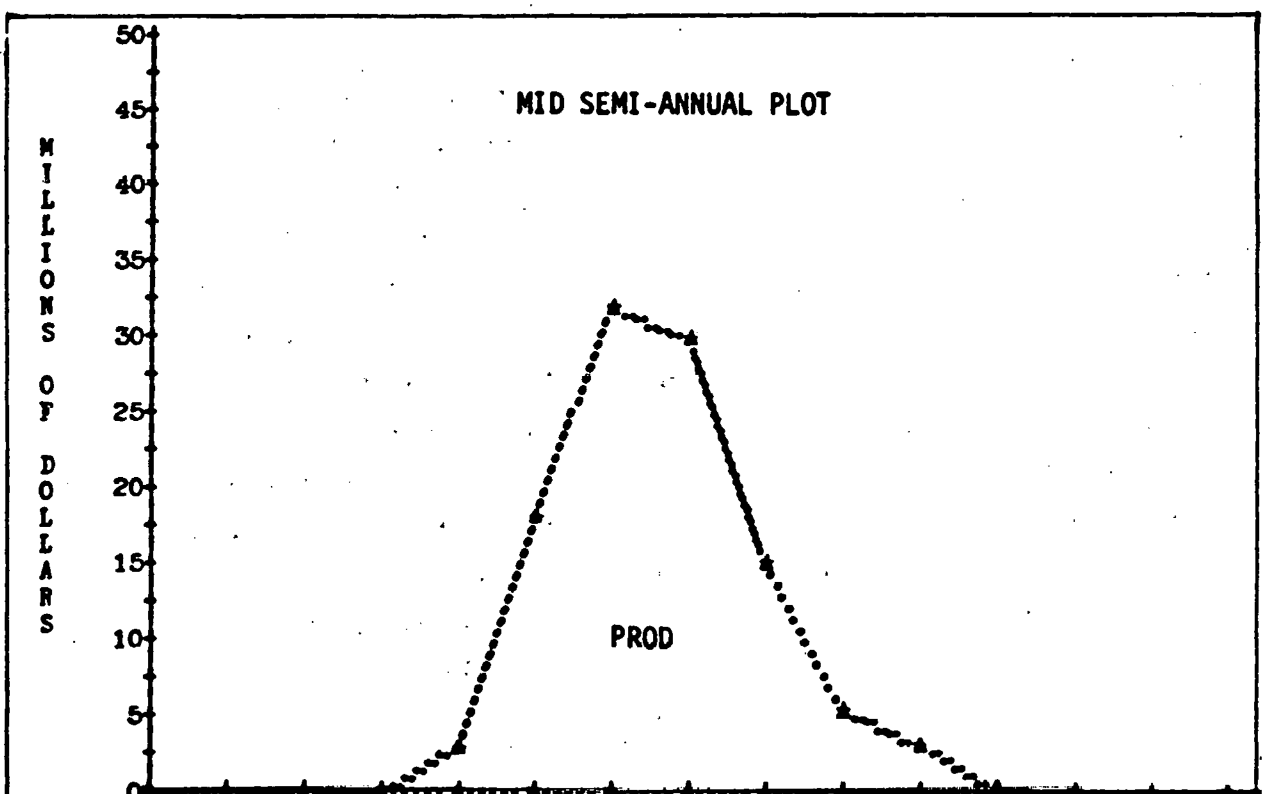
Weight — 9,750.0 lb

Packing containers

Mirror panels — 12 per container = 160 reusable required

Drive unit — 1 per pallet — 1000 reusable required





GFY	1986	1986	1987	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992	1992
DDT•E	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	0•0	0•0	0•0	3•1	18•2	32•0	30•0	15•3	5•4	3•2	•4	•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	0•0	0•0	0•0	3•1	18•2	32•0	30•0	15•3	5•4	3•2	•4	•0	0•0	0•0

Figure 5-6. Collector Equipment Summary Chart

electrical-mechanical, and electronic equipment, Stearns-Roger experience on trenching, concrete work and installation, and A. D. Little experience in designing high-rate production facilities. Estimators used 1977 industrial equipment, material, and labor costs reflecting appropriate fabrication, assembly and installation locations. Essentially, the scope of work (Subsection 5.4.1), the programmatic concepts indicated in Section 3 and the available pilot plant drawings were used to size and refine the labor hours and material dollar estimates and appropriate labor rates were applied. Specific methodology is described below.

5.4.4.1 Procedure. First commercial manufacturing costs are based on first cost estimates while Nth plant estimates have been determined from the resource requirements called out in a heliostat baseline production facility designed by the A. D. Little Company. Installation cost methodology and labor rates are the same for both first and Nth plants, and unlike pilot, no visibility or scrap factors have been applied.

5.4.4.1.1 First Commercial. First commercial manufacturing costs have been developed from a detailed estimate of first unit labor hours and material dollars taken from engineering drawings and schematics by experienced manufacturing estimators. The estimators worked with MDAC manufacturing and industrial engineers to interpret drawing implications, and applied industry-wide fabrication and assembly unit 100 labor standards and vendor quotes for average material costs for 1,760 units in arriving at a basic estimate. Results were raised to first unit costs and then brought back down an 87% cost reduction curve (CRC) for labor and a 95% curve for materials. The CRC has been employed in a manner that projects the average unit cost of the 23,414 units produced between unit number 1,760 and unit number 25,174 which presumes a cost reduction hiatus during the Demonstration Plant(s) phase of the program. The CRC procedure has a basic effect of discounting pilot plant materials costs by 21%.

The standards hour base must be adjusted to provide for all the extra involvement required to produce hardware. Additional hours have been added to the standards base to account for special processes (passivating, painting, etc.), inefficiency, lead supervision, rework, liaison, and personnel fatigue and delay. Also, other direct costs for manufacturing support, including quality assurance, tooling subsistence, sustaining planning, industrial engineering, cost control and "free" stock (nuts and bolts) have been considered. Costs for these elements are applied using standard pricing factors developed from MDAC experience.

5.4.4.1.2 Nth Commercial. The Nth commercial manufacturing costs have been developed from resource loads identified with the baseline production facilities designed for the purpose of fabricating and assembling the MDAC heliostat. Operator and support positions required for each item of production equipment or responsibility within the production facilities were identified, counted, and classified by skill in order to accumulate staffing by CBS as well as overall staffing. These results were factored to account for personnel fatigue and delay free stock and tooling subsistence. Also, since equipment requirements necessary to meet the production rate have been factored to allow for downtime, the number of positions staffed have been increased and in effect manning and total annual hours worked are tied directly to equipment operation time and plant output. Thus, average labor hours per CBS item are simply the result of dividing annual manhours worked by the annual output. All staffing that could not be directly identified with a hardware item and is not included in the burden factor has been allocated over all CBS elements.

Material costs have been derived in a manner similar to that employed for the first commercial plant except that the cost of the 25, 174th unit has been used as the average material cost per unit for the Nth plant. This results in about a 26% basing discount on the average pilot plant cost for materials. However, a considerable amount of materials that came in as processed parts on pilot are fabricated in-house on Nth and are costed at raw material prices since the labor is already covered.

5.4.4.1.3 Transportation and Field Installations. Transportation, foundation excavations, wire trenching, foundations, and heliostat processor and controller installation and checkout are all based on the resource loading technique. Using a breakdown and analysis of the SRE experience, the necessary activities, equipment, crews and timelines have been established. The timelines implicitly allow for basic field efficiencies since they are based on actual experience. However, an additional factor covering personnel fatigue and delay has been added.

This process was accomplished directly for first commercial, but for the Nth plant, the resource loads developed for pilot plant installation were unitized and carried down a 97% CRC to the hours of unit number 25,174. This was treated as the average cost of Nth plant installation. Since the same methods were loaded for both pilot plant and first commercial, this procedure is intended to portray at least a minimum in methods improvement by the time the Nth plant is installed.

These results have been overlayed by level-of-effort manloads covering field supervision, logistics, and the technical support associated with for electronics installation, calibration and checkout. The manloads were developed for pilot plant by the discipline involved and related to first and Nth commercial using a 97% CRC applied in the same manner as for in-plant production.

Transportation for both first and Nth is based on the A. D. Little effort. They estimated the number of drivers and handlers based on an analysis of average daily hardware quantities, truck capacities, and travel distances and holding time. Also, packaging and handling equipment characteristics were considered. The same hours were used for both first and Nth plants.

The analysis of foundation costs have been performed by Stearns-Roger after examining 36 alternative foundations and methods of installation. They base foundation materials on current quotes for concrete and rebar, assuming a local batch plant. The indicated installed cost relies on a special item of equipment designed by Stearns-Roger that places the preformed foundation.

The site plant move costs have been estimated by MDAC Facilities Engineering. Hours and material for moving the site plant are directly estimated from floor space, amount and type of equipment, and typical disassembly, moving, and reinstallation requirements. Design, surveillance, and site preparation involved in moving the site plant are based on factors.

5.4.4.1.4 Labor and Overhead Rates. Manufacturing labor rates are based on Bureau of Labor statistics data on average hourly earnings of production workers in five representative United States cities as well as actual rates paid by MDAC and other manufacturers at volume production facilities in other cities. A rate presentative of lower cost western city rates has been selected.

Manufacturing burden, fringe and G and A rates have been projected at those experienced at MDAC's TICO facility in Florida. This plant employs a work force in numbers approximating the requirement range of the Nth and first commercial production facilities. The plant is dedicated to the output of a single product line worth approximately $2,000 per unit produced at a rate of from 36,000 to 60,000 units per year. The plant also produces special electronics support equipment in lesser numbers.

The MDAC cadre at the installation site is costed at current Huntington Beach remote site rates. Contract labor rates are based on a current Stearns-Roger survey of Barstow area journeyman trade contracts covering base rates, fringes, employment taxes, funds, foreman differential, and subsistence. These rates have been weighted by skills requirements and factored by typical generial contractor overhead rates.

5.4.4.2 Source of Estimates. The source of estimates have been basically addressed in the preceding discussions. Except for free stock (nuts and bolts), concrete and rebar, all material prices are based on supplier quotes for 1,760 units. Free stock is based on a historical factor while concrete and rebar are based on nondiscounted vendor quotes. Quotes for certain high cost items were obtained from the following suppliers:

Item	Supplier
Foam	Dow
Mirrors	Binswanger, Buchmin
Steel	U. S. Steel, Republic Steel, Tubesales, Kaiser
Castings	Lincoln, Dayton, Golden State, Steel Casting
Drives	Grow Geur, Compudrive Corporation
Concrete	Local Batch
Wire	Okonite, Square "D"
Bearings	Marlin Rockwell (TRW), Kaydon, Timken

In addition, continual discussions have been held with many of these suppliers along with others such as the Ford Glass Division, LOF Glass, PPG Glass, Guardian Glass, Sheldahl and Kaiser Steel concerning volume production costs.

All labor estimates are based on judgments and standards applied by experienced estimators in various areas of expertise. Separate estimators were employed in deriving sheet metal fabrication, machining and mechanical assembly, electronic fabrication and assembly, factilities, logistics and field installation hours. Stearns-Roger estimators were employed to estimate foundation and trenching costs, while A. D. Little employed an experienced manufacturing and industrial engineering team to determine Nth plant moving requirements.

5.4.4.3 Driving Assumptions and Scenarios. Several major issues are of special important to the costing results that have been presented. They involve the specific configuration of system and collector subsystem hardware, the market for collectors, and the projected production and installation scenarios. Of course, all of these issues are highly interrelated, and at times, it is difficult to distinguish between cause and effect.

5.4.4.3.1 Hardware. The collector hardware for the commercial plant is assumed identical in design as that projected for the pilot plant, except that an open-loop control system has been costed and the number of processor integrated circuits are presumed cut from over 100 on pilot plant to less than 20 on the commercial. Although, in accordance with costing groundrules, it is unlikely that further potential cost savings hardware changes, such as noninverting heliostats, first surface mirrors, and others would not be considered during the evolution from pilot plant through demonstration plants and on into commercial applications.

The impact of the open-loop system is that it requires no sun sensor, sensor poles, wiring and foundations, and no tracking mirror and associated support structure are needed. This system does require 500 more heliostats and proportional electronics than would be required for a closed-loop system. However, the same position sensor is adequate for either closed-loop or open-loop systems. The Orbidrive is also assumed adequate. The net impact of the open loop, as costed, is a somewhat lower commercial plant investment cost per square meter. The cut in integrated circuits reduces assembly costs with only a small increase in average cost per integrated circuit.

One other important impact is that of the six hour thermal storage capability. This capability requires a solar multiple of 1.7 versus a multiple of 1.4 with only 3 hours of storage baselined. For first commercial, the extra 0.3 in solar multiple adds approximately 3,800 more heliostats or $16 million in collector costs alone, when scaled on a 93% cost reduction curve.

5.4.4.3.2 Market. The projected market for collectors over the next 20 to 30 years has had a significant impact on costing results. The projections are based on Sandia documentation published at the start of 1977 tempered by earlier ERDA projections. The basic scenario calls for a win of a pilot plant in 1978 as well as a demonstration plant in the first part of the 1980s. First commercial starts in the latter part of 1986 following a brief hiatus in collector production. Production of the Nth plant occurs in the mid-1990s and assumes market sharing with competitors.

This scenario leads to several important cost assumptions. The first is that the win of pilot and demonstration plants will allow investment in all nonrecurring costs prior to commencement of commercial production. Any nonrecurring costs will be allowed only if more than counterbalanced by recurring cost savings. Remaining production capital is amortized within the overhead rates, so that no nonrecurring expense is shown for the first or Nth commercial plants.

The assumption of competition in the 1990s market causes Nth plant rate production to occur at a later date than could otherwise be achieved, and also implies a lower rate of production. Were it not for this market interplay, the assumed Nth plant 60,000 unit annual output rate might be surpassed by the end of 1990 and a higher Nth plant rate considered.

As projected, the 1990s market scenario greatly limits the extent of basic industry vertical integration. The rate does allow a significant degree of automation both in the processes and in the transfer of hardware which eliminates a great deal of factory labor. However, this market suggests that sales may be spread over a multistate area so that installation, general contractor or work force commonality may not be realized to any great degree from time to time or between customers or locations. This is currently a typical situation associated with power plant installations. The impact is that, as with balance of plant items, very little installation cost reduction is presumed between pilot and Nth commercial plant. Obviously, changes in the assumed market characteristics could have a substantial impact on cost projections, and it may be that MDAC's assumptions are conservative considering the future perspective of electrical energy production and demand.

5.4.4.3.3 Production and Installation. Based on hardware and market implications, a conceptual production and installation scenario has been defined (see Volume III, Book 1 of the PDR). Essentially, the costed plans call for two facilities — a main plant where all major assemblies are manufactured and a "mobile" site plant where the major assemblies are trucked by MDAC-employed drivers to be final assembled into heliostats. Although conceptual; specifics have been developed on machines, jigs, and other equipment, their footprints and implied plant size, position manning and supervision, quality control points and manning, and other resources in appropriate numbers and lines to assure the projected output requirements. Welding, bonding and other assembly operations for Nth facilities are mostly automated and are semiautomated for initial facilities. Nth facilities also feature automatic line transfer equipment.

The site plant is located adjacent to the collector field and as heliostats are completed, they are moved and mounted on foundations using a specially rigged lift truck. Special equipment is also employed to align and calibrate the heliostats. Under this concept, the site plant must be moved to each new installation. However, the high cost of transporting the large fully assembled heliostats long distances over public roads are saved, and it is desirable to do as much assembly in a factory environment as possible, also for cost savings reasons.

The main and site plant work force is relatively unskilled with only about 10 to 15% of the workers requiring prior training. No special, direct charging, analysts such as manufacturing, industrial, logistics, quality or facility engineers are employed and such services will be obtained on a consulting basis when and if necessary. Also, the nature of many of the machine/positions is such that one machinist can operate two machines and in other areas where nonconforming items are visually obvious an operator also may be responsible for "go/no-go" inspections. These policies have the effect of minimizing both the total labor force as well as the average wage rate and are possible because of the large amount of production spec tooling, numeric control, and automation.

Details of the Nth plant conceptual production scenario are particularly important because they provide a solid frame of reference for supporting the feasibility of achieving low collector costs per square meter using resource load costing methods. Correlation to pilot plant production details also provides a check on first commercial plant costing. However, as closely as the details and the costs may tie, the scenario is still only a baseline scenario which pegs costs at $90 per square meter only if the concept endures. The latter not only depends on the market and hardware configuration but also on whether or not there may be an even better way to produce, transport, and install the hardware.

Depending on the results of further studies, other scenarios may become attractive. Typically, it may be less costly to ship half section heliostats from the main production facility directly to the point of installation where an automated piece of equipment completes the installation. With this concept, a main assembly plant might be integrated with glass and mirror production were the volume is great enough. In another case, it may be economic to locate various parts of the main plant in different sections of the country. Also, production, procurement, transportation and handling, installation, or alignment and calibration methods may be improved or become more mechanized.

The potential combinations are numerous. Adding the possibility of further savings in materials, which is by far the largest cost area, due to alternatives, competition, process changes, supplier control or vertical integration, it is clear that the projected cost of the Nth heliostat field should be considered a peg point for even lower cost goals.

5.4.5 Collector Cost Reduction

The preceding discussion has provided an indication of why commercial collector costing results have turned out as they have. Further insight may be gained through a comparison with SRE and pilot plant cost data. Figure 5-7 shows collector cost per square meter for each phase of the program except the demonstration plant. The SRE costs are cleansed approximations of actual recurring costs for the inverting heliostat and do not include installation charges.

The chart shows dramatic changes in the labor versus material relationship which goes from something over 2 to 1 labor to material down to 1 to 2.6 labor to material. This change is even greater than it appears

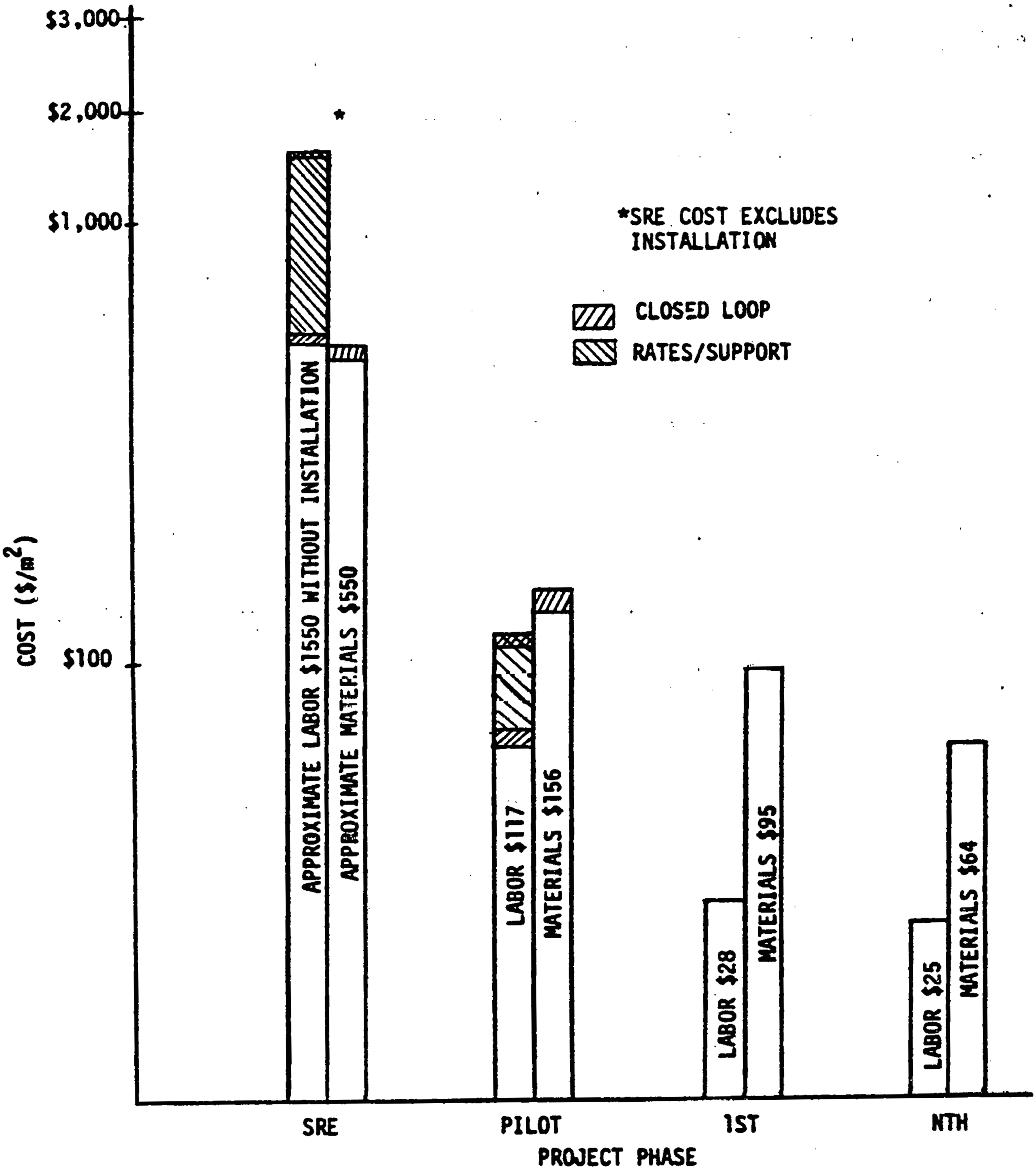


Figure 5-7. Collector Cost Reduction

because several buy items such as torque tubes and pedestals are made "in-house" for the Nth plant. The reasons for this change may be logically explained from SRE through Nth commercial.

5.4.5.1 SRE to Pilot Plant. The SRE inverted heliostat was produced in a typical prototype manner using soft tools and experiencing all the usual delays and first time production problems. The nature of prototype production, if not trial and error, is at least one of a close, informal and slow association between engineers and manufacturing personnel. Further materials may not come in on time or they may come in totally "out of spec," and setup times and vendor tools must be allocated over only a few units. Often items must be reworked causing additional setup or changes in tooling. Finally, a great deal of time may be spent in working out the specific method for actually accomplishing particular manufacturing operation.

The pilot plant estimates have been developed in typical pricing fashion with vendors submitting quotes for the entire quantity and labor based on a going operation. The latter is achieved by using standards for production of the 100th unit (some firms use unit 500) which are carried back up the cost reduction curve to a synthetic first unit cost. The synthetic is intended to be free of prototype problems, and represents what the cost would be if the initial unit were produced as designed on checked out tooling with all materials conforming and available on schedule.

The result serves as the peg point for estimating costs of producing on a going production line at the desired quantity down the cost reduction curve. As such, the synthetic first unit cost for pilot plant is only about 25% of actual SRE labor costs, and applying normal CRC techniques for 1760 units, the average pilot plant labor cost is less than 10% of SRE labor. This quantity is well within the confidence limits for applying cost reduction curves.

5.4.5.2 Pilot Plant to First Commercial. As indicated in Section 5.4.4.1, collector cost results for first commercial are the result to some extent of going to open-loop control, and mainly, of extending the pilot plant material and synthetic first unit costs down separate curves to the average cost between units 1760 and 25,174. These quantities are also well within the range of CRC confidence and the results may be supported logically.

By definition, the cost reduction curve arithmetically declines rapidly and then levels out as higher production volumes are reached. Proceeding into volume production, the curve represents the results that may be achieved with various degrees of tooling sophistication, experience, production line improvements, overhead amortization, process changes, production design improvements and other cost reduction drivers. Production facilities are designed to incorporate from the start as many cost saving features as may be imagined and economically justified by the ultimate as well as near-term volume, so that as in the case of the first commercial cost reduction does not just happen but is planned from the start causing rapid cost reduction as volume approaches planned rate production. Table 5-7 shows changes in tooling concepts between pilot and first commercial and, as indicated, tooling is well on its way to automation. Full automation will proceed as expected sales are confirmed.

5.4.5.3 First to Nth Commercial. Nth commercial costs nearly reflect the advantages of a highly automated line, as shown in Table 5-7, where capital leverage become significant and the labor force is minimized. The reduction in labor is actually more than is apparent because certain important buy items have become make items. This also lowers material costs because such items are now costed at raw material prices rather than the much higher processed cost. The overall results and causes already have been discussed and the only point that should be repeated is that the Nth plant cost represent a specific conceptual scenario that will survive only if a better one does not exist.

5.5 RECEIVER AND TOWER SYSTEM (4190.2)

This element comprises all items related to the receiver including the tower and platform, receiver unit, riser piping, downcomer piping, insulation and foundation and site preparation. Costs are to provide for the labor

Table 5-7. Production Process Changes

	Pilot Plant	First Commercial	Nth Commercial
Reflector	Mechanical press bonding	Mechanical press bonding semiautomatic	Mechanical press bonding fully automatic
Reflector Support Structure	Roll formed channel hand spot welded	Roll formed channel semiautomatic spot welded	Roll formed channel fully automatic spot welded
Drive System	N/C machining single	N/C machining	N/C machining
	Single operations	Multiple operations	Auto line transfer
Pedestal	Semiautomatic fusion welding	Automatic fusion welding	Automatic fusion welding
Electronics	Semiautomatic insertion	Semiautomatic insertion	Semiautomatic insertion
	Flow solder	Flow solder	Flow solder
			Automatic line transfer
Final Assembly	On site	On site	On site
Processes	Batch	Batch	Automatic line transfer

and material required to fabricate, deliver, assemble, install, checkout, and activate one receiver equipment set, including test hardware and preparation of all installation, maintenance and operating instructions.

5.5.1 Receiver and Tower Equipment Costs

Costs have been estimated by Rocketdyne Division of Rockwell International and Stearns-Roger, Inc. to be as follows:

	Recurring (million)		
Title	Material	Labor	Total
Receiver unit	$6.36	$11.13	$17.48
Steam generator	0.00	0.00	0.00
Rise and horiz piping	0.30	0.41	0.71
Downcomer and horiz piping	0.83	0.64	1.48
Tower and platform	1.65	4.45	6.10
Foundation and site prep	0.96	2.43	3.38
Des eng test and plan	0.00	0.00	0.00
Total (4190.2)	$10.10	$19.06	$26.16

Additional cost detail is provided in Table 5-8, and Table 5-9 provides a technical description of the costed items.

5.5.2 Receiver and Tower Equipment Schedule, Funding and Important Drivers

Receiver schedule and funding information is shown on Figure 5-8. Production starts 61 months prior to IOC; this schedule results in funding that peaks at $7.6 million in the first half of 1988.

The 61-month fabrication and construction period is based on flow time analysis of recurring tasks utilizing specifications from previous commercial design effort. At the beginning of the program a 6-month period will be utilized for a review of prior solar thermal power plant experience and modifications and incorporation of design features to update the commercial plant design. It is expected that the overall system requirements will be

Table 5-8. Receiver Cost Detail

6002 WBS NUMBERS 13.26.21. DATE: 77/05/23.

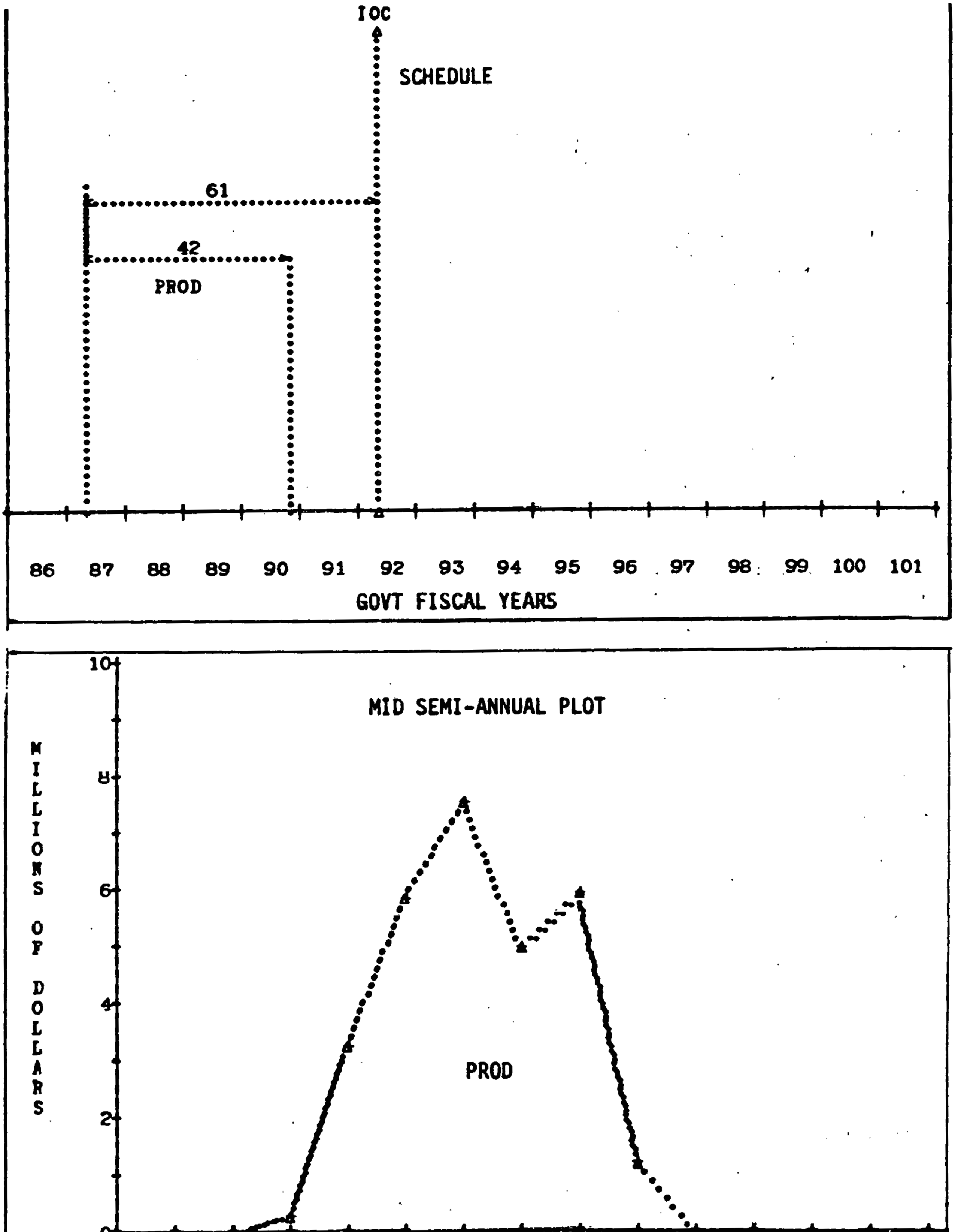
WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	RECURRING (MIL) LABOR	RECURRING (MIL) TOTAL	TOTAL NR+R
4190.211	ABSORBER UNIT	0.00	2.94 V	8.93 I	11.87	11.87
4190.212	PIPING	0.00	1.55 V	1.13 I	2.68	2.68
4190.213	SUP.STR.PLATFORMS	0.00	.88 I	.05 I	.93	.93
4190.214	INST. + CTR.	0.00	.31 I	.02 I	.33	.33
4190.215	PACKING + TRANS	0.00	.05 I	.15 I	.19	.19
4190.216	FIELD ERECTION +	0.00	.63 I,H	.85 I,H	1.48	1.48
4190.21	SUBTOTAL	0.00	6.36	11.13	17.48	17.48
4190.23	FROM TUR.GEN.BLDG	0.00	.25 C,H	.38 I	.63	.63
4190.232	FROM THERMAL STOR	0.00	.06 C,H	.03 I	.09	.09
4190.23	SUBTOTAL	0.00	.30	.41	.71	.71
4190.241	TO TURBINE GEN.BL	0.00	.74 C,H	.53 I	1.27	1.27
4190.242	TO THERMAL STORAG	0.00	.10 C,H	.11 I	.21	.21
4190.24	SUBTOTAL	0.00	.83	.64	1.48	1.48
4190.271	TOWER + FOUNDATIO	.00	0.00	0.00	0.00	.00
4190.272	RECEIVER	0.00	0.00	0.00	0.00	0.00
4190.273	RISER.DOWNCOMER+H	.00	0.00	0.00	0.00	.00
4190.27	SUBTOTAL	.00	0.00	0.00	0.00	.00
4190.2111	ABSORBER	0.00	2.90 ✓	8.84 I	11.74	11.74
4190.2112	DRUM	0.00	.00 ✓	0.00	.00	.00
4190.2113	DOORS.HOUSING.LIN	0.00	.04 ✓	.08 I	.12	.12
4190.211	SUBTOTAL	0.00	2.94	8.93	11.87	11.87

Table 5-9. Technical Description Receiver and Tower Equipment (Page 1 of 2)

Receiver Unit Assembly	
Diameter	56 ft
Height	132 ft
Number of absorber panels	24
Exposed surface	14,778 ft^2
Absorber Panel	
Height	84 ft
Width	8.0 ft
Weight	14,500 lb
Number of tubes	170
Tube OD	0.5 in
Tube ID	0.269 in
Tube material	Incoloy 800
Surface coating	Pyromark
Insulation	Blown, closed pore FG
Thermal expansion	Sliding channels
Absorptivity, min	0.9
Peak heat flux, MW/m^2	0.85
Outlet temperature, °C (°F)	516/349 (960/660)
Inlet temperature, °C (°F)	218/104 (425/220)
Outlet pressure, MN/m^2 (psia)	10.4 (1,500)
Inlet pressure, MN/m^2 (psia)	13.8 (2,000)

Table 5-9. Technical Description Receiver and Tower Equipment (Page 2 of 2)

Riser Piping	
Pipe	ASTM A106C carbon steel, 10 in diameter, schedule 160
Supports	Variable spring, constant, and rigid pipe guides
Downcomer Piping	
Pipe	ASTM A335P22 chrome molly, 13.5 in diameter, schedule 160
Supports	Variable spring, constant and rigid, rigid pipe guides
Insulation	
Riser	3.5 in thick
Downcomer	5.5 in thick
Tower and Platform	
Tower	12,038 cu yd concrete
Elevator	790 ft
Caged ladder	790 ft
Platforms	50 tons steel, 5000 ft^2 grating, 1500 linear ft handrail
Aircraft lights	Strobe
Foundation and Site Preparation	
Earthwork	45,813 cu yd total
Foundation	10,908 cu yd concrete



GFY	1986	1986	1987	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992	1992
DDT•E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	0.0	.3	3.3	5.9	7.6	5.0	6.0	1.2	.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	.3	3.3	5.9	7.6	5.0	6.0	1.2	.0	0.0	0.0	0.0	0.0

Figure 5-8. Receiver and Tower System Summary Chart

frozen by the middle of the first year and that component and subsystems specification can be written with RFQs going to the vendors and subcontractors by the third quarter. From this point is will take approximately 4 months before vendors and suppliers can be under contract. The only exception to this is the Incoloy 800 tubing for the absorber which requires release to the vendor within 8 months after contract go-ahead.

5.5.3 Receiver and Tower Equipment Costing Methodology

The costing methodology incorporates the approach used by the Rocketdyne Division of Rockwell International for the receiver unit along with the approach used by Stearns-Roger, Inc. for the tower, riser and downcomer piping, and foundation.

5.5.3.1 Overall Procedure. Costing of the receiver unit is based on Rocketdyne experience concerning the design, manufacture, and test of the subsystem research experiment and Engineering and Manufacturing Department expertise on similar tasks. Estimates used 1977 equipment, material, and labor costs reflecting appropriate fabrication, assembly, and installation at the SCE Coolwater Station in Barstow, California. Estimates were made from detailed equipment, parts, and materials lists, quotations from established vendors and up-to-date catalog prices. All labor costs reflect current wage rates at Rocketdyne for appropriate cost centers, which are in agreement with rate levels approved by the United States Government. In-field costs for construction are based on today's prevailing rates in the Barstow area.

Costing of the tower, riser and downcomer piping, and foundation is based on Stearns-Roger experience in the construction and installation of piping network concrete foundations, and structural steel work. Estimates were generally based on historical factors such as composite values per cubic yard for concrete and earthwork and a percentage of the piping system for riser/downcomer support structures. Field labor costs for construction reflect today's prevailing rates in the Barstow area.

5.5.3.2 Sources of Estimates. All valves, controls, and components which are to be purchased were based either on vendor quotes or on catalog price lists. Raw material, primarily Incoloy 800 tubing, was based on quotes from Huntington Alloy, Inc., the only supplier of Incoloy 800 in the United States. Manufacturing costs were based very strongly on experience with SRE and on Manufacturing Department knowledge of learning curves with which they are able to estimate reduction in costs for a given product as the production level increases. Construction costs for the receiver structure, as well as mounting the absorber panels on the structure, were based on estimates provided by Rocketdyne's Facilities and Industrial Engineering Department. They utilized the 1976 edition of Process Plant Construction Estimating Standards published by Richardson Engineering Services, Inc., and the Estimators Piping Manhour Manual published by Page and Nation.

5.5.3.3 Driving Assumptions/Scenarios. Fabrication costs for absorber panels reflect the application of a high-speed seam welding technique developed during SRE panel fabrication. This technique is ten times faster than previous practice and received the ASME code stamp in October 1976.

5.5.4 Receiver Cost Reduction

Pilot plant receiver panel costs reflect actual experience on panels produced during the Subsystem Research Experiment (SRE) phase of the contract. The SRE costs were adjusted to eliminate known rework effort or problem areas inherent in a research environment and further reduced by 10% to arrive at pilot plant costs. However, these reduced costs still reflect limited production experience and probably represent the upper portion of a cost band when projected out for commercial production. The more detailed industrial engineering, production planning, and tooling certification expected with a production run should enable a further cost reduction from that shown for the first commercial plant.

An area of potential cost savings has been identified with respect to both pilot and commercial plants. This is in the area of the utilization of Section I of the ASME Boiler Code as the driving document governing design and fabrication of the receiver. This document considers Incoloy 800 as a nonferrous alloy. As such, it is required that 1.7 mm (0.065 in) be added to the wall thickness after one calculates that which is necessary to have the required hydraulic stress in the wall. As such, this effectively doubles the wall thickness required for a given passage size. As a net result, we have had to include approximately twice the metal in the receiver as would be necessary if Incoloy 800 was not subject to this requirement. (As a matter of interest, stainless steels and low-alloy steels are not subject to this requirement.)

The pilot plant and first commercial plant receiver designs retain this boiler code requirement which is reflected in higher absorber panel and piping costs. However, for the Nth commercial plant it could be assumed that this requirement does not apply to Incoloy 800 and the design might be revised to incorporate thin wall tubing and fewer tubes of greater diameter. This design change could result in a cost reduction in both material and labor of approximately $0.9 million. In addition, the Nth commercial plant design could be revised to use low-alloy steel in place of Incoloy 800 for the receiver piping. This design change results in a reduction in material cost of approximately $0.8 million.

An additional area causing cost increase is the requirement for 10,000-cycle fatigue life. This is calculated in accordance with Section VIII, Division 2, of the ASME Boiler Code and as such is quite conservative and requires cooling to a greater level than would be required if one used less stringent design criteria. These provisions were incorporated into Section VIII based on experience in the nuclear industry. It is suggested that safety requirements inherent in the nuclear industry are in no way applicable to a solar thermal power plant. This requirement was retained in the pilot plant and first commercial plant receiver designs with associated higher costs. However, for the Nth commercial plant, the design changes described in the preceding paragraph eliminated the need for this fatigue life requirement and the resulting cost savings are included in the dollar reductions identified above.

A third area of cost reduction, primarily associated with the commercial plant, is simply the learning curve that one would enjoy after building the first commercial plant, resulting in a lower cost of labor per panel when building the Nth commercial plant. This learning curve effect, combined with similar learning in field erection effort, could result in a reduction in labor cost.

Commercial plant tower, riser, downcomer, and foundation costs reflect the one-of-a-kind approach generally used by the construction industry in estimating project costs. If a number of identical commercial plants were built in the same general area within a reasonable time period, the resulting economies of multiple plant activity could result in a substantial cost reduction from the first commercial plant to the Nth plant.

5.6 THERMAL STORAGE EQUIPMENT (4190.3)

The thermal storage equipment element includes the heat storage equipment portion of the central receiver plant including the thermal storage unit, heat exchangers, instrumentation and control units, foundation and site preparation, and associated piping, valves, fittings, and pumps. Costs are to provide for the labor and material required to fabricate, deliver, assemble, install, checkout, and activate one thermal storage equipment set and associated materials. Also included are any test hardware and preparation of installation, maintenance, and operating instructions.

5.6.1 The-mal Storage Equipment Costs

Costs have been estimated by Rocketdyne Division of Rockwell International and McDonnell Douglas Astronautics Company as follows:

	Recurring (million)		
Title	Material	Labor	Total
Thermal storage unit	$6.40	$0.00	$6.40
Circulation equip	2.44	0.92	3.36
Heat exchangers	3.33	0.86	4.19
Instr and control	0.71	0.00	0.71
Foundation and site prep	0.73	0.00	0.73
Des eng tst and plan	0.05	1.09	1.15
Total	$13.67	$2.87	$16.53

Additional cost detail is provided by Table 5-10. Table 5-11 is a brief technical description of the costed items.

5.6.2 Thermal Storage Equipment Schedule, Funding, and Important Drivers

The funding and schedule for this element is provided in Figure 5-9, which indicates that construction begins 55 months prior to IOC. The first 12 months involves establishing detailed design specifications and writing, release, receipt, and evaluation of RFP's for equipment TSV tanks and the prime installation subcontract. Purchase of major cost and long-lead-time items is initiated at the beginning of the second year and is completed within 3 months. During the first quarter of the second year detailed designs submitted by vendors will be evaluated and approval will be given for initiation of fabrication. On-site construction will begin at the middle of the second year when all earthwork as well as the receiver tower is completed. On-site tank construction will be initiated at the beginning of the third year and will last approximately 12 months. Filling of the four thermal storage unit tanks will occur during the first half of the fourth year with initial subsystem checkout occurring during the second half of the fourth year. All systems will be installed by the mid-point of the fourth year and TSS electrical and control checkout will be initiated and completed during the second half of the fourth year. The remaining 12 months prior to IOC will involve individual subsystem checkout and integrated system checkout. Beginning with the second half of the fifth year, operations consisting of bed conditioning and particulate removal from the thermal storage unit will occur whenever steam is available from the remaining portion of the plant. During the fifth year checkout period all instrumentation and controls will be integrated and operated with appropriate software under command of the master controller. Peak funding occurs in the last half of 1989, at $4.7 million. The funding load reflects the fact that construction is primarily completed for the thermal storage subsystems at the mid-point of the fourth year. From this point to IOC primarily involves checkout and intermittent operation depending upon the availability of steam. Important drivers on this schedule are the lead times required for the material and installation of the four thermal storage tanks, purchase of the heat exchanger units, and the installation of the piping and control systems. The schedule is based on the fact that the site construction and installation of equipment cannot begin until the tower is completed at the end of the first half of the third year.

Table 5-10. Thermal Storage Cost Detail

6003 WBS SERIES 13.30.01. DATE: 77/05/23.

WBS	TITLE	NON-RECUR (MIL)	----RECURRING (MIL)---- MATERIAL	LABOR	TOTAL	TOTAL NR+R
4190.311	STOR.TANKS+HEATER	0.00	4.88 M	0.00	4.88	4.88
4190.312	INSULATION	0.00	.69 H	0.00	.69	.69
4190.313	ULLAGE MAINT.EQ.	0.00	.67 C	0.00	.67	.67
4190.314	FLUID MAINT. EQ.	0.00	.15 V	0.00	.15	.15
4190.31	SUBTOTAL	0.00	6.40	0.00	6.40	6.40
4190.321	PIPING+SPT STANDS	0.00	1.28 H	0.00	1.28	1.28
4190.322	VALVES	0.00	.36 V	0.00	.36	.36
4190.323	PUMPS	0.00	.42 V	0.00	.42	.42
4190.324	INSULATION	0.00	.30 H	0.00	.30	.30
4190.325	STEAM DRUMS	0.00	.06 C	0.00	.06	.06
4190.326	WATER/STEAM PIPIN	0.00	.02 H	.03 H	.05	.05
4190.327	FLD ERECTION+INST	0.00	0.00	.89 H	.89	.89
4190.32	SUBTOTAL	0.00	2.44	.92	3.36	3.36
4190.331	DESUPER HEATERS	0.00	.03 C	0.00	.03	.03
4190.332	STEAM GEN. HEAT E	0.00	1.21 V,A,H	.86 A,H	2.07	2.07
4190.333	THERMAL STORAGE H	0.00	1.90 M	0.00	1.90	1.90
4190.334	INSULATION	0.00	.17 H	0.00	.17	.17
4190.335	SUPPORT STR.	0.00	.02 H	0.00	.02	.02
4190.33	SUBTOTAL	0.00	3.33	.86	4.19	4.19
4190.351	TANK FOUNDATIONS	0.00	.12 I,C	0.00	.12	.12
4190.352	OTHER FOUNDATIONS	0.00	.09 I	0.00	.09	.09
4190.353	DIKES OR EMER. CO	0.00	.41 I	0.00	.41	.41
4190.354	SITE PREP.	0.00	.05 I	0.00	.05	.05
4190.355	SAFETY PROT.EQUIP	0.00	.06 I	0.00	.06	.06
4190.35	SUBTOTAL	0.00	.73	0.00	.73	.73

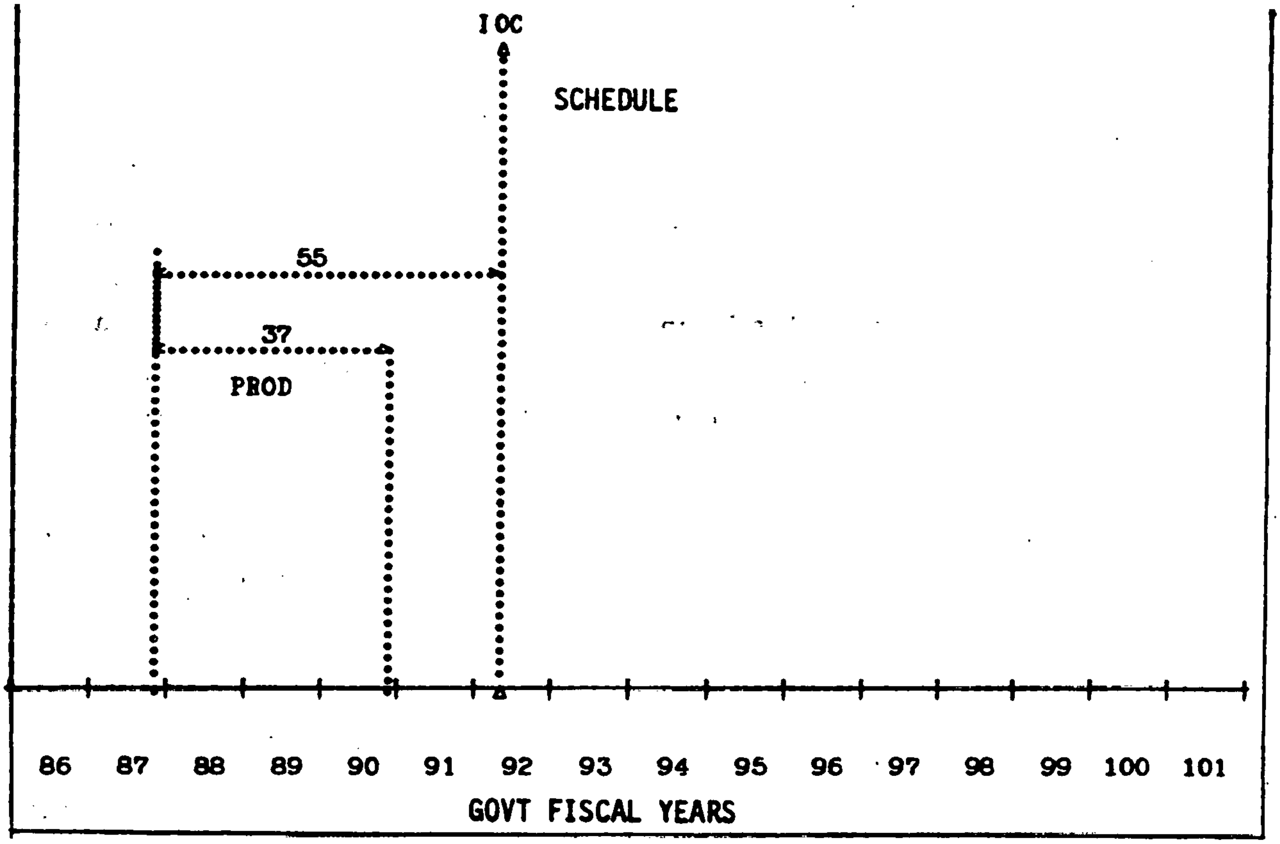
Table 5-11. Technical Description Thermal Storage Equipment (Page 1 of 2)

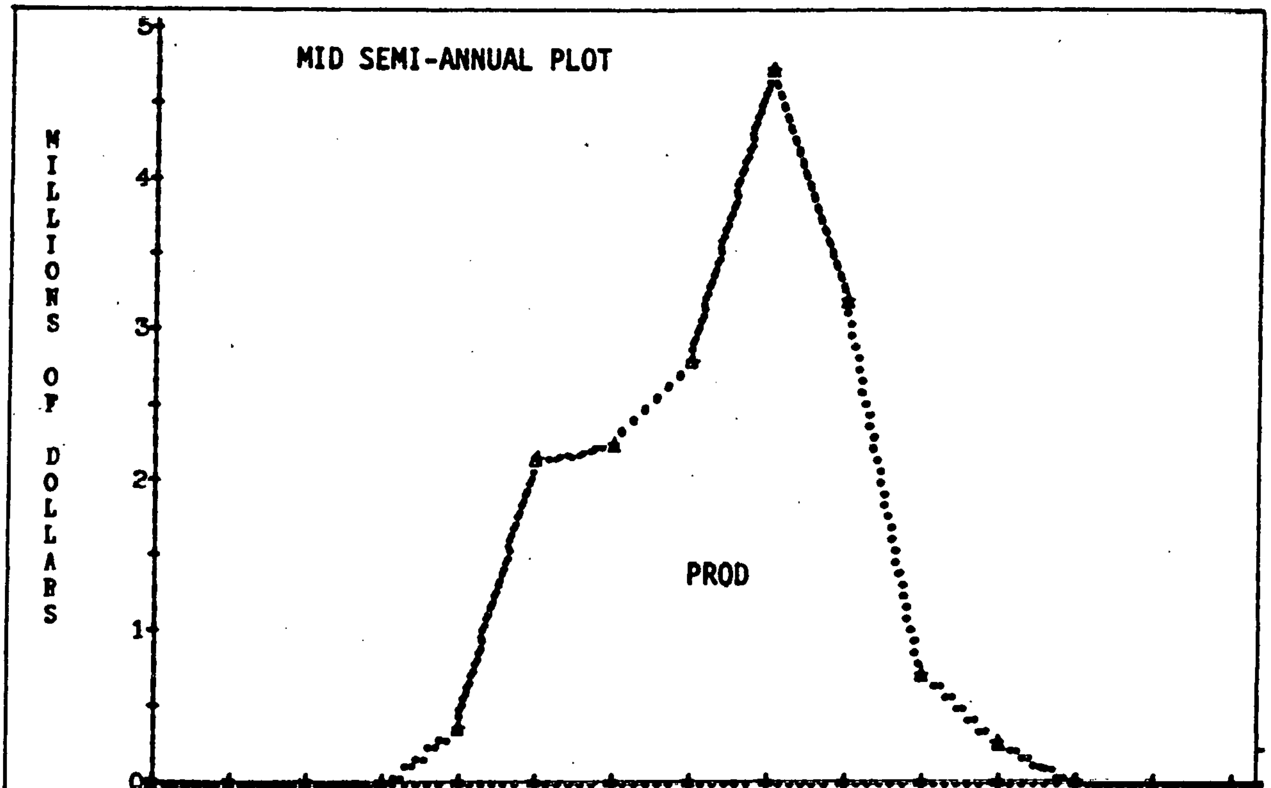
Assembly	Description
Thermal storage unit	Four identical units; each a cylindrical tank, axis vertical, installed above ground, 27.6 m(90.5 ft) diameter by 18.3 m(60.0 ft) high; 10,900 m^3 (386,000 ft^3, 2,890,000 gal) volume; each containing 20.3 x 10^6 kg(22,300 ton) of granite rock and coarse silica sand (approximately 2:1 rock:sand by volume) and 2.2 x 10^6 liters (583,000 gal) of Caloria HT43 heat transfer fluid. Fluid temperature range: 232 to 316°C (450 to 600°F). Fabricated of ASTM A537-70 Grade B structural steel by field-welded construction
Ullage maintenance unit	Storage and control of ullage gas with compressed gas storage at 1.20 MPa (175 psia); tank pressure control, venting, insert gas (nitrogen) control, volatile vapor recovery and control
Fluid maintenance unit	Full-flow, continuous filtration with dual 80-mesh filters in main fluid line upstream of pump; periodic distillation with vacuum distillation unit in side-stream to remove polymerized materials; periodic fluid makeup
Desuperheater	Direct-contact mixing chamber with water injected through multiple atomizing nozzles into superheated steam; single unit: ten nozzles
Thermal storage heater	Five identical exchangers in parallel; each is TEMA type DFU, with removable U-tube bundle, 2 shell passes, 6 tube passes; steam/water on tube side; 1,672 m^2 (18,000 ft^2) heat transfer area per exchanger; carbon steel

Table 5-11. Technical Description Thermal Storage Equipment (Page 2 of 2)

Assembly	Description
Steam generator	Five modules in parallel. Each module consists of three separate stages in series consisting of feedwater preheater, boiler, and superheater; steam/water on shell side; carbon steel. Preheater is straight tube, floating head, counterflow exchanger with 435 m^2 (4684 ft^2) heat transfer area per exchanger Boiler is horizontal U-tube kettle boiler with 1204 m^2 (12,948 ft^2) heat transfer area per exchanger Superheater is horizontal U-tube, crossflow exchanger with 594 m^2 (6389 ft^2) heat transfer area per exchanger
Fluid charging loop pump	Five identical pumps in parallel; centrifugal, high temperature type, with single-speed electric motors; each pump has flow of 260 kg/s(600 lb/s); and 0.19 MWe (260 hp) motor input at maximum charging rate (51 MWt)
Fluid extraction loop pump	Five identical pumps in parallel; centrifugal, high-temperature type, with single-speed electric motors; each pump has flow of 216 kg/s(490 lb/s), 0.19 MWe (250 hp) *motor input at maximum extraction rate (57 MWt)

*Required input motor power; not full motor capacity





GFY	1986	1986	1987	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992	1992
DDT•E	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	0•0	0•0	•0	•4	2•2	2•2	2•8	4•7	3•2	•7	•3	•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	0•0	0•0	•0	•4	2•2	2•2	2•8	4•7	3•2	•7	•3	•0	0•0	0•0

Figure 5-9. Thermal Storage Equipment Summary Chart

5.6.3 Thermal Storage Equipment Costing Methodology

The costing methodology incorporates the approach used by the Rocketdyne Division of Rockwell International for all elements other than the steam generator portion of the heat exchangers along with the approach used by McDonnell Douglas Astronautics Company for the steam generator heat exchangers.

5.6.3.1 Overall Procedure. Costing is based on Rocketdyne Division experience with the design, manufacture, and testing of the subsystem research experiments and the facility engineering department experience on similar construction projects. Estimates used 1977 industrial, equipment, material, and labor costs reflecting appropriate fabrication and assembly and installation at a desert site similar to the SCE Coolwater Station at Barstow. Estimates were made from a detailed equipment, parts, and materials list, quotations from established vendors, and up to date catalogue prices. The tank construction and system installation phase beginning at the mid-point of the third year includes in-house engineering as well as field engineering to coordinate and supervise the field installation. Engineering checkout commences at the beginning of the fifth year, with cost primarily incurred by field operating personnel. Technical support of operations is included for the time period beginning the middle of the sixth year. Engineering effort has been man loaded for each task based on experience with similar field construction projects.

Engineering costs were based on current wage rates at Rocketdyne for appropriate cost centers which are in agreement with costs in the power plant construction industry. Subcontractor costs reflect appropriate A&E burden and fee factors. Construction costs are based upon today's prevailing craft rates in the Barstow area.

Fabrication costs of the steam generator heat exchangers are based on a cost estimating relationship derived from vendor quotes for several sizes and an earlier estimating manual curve. Appropriate indirect and field labor factors were applied to these costs based on historical experience.

5.6.3.2 Sources of Estimates. Rocketdyne's Facility Engineering Department utilized a 1976 edition of the Process Plant Construction Estimating Standards published by Richardson Engineering Services Inc., "Estimators Piping Man-Hour Manual," published by Page and Nation, and the "Electrical Tradebook," published by Biddle Trade Publishing Co. for electrical and mechanical cost and installation. Vendors were contacted for estimates on the fabrication of the thermal storage heater and steam generator heat exchangers, the thermal storage tank, principal control valves, the fluid circulation pumps, and the desuperheater. Heat exchanger price quotations were obtained from Southwestern Engineering, Therm-xchanger Co., Wiegmann and Rose, Industrial Fabricating Co. and Yuba Heat Transfer Corp. Thermal storage tank quotations were obtained from Pittsburg Des Moines Co. and Pacific Fabricators. The FMU filter and distillation units were priced from vendors supplying identical or similar components. Hand valves, relief valves, check valves, transducers, and miscellaneous fluid component prices were obtained from current catalogues. Electronic controllers, switching, and signal conditioning subassembly units were based on costs of a similar control and instrumentation subsystem built three years ago by Rocketdyne and updated with appropriate cost escalation.

5.6.3.3 Driving Assumptions/Scenarios. The 66-month fabrication and construction period for the thermal storage subsystem is based on coordination with the other major subsystems (heliostat and receiver) which are the principal drivers for establishing program schedule. At the beginning of the program a 6-month period will be utilized for a review of prior solar thermal power plant experience and modifications and incorporation of design features to update the commercial plant design. It is expected that the overall system requirements will be frozen by the middile of the first year and that component and subsystems specification can be written with RFQs going to the vendors and subcontractors by the third quarter. From this point it will take approximately 4 months before vendors and suppliers can be under contract. Components and subsystems that require detailed design work by vendors will contain a review period prior to initiation of vendor fabrication or installation. Site installation and construction cannot begin before the completion of earth work which is at the middle of the second year. It is expected that the four TSU tanks will be erected and all major components and piping stalled by the middle of the fourth year. The control system installation checkout will occur during the fourth year. The storage unit tanks will be filled with rock/sand storage medium and the heat transfer fluid during the latter part of the fourth year and the first part of the fifth year. System checkout will occur during the fifth year, beginning with thermal storage subsystem only. Complete integration testing with other major subsystems will begin the latter part of the fifth year into the sixth year and to the beginning of IOC. After filling the thermal storage unit with storage medium and the checkout of the controls, the bed conditioning can begin any time that steam is available from the heliostat receiver subsystems. It is planned that complete functional operation will be achieved by the end of the fifth year to provide uninterrupted integrated system tests during the first half of the sixth year.

5.6.4 Thermal Storage

Cost reduction in the commercial plant will depend to a great extent on the experience with the pilot plant operation and the scope of laboratory testing. For the most part the commercial plant is made of standard commercially available components and it is not expected that the price of these will be lower by the usage rate of the solar thermal electrical power generation systems. The greatest potential for cost reduction in the thermal storage subsystem is in the construction of the thermal storage units, the construction and use of the input and output heat exchangers and the long term experience to be gained with the heat transfer fluid. Estimates for the nth commercial plant reflect a reduction of approximately $1.0 million from the first commercial plant resulting from economies of multiple plant procurement.

5.6.4.1 Thermal Storage Unit Cost Savings. Reduction of thermal storage unit cost can be achieved through thinner wall tank designs, simplified distribution manifold design, and cost saving rock/sand installation. As presently designed the thermal storage unit tank wall is quite thick to withstand the loads thought to be imposed by the rock and sand. Presently established design procedures result in wall thicknesses more than adequate and may be overly conservative in establishing tank designs. It is anticipated that pilot plant stress results and further analyses will provide better insight into the commercial tank design and it possibly might result in thinner wall lower cost tank. There is adequate time at this point to conduct component or model testing to verify the stresses that will result from the pilot plant operation and provide new, more precise modeling of the stress pattern for commercial plant design.

A second item of cost saving with the thermal storage unit are the distribution manifolds at the top and bottom of the rock bed. As designed for the SRE system there are approximately 10 in^2 for each hole which over a wide range of flows gave no indication of stratified flow. The manifold for the pilot plant will be designed with 40 in^2 per hole and it is felt at this point of time that this will be adequate for the fluid distribution. However, there is some indication that the rocks and sand enhance fluid diffusion and distribution and it is possible in the commercial plant that the distribution manifolds may be further simplified. It is expected that engineering laboratory tests in this area will be very fruitful and there is adequate time to provide detailed information prior to construction of the commercial plant manifolds.

The third area of possible cost reduction in the TSU is in the loading procedure and void fractions of the solid storage media. The SRE was loaded slowly to ensure uniform distribution and good packing density and was on the conservative side to provide the most favorable environment for the thermocline. It is possible in the pilot and commercial plant the packing of the bed can be done in a much simpler fashion with resultant cost savings. The commercial plant will be built at a scale level that will allow further economics with the construction and installation of loading equipment and local quarrying that will save both loading and transportation costs. It is expected that laboratory tests with various sizes of rock and sand should result in reduced void fraction providing a further saving on the amount of fluid required. Experience with multimodal packing of solid rocket propellants indicate that void fractions below 25% are readily achievable with little or no increase in cost.

5.6.4.2 Heat Exchanger Cost Savings. The thermal storage subsystem presently contains heat exchangers of equal size for both charging and extracting heat from the thermal storage subsystem. This facilitates high flexibility in operation by providing steam to the turbine while simultaneously receiving steam from the receiver. This type of system captures the maximum amount of solar energy but requires a duplicate set of heat exchangers. During operation of the pilot plant experience will be gained as to the value of having both sets of heat exchangers and it may be possible that a significant cost saving in this area could be achieved by reducing the flexibility of the plant with the use of only one set of heat exchangers; however, before this can be determined a series of cost tradeoffs based on operating experience will be needed to identify any potential cost benefits.

The second source of cost saving in the heat exchanger area is the design potential of designing and fabricating heat exchangers that will require zero maintenance during the 30-year plant life. Since corrosion effects are not expected to be a predominant factor in heat exchanger life, it is possible that detailed stress analysis and model testing may evolve designs that will minimize thermal stresses which at this time are identified as the main source of maintenance. Industry experience has shown that heat exchanger maintenance is quite expensive and approaches the cost of new heat exchangers in many cases every 5 to 10 years. The use of heat exchanger configurations and design features that minimize thermal stresses during startup and shutdown may produce significant benefits in reducing heat exchanger maintenance.

5.6.4.3 Operational Cost Savings. It is expected that experience with the pilot plant will result in significant cost savings on the commercial plant through reduction in operating personnel by providing more automatic operation plus the identification of improvements that can be achieved in high maintenance areas. Reduction of operating personnel is best achieved by providing troublefree automatic operation, where possible, with a minimum of downtime and outage. The solar thermal plant should ultimately enjoy a higher reliability than its fossil fuel or nuclear counterpart since a downtime occurs each day during early morning hours which allows repair and maintenance to prevent unscheduled outage. It is expected that detailed maintenance records will be kept on the pilot plant to provide maintenance procedures on the commercial plant that will result in a maximum of ontime availability. Operating personnel can be minimized by providing trouble-free operation and providing comprehensive diagnostic and repair procedures in the master control memory that will identify potential problem areas and sources of failures based upon continuous monitoring and prescribed diagnostic operational programs accessible for immediate integration. Components deteriorating in performance may be identified before on-line failure occurs and can be repaired, adjusted or replaced during the normal downtime from midnight to 6 AM. In a plant as complex as electrical power generation systems diagnostic time can be decreased through a memory bank of probable sources of failure that will rapidly pinpoint failed components or more importantly, predict a possible failure and thus enable a component to be replaced before on-line failure occurs.

5.7 THERMAL STORAGE MATERIAL (4190.4)

This element includes the organic and inorganic heat storage materials. Costs provide the labor and material required to procure the materials and install the storage material in the thermal storage subsystem.

5.7.1 Thermal Storage Material Costs and Technical Characteristics

Costs provided by the Rocketdyne Division of Rockwell International are shown below:

	Recurring (million)		
Title	Material	Labor	Total
Inorganic material	$0.68	$0.00	$0.68
Organic material	2.65	0.00	2.65
Delivery	0.64	0.00	0.64
Handling at site	0.93	0.00	0.93
Total	$4.90	$0.00	$4.90

These costs cover 8,800 m^3 (2,330,000 gal) of Caloria HT43, and 81.1x10^6 kg (89,300 ton) of graded river gravel and sand approximately in a 2:1 ratio of rock to sand by volume. The river gravel is nominally 25 mm (1 in) in size, and the sand is a coarse silica grade nominally 1.5 mm (1/16 in) in size. The Caloria HT43 is a readily available product from the Exxon Corporation and has been proved successful meeting the thermal storage subsystem requirements of the commercial plant in the SRE systems and laboratory tests.

5.7.2 Thermal Storage Material Schedules, Funding, and Important Drivers

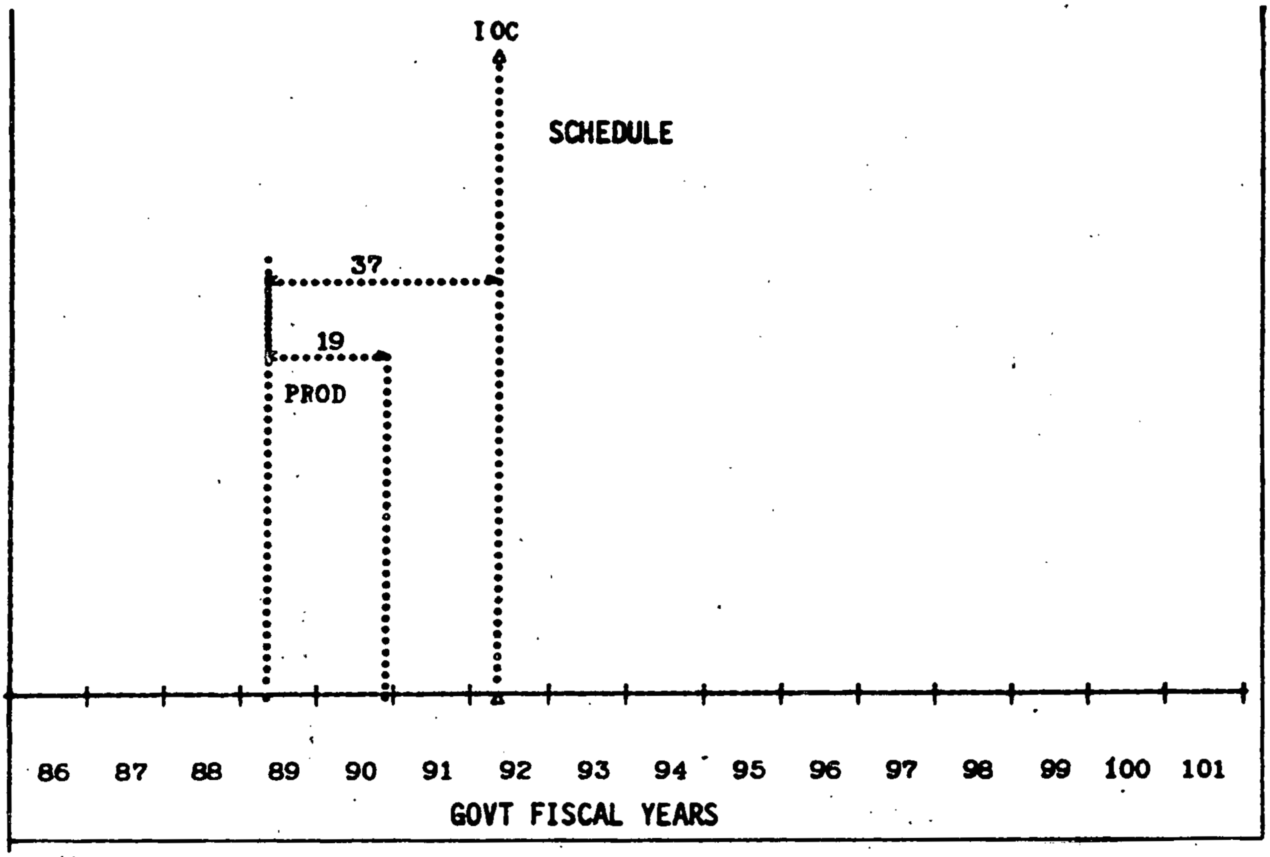
The funding indicated in Figure 5-10 shows cost peaking in the first and last quarter of the fourth year and the first quarter of the fifty year during the period of filling the thermal storage unit with rock and heat transfer fluid. Procurement starts 37 months prior to IOC, continues for 19 months, and is not critical as far as lead time and supply are concerned. Contact with the supplier indicates that they may have to produce this material over a period of time on the order of 6 to 9 months, but delivery can be made from storage as needed in the required filling. It is anticipated that the Caloria will be hauled on site by rail car and it is anticipated that filling will be rapid and demurrage charges will be little or zero.

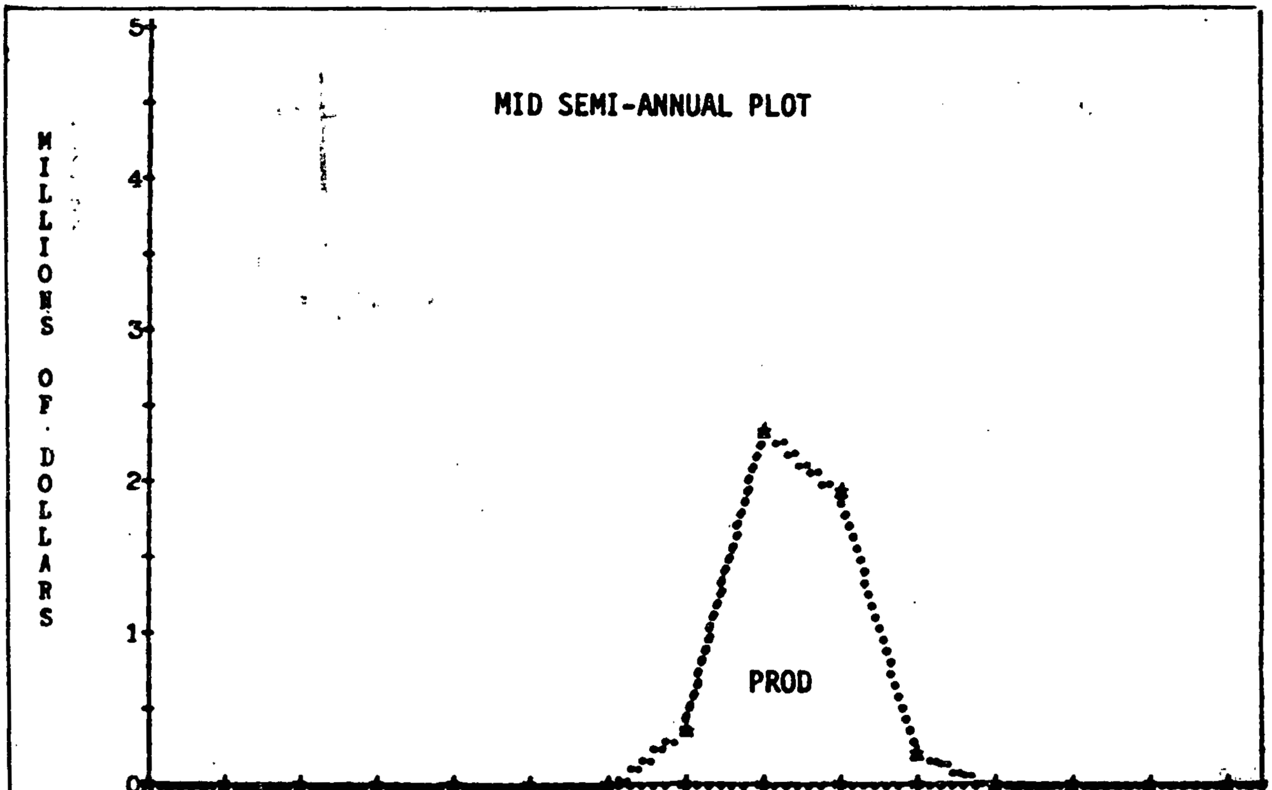
5.7.3 Thermal Storage Material Costing Methodology

The costing approach used by the Rocketdyne Division of Rockwell International is described in the following paragraphs.

5.7.3.1 Overall Procedure. Cost for the storage medium were established by contacting suppliers of the required material.

5.7.3.2 Sources of Estimates. The source of cost with the Caloria HT43 was supplier Exxon Corporation which quoted a price of $0.86 per gallon at Houston. The Caloria HT43 has been in production for several years and is available for delivery in large quantities from its Houston facility. The cost of the rock and sand is based upon local supply within 50 miles of the anticipated location of the commercial plant and is based upon a $3 per ton quarry pirce for rock plus $12 per ton quarry price of the sand.





GFY	1986	1986	1987	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992	1992
DDT•E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	0.0	0.0	0.0	0.0	0.0	.4	2.3	2.0	.2	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	.4	2.3	2.0	.2	0.0	0.0	0.0	0.0

Figure 5-10. Thermal Storage Material Summary Chart

5.7.3.3 Driving Assumption/Scenarios. The use of the Caloria HT43 in rock bed is based upon economics derived from prior analysis and tests during the SRE program. These studies and tests showed the use of this combination results in the most economic storage of thermal energy for the required conditions, is readily available in large quantities, and can be scaled and utilized in a wide range of sizes with the best potential for lasting thirty years with a minimum of maintenance.

5.7.4 Cost Reduction-SRE to Pilot Plant through Commercial Justification

The use of selected storage medium was based on the most economic approach to storing energy at the temperature conditions required based upon todays technology and available materials. Cost reductions can be achieved through three tasks. First, the availability of lower cost storage material would be a direct cost saving for the commercial plant. Secondly, the availability of a heat transfer fluid that would require a lower degree of fluid replenishment because of degradation at the 600°F operating temperature would also result in cost savings. A third route to cost saving in the thermal storage medium would be to reduce the void fraction with a higher packing density of the low-cost solid medium thus reducing the fluid inventory. The latter cost savings can be significant and very possibly achievable through advanced bed packing techniques that may involved multi modal packing beyond the bi modal packing that was used on the SRE and is presently anticipated for the pilot plant system. Bed packing for SRE achieved a void fraction between 28 and 30%. By using a wider graded range of solid material the bed packing can be reduced significantly well below the 25% value. It is expected that this could be achieved with engineering laboratory tests of various size particles. However, this testing must be done in concert with the manifold hold spacing and sizing to provide proper fluids distribution without particulate contamination of the manifold system. There is adequate time between the present and the design period for the commercial plant to investigate improved media packing that should result in significant cost savings for the commercial plant.

5.8 TURBINE PLANT EQUIPMENT (4300)

This element includes the turbine generator, supply and exhaust headers, condensing equipment, cooling equipment, water circulating equipment, water treatment equipment, instrumentation and controls, and connective piping and insulation. Not included in this element are surveys, design and other engineering work, procurement effort and construction direction, which are normally included under the Indirect effort (8100). Costs are to provide for site preparation, for all material and equipment, and for the subcontracted labor and services necessary to transport, fabricate, assemble, install and checkout materials and equipment at the first commercial site.

5.8.1 Turbine Plant Equipment Costs

The costs shown below have been estimated by Stearns-Roger:

	Recurring (million)		
Title	Material	Labor	Total
Turbine generator	$13.01	$1.14	$14.15
Hear rejection sys	3.18	0.65	3.83
Condensing sys	0.30	0.02	0.32
Feed heating sys	2.03	0.14	2.16
Water cir/treat	2.24	0.14	2.38
Total	$20.76	$2.09	$22.84

Detailed costs are provided in Table 5-12 and the equipment is described in Table 5-13.

5.8.2 Turbine Plant Equipment Funding

Figure 5-11 shows Turbine Plant Equipment funding and schedule. This element starts 60 months prior to IOC and continues over the entire period. Peak funding is $7.4 million in the first half of 1989.

Table 5-12. Turbine Plant Equipment Cost Detail

6B WBS SERIES 13.49.30. DATE: 77/05/23.

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
4300.11	TURBINE GEN.+ACCE	0.00	12.74	.55	13.29	13.29
4300.12	FOUNDATIONS	0.00	.23	.56	.80	.80
4300.13	STANDBY EXCITERS	0.00	.00	0.00	.00	.00
4300.14	LUBRICATING SYS.	0.00	.03	.00	.03	.03
4300.16	REHEATERS	0.00	.00	0.00	.00	.00
4300.17	WEATHER PROOF HOU	0.00	.01	.02	.03	.03
4300.1	SUBTOTAL	0.00	13.01	1.14	14.15	14.15
4300.21	HEAT REJECTION EQ	0.00	1.94	.06	1.99	1.99
4300.22	INSTALLATION COST	0.00	.29	.02	.31	.31
4300.23	EXHAUST DUCT	0.00	.00	0.00	.00	.00
4300.24	EVAPORATION POND	0.00	.95	.58	1.53	1.53
4300.2	SUBTOTAL	0.00	3.18	.65	3.83	3.83
4300.31	CONDENSATE SYS.	0.00	.30	.02	.32	.32
4300.32	TURBINE BYPASS SY	0.00	.00	0.00	.00	.00
4300.3	SUBTOTAL	0.00	.30	.02	.32	.32
4300.41	REGENERATIVE HEAT	0.00	.56	.05	.60	.60
4300.42	PUMPS	0.00	1.47	.09	1.56	1.56
4300.43	PIPING + TANKS	0.00	.00	0.00	.00	.00
4300.4	SUBTOTAL	0.00	2.03	.14	2.16	2.16
4300.51	MAKEUP TREAT.SYS.	0.00	.11	.01	.11	.11
4300.52	CHEM.TREAT.+CON.P	0.00	2.13	.13	2.26	2.26
4300.5	SUBTOTAL	0.00	2.24	.14	2.38	2.38

Table 5-13. Technical Description Turbine Plant Equipment (Page 1 of 2)

Turbine Generator

112,000 kW, 1,465 psia — 950°F, single automatic admission, condensing. Also included is:

Lube oil filter and pump set — 15 gpm

Lube oil filter

Lube oil purifier — 15 gpm, centrifuge separator

Lube oil transfer pump — 50 gpm, gear type

Condenser hot well pumps — 1,850 gpm, 280 TDH, vertical installation

200 hp

Condenser vacuum pumps — 12.5 SCFM, 1 in HGA mech. vac.

Lube oil storage tank — 6,000 gal, 2 compartment

Turbine gland seal drain tank — 3 ft dia, 6 ft height

Turbine drains tank — 3 ft dia, 5 ft height

1,800 kW diesel generator set

Equipment foundations (cost under 4,103.1)

Turbine Supply Header

Main stream line from receiver (excluding downcomer piping on tower) to turbine.

Condenser/Cooling Equipment

Shell and tube, water-cooled condenser, with 135,000 ft^2 cooling surface.

Feedwater Equipment

Condensate transfer pumps — 300 gpm, horizontal installation

Receiver feedwater pumps — 6,300 RPM, 2,500 hp

Booster pumps

Table 5-13. Technical Description Turbine Plant Equipment (Page 2 of 2)

Feedwater Equipment (Continued)

Condensate storage tanks — two — 100,000 gal

Flash tank

Low-pressure feedwater heater — stainless steel

High-pressure feedwater heater — carbon steel

Deaerating heater

Water Circulating/Treatment Equipment

Demineralizer caustic feed pump (4)

Demineralizer acid feed pump (2)

Demineralizer caustic storage tank — 6,000 gal

Makeup demineralizer sand filters

Feedwater chemical feed tanks and pumps

Makeup demineralizers — 100 gpm

Inline demineralizers — 1,800 gpm

Raw water clarifier

Instrumentation and Control

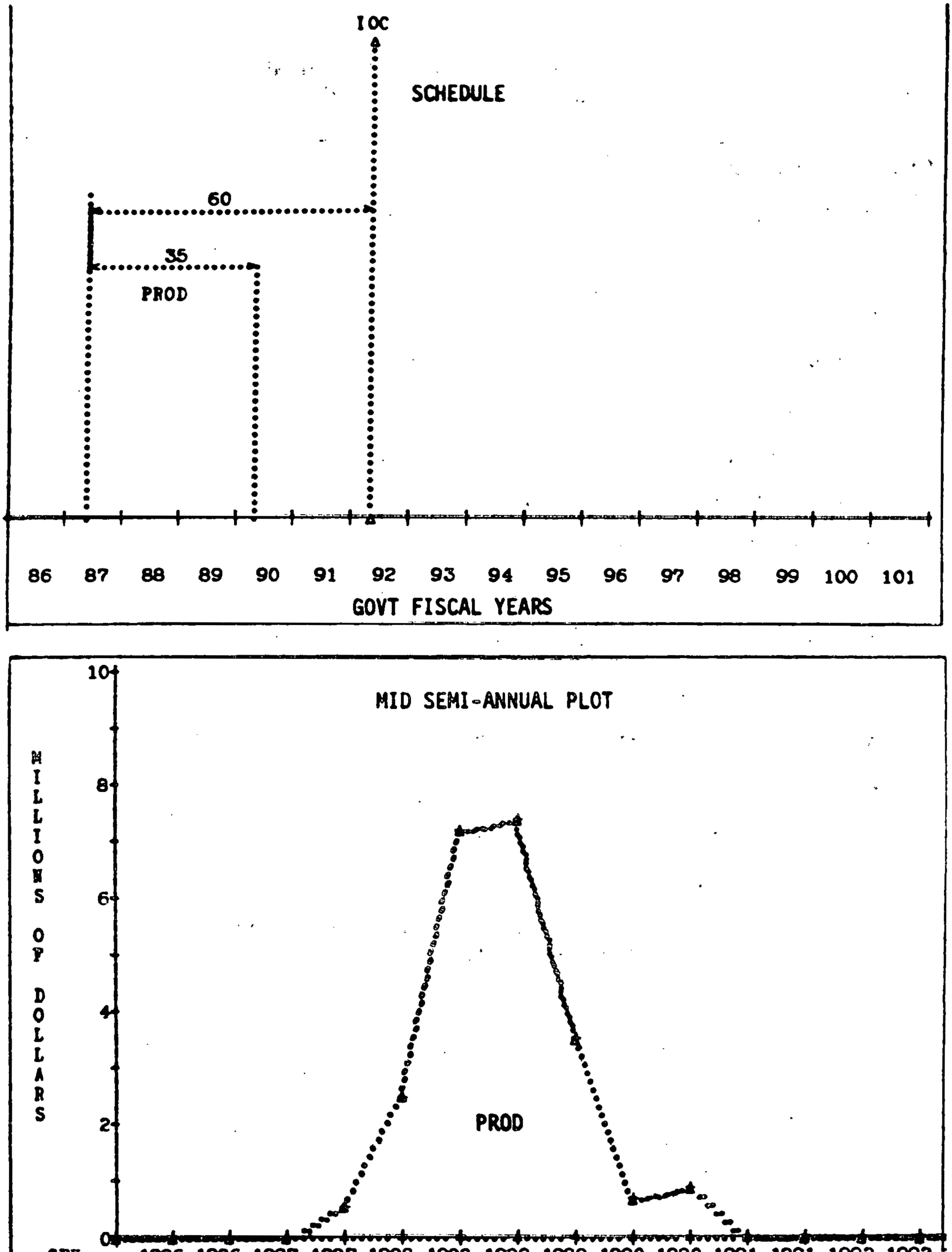
Minicomputer, digital and analog controls, control panels and miscellaneous instruments and controls.

Piping

Piping system required in the turbine-generator subsystem other than headers.

Thermal Insulation

Thermal insulation and lagging required for the turbine-generator subsystem piping systems and equipment.



GFY	1986	1986	1987	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992	1992
DDT•E	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	0•0	0•0	•0	•5	2•5	7•2	7•4	3•5	•7	•9	•1	0•0	0•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	0•0	0•0	•0	•5	2•5	7•2	7•4	3•5	•7	•9	•1	0•0	0•0	0•0

Figure 5-11. Turbine Plant Equipment Summary Chart

5.8.3 Costing Methodology

Costing is based on Stearns-Roger experience with power plants of this size and utilizes current industrial equipment, material and labor costs reflecting the Barstow area. Estimates were made from the equipment list which defines the scope of work. Quotes were obtained or catalogs consulted for equipment and materials and site fabrication, assembly, and installation hours and dollars estimated based on experience and desert Southwest labor rates. From these costs, the costs of the other major construction accounts (i.e., earthwork, concrete, piping, painting, and insulation) are prorated based on previous power plant relationships for units of this size. Costs of instrumentation and control were estimated separately using typical equipment prices and experience on installation.

5.9 ELECTRIC PLANT EQUIPMENT (4401)

This element includes power conditioning, station service equipment switchboard, power and control wiring, power distribution, protective equipment and instrumentation, controls and communications. Not included in this element are surveys, design and other engineering work, procurement activities and site construction direction which are normally included under the Indirect effort (8100). Costs are to provide for site preparation, for all material and equipment, and for the subcontracted labor and services necessary to transport, fabricate, assemble, install, and checkout materials and equipment at the commercial site.

5.9.1 Electric Plant Equipment Costs

Stearns-Roger has estimated costs a follows:

	Recurring (million)		
Title	Material	Labor	Total
Transmission plant	$0.01	$0.01	$0.02
Switchgear	0.67	0.17	0.84
Station service eq	1.07	0.69	1.76
Switchboards	0.00	0.00	0.00
Protective eq	0.03	0.21	0.23
Elec STR wiring	0.15	0.11	0.27
Power wiring	0.10	0.07	0.17
Total	$2.03	$1.26	$3.29

A detailed cost is provided in Table 5-14 and the technical description of this equipment is provided in Table 5-15.

5.9.2 Electric Plant Equipment Funding

Electric plant equipment schedule and funding are shown in Figure 5-12. The schedule shows activity starting 44 months prior to IOC and continuing for 30 months. Funding peaks in the first half of 1990 at $1.6 million.

5.9.3 Costing Methodology

Costing is based on Stearns-Roger, experience with power plants of this size and utilized current industrial equipment, material and labor costs reflecting the Barstow area plant location. Estimates were made from the equipment list which defines the scope of work. Quotes were obtained or catalogs consulted for equipment and materials and site fabrication, assembly, and installation hours and dollars estimated based on experience and desert southwest labor rates. From these costs, the costs of the other construction accounts (i.e., earthwork, concrete, painting, electric structures and containers, wiring, and instrumentation) are prorated based on many previous power plant cost relationships for units of this size.

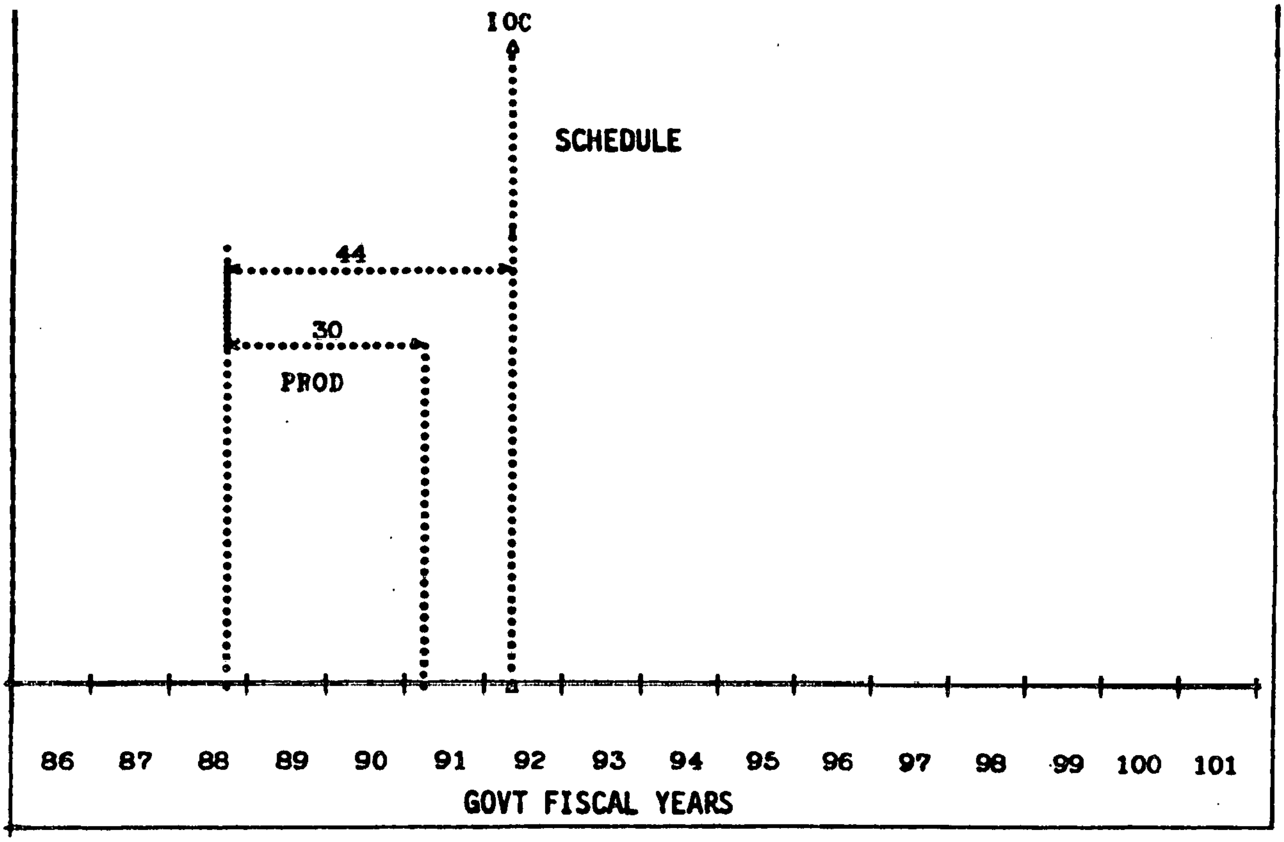
Table 5-14. Electric Plant Equipment Cost Detail

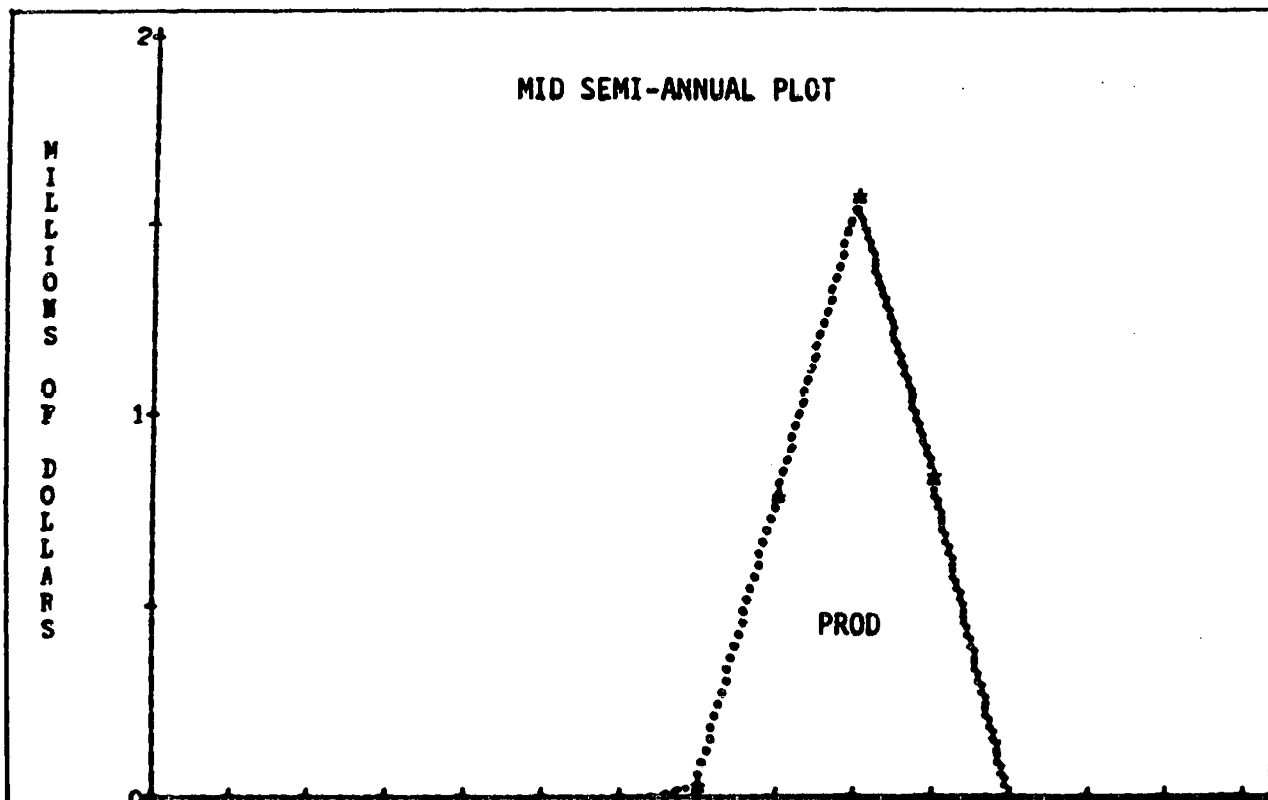
66 WBS SERIES 14.07.16. DATE: 77/05/23.

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL MH-?
4401.11	GENERAL CIRCUITS	0.00	.16	.11	.27	.27
4401.12	STATION SERVICE	0.00	.51	.06	.57	.57
4401.1	SUBTOTAL	0.00	.67	.17	.84	.84
4401.21	ST.SFR.-ST.UP TRA	0.00	1.01	.68	1.69	1.69
4401.22	LOW VOL.UNIT SUB.	0.00	.02	.01	.03	.03
4401.23	AUXILIARY PWR.SOU	0.00	.04	.01	.05	.05
4401.2	SUBTOTAL	0.00	1.07	.69	1.76	1.76
4401.41	GENERAL ST.GR.SYS	0.00	.03	.21	.23	.23
4401.42	FIRE PROTECT. EQ.	0.00	.00	0.00	.00	.00
4401.4	SUBTOTAL	0.00	.03	.21	.23	.23

Table 5-15. Technical Description Electric Plant Equipment

Switchgear	4, 160 V switchgear and motor controls, distribution panels - 22-5 kV, 1, 200 A, 250 MVA circuit breakers
Station Service Equipment	Main power transformer 115-13. 2 kV Auxiliary power transformer 13. 2-4. 16 kV 115-13. 2 kV transformers Oil-fired steam generator Station battery and battery charger
Protective Equipment	Generator circuit breaker cubicle Generator surge protection cubicle Generator ground cubicle
Electrical Structures and Wiring Containers	Cable trays, duct banks, manholes
Power and Control Wiring	Wiring and conduit for power plant
Instrumentation, Master Control and Communications	Instrumentation, wiring, in-plant communication





GFY	1986	1986	1987	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992	1992
DDT.E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	0.0	0.0	0.0	0.0	0.0	.0	.8	1.6	.8	.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	.0	.8	1.6	.8	.0	0.0	0.0	0.0

Figure 5-12. Electrical Plant Equipment Summary Chart

5.10 MASTER CONTROL (4402)

This element includes integration and software, computers and peripheral equipment, manual controls and displays, signal interface unit, computer interface unit, and communications wiring. Costs are to provide for the labor and material required to design, fabricate, assemble, deliver, install, checkout, and both active and support acceptance test for one master control set, including installation, maintenance, and operating instructions.

5.10.1 Master Control Costs

Costs estimated by MDAC and Rocketdyne and Stearns-Roger are presented as follows:

	Recurring (millions)		
Title	Material	Labor	Total
Computer	$0.04	$0.00	$0.04
Peripheral eq	0.04	0.00	0.04
Ctr panel and board	0.05	0.00	0.05
Inter eq sig & co	0.34	0.00	0.34
Software D&D	0.00	0.00	0.00
Software/hdwr tes	0.00	0.21	0.21
Hardware design	0.00	0.00	0.00
Control wiring	0.77	0.13	0.90
Field inst & C/	0.00	0.20	0.20
Total	$1.24	$0.54	$1.78

Figures 5-13 provides a schematic upon which these costs are based. Addition, minor software modifications for specific sites is covered under software/hardware test.

5.10.2 Master Control Funding

Schedule and funding for this subsystem are shown in Figure 5-14. Production begins 34 months prior to IOC and continues for 27 months.

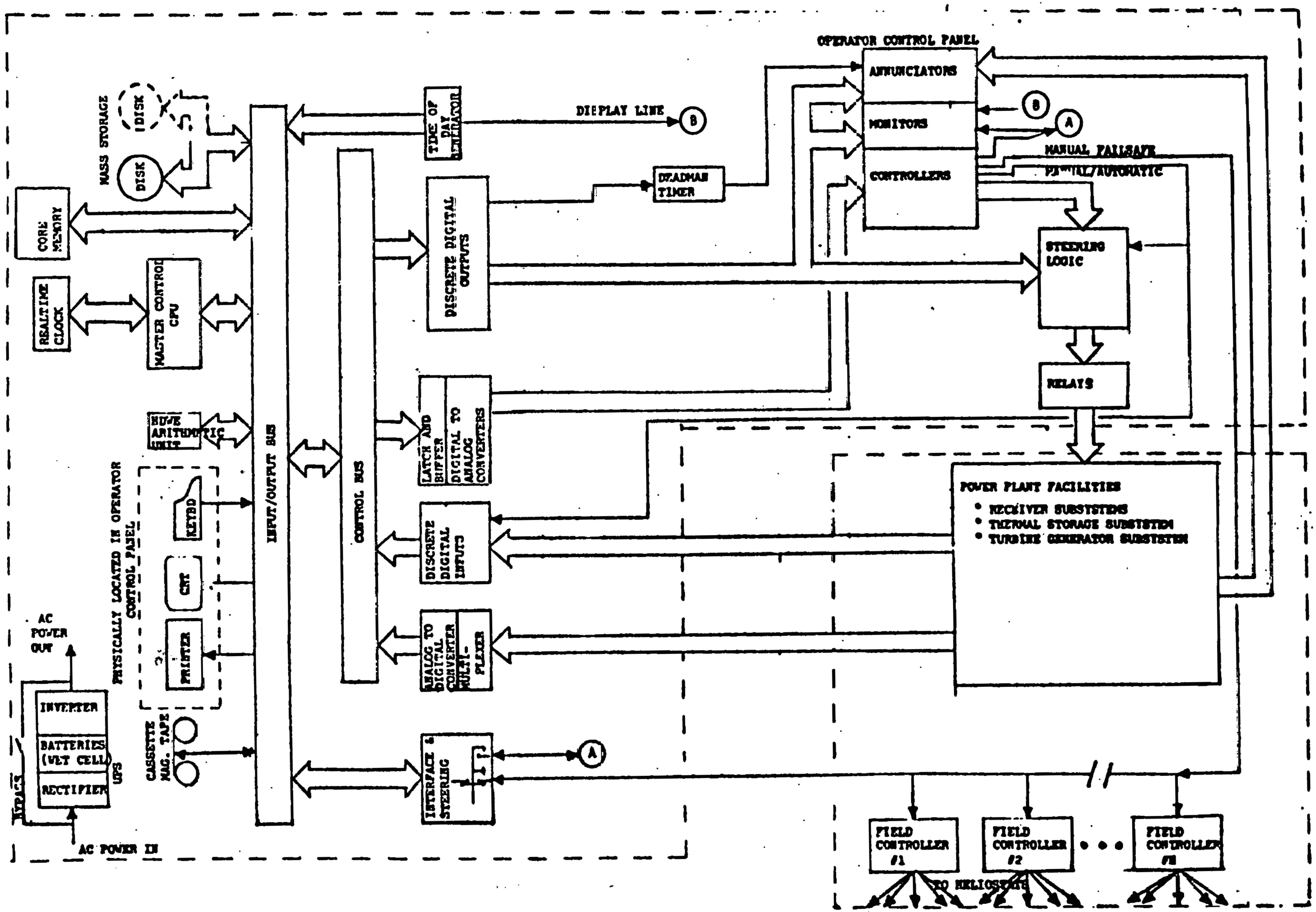
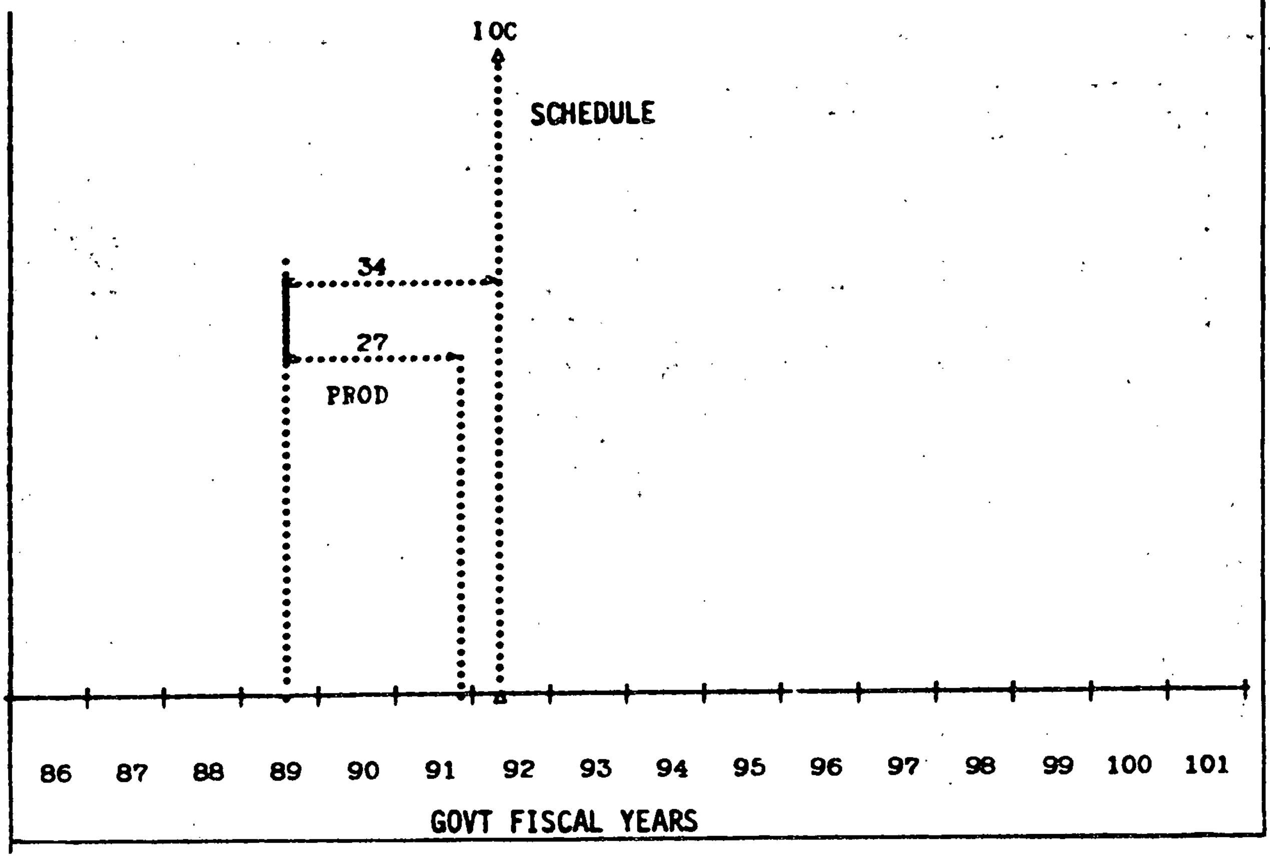
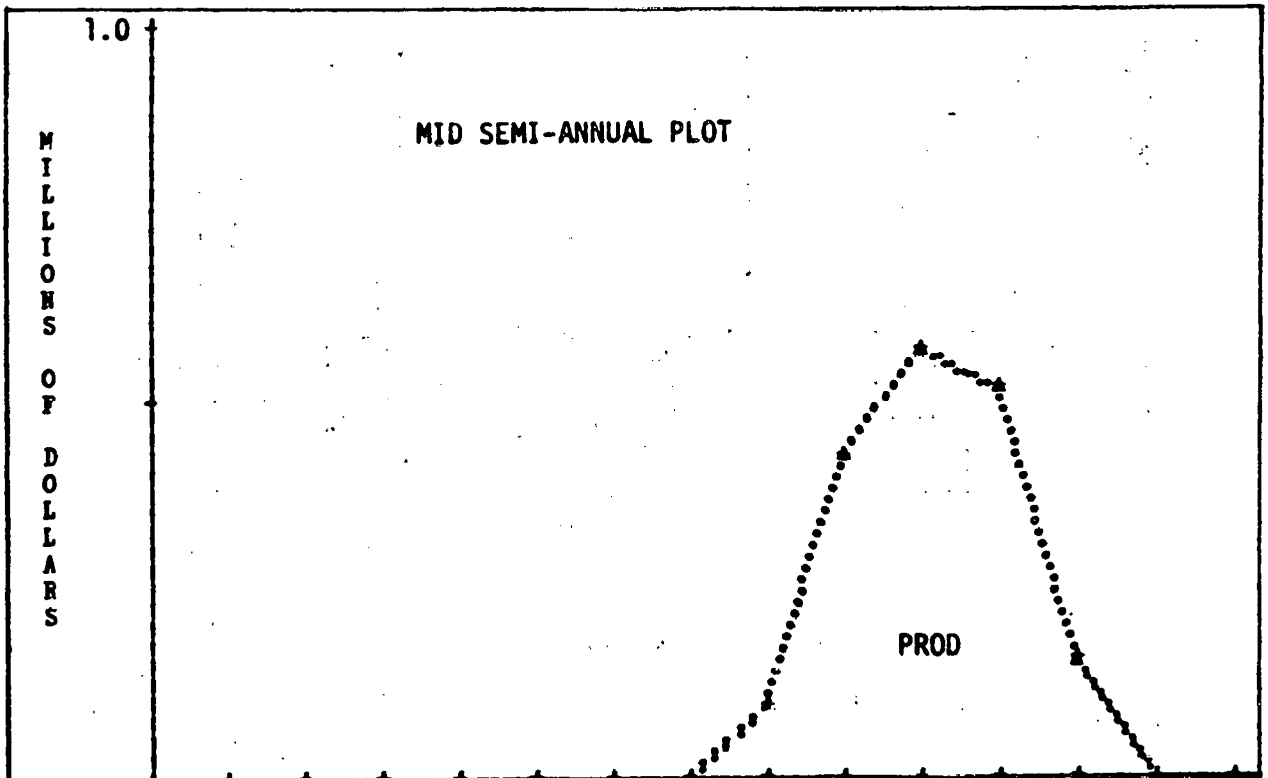


Figure 5-13. Commercial Plant Master Control Architecture





GFY	1986	1986	1987	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992	1992
DDT·E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.4	.6	.5	.2	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.4	.6	.5	.2	0.0	0.0

Figure 5-14. Plant Master Control Summary Chart

5.10.3 Cost Methodology

Generally, hardware and test costs are based on MDAC experience in electronics systems and are based on pilot plant estimates. These estimates used 1977 industrial equipment, material and labor costs reflecting appropriate fabrication, assembly, and installation locations and have been made with an equipment list derived from the schematic shown in Figure 5-13. This list, along with some preliminary data handling rates, was employed in a search for equipment and associated costs. Software/hardware test was manloaded according to the required tasks. These results were factored in accordance with complexity judgments provided by MDAC electronic engineers and software specialists. Field installation has been estimated for commercial plants directly from MDAC Logistics provided manloads, and wiring costs were also estimated directly for commercial by MDAC and the subcontractors.

5.11 MISCELLANEOUS PLANT EQUIPMENT (4500)

This element includes the field communications, transportation and handling equipment, furnishing and fixtures and other maintenance and service equipment. Not included in this element are surveys, design and other engineering work, procurement activities and site construction direction which are included under the Indirect effort or under other subsystem elements. Costs are to provide for site preparation, for all material and equipment, and for the labor and services necessary to transport, fabricate, assemble, install, and checkout materials and equipment at the plant site.

5.11.1 Miscellaneous Plant Equipment Costs

Costs have been estimated by Stearns-Roger and MDAC as follows:

	Recurring (million)		
Title	Material	Labor	Total
Trans & lifting eq	$1.90	$0.28	$2.18
Air & water ser	0.39	0.06	0.45
Communications eq	0.01	0.00	0.01
Furnishings & fix	0.57	0.00	0.57
Total	$2.87	$0.35	$3.21

Table 5-16 provides a description of this equipment.

Table 5-16. Technical Description Miscellaneous Plant Equipment

Communications
Publications, signal lights, radio equipment
Transportation and Handling
Turbine room crane Miscellaneous lifting equipment Receiver panel ship and handling fixture Reflector sling Seg. transporter truck Special field installation and maintenance rig Shipping containers - various Segment lifting device
Furnishing and Fixtures
Lab equipment
Environmental Control
10 acre, lined evaporation pond
Other Equipment
Bearing cooling water pumps (2) Potable water pumps (2) Sump pumps Fire pumps (electric motor and diesel engine-driven) - 1,500 gpm, 200 hp Jockey pump (fire header pressure maintenance) - 50 gpm Bearing cooling water head tank (1) Potable water storage tank (2) - 6,000 gal Service air compressor - 350 SCFM, 100 psig Instrument air compressors (2) - 250 SCFM, 100 psig Potable water filter Instrument air dryer Potable water chlorinator Sewage treatment plant - 4,000 gpd aeration unit Bearing cooling water heat exchangers Service air receiver Instrument air receiver Oil skimmer Ionization facility Heliostat maintenance override unit Receiver tube flush equipment Heliostat cleaning vehicle - 5,000 gal Receiver scaffold Miscellaneous ropes, cables, spanners, platforms, safety gear, drills, etc.

5.11.2 Miscellaneous Plant Equipment Funding

Miscellaneous plant schedule and funding are shown in Figure 5-15. As indicated, the effort starts 40 months prior to IOC and 16 months is allowed for procurement, manufacture, delivery and installation. Funding peaks at $1.6 million in the first half of 1988.

5.11.3 Costing Methodology

Costing is based on Stearns-Roger experience concerning equipment for power plants of this size and on MDAC and Rocketdyne experience in estimating the additional equipment related to the nonconventional portion of the plant. Estimators used 1977 industrial equipment, material, and labor costs reflecting appropriate fabrication, assembly and installation locations. Estimates were made from the equipment list which defines the scope of work. Quotes were obtained or catalogs consulted for equipment and materials relating to the conventional portion of the plant.

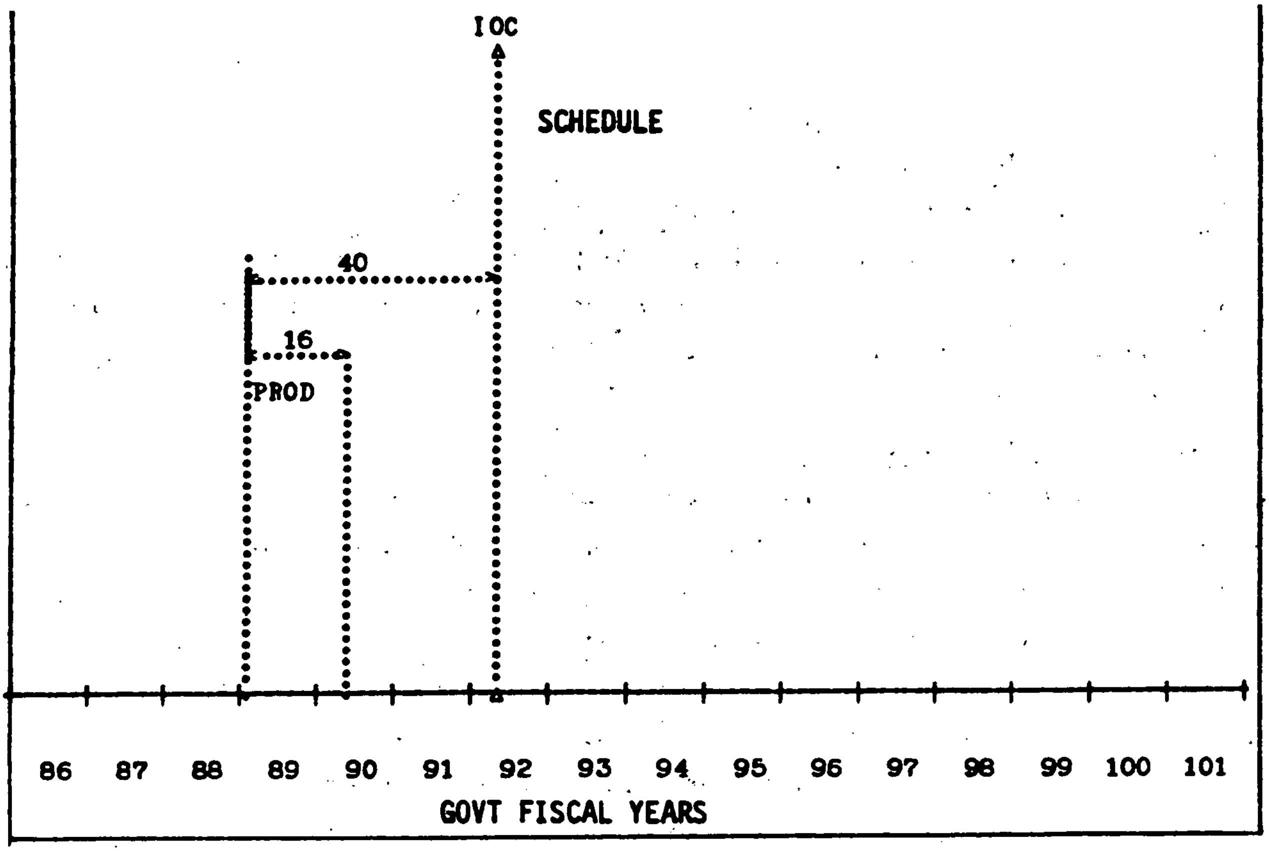
Equipment costs related to the nonconventional portions of the plant were mainly estimated from design concepts. Based on preliminary drawings, detail estimates were made using quotes, catalogs and manufacturing estimating judgment using detail estimating procedures for labor to fabricate special equipment.

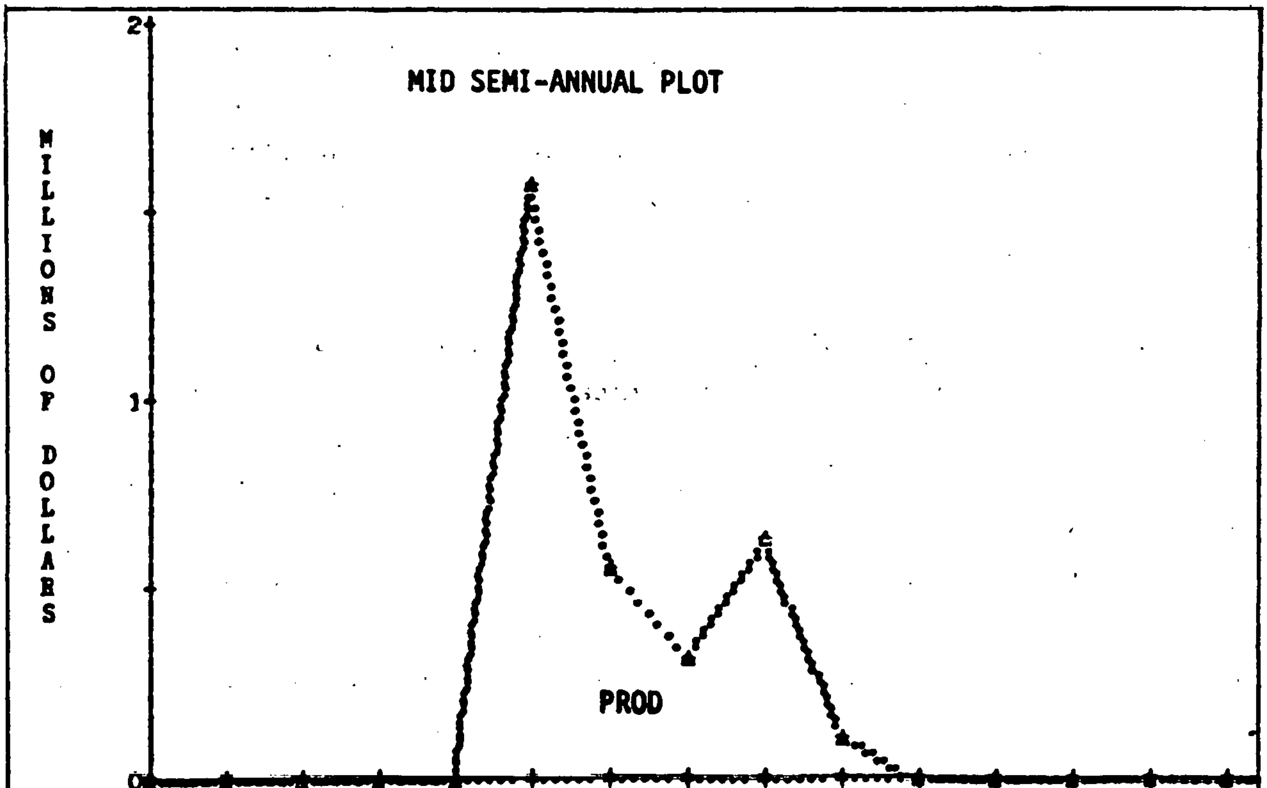
5.12 QUALITY ASSURANCE AT THE INSTALLATION SITE (7000)

No quality assurance costs are indicated because the effort involved is distributed within other CBS costs. Stearns-Roger estimates that Quality Assurance at the construction site generally amounts to 1% of the direct construction labor or 2% of the engineering. Quality is mainly assured before the hardware reaches the site and may amount of anywhere from 5 to 20% depending on the hardware and the "hardness" of tooling. Of course, final quality is assured through the considerable amount of subsystems and system checkout and startup effort that has been costed in other CBS elements.

5.13 DISTRIBUTABLE AND INDIRECTS COSTS (8000 and 8100)

This element includes construction facilities, construction equipment, construction services, A&E services, solar integrator, construction manager, startup, and other costs.





GFY	1986	1986	1987	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992	1992
DDT.E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	0.0	0.0	0.0	1.6	.6	.3	.6	.1	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	0.0	1.6	.6	.3	.6	.1	0.0	0.0	0.0	0.0	0.0

Figure 5-15. Miscellaneous Plant Equipment Summary Chart

The costs charged to this element are to provide for the labor, material and equipment required to design, specify, contract, support construction, manage, train for, activate, checkout, and support the checkout program for the conventional portion of the plant and to generally manage systems.

5.13.1 Distributable and Indirects

Costs of this element as estimated by Stearn-Roger and MDAC are as follows:

Title	Recurring (million) Material	Labor	Total
Distributables	$2.91	$ 5.19	$ 8.10
Indirects	0.00	17.50	17.50
Total	$2.91	$22.69	$25.60

Table 5-17 provides detailed cost, and Table 5-18 provides a more detailed description of these costs. No cost is shown for 8040.2, "Insurance; Construction Equipment and Autos", because this cost is covered under 8040.4, "Construction Equipment." Taxes are covered in labor rates or not applicable.

5.13.2 Distributable and Indirects Cost Funding

The schedule and funding for this element are shown on Figure 5-16. The effort starts 67 months prior to IOC and continues throughout the production effort. This span is required to cover indirect effort, but the distributables are funded over a shorter span beginning just before the start of field construction.

5.13.3 Cost Methodology

Costing is based on Stearns-Roger experience concerning indirect costs for power plants of this size and utilizing current industrial equipment, material and labor costs reflecting the Barstow area for the first commercial plant as well as MDAC experience. Cost analysis of recent conventional plants has been made to determine appropriate experience factors and the results applied to the direct field cost to estimate construction facilities,

Table 5-17. Distributables and Indirects Cost Detail (Page 1 of 2)

80 AND 81 SERIES WBS FIRST COM 19,01,57, DATE: 77/05/24,

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NR+R
8030	CONTRACTOR F,O, P	0,00	0,00	,91	,91	,91
8040	OTHER CONSTR, ITEM	0,00	2,91	4,28	7,19	7,19
8000	SUBTOTAL	0,00	2,91	5,19	8,10	8,10
8100,1	A-E SERVICES	0,00	0,00	5,40	5,40	5,40
8100,2	CONSTRUCTION MGMT	0,00	0,00	8,68	8,68	8,68
8100,3	SOLAR SUBSYS,INT,	0,00	0,00	1,25	1,25	1,25
8100,4	ENGR,-DES, OF S,S	0,00	0,00	,00	,00	,00
8100,5	MASTER CONTROL DE	0,00	0,00	,00	,00	,00
100,6	PLANT START UP -	0,00	0,00	2,17	2,17	2,17
8100	SUBTOTAL	0,00	0,00	17,50	17,50	17,50
8040,1	INSUR,INJ, - DAMA	0,00	0,00	,72	,72	,72
8040,2	INS CONS,EQ,-AUTO	0,00	,00	0,00	,00	,00
8040,3	TEMPORARY CONSTR,	0,00	0,00	,61	,61	,61
8040,4	CONSTRUCTION EQ,	0,00	0,00	1,69	1,69	1,69
8040,5	CONSTRUCTION SER,	0,00	0,00	,97	,97	,97
8040,6	SPARE PARTS	0,00	2,91	,29	3,20	3,20
8040,7	FED,-STATE TAXES	0,00	,00	0,00	,00	,00
8040,8	FOREIGN DUTIES-TA	0,00	,00	0,00	,00	,00
8040	SUBTOTAL	0,00	2,91	4,28	7,19	7,19
100,11	PRELIM,DESIGN SER	0,00	0,00	1,62	1,62	1,62
8100,12	DETAILED DES, SER	0,00	0,00	3,78	3,78	3,78
8100,13	ENGR, SUPPORT	0,00	0,00	,00	,00	,00
8100,1	SUBTOTAL	0,00	0,00	5,40	5,40	5,40

Table 5-17. Distributables and Indirects Cost Detail (Page 2 of 2)

80 AND 81 SERIES WBS FIRST COM 19.01.57. DATE: 77/05/24.

WBS	TITLE	NON-RECUR (MIL)	RECURRING (MIL) MATERIAL	LABOR	TOTAL	TOTAL NM+R
8100.41	COLLECTORS	0.00	0.00	.00	.00	.00
8100.42	RECEIVERS	0.00	0.00	.00	.00	.00
8100.43	STORAGE	0.00	0.00	.00	.00	.00
8100.4	SUBTOTAL	0.00	0.00	.00	.00	.00
8100.51	SOFTWARE DESIGN	0.00	0.00	.00	.00	.00
8100.52	HARDWARE DESIGN	0.00	0.00	.00	.00	.00
8100.53	SOFTWARE/HDWR.DES	0.00	0.00	.00	.00	.00
8100.5	SUBTOTAL	0.00	0.00	.00	.00	.00
8040.61	TURBINE PLT EQ.	0.00	.03	0.00	.03	.03
8040.62	ELEC. PLANT EQ.	0.00	.03	0.00	.03	.03
8040.63	COLLECTOR PLT.EQ.	0.00	.92	.29	1.21	1.21
8040.64	RECEIVER EQ.	0.00	1.69	0.00	1.69	1.69
8040.65	THERMAL STORAGE E	0.00	.25	0.00	.25	.25
8040.6	SUBTOTAL	0.00	2.91	.29	3.20	3.20

Table 5-18. Distributables and Indirects (Page 1 of 2)

Construction Management

This CBS item includes:

1. Site management
2. Contracts administration
3. Engineering interpretation
4. Source inspection (materials and manufactured items)
5. Quality Assurance (of on site construction)
6. Labor Relations
7. Safety Inspection
8. Scheduling (and updating)
9. Accounting (computer, cost control, cost trend forcasting, etc.)
10. Material Accountability and Control
11. As-built drawings

Construction Facilities

Included in this CBS item are:

1. Temporary buildings
2. Temporary earthwork and foundations
3. Temporary piping and electrical
4. Plant cleanup
5. Temporary utilities

Construction Equipment

Included in this CBS item are:

1. Contractor's construction equipment
2. Small tools
3. Gas and oil
4. Construction equipment maintenance

Construction Services

Included in this CBS item are:

1. Constructor's field supervision and accounting
2. Field engineer
3. Security
4. Material receiving and warehousing
5. Safety and first aid personnel
6. Telephone and telegraph
7. Field office supplies and equipment
8. All-risk insurance
9. Payroll taxes and insurance
10. Permits

Table 5-18. Distributables and Indirects (Page 2 of 2)

11. General expendable supplies
12. Safety equipment and supplies
13. Operator Training
14. Purchased Utilities

Architect and Engineering Services

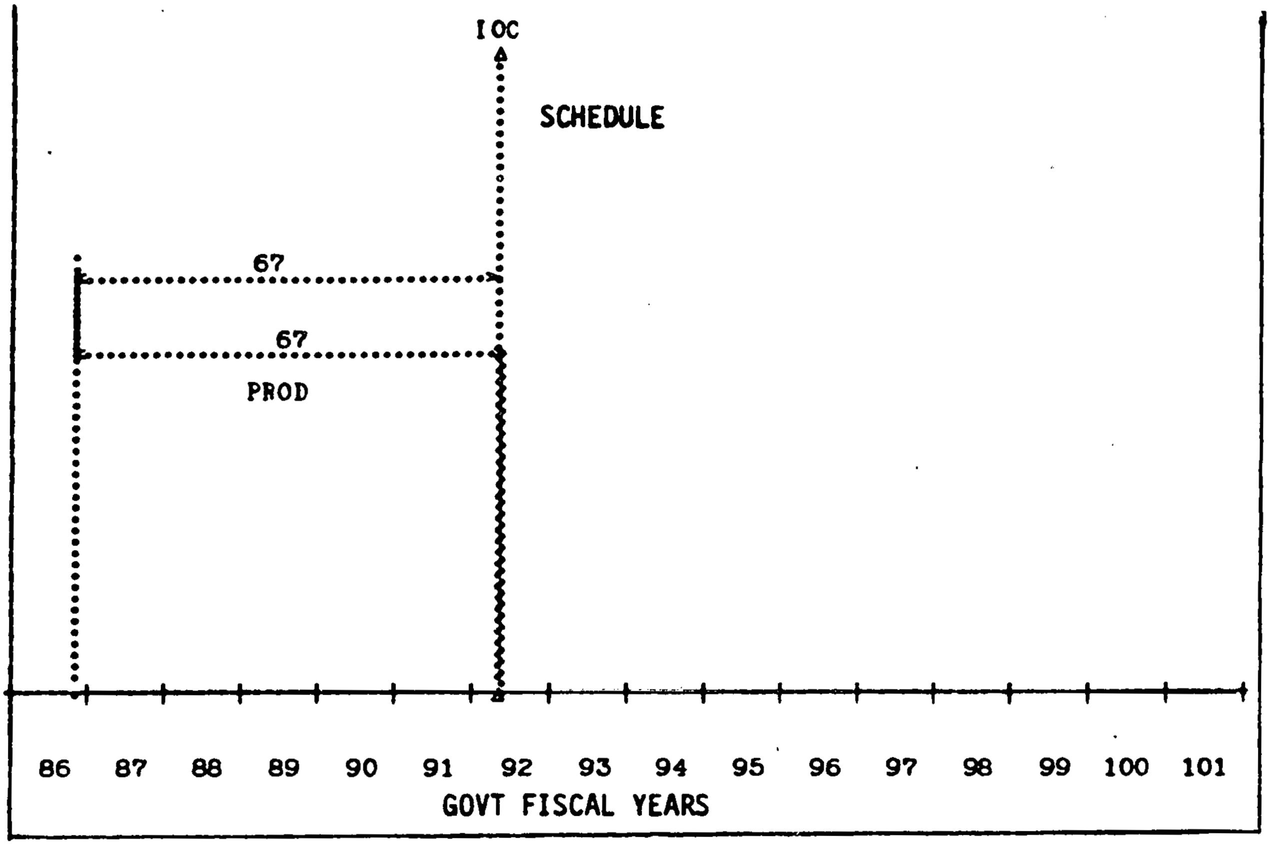
Included in these CBS items are engineering management, preliminary and detailed design services, specifications and procurement of materials and equipment.

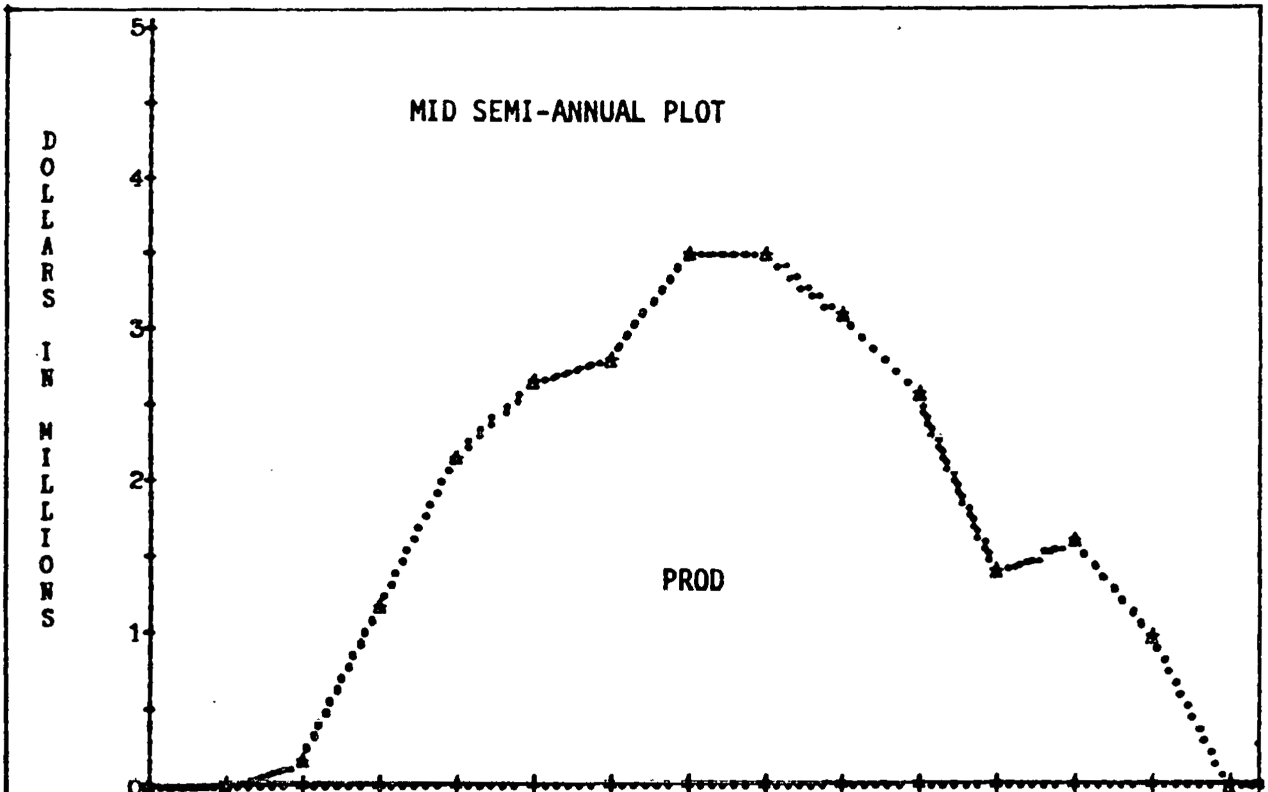
Plant Startup

These CBS items include initial plant startup.

Spares

This item includes initial investment spares for all subsystems.





GFY	1986	1986	1987	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992	1992
DDT•E	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
PROD	0•0	•2	1•2	2•2	2•7	2•8	3•5	3•5	3•1	2•6	1•4	1•6	1•0	0•0
OPER	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0	0•0
TOTAL	0•0	•2	1•2	2•2	2•7	2•8	3•5	3•5	3•1	2•6	1•4	1•6	1•0	0•0

Figure 5-16. Distributables and Indirects Summary Chart

equipment and services costs, and training and startup cost. In addition preliminary training requirements for the nonconventional elements were evaluated and costed based on estimator judgment. A&F construction management and startup costs are also based on experience factors while solar integration contractor costs were manloaded by task. Spares were estimated based on Stearns-Roger experience on plants of similar size for the conventional portion of the pilot plant and on preliminary failure rate data for the unconventional portion of the plant. Spares requirements for the latter type of equipment were determined for each important potential failure item and the resulting quantity extended by unit costs determined in costing the equipment subsystems in order to obtain a cost figure. Spares cost for the conventional equipment were determined using experience factors applied to hardware cost.

5.14 CONTINGENCY (8300)

No contingency is estimated for the commercial system. MDAC has made a "best estimate" of these costs, and notwithstanding inflation, there may be as much reason to believe they will go down as go up considering the possibility of cost saving due to design improvements or breakthroughs or to programmatic innovation. This differs from pilot plant where there is not sufficient time to fully experience such changes. The estimates should be treated more as a target or goal at this time based on good advanced estimating technique and one which American Industry should be able to reach and quite possibly underrun.

5.15 ANNUAL OPERATIONS AND MAINTENANCE (1000, 2000, AND 3000)

This element includes the effort and follow-on spares necessary to operate and maintain the systems and subsystems over a 1-year period.

5.1.5.1 Operations and Maintenance Costs. Costs for the systems operation, have been estimated by Rocketdyne Stearns-Roger, and MDAC, are as follows:

	Recurring (million)		
Title	Material	Labor	Total
Oper & maint	$0.07	$1.68	$1.74
Test prog tech su	0.00	0.00	0.00
Spare parts	0.86	0.38	1.24
Total	$0.93	$2.06	$2.98
EPG & MC	$0.01	$0.00	$0.01
Collector	0.61	0.38	0.99
Receiver	0.15	0.00	0.15
Thermal storage	0.09	0.00	0.09
Total spares	$0.86	$0.38	$1.24

Typical staffing is shown in Table 5-19 and is based on advice provided by Southern California Edison and an analysis of special maintenance requirements by MDAC logistics and supported by the subcontractors.

5.15.2 System Operation Funding

Funding for this phase of the program has been level loaded starting eight months after IOC and continuing for 12 months. The level of funding is $1.5 million per semiannual period, as shown in Figure 5-17.

5.15.3 Cost Methodology

Costing is based on utility experience on conventional plants and on preliminary failure rate data and FMEAs for the unconventional portion of the plant as well as MDAC experience in timelining operational activities. For unconventional equipment maintenance requirements, failure rates were employed to estimate the number of plant-wide failures per year for each important potential failure item. Estimates of the average time required to locate the failure, to remove and replace the item and return have been extended by the failures per year to arrive at expected hours per year.

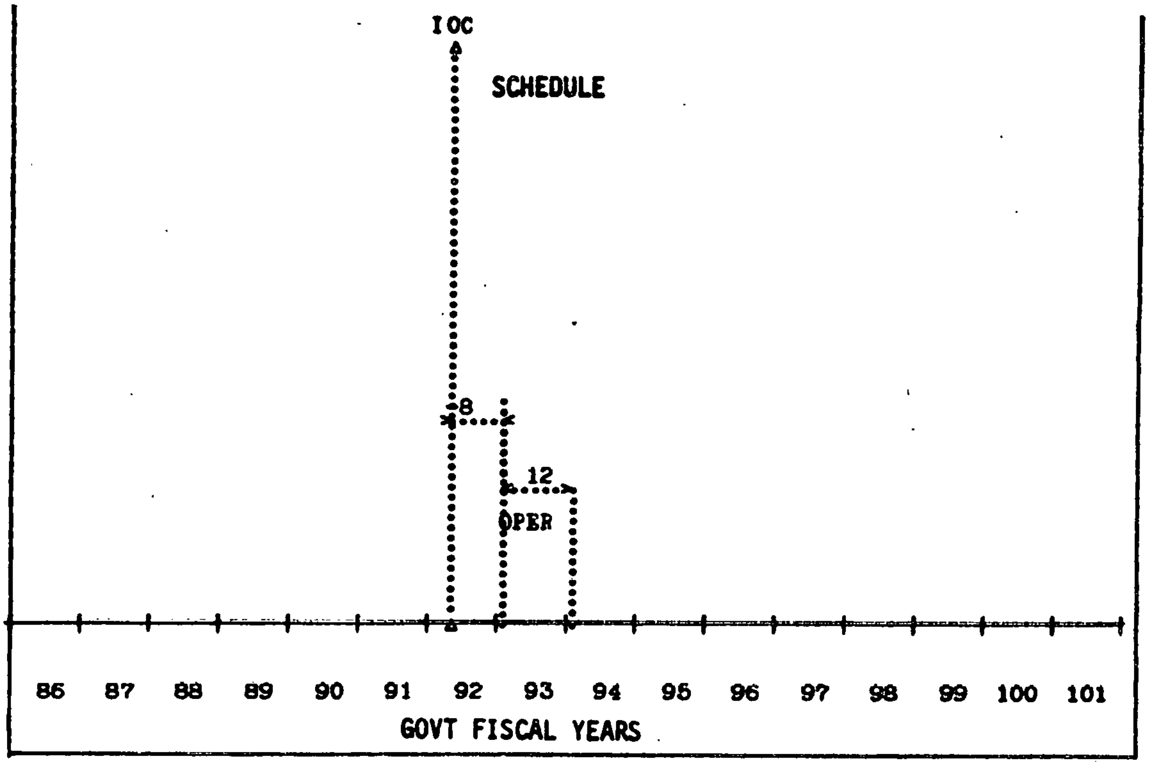
Table 5-19. Technical Description Operation Manload

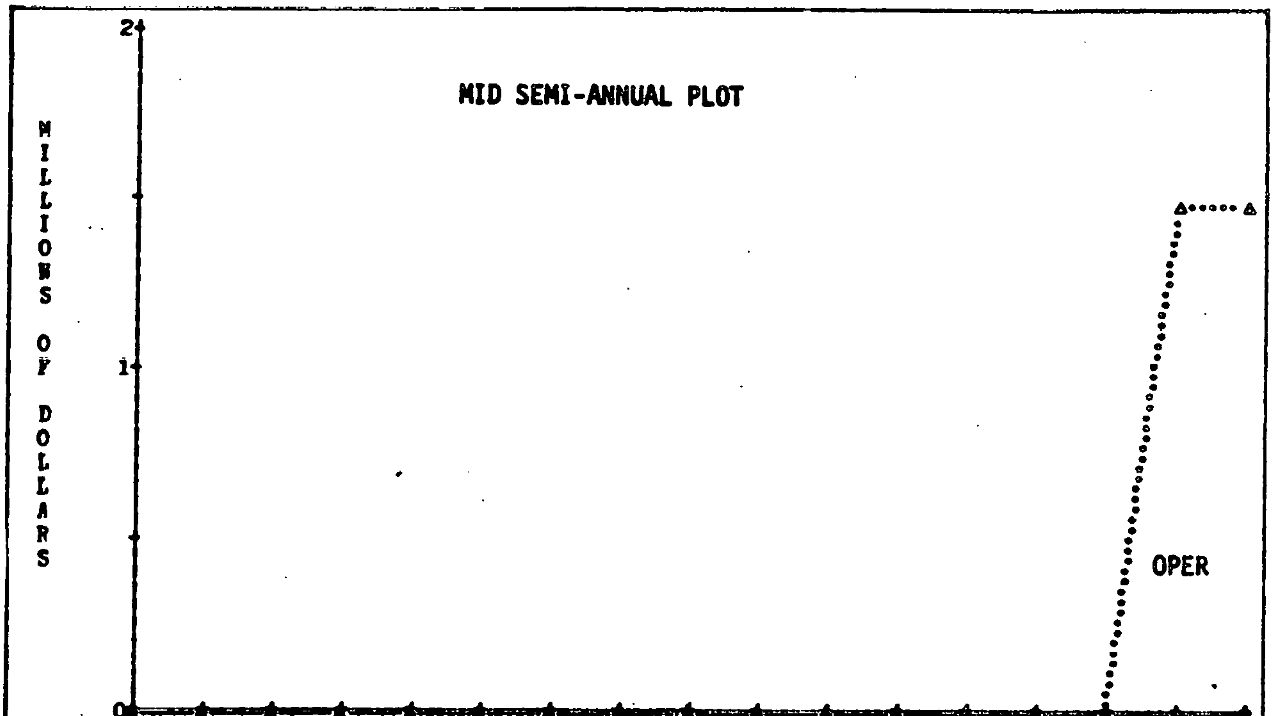
	5 days	7 days
Senior Operator		3
Assistant Operator		1
Plant Engineer		1
Electrical Technician		3
Structural/Mechanical Technician		3
Electromechanical Technician	5	
Mechanical/Electrical Technician	5	
Heavy Equipment Operator	4	
Rigger	4	
Cleaner	20	
	38	11
5 Day Personnel 38		
7 Day Personnel 11 x 7/5 =	15	
Total 5 Day Basis	53	

Master Control Maintenance - Service Contract

Consumables - Washing Solution

Support - Covered in Labor Rates





GFY	1986	1986	1987	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992	1992	1993	1993
DDT•E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.5
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.5

Figure 5-17. Annual Operations and Maintenance Summary Chart

Also, preventative maintenance hours per item have been estimated by Effectiveness Engineering considering failure rates and FMEAs and conventional plant experience on boiler tube. A similar basis was used to estimate repair cost for replaced and repairable parts.

Heliostat cleaning cost has been another area of interest and has been estimated by defining required equipment and manpower to operate the equipment and timelining the effort, assuming use of the resources and a particular cleaning frequency. The results may be directly converted to annual labor, material equipment, and facilities cost.

The results of the above analysis for each subsystem have been complied and integrated with the functional manning estimate for a conventional plant to determine plant staffing requirements. In addition, an allowance for contract labor support to handle minor nonrecurring modifications and construction problems during the initial phase has been included as a percentage of O&M and other test operations phase costs.

Spares were estimated based on Stearns-Roger experience on plants of similar size for the conventional portion of the plant and on preliminary failure rate data for the unconventional portion of the plant. Spares requirements for the latter type of equipment were determined for each important potential failure item and the resulting quantity extended by unit costs determined in costing the equipment subsystems in order to obtain a cost figure. Spares cost for the conventional equipment were determined using experience factors applied to hardware cost.

The master control maintenance contract is based on published quotes for monthly maintenance on each item of equipment. Additional costs for this item prior to the operation phase are included in the master control investment costs. Washing solution costs are based on vendor quotes.

Section 6
PLANT PERFORMANCE DATA

The purpose of this section is to provide detailed performance estimates for the baseline commercial system in direct response to the Sandia cost and performance data request letter of December 15, 1976. The baseline commercial system which served as a reference for these performance predictions was one rated at 100 MWe with a solar multiple of 1.7 and a 6-hour storage capability (at a 70 MWe net output). A detailed discussion of the baseline commercial system is contained in Volume II, Section 3.

6.1 COLLECTOR FIELD PERFORMANCE

The overall performance of a collector field can be expressed as the product of a geometric performance factor and an optical or attenuation factor. The geometric factor includes considerations of field cosine, blocking and shadowing between adjacent heliostats, blocking and shadowing resulting from sensor posts (if closed-loop control is used) and the tower, and receiver spillage resulting from heliostat flexure, guidance, and alignment errors. The overall geometric factor for various sun elevation and azimuth angles is shown in Figure 6-1. Only physically possible sun locations are treated which are bounded by the light dashed lines labeled winter solstice and summer solstice. Implicit in this figure is a constant receiver interception factor of 0.958. This value was arrived at by using the following heliostat error budget:

- Surface flexure (1σ) 2.88 mrad
- Guidance (flat error) ±0.6 mrad
- Alignment (1σ) 2.50 mrad

with all Gaussian distributions truncated at 2 and assuming a 3 point vertical aim strategy on the receiver of 0, ± 6 m. Although the interception factor was defined for an equinox noon operating point, further analysis has indicated that it holds at a reasonably constant average level throughout the year, with some minor discrepancies occurring at low sun elevation angles. Excluding the heliostat flexure error defined above which accounts for heliostat panel-to-panel variations in reflected beam accuracy due to structural deflection, no additional error was included for surface waviness of the individual glass panels. Such waviness errors depend on the quality of the glass and the panel

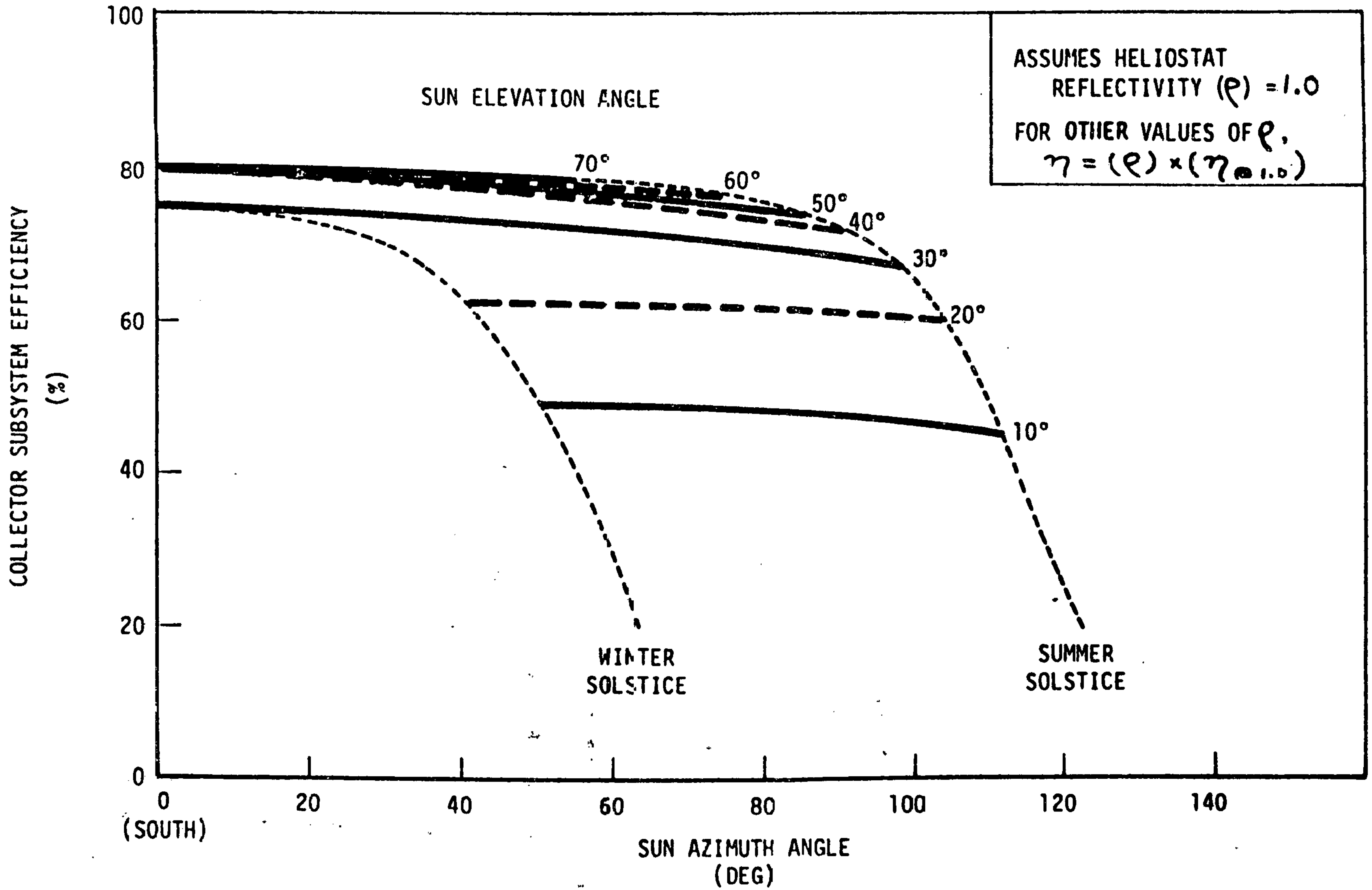


Figure 6-1. Collector Field Performance

fabricating techniques and equipment. Since this error is in general fairly small for panels of acceptable quality, it was ignored for this exercise. On-going investigations are concerned with the nature of surface waviness errors and methods to minimize their effects.

The results of a separate beam interception analysis carried out for the baseline pilot plant configuration are shown in Table 6-1. When extended to the commercial system, these results are somewhat optimistic since the overall interception factor for the commercial receiver is generally 2 percent lower than the corresponding pilot plant value. In using the data presented in Table 6-1, a root-sum-squared summation process should be applied to all entries to estimate the actual spillage. The summation process should include all entries in the column labeled "Independent of Wind and Temperature" plus those wind and temperature related quantities at the wind speed and temperature level of interest.

As backup material for the spillage analysis presented in Table 6-1, a summary of the detailed heliostat error analysis is presented on the five pages which make up Table 6-2. The first two of these pages treats errors which would be common to both a closed-loop (beam sensor) control system or an open-loop (computer) control system. The third page of the tabulation treats errors which would be expected if the closed loop sensor control concept were employed. By contrast, the errors anticipated for two different open-loop control concepts are shown on the fourth and fifth pages of the table. The concept analyzed on page 4 employs a position sensor on the output drive devices while the data treated on page 5 corresponds to a system which employs a drive motor revolution counter.

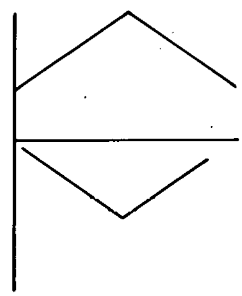
The collector field optical or attenuation factor which make up the second part of the overall collector field performance estimate include heliostat reflectivity, atmospheric attenuation and the impact of dirt accumulation and washing cycles on the mirror surface. The commercial system heliostat reflectivity of 0.94 was assumed for a newly installed heliostat. Based on data gathered during the heliostat SRE test program, an additional penalty of $\sim$3% was imposed to represent an average unwashed condition. Thus, an

Table 6-1. Closed-Loop Tracking Accuracy and Spillage

Error source	Accuracy (mr) Az/El** σ (rms)	Ind. of wind and ref temp	Percent spillage (∿σ)* Winds (m/p) 0	Winds (m/p) 3.5	Winds (m/p) 8	Winds (m/p) 12	Temperature (°C) 0	Temperature (°C) 15	Temperature (°C) 28	Temperature (°C) 35
1. Tower/Receiver	0.4/0.1	0.1	0	0	0.1	0.2	0.1	0.1	0.1	0.1
2. Surface Waviness	1.0/1.0	0.6	0	0	0	0	0	0	0	0
3. Specular Dispersion	0.8/0.8	0.5	0	0	0	0	0	0	0	0
4. Surface Bending										
A. Gravity	0.7/0.7	0.4	0	0	0	0	0	0	0	0
B. Winds	0.6/0.8	0	0	0	0.2	0.5	0	0	0	0
C. Temperature	0.7/1.0	0	0	0	0	0	1.5	0.6	0	0
5. Mirror Alignment	1.0/1.0	0.6	0	0	0	0	0	0	0	0
6. Control Dynamics	0.8/0.8	0.3	0	0	0.2	0.4	0	0	0	0
7. Sensor	0.7/1.2	0.4	0	0	0.2	0.5	0.2	0.2	0.2	0.2

*NOTE: Spillage does not have a normal distribution
**SRE data has been used to establish these numbers.

Table 6-2. Reflected Beam Errors Common to Both Closed and Open Loop(1) (Page 1 of 2)

Error source	Azimuth (mr) σ (rms)	Elevation (mr) σ (rms)	Subsystem Requirement	Comment
1. Tower/Receiver	Near/Far*	Near/Far		
A. Wind and temperature	0.4/0.2	0	Tower movement caused by design environment winds and temperature shall not move the tower in the horizontal direction more than 2 in (1σ) or ± 4 in (95%).	Structure analysis indicates that the bending at 26 mph will be 1 in.
B. Foundation	0.2/0.1	0.2/01	The foundation shall be constructed in such a manner that the degree of sinkage or foundation time creep will not cause the center of the tower to move more than 1 in (1σ) or ± 2 in (95%) in the horizontal and vertical direction between alignment periods.	
2. Surface waviness	1.2	1.2	After mounting glass, slope from normal shall be less than 0.6 mr (1σ).	Based upon SRE test data.
3. Specular dispersion	0.8	0.8	Before glass is mounted, 95% of reflected beam shall be within 4 mr.	Based upon SRE test data.
4. Surface bending				
A. Gravity	0.5	0.5	Bending from gravity shall not cause slope more than shown.	Based upon a structure analysis program (NASTRAN) and solar power collection system model (CONCEN).
B. Winds (Static 26 mph)	0.6	0.8	Same	
C. Temperature (60°→104°F)	0.6	0.8	Same figure  Error Slope	
5. Mirror alignment	1.0	1.0	After mounting mirror, the normal of each mirror normal shall be within 0.5 mr (1σ) of desired normal.	
6. Refraction (Heliostat/receiver)	0	0.3	Environmental	
Total (RSS)	2.1	2.2		

*Near/far refers to the location of the heliostat with respect to receiver

Table 6-2. Reflected Beam Errors Common to Both Closed and Open Loop(1) (Page 2 of 2)

Error source	Azimuth (mr) σ (rms)	Elevation (mr) σ (rms)	Subsystem Requirement	Comment
1. Control system	Near/Far	Near/Far		
A. No winds	0.3	0.2	a. Motor pulse granularity shall not be more than 2 rev/pulse.	Based upon SRE data. Includes effect of hysteresis, backlash, etc.
B. Signal granularity	0.2	0.2	b. A/D converter shall be at least 8 bits.	
C. Winds	0.7	0.4	Backlash of 1 mr	Based upon SRE data and Monte Carlo simulations. Winds of 20/6 mph.
2. Sensor				
A. Alignment	0.5/0.2	0.5/0.2		
B. Foundation movement between alignment	0.2	1.0	Foundation shall maintain pole in vertical direction within 1 m(σ) between alignment periods.	Based upon SRE data, has some temperature effects in data.
C. Movement caused by			Pole bending frequency shall be greater than 2 Hz. Filter shall reduce oscillation by at least a factor of 4.	May require a higher data sample rate than 2 seconds.
a. Winds	0.1	0.2/0.1		
b. Temperature	0.1	0.7/0.4		
D. Slope error	0.2	0.2	The sensor slope shall be ± 0.023°/V (95%) of the nominal value.	
E. Intercept	0.1	0.1	At 0 voltage reading, the beam error shall be less than ± 0.2 mr (95%)	
F. Rotation	0.1	0.1	Rotation axis of sensor shall have coupling error less than 0.1 mr (1σ).	
3. Alignment of sensor mirrors	0.5	0.5		
Total (RSS)	1.1/1.0	1.5/1.3		
1. Control system				
A. No winds	0.3	0.2	a. Single pulse to motor shall not result in more than 2 rev.	Based upon SRE data. Includes effect of hysteresis, backlash, etc.
B. Signal granularity	0.4	0.4	b. 13 bit accuracy on drive output location.	
C. Winds	0.7	0.4	Compliance not less than 130,000 in-lb/deg. Backlash less than 1 mr.	Based upon SRE data and Monte Carlo simulation. Winds of 20/6 mph. α = 90°, β = 135°
2. Refraction (Sun to heliostat)	0.1	0.4	Software refraction model shall be accurate within 0.4 mr.	Requires software to calculate atmospheric refractions model. Error based upon radar refraction models. Could use one sun tracker.
3. Command (After alignment see error budget for command calculation)	2.0	2.0	Alignment method shall be accurate to less than 0.8 mr.	
4. Pedestal foundation Movement between alignments	1.5	1.5	Foundation will not allow pedestal to move more than 0.75 mr (1σ) in a 4 month period.	Based upon SRE data over four month data. Questions on measurement accuracy of data.
5. Bending from drive to mirror structure	0.3	0.6		Based upon structure analysis program (NASTRAN)
6. Pedestal deflection from winds	0.6	0.6		
Total (RSS)	2.7	2.8		
1. Control system				
A. No winds	0.8	0.8	Backlash less than 1 mr	Based upon SRE data. Includes effect of hysteresis.
B. Sensor granularity	0.1	0.2	One revolution counter	
C. Winds	3.9	1.8	Compliance not less than 130,000 in-lb/deg. Backlash less than 2 mr.	Based upon SRE data and Monte Carlo simulation. Winds of 20/6 mph. α = 90°, β = 135°
2. Refraction (Sun to heliostat)	0.1	0.4	Software refraction model shall be accurate within 0.4 mr.	Requires software to calculate atmospheric refraction model. Error based upon radar refraction models. Model would not require measurement of atmospheric conditions.
3. Command (After alignment see error budget for command calculation)	2.4	2.4	Alignment method shall be accurate to less than 1 mr.	
4. Pedestal foundation movement between alignment	1.5	1.5	Foundation will not allow pedestal to move more than 0.75 mr (1σ) in a 4 month period.	Based upon SRE data over four months. Some question as to accuracy of measurements.
5. Bending from drive to mirror structure	0.3	0.6		
6. Pedestal deflection from winds	0.6	0.6		Based upon structure analysis program (NASTRAN)
7. Gravitational moment	0	0.3	Gravitational moment shall be known within ± 27% (2σ).	Software will have to calculate gravitational moment and compensate elevation command.
Total (RSS)	5.0	3.6		

effective reflectivity of 0.91 was assumed in sizing the commercial system. The atmospheric attenuation factor appropriate for the commercial system depends on the local nature of the environment, particularly water vapor and aerosol content in the air. Analysis carried out using the LOTRAN II computer code indicated that an average transmittance factor of 0.953 would exist assuming a subarctic winter environment and a 50 km (31 mile) visible range. Combining the reflectivity and atmospheric attenuation effects into a common optical factor, a value of 0.867 would be an appropriate adjustment factor to the previously discussed geometric factors.

From a collector field operational standpoint, the heliostats would be activated in the morning as soon as they are capable of making a positive energy contribution to the system even in the form of a net component heatup. In theory, the heliostats could be activated as soon as the sun crosses the horizon. In reality, a series of factors make such an early startup somewhat factitious. These factors include the generally poor isolation at low sun angles, excessive blocking and shadowing between adjacent heliostats, and natural obstructions which occur in the surrounding terrain. Current estimates indicate that these factors should lose their significance by the time the sun reaches a 10 sun elevation angle. It has been assumed in all MDAC commercial system performance predictions that the receiver on the average will be producing derated steam by a 15° sun elevation angle. Startups prior to this time will depend to a great extent on local insolation and terrain conditions for the selected site.

6.2 RECEIVER PERFORMANCE

An estimate of receiver radiation loss as a function of incident power on the absorbing surfaces is shown in Figure 6-2 for both rated and derated steam conditions. The trend of increasing radiation loss with increasing incident power occurs because of the higher metal surface temperatures that result. The 560 MWt upper limit on incident power is a collector field limit. Larger power loads could be accommodated by the receiver although repeated cycling at the higher level would begin to compromise tube life. The limit shown for derated steam operation is due to a Sandia imposed constraint on the thermal storage charging rate. As far as the receiver is concerned,

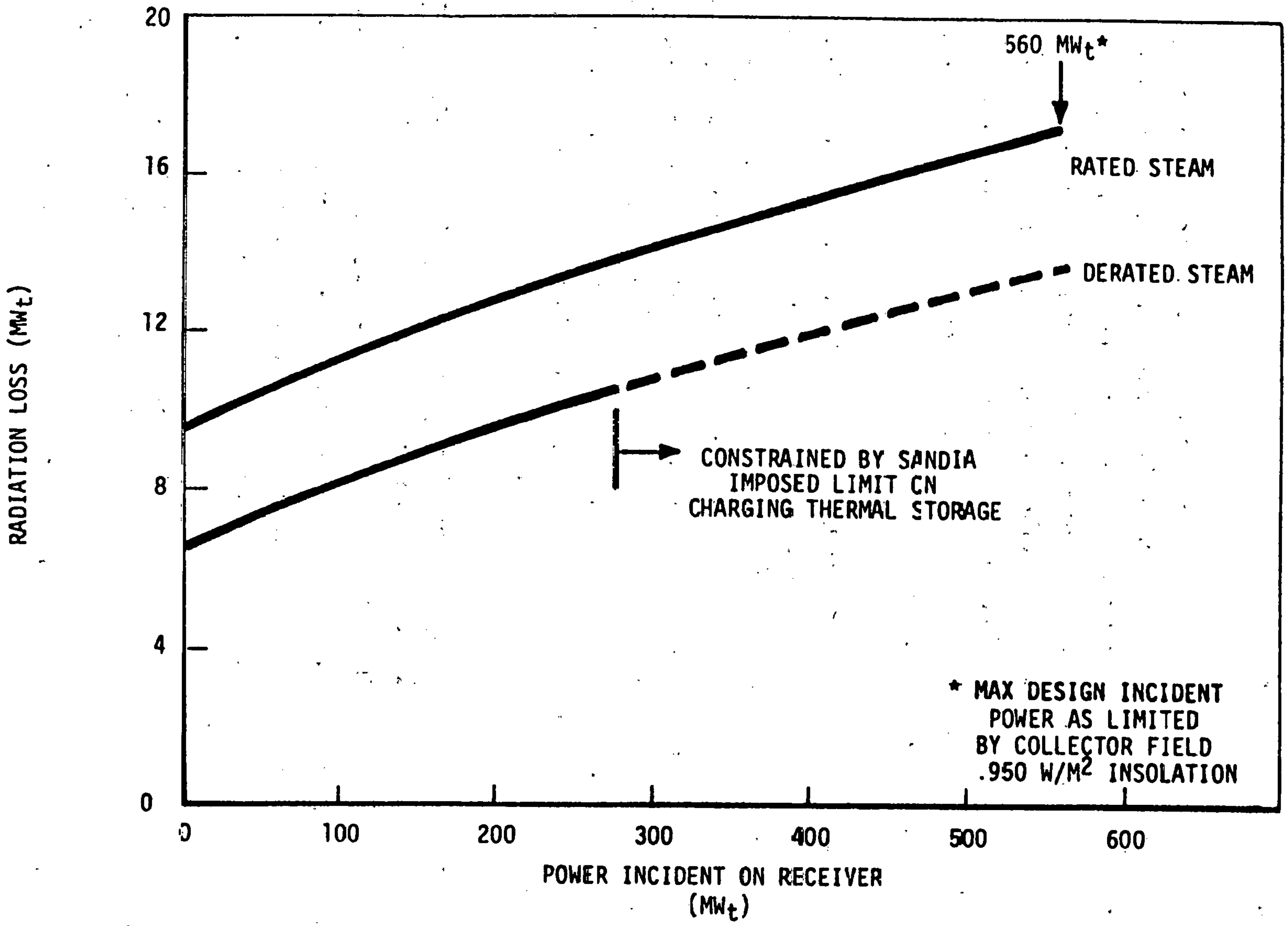


Figure 6-2. Impact of Incident Power on Radiation Loss (Commercial Receiver)

incident power in excess of the 560 MWt could be handled by the panels although insufficient water flow would be a limiting factor before the full 560 MWt level was reached.

An estimate of the convective heat loss for both rated and derated receiver steam operation is shown in Figure 6-3. Since neither forced or natural convection dominates, the indicated values represent a root-sum-squared operation of the two convection components. These estimates assume the maximum design point power is incident on the receiver surface. For a 50% incident power level, the indicated convective losses should be multiplied by 0.953 to account for the slightly cooler average surface temperature which occurs due to the lower incident power level.

The thermal power loss through the main steam lines are shown in Figures 6-4 and 6-5 for the main steam downcomer and horizontal distribution line to thermal storage respectively. The main steam downcomer was assumed to be 45.7 cm (18 in) in diameter with a 5-1/2-in layer of calcium silicate insulation. A downcomer length of 275 m (900 ft) was assumed which includes some expansion provisions. The steam line running from the base of the tower to the thermal storage charging heat exchanger was assumed to be 30.5 cm (12 in) in diameter with a 10.2 cm (4 in) layer of calcium insulation. A total running length of 76.2 m (250 ft) was also assumed.

6.3 MASS FLOW RATE AT TURBINE BUILDING AS A FUNCTION OF POWER

The relationships between mass flow and thermal power at the turbine building are shown for both derated and rated steam operation in Figure 6-6. The inlet to the turbine building was assumed to be synonymous with a point at the base of the tower, just upstream of the tee, which separates turbine and thermal storage steam. A location at the actual inlet to the turbine building, downstream from the tee would never experience a derated steam flow condition. The solid portions of the two lines indicate the anticipated operating ranges practical for the commercial receiver. The lower limits of the two (solid) lines are somewhat arbitrary since they depend on detailed operational behavior of the control valves as well as the exact pressure drop and hydrostat effects of the commercial receiver.

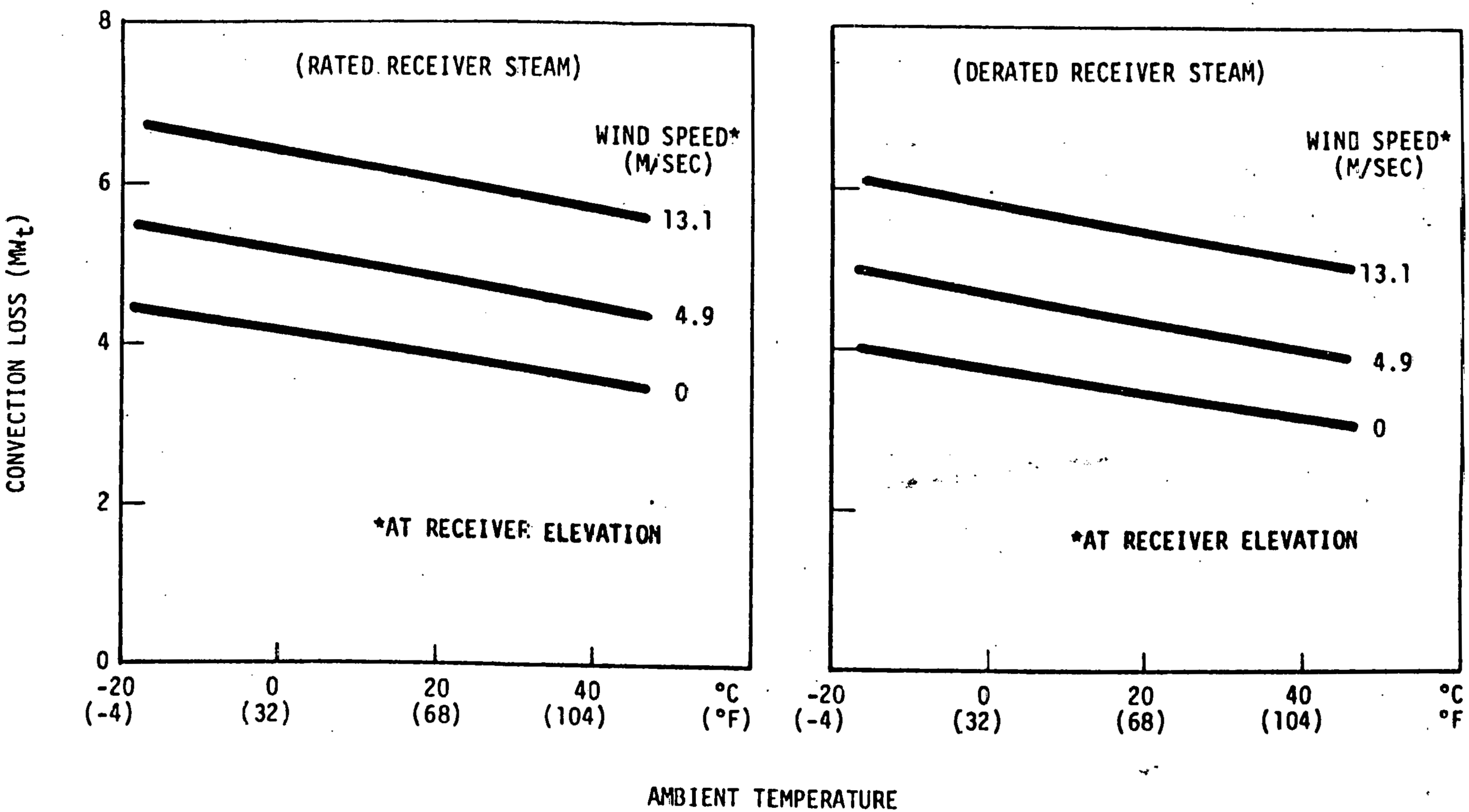


Figure 6-3. Impact of Ambient Temperature and Wind Speed on Receiver Convection Losses (Commercial System)

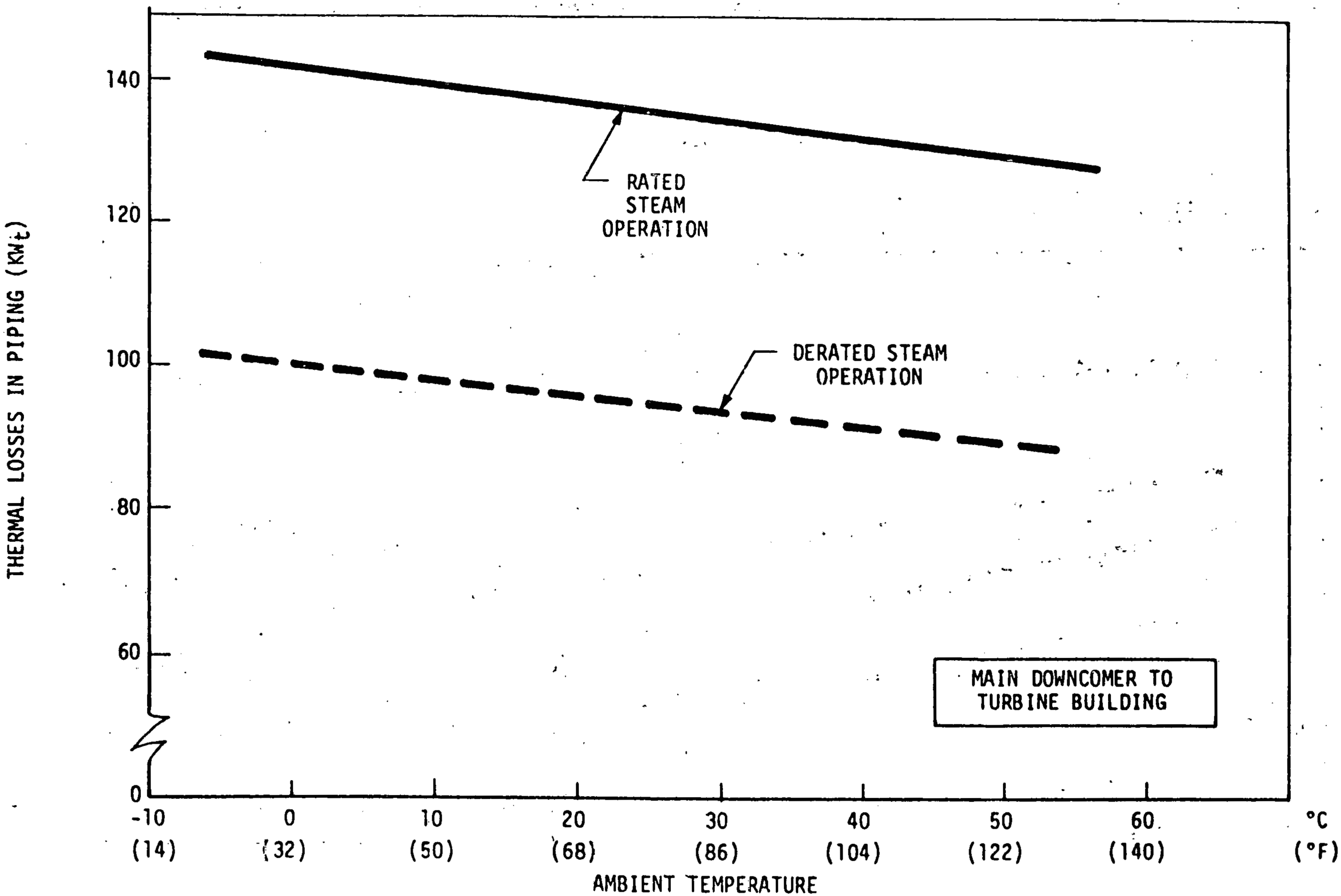


Figure 6-4. Impact of Ambient Temperature on Piping Thermal Losses (Commercial System)

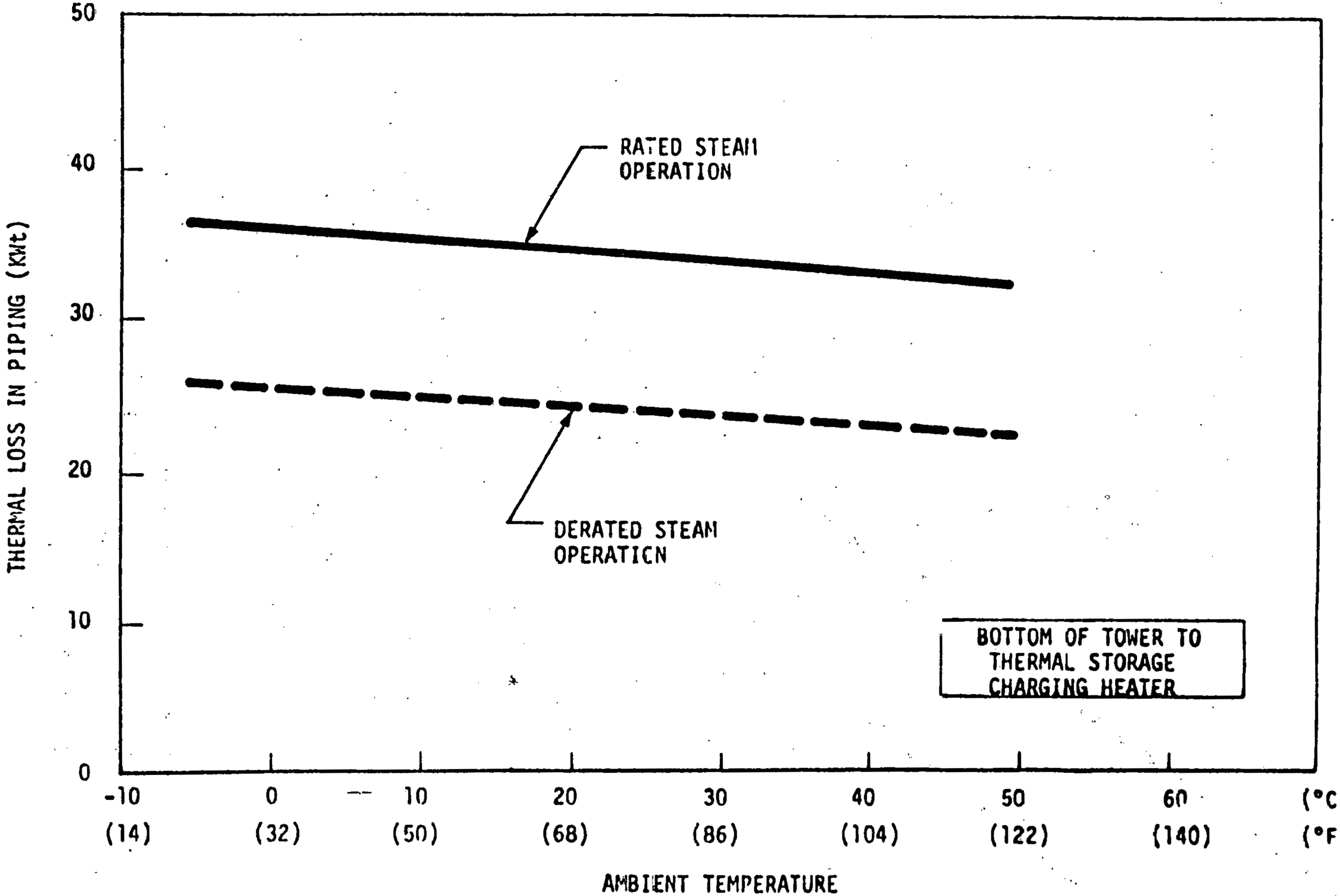


Figure 6-5. Impact of Ambient Temperature on Piping Thermal Loss (Commercial System)

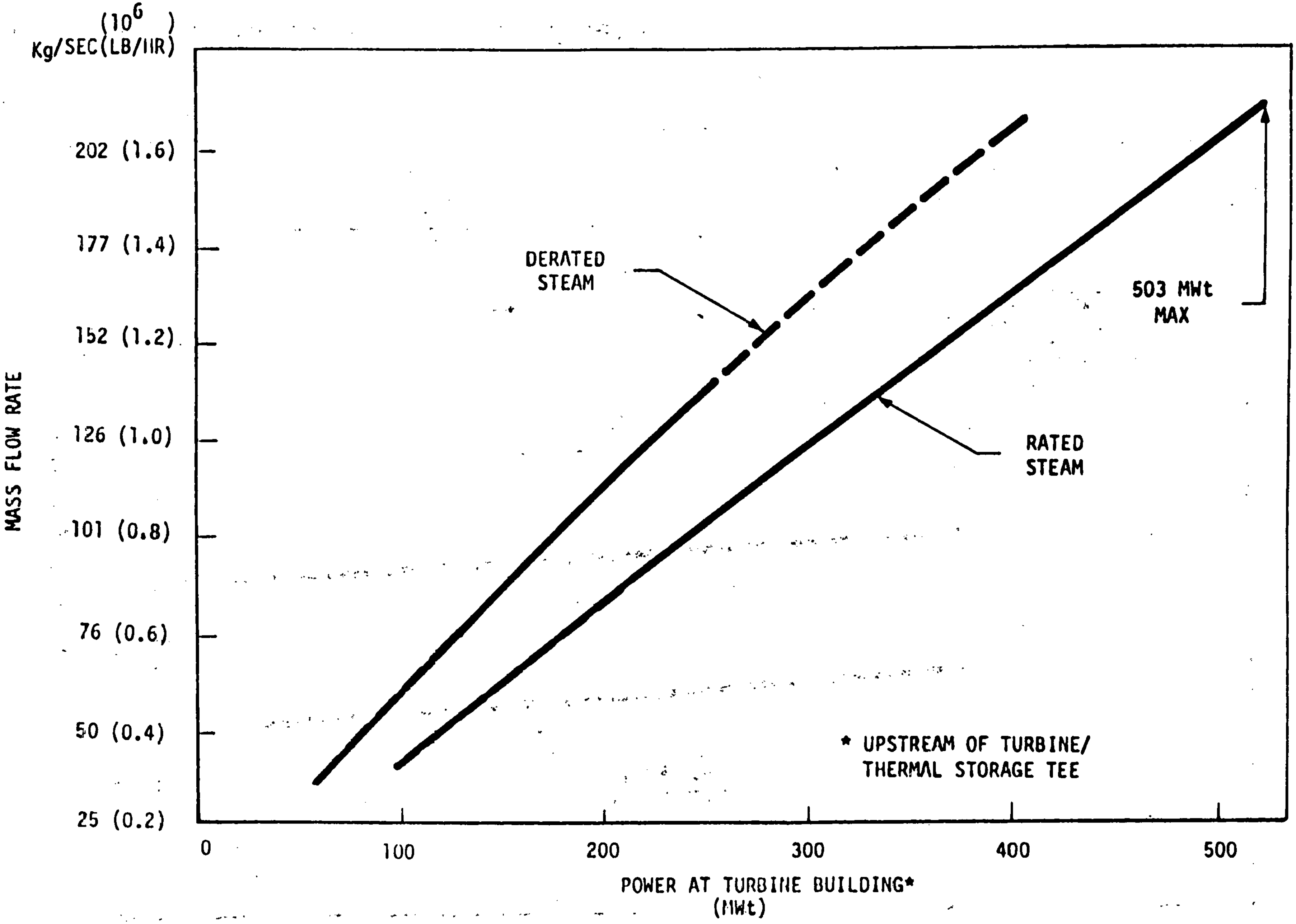


Figure 6-6. Steam Flow at Inlet to Turbine Building*

The top part of the derated steam curve appears dashed since it exceeds the derated steam operational limitation established by Sandia (charging rate for thermal storage shall be 50% of the maximum power absorbed by the receiver or the difference in thermal power between the design system solar multiple and a solar multiple of 1.0). In reality, from a receiver standpoint, there is no reason why the receiver could not be operated to the top of the dashed line which would correspond to the flow limitation established for rated steam. The thermal storage charging equipment, of course, would have to be sized to accommodate the higher derated steam flow rate.

6.4 THERMAL STORAGE CHARGING EFFICIENCY

The thermal storage charging efficiency can be determined by subtracting the sum of the heat losses which occur for the charging equipment from the thermal energy available for charging. The steady state heat losses for the charging components (heat exchangers and piping) were estimated to be 0.04 MWt when the components are at their normal operating temperature. Making the conservative assumption that the heat loss was constant for a 24-hour period, the total daily loss would be 0.96 MWHt. Assuming also that sufficient energy entered the storage tank to fully charge the unit to 1,891 MWHt (see Section 2, Volume V for detailed tank sizing assumptions), the charging efficiency on that day would be 99.95%. If the tanks were less than fully charged during the 24-hour period of interest, a lower efficiency would occur due to the constant equipment thermal loss which represents a constant drain on the thermal energy.

6.5 GROSS THERMAL ELECTRIC CYCLE EFFICIENCY

The gross cycle efficiency of the thermal electric conversion as a function of mass flow is shown in Figure 6-7 for both operating from receiver steam and thermal storage steam exclusively. This data assumes a turbine back pressure of 6.35 cm Hg (2-1/2 in Hg). The maximum and minimum flow rates permitted for the turbine are shown in the figure. The minimum value is approximate since the turbine comes up from zero flow during a startup on either receiver or thermal storage steam. However, a slightly derated steam condition would be used up to about the 25% power level.

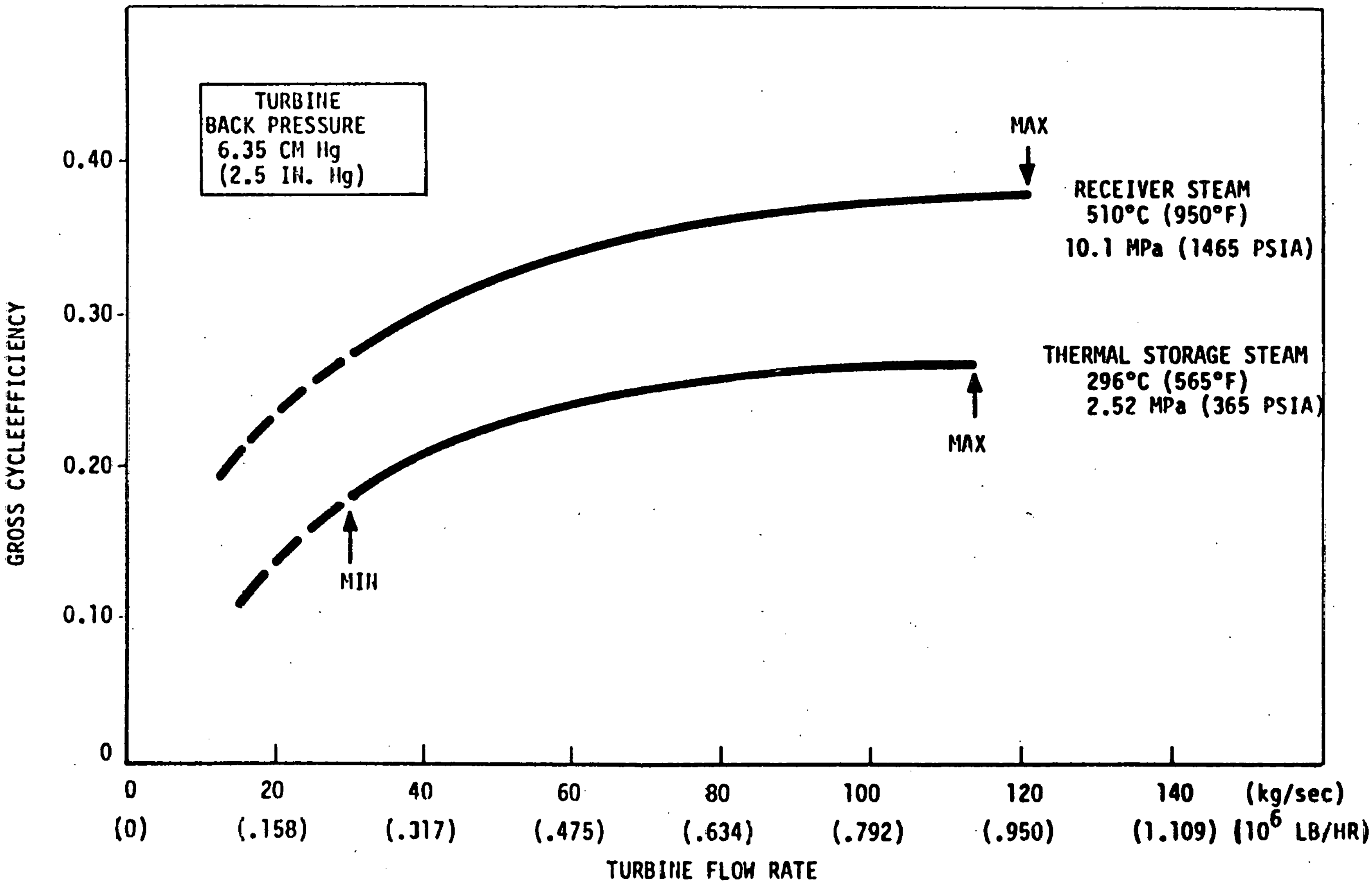


Figure 6-7. Impact of Flow Rate on Turbine Cycle Efficiency (Commercial Turbine)

6.6 NET THERMAL ELECTRIC CONVERSION EFFICIENCY (FROM RECEIVER)

The net thermal electric conversion efficiency for operation directly from receiver steam and operation from thermal storage steam is shown in Figure 6-8 for an assumed 2-1/2 in. Hg turbine back pressure which corresponds to a 23°C (73°F) wet bulb temperature. Since the system uses wet cooling for heat rejection, the turbine back pressure and resulting net cycle efficiency depend on the ambient wet bulb temperature. Appropriate multiplying factors for higher values of wet bulb which are to be applied to the values shown in Figure 6-8 are contained in the following tabulation.

	Multiplying Factors	
Wet Bulb Temp	Operation from Receiver Steam	Operation from Thermal Storage Steam
≤ 23°C (73°F)	0.1	1.0
25.6°C (78°F)	0.997	0.996
31.1°C (88°F)	0.985	0.979
36.1°C (97°F)	0.973	0.958

The curves exclude consideration of the parasitic loads listed in the figure. In general, these would affect the receiver steam curve although the thermal storage curve could be influenced by these if the system were operating in the intermittent cloud mode. The maximum and minimum power outputs are also indicated. These values correspond to the maximum and minimum flow rates defined for the turbine in Figure 6-7. Again, as was discussed in Figure 6-7, the indicated minimum values are approximate.

6.7 NET THERMAL ELECTRIC CYCLE EFFICIENCY (FROM THERMAL STORAGE)

(See Section 6.6)

6.8 MAXIMUM RATE OF CHANGE OF TURBINE GENERATOR OUTPUT

The maximum recommended rate of change of turbine generator load is shown in Figure 6-9, based on data taken from Westinghouse turbine startup instructions for 100 MW non-reheat units. These curves assume that the inlet temperature of the steam is held constant with load changes occurring

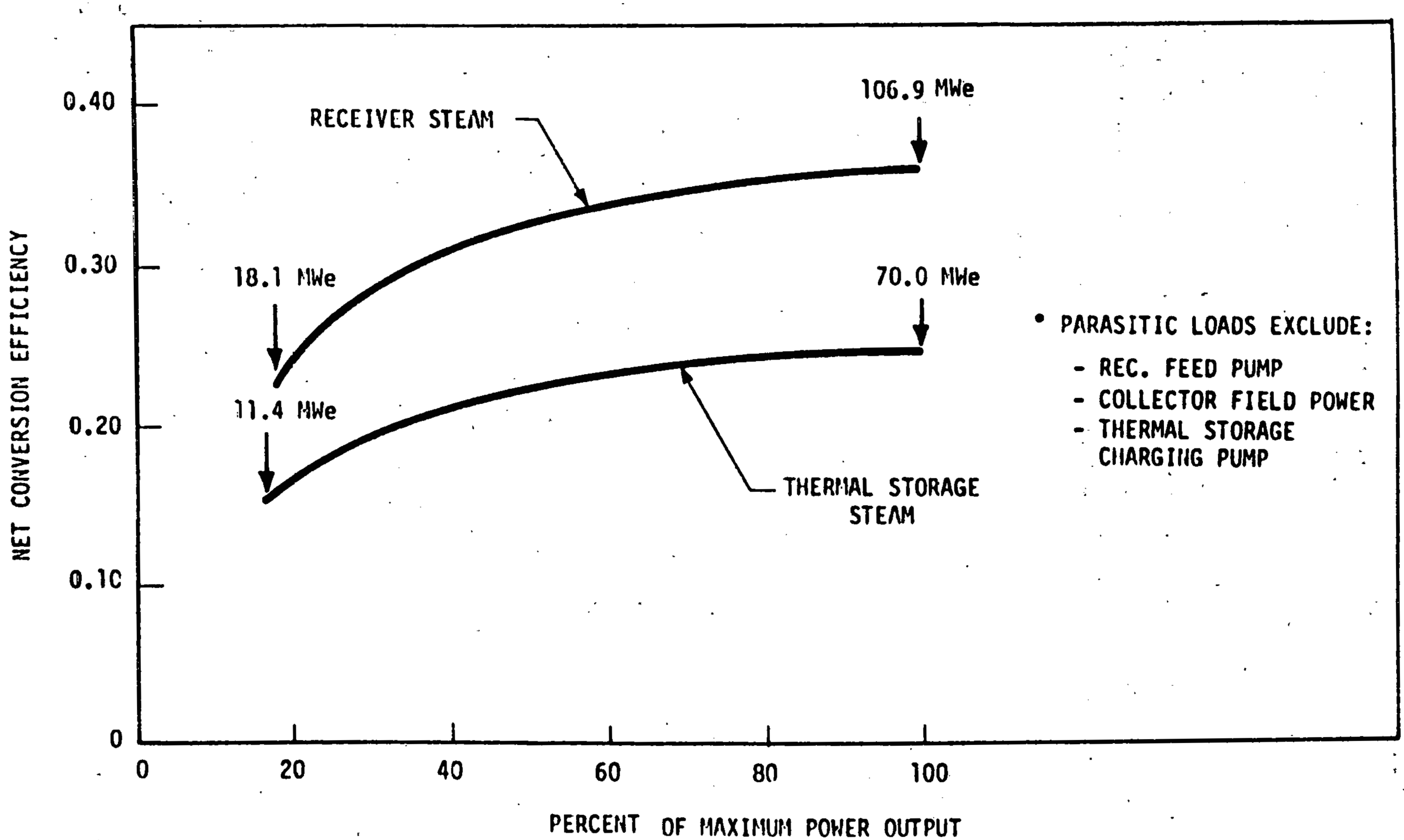


Figure 6-8. Net Thermal Electric Conversion Efficiency (Commercial Turbine)

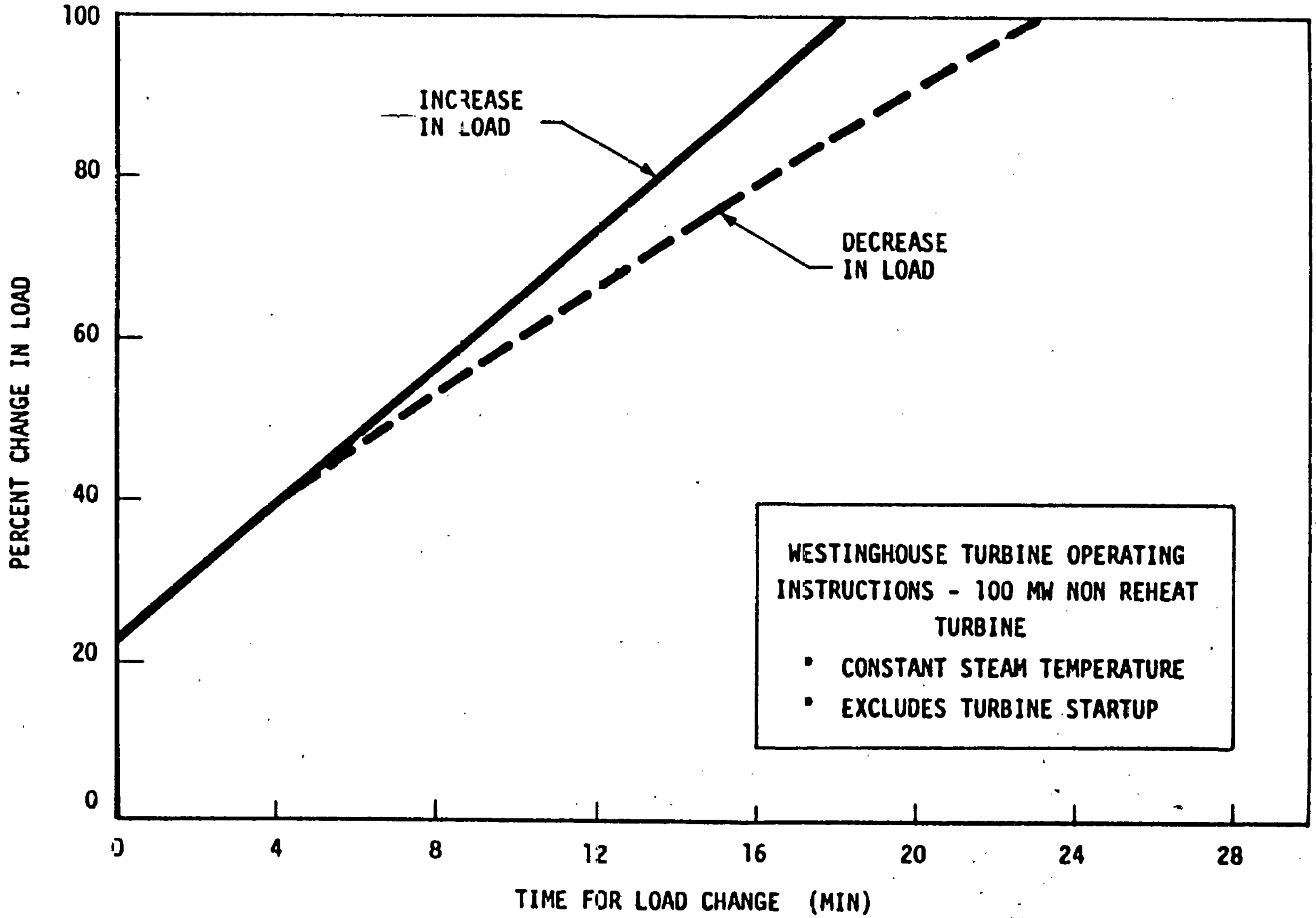


Figure 6-9. Recommended Time Rate of Change of Load (Commercial Turbine)

only as a result of changes in mass flow. It is seen that an instantaneous change of ∿22% in load is acceptable during normal operation. Using this curve, transitions between receiver and thermal storage steam with the resulting change in load could be made in ∿2 min. Under emergency conditions, load changes could be made at a significantly faster rate, particularly during a turbine trip. These curves are to be used during normal turbine operating periods and exclude turbine startup periods.

6.9 AUXILIARY POWER REQUIRED TO CHARGE THERMAL STORAGE

The auxiliary power requirements to charge thermal storage as a function of power at the storage inlet are shown in Figure 6-10. This curve includes not only the thermal storage charging pumps, which consume 750 kW at a charging rate of 255 MWt, but also allocated values of the receiver feed pump and the collector field.

6.10 AUXILIARY POWER REQUIREMENTS FOR RECEIVER FEED PUMPS

The auxiliary power requirements for the receiver feed pumps as a function of percent of maximum flow are shown in Figure 6-11. The curve assumes that the two parallel half capacity pumps are turned down together. If they were turned down sequentially, a slight jog would occur at the point where the first pump were turned completely off and the second pump were operating at its design flow.

6.11 AUXILIARY POWER REQUIREMENTS FOR THE COLLECTOR FIELD

The auxiliary power required to operate the collector field on a steady state basis is 350 kWe. Since the AC motors on the heliostats operate for only a few 60-cycle pulses at a time, at any one time most heliostats would not be drawing power. The 350 kWe represents the time average over the field.

6.12 RECEIVER STARTUP TIME TO DERATED STEAM

The time to start the receiver and begin charging thermal storage depends on the insolation level, the sun location which influences collector field efficiency, and the preheat status of the piping and heat exchanger components. For a warm start condition on an equinox morning, charging of thermal

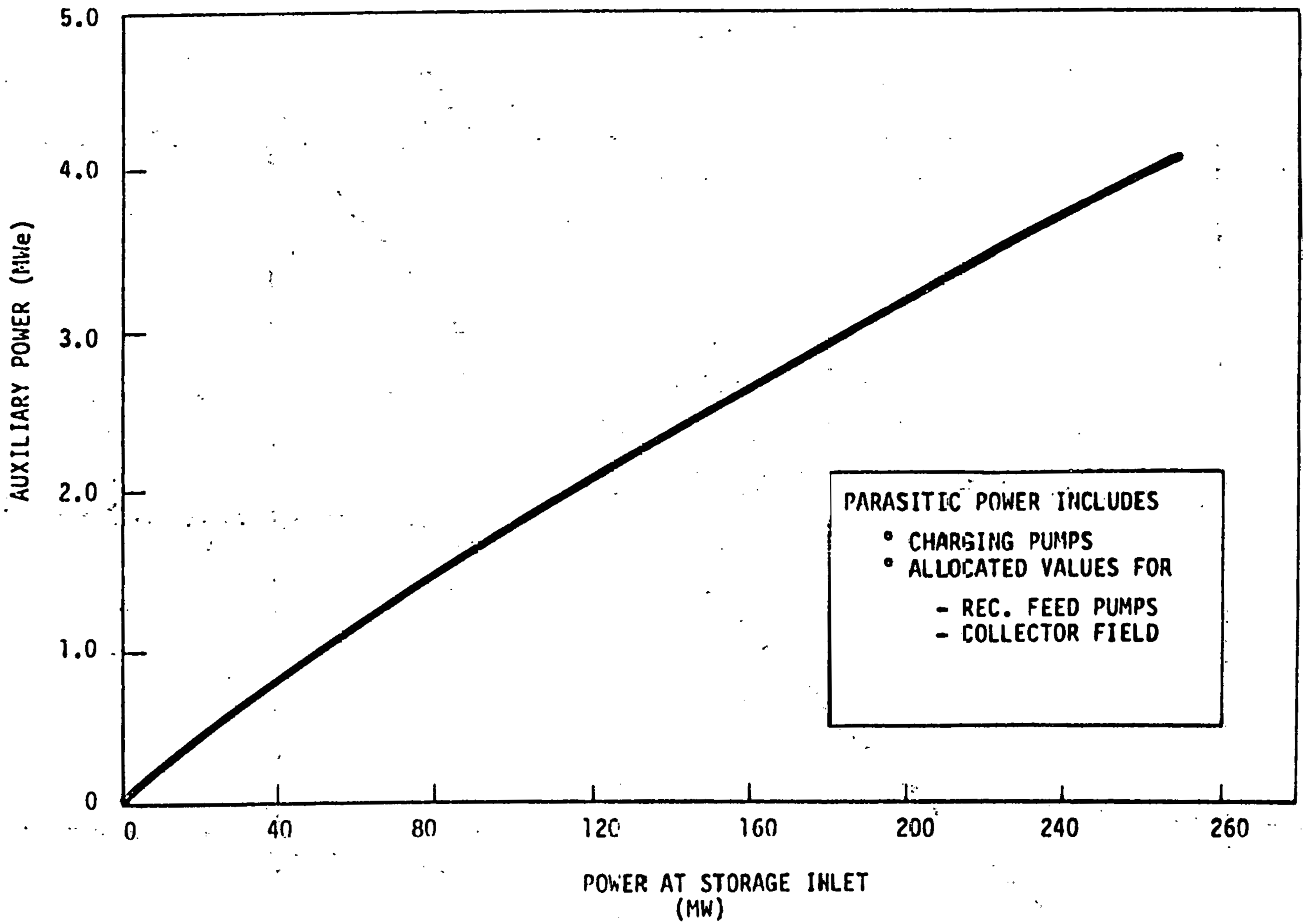


Figure 6-10. Auxiliary Power Requirements to Charge Thermal Storage (Commercial System)

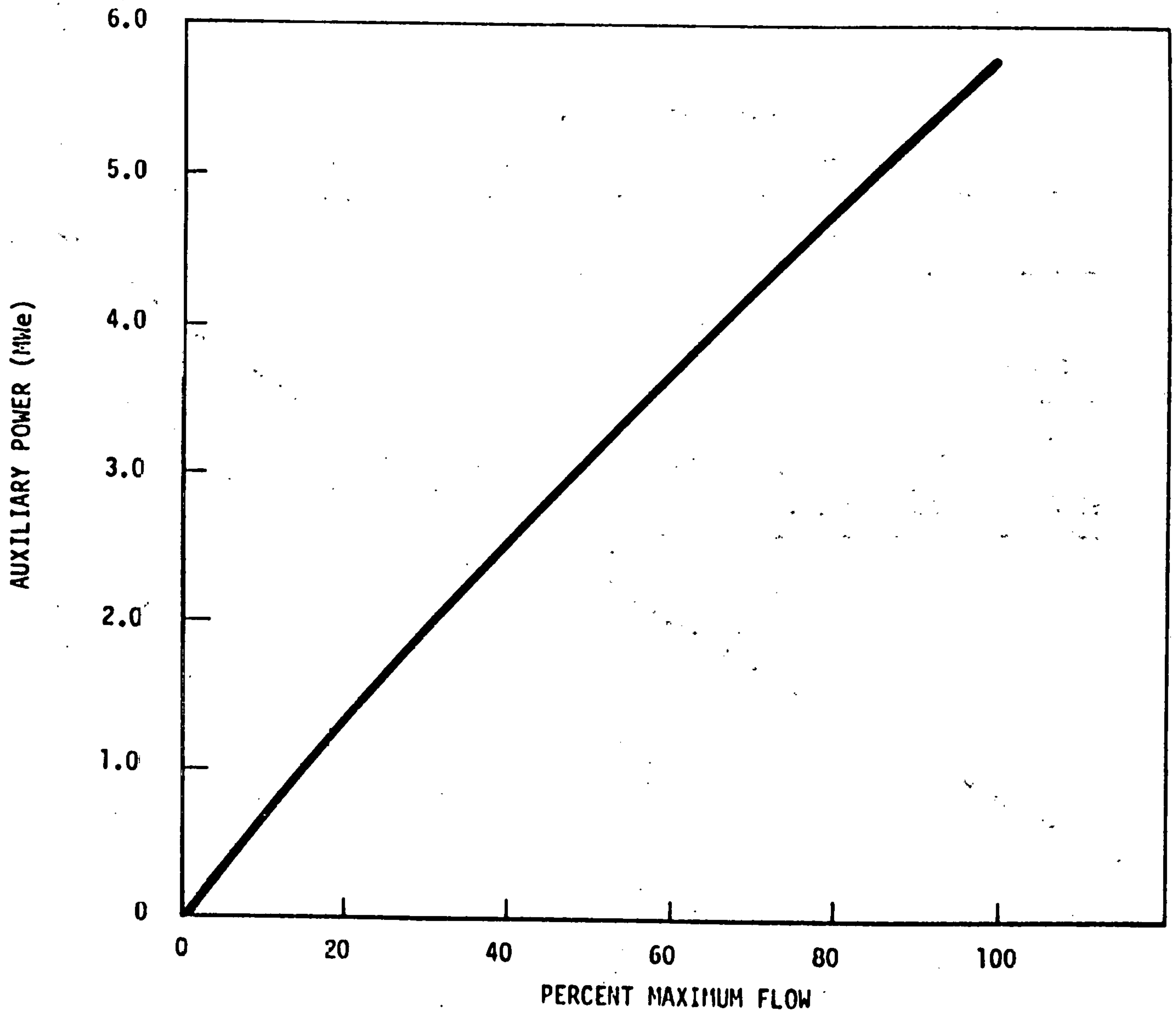


Figure 6-11. Auxiliary Power Requirements for the Receiver Feed Pumps (Commercial System)

storage could be initiated approximately 18 min after acquisition of the sun. For a hot start condition, the startup time could be shortened to approximately 15 to 17 min. For a noon startup, the time to initiate charging of thermal storage could be considerably shorter due to the higher insolation and collector field efficiency.

6.13 TIME REQUIRED TO PRODUCE TURBINE GRADE STEAM

As in the case of a receiver startup, the time to go to rated receiver steam depends on the insolation, the collector field efficiency, and the turbine conditions (temperature and acceleration/loading rate). In general, if the receiver is being used as the primary source of steam to start the system, the rate at which the turbine can be ramped is limited by the turbine. This effect is illustrated in Figures 6-12 through 6-14 which depict cold, warm, and hot system startup using receiver steam. If thermal storage steam is used as the primary source of power to start the turbine, the receiver would be ramped up as fast as available thermal power permits subject to thermal stress limitations. Figures 6-15 and 6-16 depict a system startup using thermal storage steam to power the turbine and rapid receiver ramping for both a warm and hot startup condition. In this case, a transition time of 10 to 20 min could be anticipated assuming sufficient insolation is available.

6.14 TIME TO START THE TURBINE FROM THERMAL STORAGE

The time required to start the turbine from thermal storage depends on the initial thermal status of the turbine. Figures 6-15 and 6-16 show such a startup for a warm and hot turbine condition. For a warm start condition, $\sim$72 min would be required whereas for a hot start condition, $\sim$43 min would be required. In either case, the startup is assumed complete once the 70% load point has been reached since that represents the maximum turbine output level when operating from thermal storage steam.

6.15 TIME LAGS INVOLVED IN SWITCHING TURBINE OPERATING MODE

In order to estimate time periods required to switch turbine operating modes, three factors were considered. These were turbine valve travel time, recommended time rate of change of turbine load, and system capability to vary steam rate. From the standpoint of valve travel time, they can be

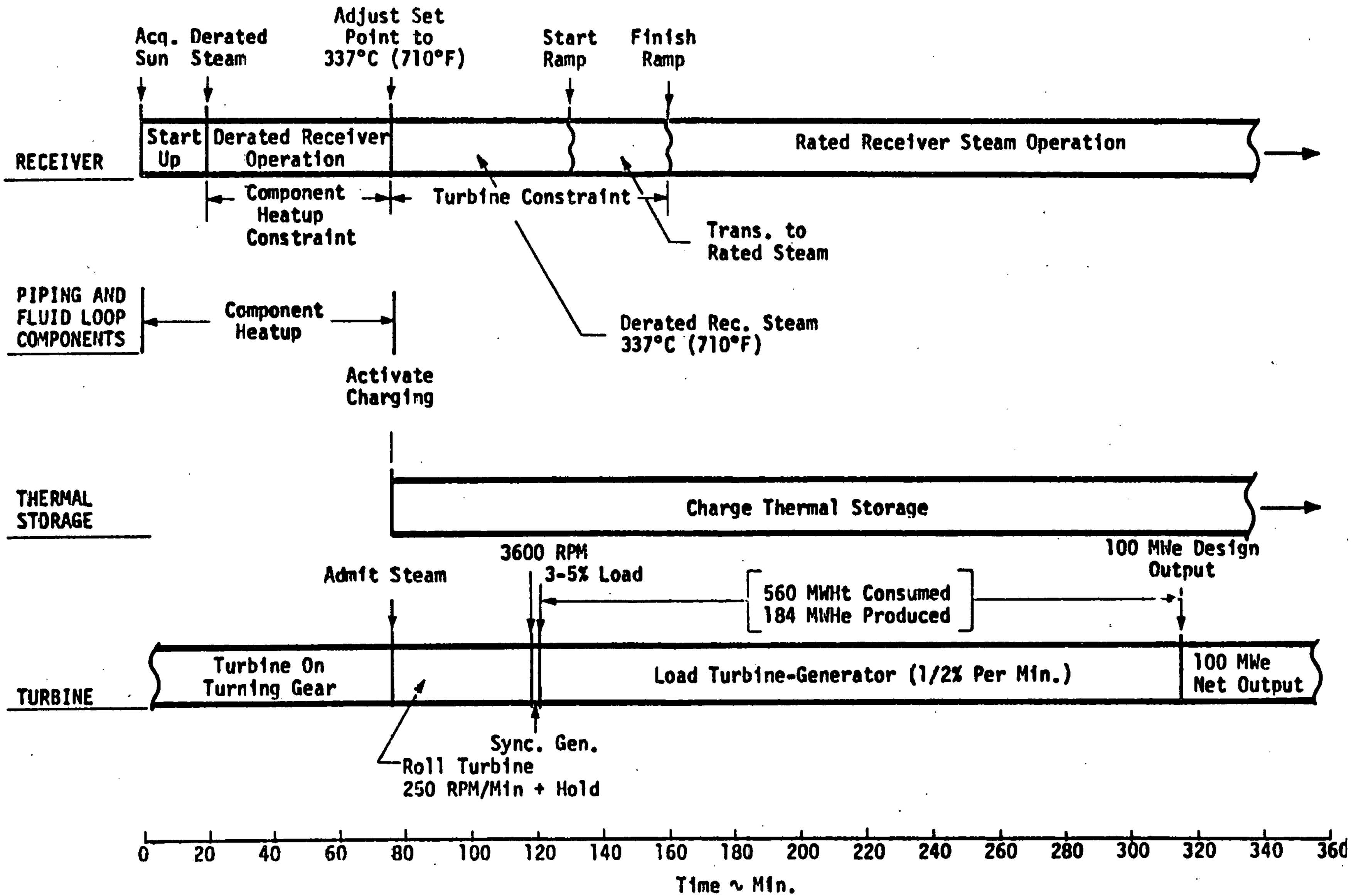


Figure 6-12. Cold System Startup from Receiver (Commercial System)

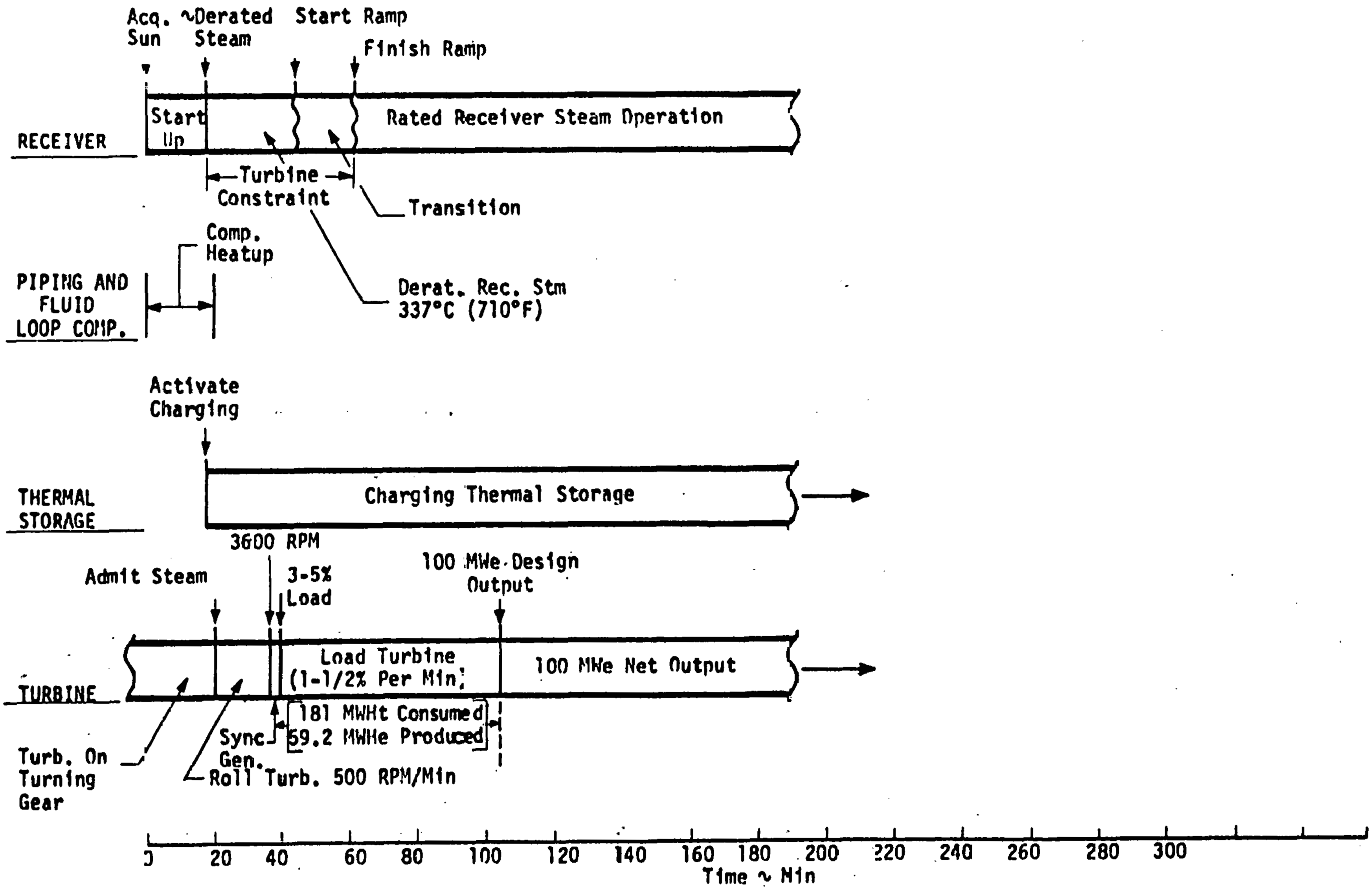


Figure 6-13. Warm System Startup from Receiver (Commercial System)

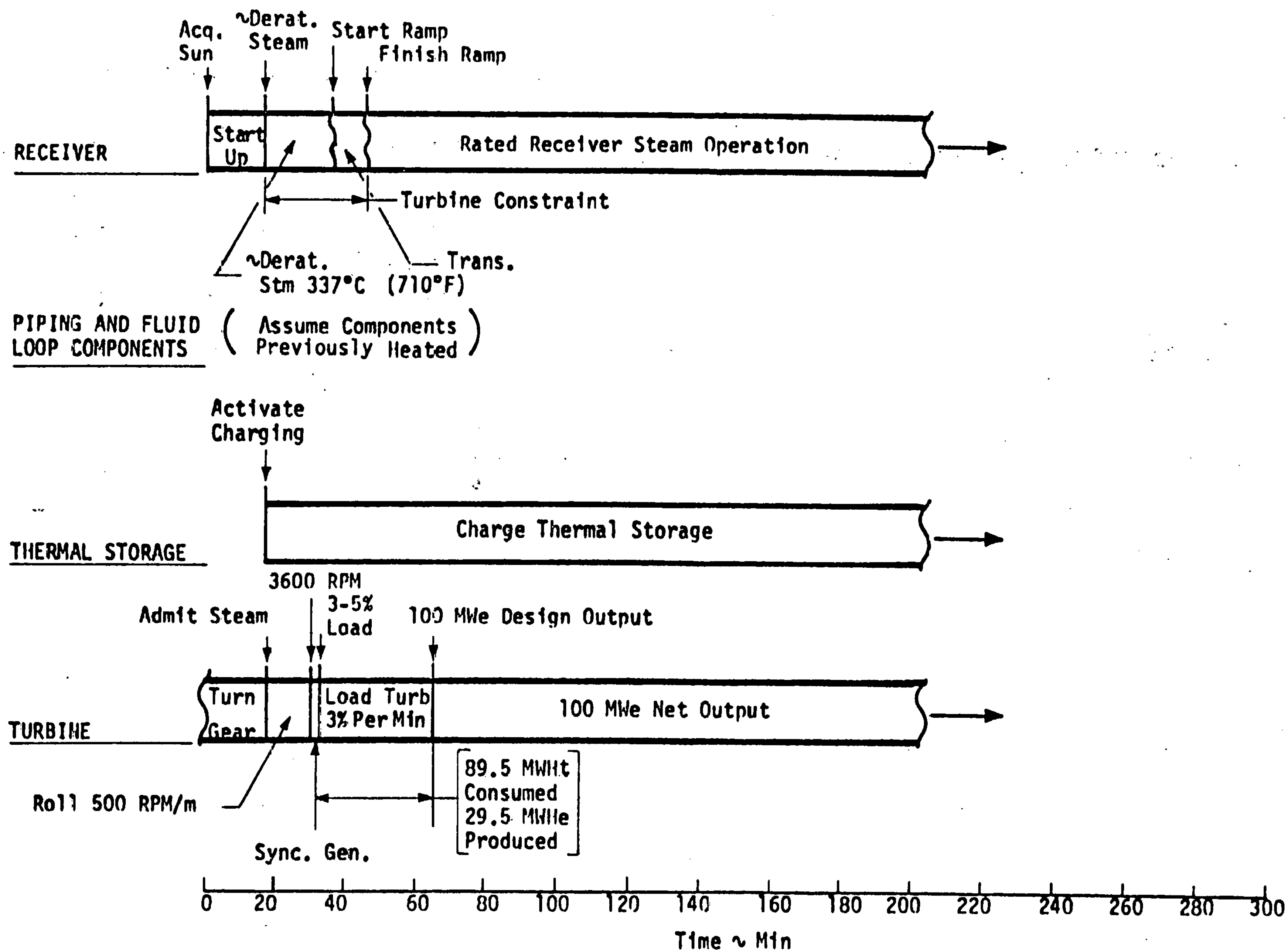


Figure 6-14. Hot System Startup from Receiver (Commercial System)

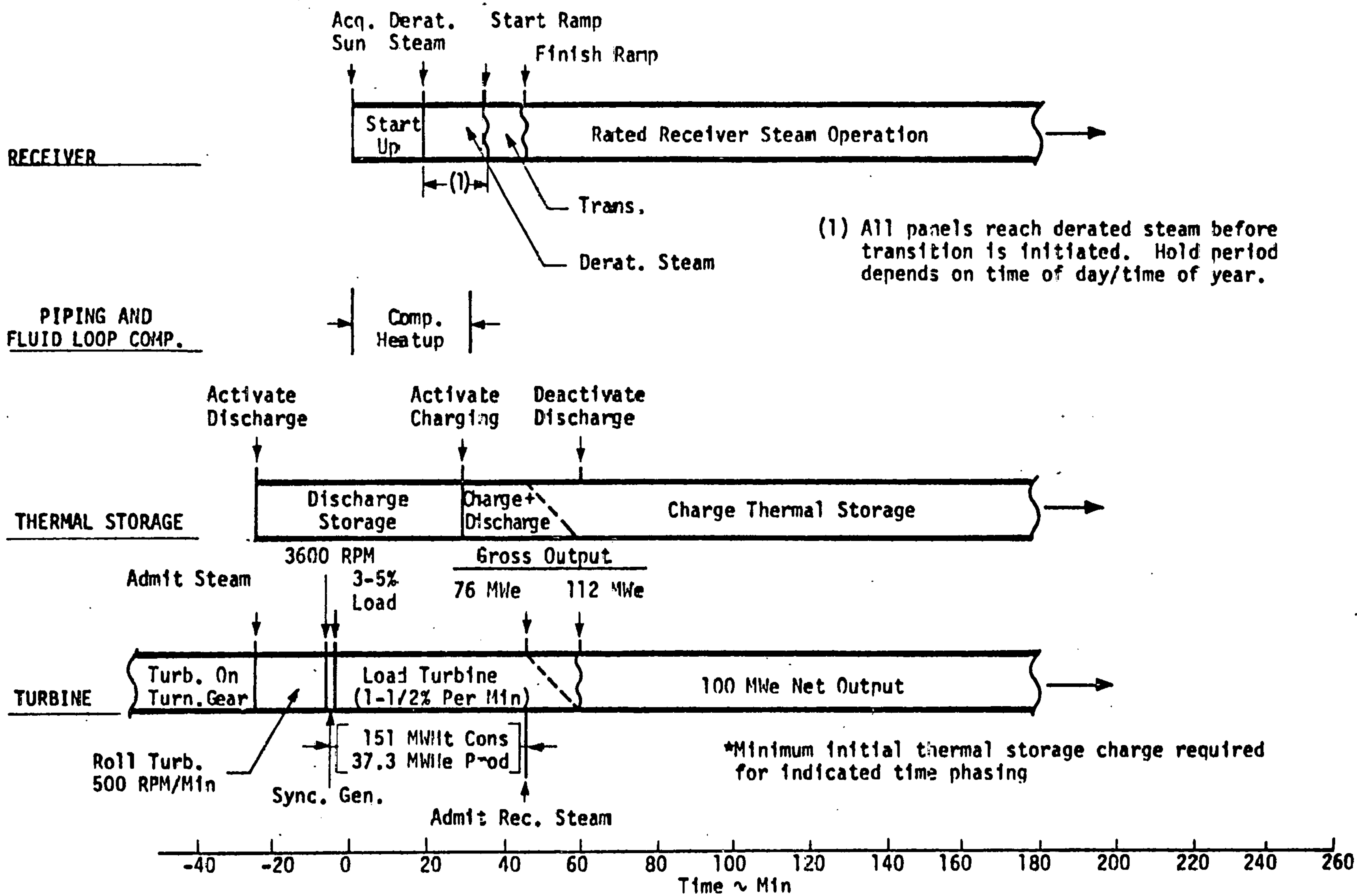


Figure 6-15. Warm System Startup from Thermal Storage* (Commercial System)

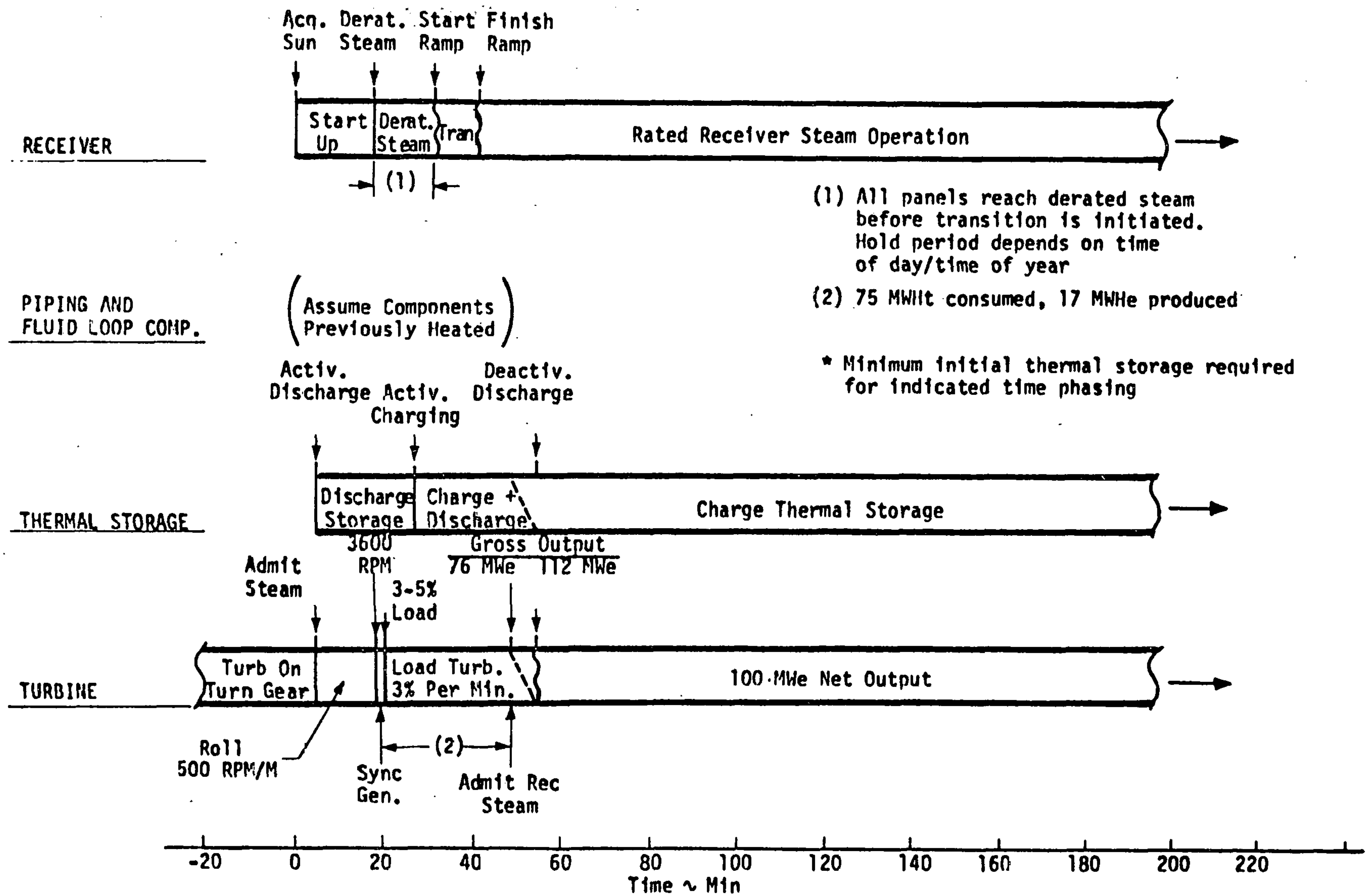


Figure 6-16. Hot System Start from Thermal Storage * (Commercial System)

exercised from a full open to full closed position in a matter of seconds and therefore, impose an insignificant constraint on turbine switchover time. From the standpoint of recommended time rate of change of turbine load, Figure 6-9 illustrates Westinghouse recommendations for their 100 MW nonreheat turbines. Separate curves are shown depending on whether load is increased or decreased. Implicit in these curves is the assumption of constant inlet steam temperature. If variations in inlet temperature were included, families of curves would be produced for various changes in steam temperature. In general, if steam temperature is reduced during either a load increasing or decreasing event, the transition time is reduced below that indicated on Figure 6-9.

Data pertaining to the ability of the balance of the system to provide steam at rates of change of flow which are compatible with the turbine operating lines shown in Figure 6-9 is somewhat sketchy at this time. In order to develop such data, a detailed design of the commercial system hardware and flow control elements would be required to serve as the basis of a detailed transient analysis of the system. Since this is beyond the scope of current design activity only certain qualitative statements can be made concerning the balance of the system. First, the key element in the control of switchover time is the thermal storage subsystem. Assume no change in insolation on the receiver, the dynamic characteristics of the charging side heat exchangers control the rate at which changes in receiver steam flow to the turbine could be made. On the extraction side of thermal storage, the operational dynamics of the steam generator control rates of change in admission steam flow. As a result, the current design concept for the thermal storage heat exchangers is to maintain them in a hot standby condition where a fully operational temperature is maintained. This would minimize the effects of heat exchanger thermal mass on heat exchanger responsiveness. For the present time, it is assumed that all heat exchangers could respond from a hot standby to full flow condition in a controlled manner in three to five minutes. From this assumption, the linear plot shown in Figure 6-17 was established. This number will mature as data is accumulated on a complete thermal storage test such as to be carried out in the pilot plant.

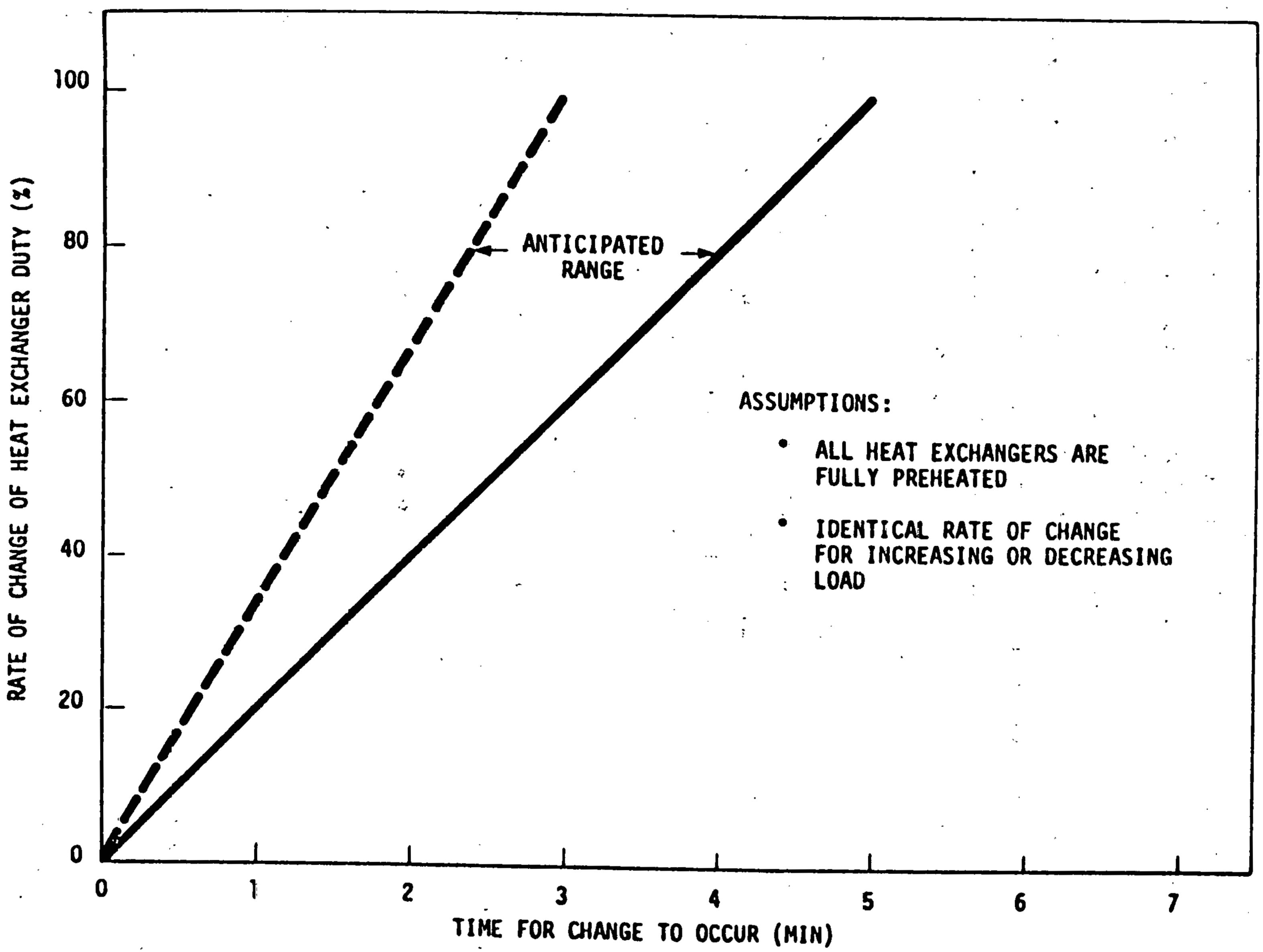


Figure 6-17. Assumed Dynamic Characteristics of Thermal Storage Heat Exchangers (Commercial System)

Based on the preceding discussion, the following estimates have been have for the particular mode switches under concern.

A. The time required to transition from exclusive use of receiver steam to operation from both receiver and thermal storage steam depends on the magnitude of the shift in steam flow and turbine load change involved. For minor changes in flow and load, <25%, a transition of ∿1 min would be expected with the heat exchangers being the limiting factor. For large changes in turbine load, the normal transition time would be limited by the lines shown in Figure 6-9.

B. The time required to transition from operating exclusively on receiver steam to operating exclusively on storage steam will be general be limited by the response characteristics of the heat exchangers assuming a minimum decay occurs in turbine load (100 to 70 MWe). The charging heat exchanger would have to be capable of transitioning to accept 100% of receiver output while the steam generator would have to accept the complete turbine load. Figure 6-17 indicates that a transition time of 3 to 5 min would be anticipated.

C. Time required to transition from operating exclusively on storage steam to operating exclusively on receiver steam would be the inverse of the process discussed in B. Since the assumed rate of change of heat exchanger duty in independent of the direction of change (increase or decrease in duty), the same 3 to 5 min transition time discussed in B would be appropriate for this transition.

D. The time lag associated in switching from charging thermal storage to discharging thermal storage or vice versa is essentially zero since these are completely independent operations as far as the thermal storage operation is concerned. Simultaneous operation of the two loops is possible and anticipated for periods of intermittent cloudiness. Time lag effects associated with changes in heat exchanger duty could be made negligibly small by the proper time phasing of the activation and deactivation of the two loops.

6.16 FEASIBILITY OF SIMULTANEOUS CHARGING AND DISCHARGING OF THERMAL STORAGE

The thermal storage is capable of simultaneous operation of the charging and discharging loops and will be one of the key features to operation during intermittently cloudy periods where a thermal storage buffering function is required.

6.17 ENERGY REQUIREMENTS TO STARTUP AND SHUTDOWN THE TURBINE

A. An estimate of the thermal energy required to start the turbine exclusively from receiver steam is shown in Figure 6-13. During the startup period, approximately 181 MWH of thermal energy is consumed with 59.2 MWhe being produced by the generator. During a typical shutdown period (assumed to be 15 min because of simultaneous change of load and temperature), 43.3 MWh of thermal energy is consumed with 14.2 MWhe being produced by the generator.

B. The thermal energy used in accomplishing a warm turbine start from thermal storage steam is shown in Figure 6-15. During that period, 151 MWh of thermal energy is consumed with 37.3 MWhe being produced by the generator. During a typical shutdown period, approximately 41.4 MWh of thermal power would be consumed with approximately 10.6 MWhe being produced by the generator.

C. For the MDAC system, the primary requirement for energy to maintain a warm shutdown condition is for turbine sealing steam which amounts to a thermal power drain of approximately 0.96 MWt. Minor steam flows would be introduced into the deaerator and high pressure heaters with a corresponding thermal power drain of $\sim$0.02 MWt. The current plan is to draw this power from the low temperature side of the caloria tank whenever possible, reducing the caloria temperature in the process from 232°C (450°F) to 149°C (300°F). No effort would be made to prevent the receiver temperature from decaying to an ambient condition unless a freezing situation were to occur. At that time, a freeze protection flow or a GN_2 purge would be initiated depending on the period of time over which the receiver would be down (a flow would be maintained for simple overnight protection whereas a GN_2 purge would be used for extended downtime periods).

D. The amount of storage capacity that would be required to provide equipment protection would be zero since energy drawn from the thermal storage tank would be at a temperature below that useful for making admission grade steam for turbine operation.

E. The time and thermal energy necessary to execute a cold turbine start is shown in Figure 6-12 for starting with receiver steam. Considering the period from initial turbine roll to full turbine load, 240 min of elapsed same would be required. During this period, 560 MWHt of thermal energy would be required from the receiver while 184 MWHe would be produced from the generator.

6.18 THERMAL STORAGE HEAT LOSS

The impact of ambient temperature and storage unit capacity on the heat loss from the thermal storage tank(s) over a typical 24-hour period is shown in Figure 6-18. Data developed in support of this figure assumed three basic storage configurations. The six hour configuration consisted of four storage tanks, each 27.4 m (90 ft) in diameter and 18.3 m (60 ft) high. The three hour configuration included two of the previously defined tanks while the 0.5 hour configuration assumed a single storage tank 17.9 m (58.6 ft) in diameter and 13.4 m (44 ft) high. All systems were assumed to follow the same basic duty cycle defined by:

A. Change storage at a constant rate for seven hours

B. Maintain a fully charged hold condition for one hour

C. Discharge the storage over a period of 6, 3, or 1/2 hour as appropriate

D. Maintain a hold condition (fully discharged state) for the balance of the 24-hour period.

In viewing the results, the 0.5-hour storage case experiences the highest heat loss because of its large surface area to volume ratio. Since the three and 6-hour cases assume identical tank size, the minor difference is due to the longer period of time the tanks for the 6-hour case were maintained at a higher average temperature due to the extended discharge period.

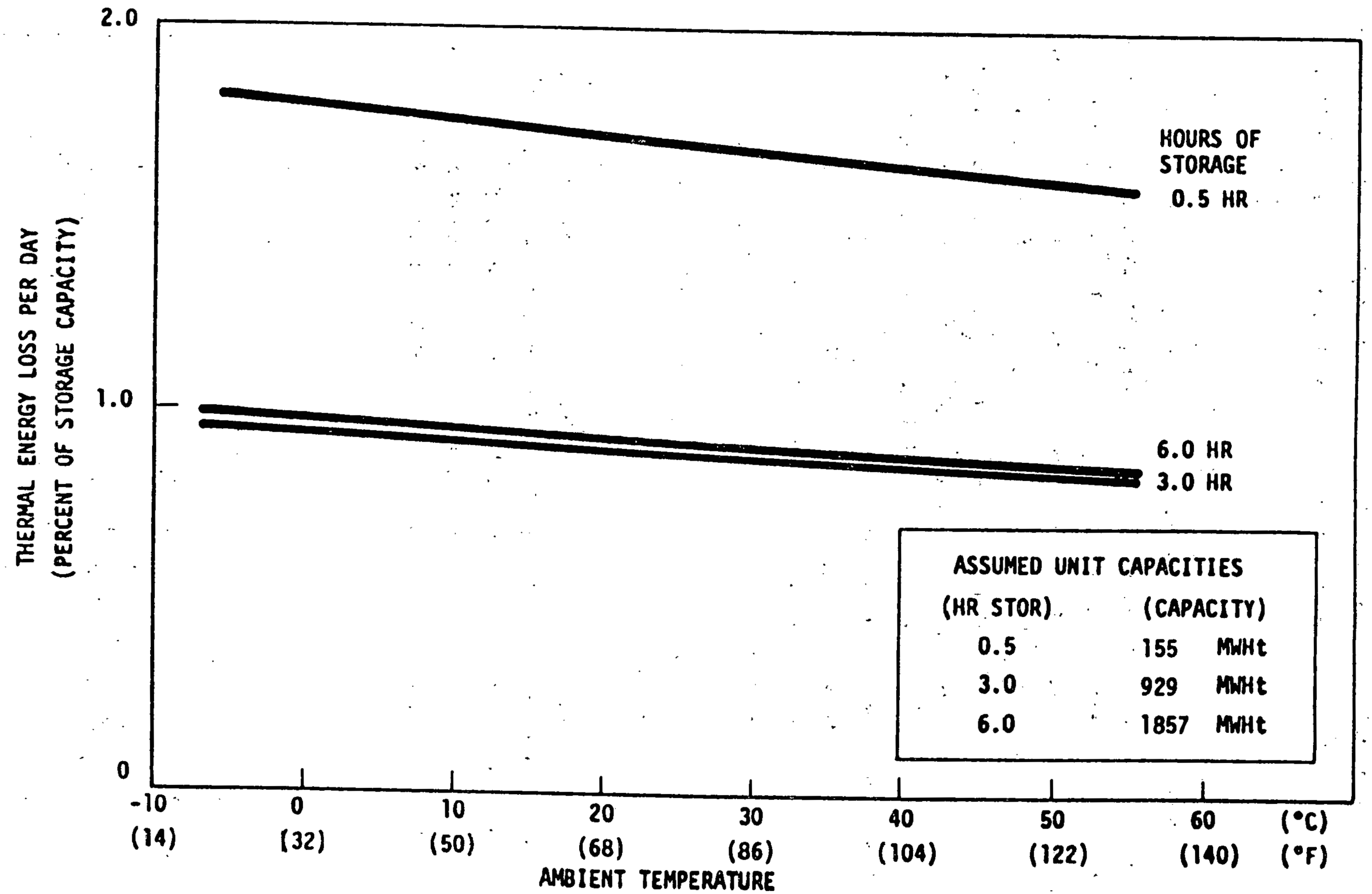


Figure 6-18. Impact of Ambient Temperature and Storage Unit Capacity on Heat Losses (Commercial System)

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Appendix A
COLLECTOR SUBSYSTEM

CONCEPTUAL DESIGN FOR A COMMERCIAL COLLECTOR MANUFACTURING PLANT

A.1 COMMERCIAL PLANT MANUFACTURING SUMMARY FOR THE COLLECTOR ASSEMBLY (HELIOSTAT)

This section summarizes a conceptual plan for a commercial plant operation for the manufacture of the heliostat. This plan was developed by MDAC with the assistance of the Arthur D. Little Company. The plan contains a discussion and description of the manufacturing concept which uses a Main Manufacturing Plant for details and subassemblies and a Site Plant for final assembly operations. This plan was sized for a steady state condition for production of 60,000 heliostats per year at the Main Manufacturing Plant with an initial startup rate of 15,000 heliostats per year. These rates provide capacity to produce heliostats in support in initial commercial power plants, build to a steady state production, and provide for further growth either through plant expansion or additional plants. Steady state production of 60,000 heliostats per year at the Main Manufacturing Plan located in the southwest supports multiple Site Plants also located in the southwest. Site Plants are sized to the requirements of the size of Power Plant being serviced; however, basic sizing has been assumed to be a site which requires 21,400 heliostats to be installed over a period of 18 months.

A.1.1 Main Manufacturing Plant

The main manufacturing plant Figure A-1 measures approximately 500 by 900 ft and represents 450,000 ft^2 of manufacturing and covered storage space. This plant size does not include space requirements for offices, which may total an additional 50,000 ft^2. The plant is designed for operation on a 5-day 2-shift basis, which allows for production constraction to 30,000 (one shift), if approximate. When operating at design capacity, there are approximately 940 production and support workers of various skills and skill levels employed at the plant on both shifts, not including supervision and administrative/clerical staff. The plant is designed to fabricate and assemble heliostat subassemblies to the point at which they can be shipped to the site plant location(s) for final assembly and transfer to the installation site.

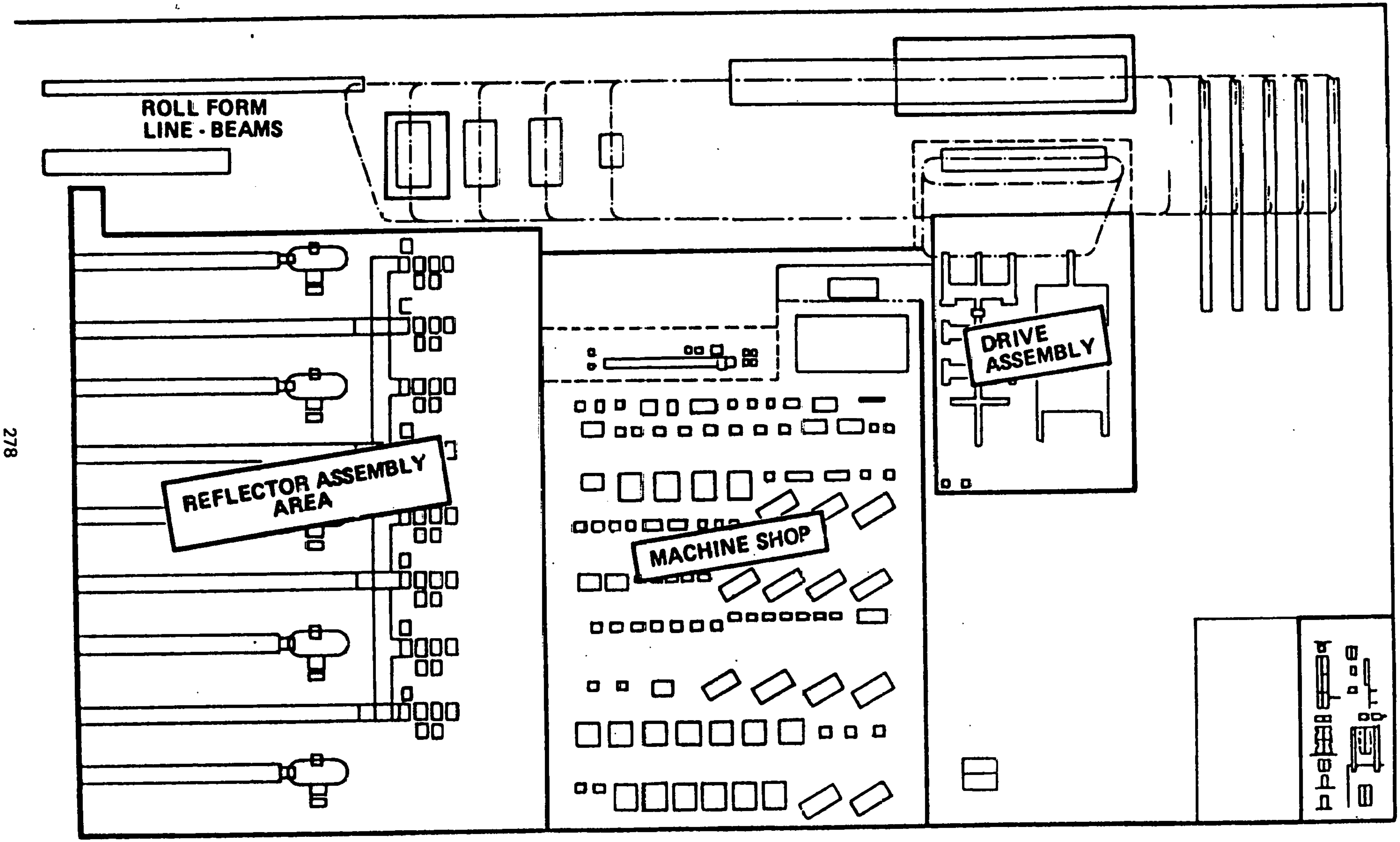


Figure A-1. Main Manufacturing Plant

Basically, the manufacturing plant consists of four fabrication/assembly areas, as follows:

- Reflector surface assembly area
- Support components fab/finish area
- Machine shop/drive assembly area
- Electrical/electronics assembly area.

To support these assembly/fabrication areas, storage areas for in-process materials and finished goods are established in close proximity to the appropriate work locations.

A. 1. 1. 1 Reflector Surface Assembly Area

The reflector assembly area occupies approximately 160,000 ft^2 of space (380 by 420 ft) and requires 300 people on two shifts to produce 360,000 reflective panels (6 per heliostat). Within this area of the plant, the following operations occur:

- Fabrication of 114 by 85 in backsheets from galvanized sheet metal in coil form.
- Lamination of foam core and backsheet at 8 work stations, Figure A-2. Curing of the bonding adhesive is accomplished in 4 compression conveyors which also transfer these foam/steel sheets to the final lamination stations.
- Lamination of foam/steel sheets with mirrored glass at 15 work stations, Figure A-3. A similar cure process in 5 compression conveyors in transit to edge sealing stations and packaging.

Glass handling is accomplished by automatic equipment which moves glass shipping frames from the receiving area to the 15 work stations, where each glass panel is mechanically (vacuum) removed from the shipping frame. Transfer from work stations to compression conveyor is by means of air cushion conveyors. Transfer from the end of the compression conveyor to shipping frames is accomplished by vacuum transfer monorail.

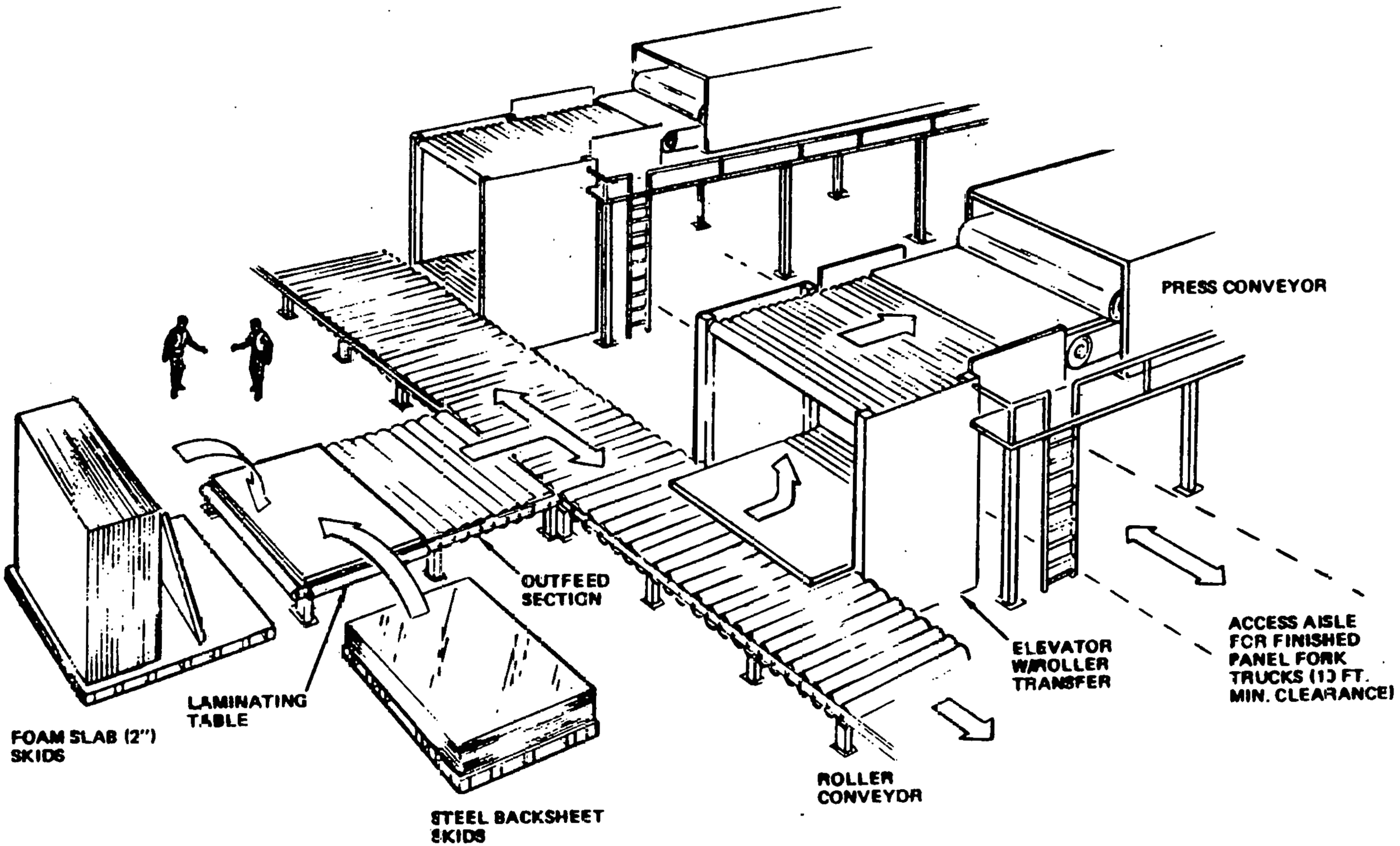


Figure A-2. Back Sheet to Foam Core Laminating Operation

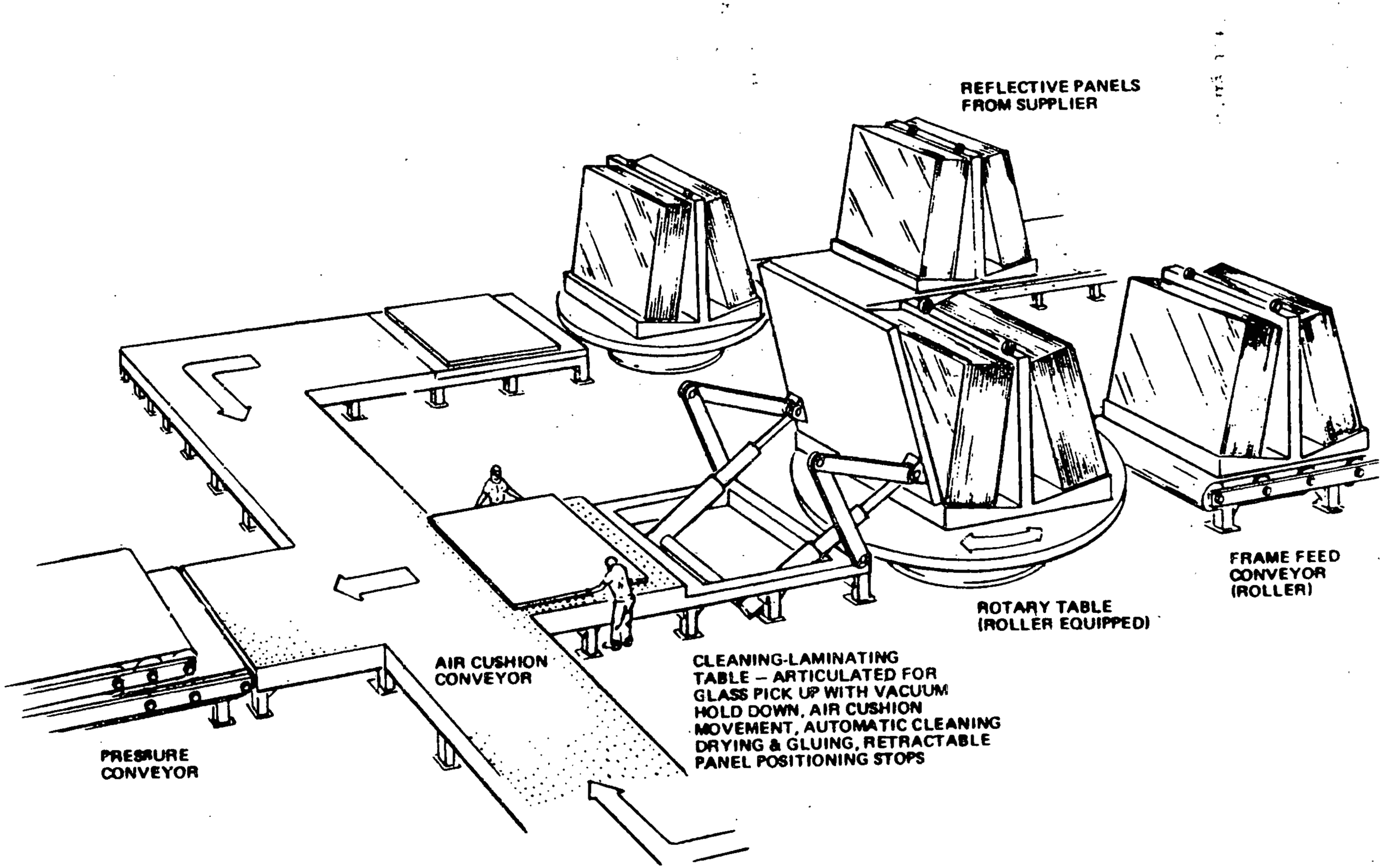


Figure A-3. Glass to Foam and Steel Laminating Station

A. 1. 1. 2 Support Components. This portion of this plant is approximately 135,000 ft^2 in size (900 by 150 ft). There are 197 workers manning three operations for two shifts to produce the following parts annually:

- 60,000 torque tubes
- 240,000 cross beams
- 60,000 pedestals

Operations carried out in this area include the following:

- Fabrication of cross beams on a shear/roll form line which is fed from coil stock slit to size which is straightened, sheared, punched and formed to the desired shape.
- Welding of pads to cross beams, collars to torque tube, collar and base to pedestal. This occurs at dedicated MIG welding stations, Figure A-4 is typical.
- Finishing line comprised of a wheelabrator, Figure A-5, vapor degreaser, Figure A-6, wash, dry, dip prime, dry tunnel, finish paint, and final dry, Figure A-7.

Parts are picked up at the various stations and carried through the finish line operations to the packaging/shipping stations. At these locations the parts are offloaded, palletized as necessary, and shipped.

A. 1. 1. 3 Machine Shop/Drive Assembly. The machine shop (66,000 ft^2) and drive assembly (17,000 ft^2) areas provide necessary operations to produce 60,000 drive units for the heliostats. All machining operations required on drive unit castings and steel stock components are included and require a total of 298 workers for two shifts. The machining operations are divided into five areas, each equipped and dedicated to produce a specific part or group of parts.

The drive assembly area consists of work stations, Figure A-8, assembling sequentially the azimuth and elevation drive housings which are then brought together for painting, final assembly and testing. Transfer between the assembly area and the paint line is accomplished by continuous monorail which also carries the drive units through the paint line, Figure A-9. A total of 63 people are required to man this operation.

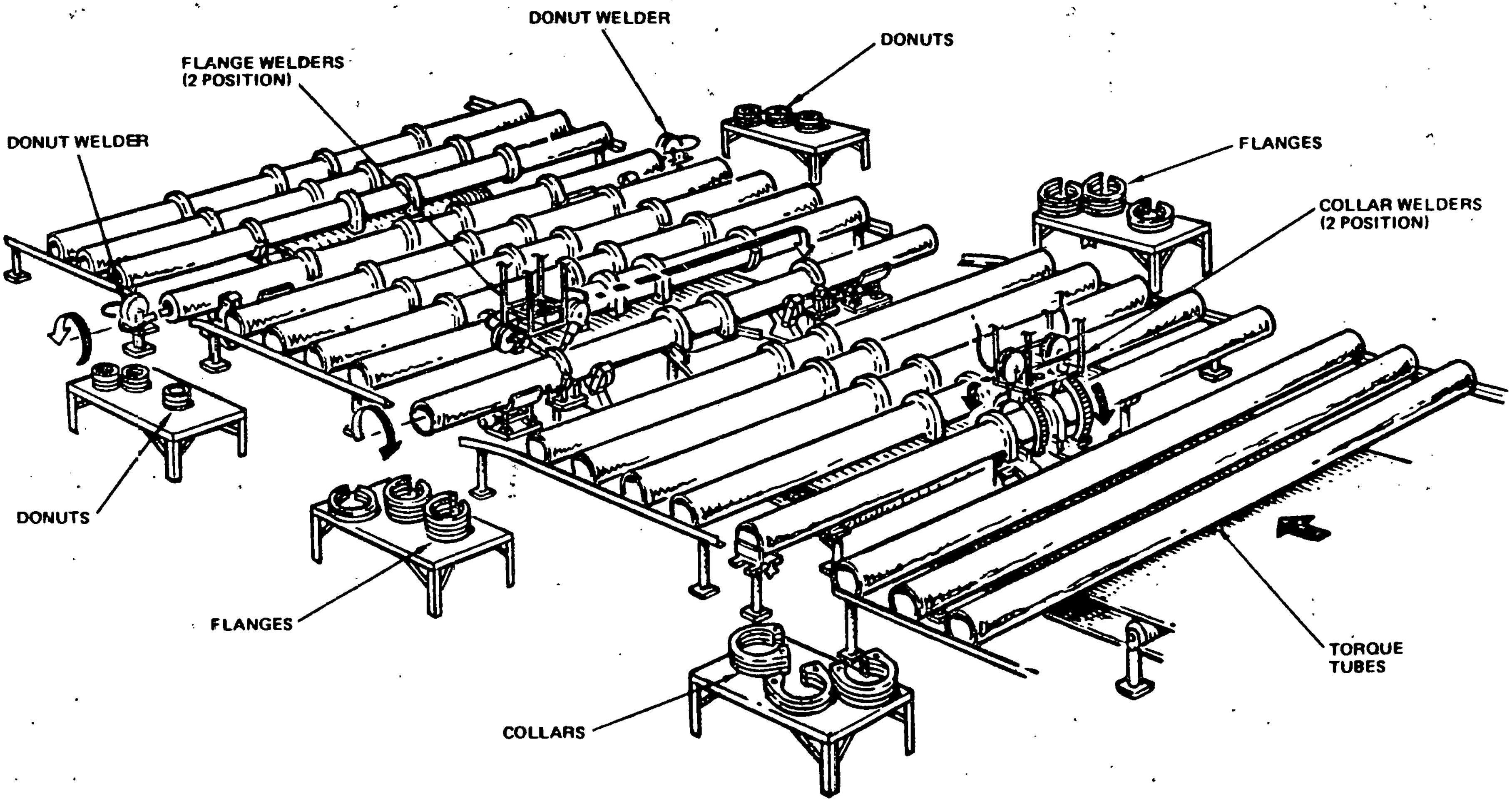
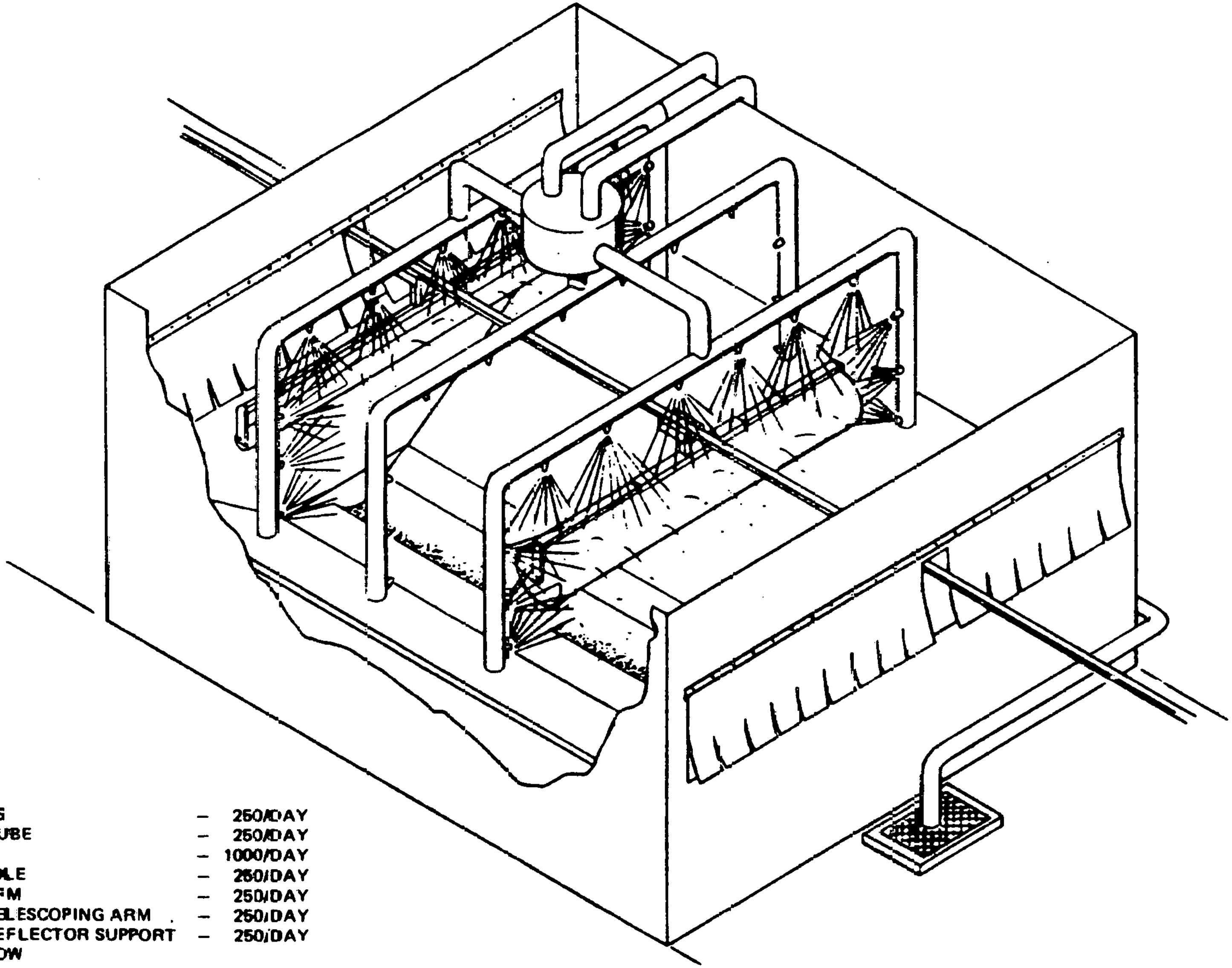


Figure A-4. Torque Tube Welding Fixture



OUTPUT:

PEDESTALS	– 250/DAY
TORQUE TUBE	– 250/DAY
BEAMS	– 1000/DAY
SENSOR POLE	– 250/DAY
SENSOR ARM	– 250/DAY
SENSOR TELESCOPING ARM	– 250/DAY
SENSOR REFLECTOR SUPPORT & MISC HDW	– 250/DAY

Figure A-5. Wheelabrator for Large Parts

OUTPUT:

PEDESTALS	–	250/DAY
TORQUE TUBE	–	250/DAY
BEAMS	–	1000/DAY
MISC HDW	–	250/DAY

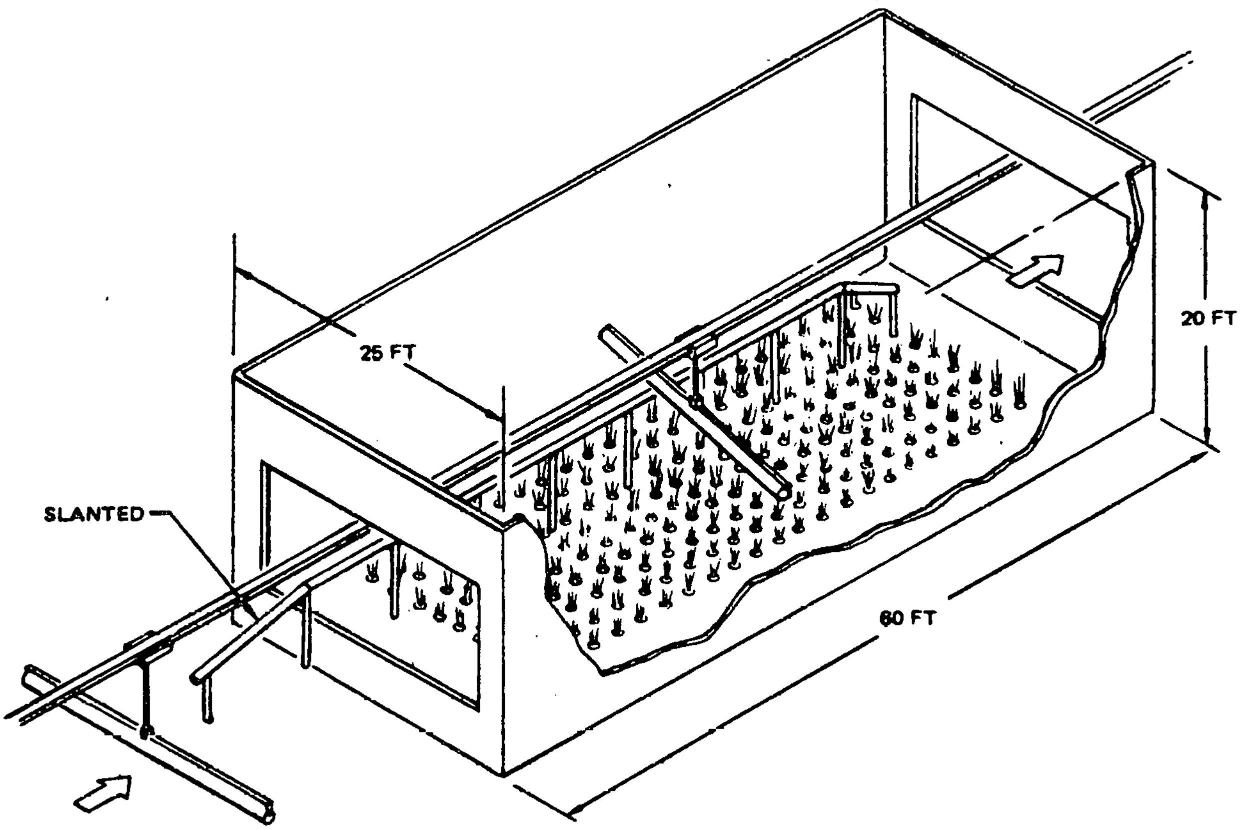


Figure A-6. Vapor Degreaser

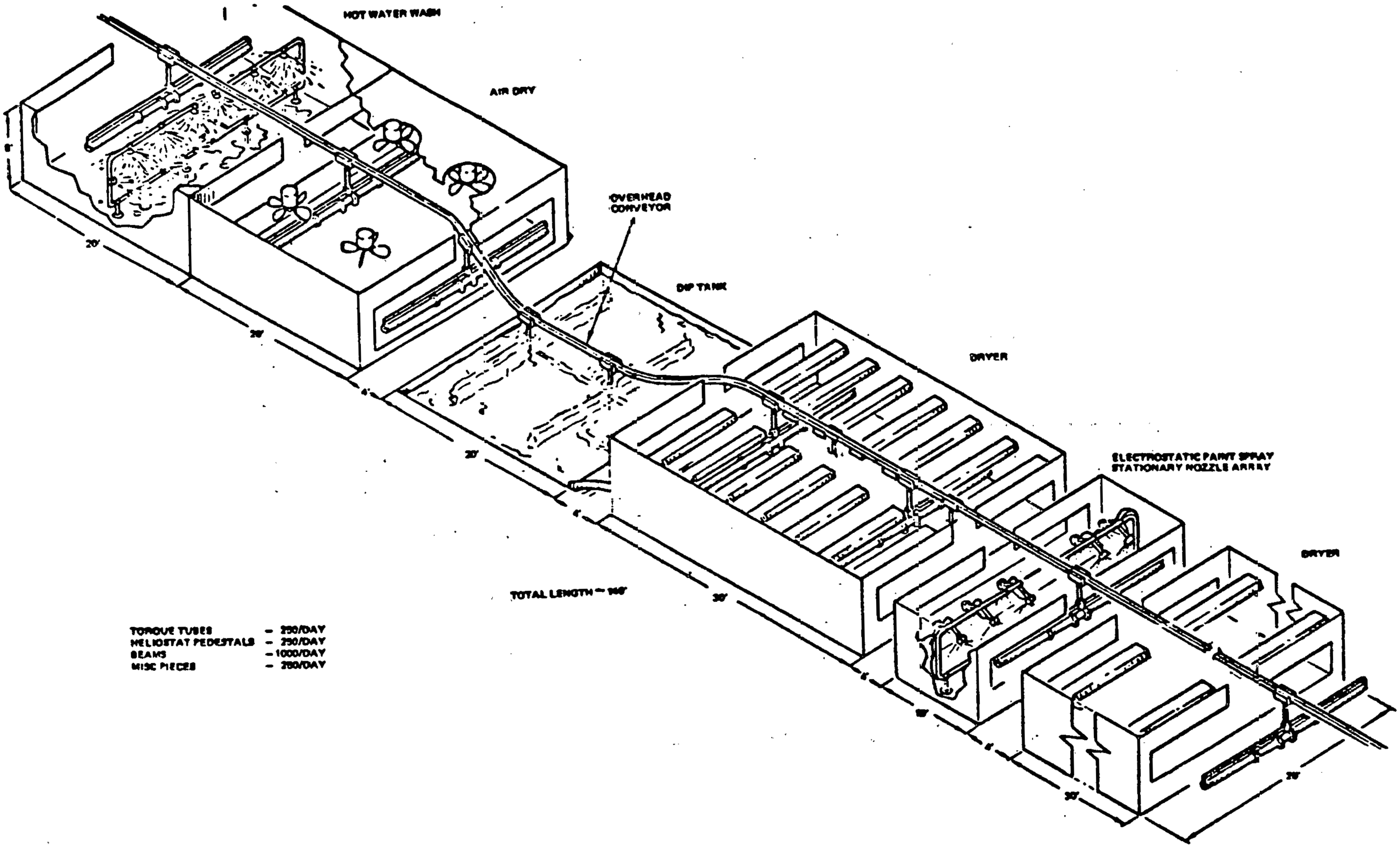


Figure A-7. Large Parts Finish Line

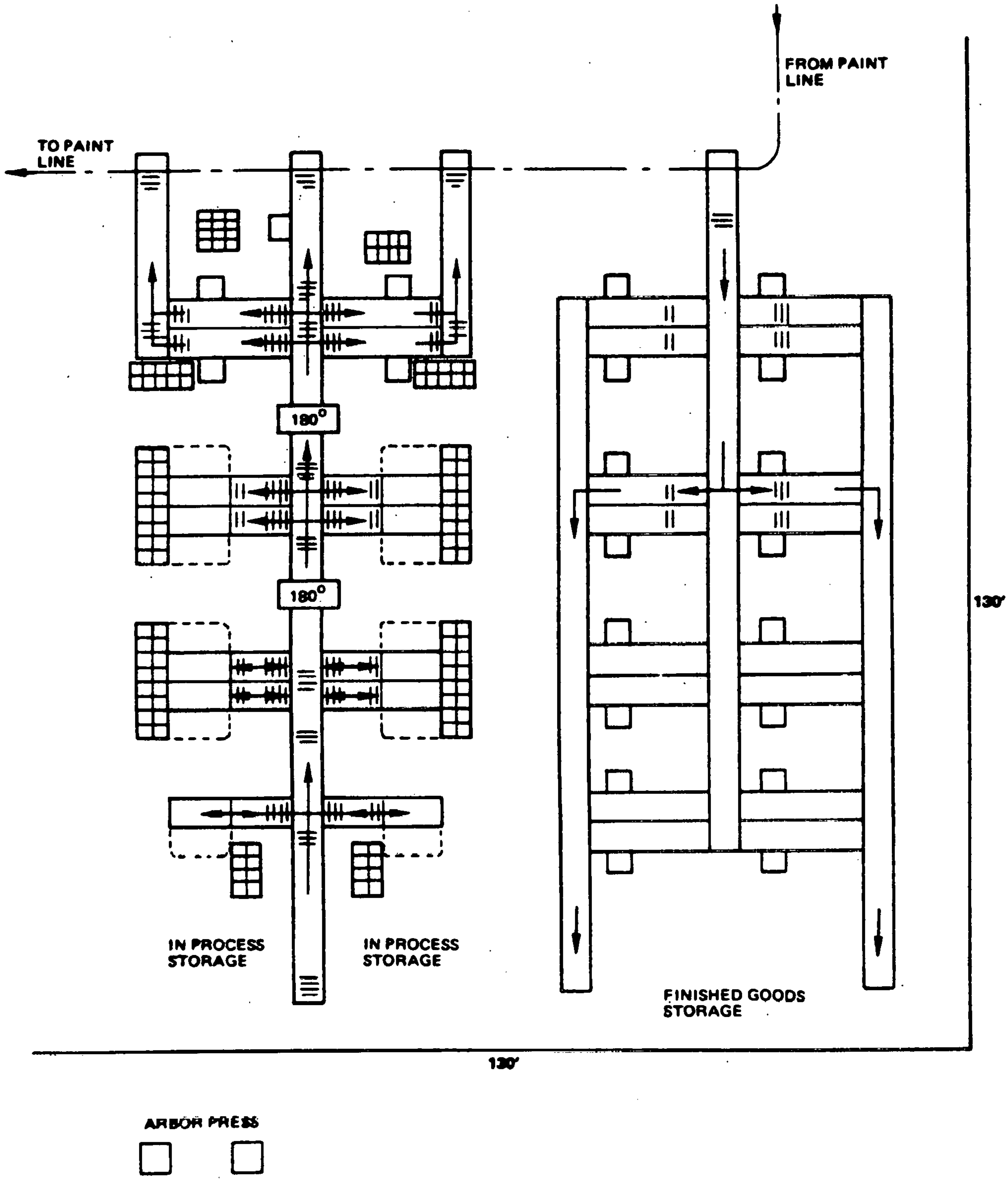


Figure A-8. Drive Unit Assembly Area

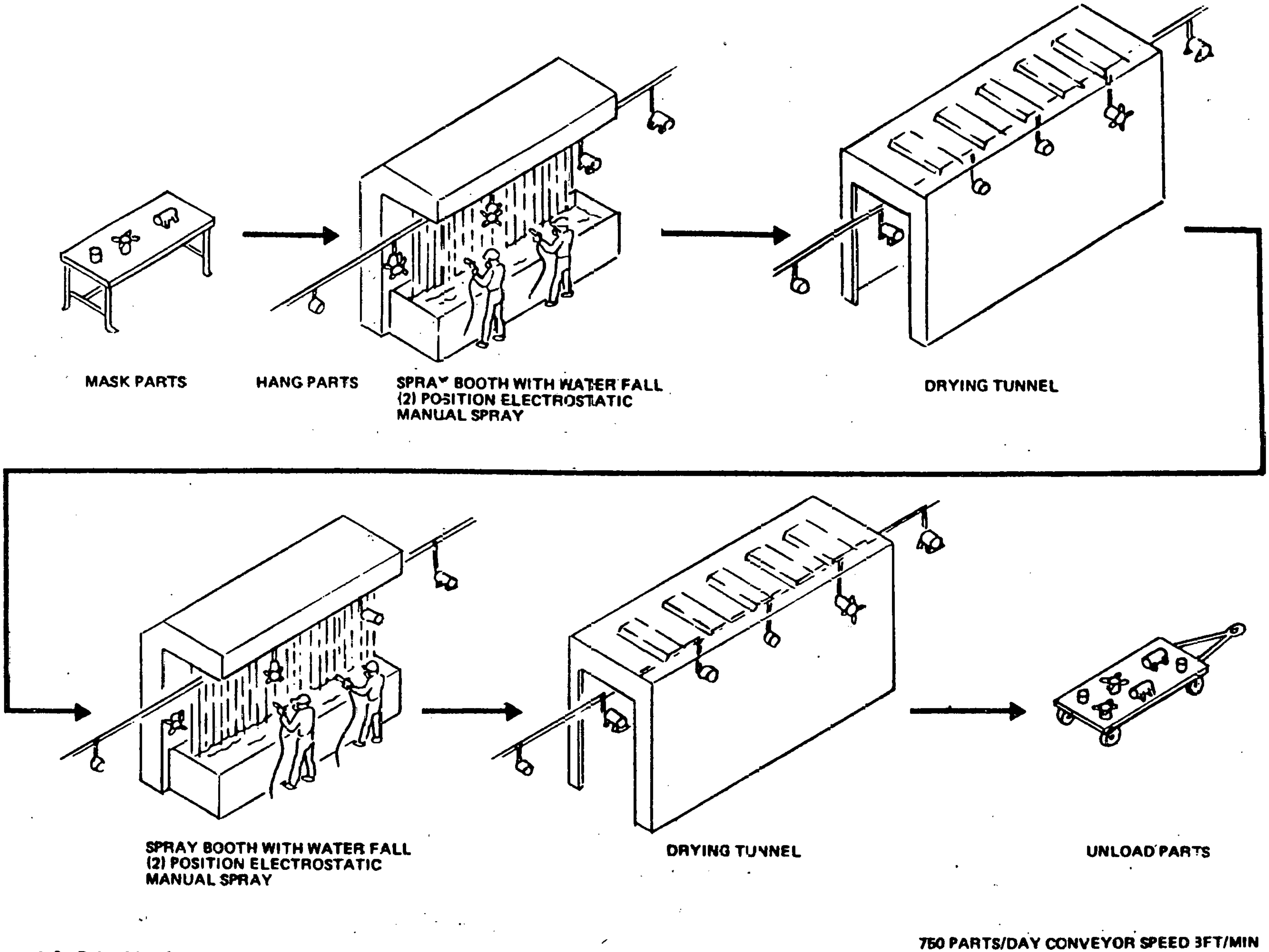


Figure A-9. Paint Line for Castings and Small Parts

A. 1. 1. 4 Electrical/Electronic Assembly. This area occupies approximately 6000 ft^2, Figure A-10, and requires a total of 63 people to annually produce:

- 60,000 heliostat controllers
- 2,500 field-processors
- 60,000 sensors.

Assembly operations are such that only one shift is necessary, which permits extension of work schedule to partial second or full second shift, if necessary.

Assembly takes place at 40 work stations and is manual with the exception of the wave solder operation following P/C board component stuffing.

The process includes a 24-hour environmental test of all P/C boards following completion and prior to final assembly into enclosures. Also included is a wire harness fabrication operation at which all wiring required in the control enclosures as well as between the enclosures and the drive unit are manufactured.

A. 1. 2 Site Manufacturing Plant

Each Site Plant measures 240 by 320 ft or a total of 76,800 ft^2, Figure A-11. The nominal assembly capacity of each Site Plant is 60 heliostat units per day, 14,300 units per year or 21,400 units in an 18 month assembly period. By design, each Site Plant is to be located adjacent to the installation site to reduce the final transport requirement for fully assembled heliostats. Based on the construction nature of the installation work the Site Plant is designed to operate on one shift; the same shift as is worked by the installation and construction crews. If a decision is made to operate the Site Plant on two shifts, the assembly capacity, size or storage requirements of this plant will be affected.

Four basic assembly operations take place in the Site Plant. They include:

- Assembly of the cross beams to the torque tube.
- Assembly of the cross beams and torque tube to the reflective panels.

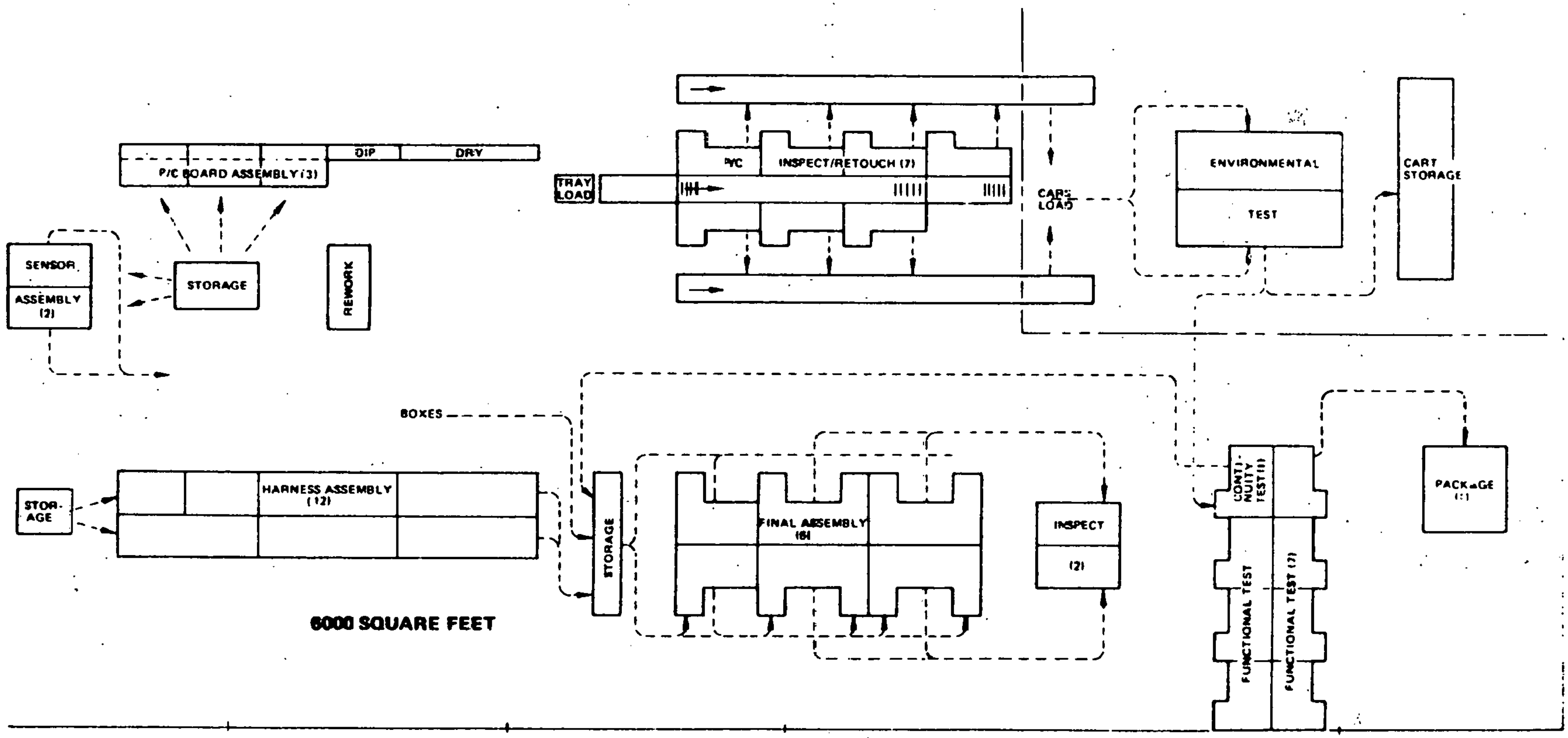


Figure A-10. Electrical/Electronics Assembly Area

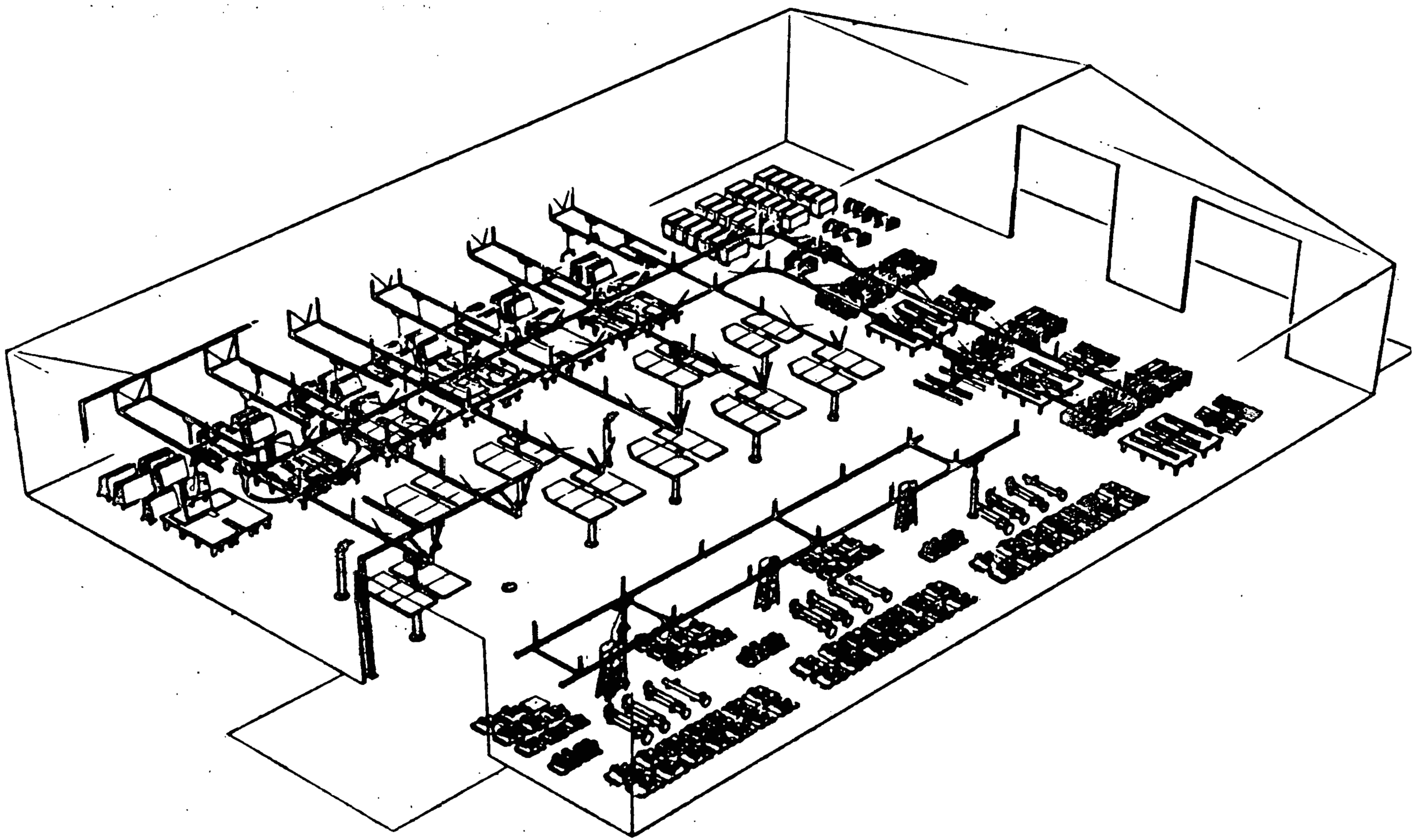


Figure A-11. Site Manufacturing Plant

- Assembly of the drive units and wiring harnesses to the pedestal.
- Assembly of the reflective array and supports to the drive and pedestal.

A. 1. 2. 1 Assembly of the Cross Beams to the Torque Tube. The cross beams and torque tubes are assembled on three work tables, Figure A-12. The four cross beams are loosely assembled onto the torque tube. The pads on the cross beams are then positioned on scribed spots on the work table and locked down. The torque tube is rotated until the centrally mounted collars lock into a given position in a holding jig at the center of the table. When the entire assembly has been locked up, the yokes of the beams will be impulse welded to the flange and ends of the torque tube. After welding, the assembly will be hoisted from the work table on a monorail and either stored in the overhead or moved to a reflective array assembly work table.

A. 1. 2. 2 Assembly of the Cross Beams and Torque Tube to the Reflective Panels. This assembly area consists of six work tables which are used to bond the assembly, Figure A-13. Operators at these stations remove the reflective panels from their shipping A-frames at stations immediately adjacent to the work tables and lay them on the work surface in predetermined positions. Mechanical aids are provided for the movement of the panels and their exact positioning on the work tables. One of the torque tube-beam assemblies is then positioned over the work surface and panels, bonding agent applied to 24 exact positions on the back surfaces of the panels, and the two structures mated and locked together. This subassembly is then left to cure for a predetermined period while the crew assemblies other arrays.

A. 1. 2. 3 Assembly of the Drive Units and Wiring Harnesses to the Pedestal. This assembly activity, Figure A-14, consists of the following steps:

- Transport of the pedestals and drive assemblies to the work station,
- Mounting of the drive unit to the top ring of the pedestal,
- Mounting of the drive cable retractor and junction box,
- Attachment of cable clamps to the pedestal and shaft housing,
- Connection of the complete wiring harness,
- A powered check of both drive elements,

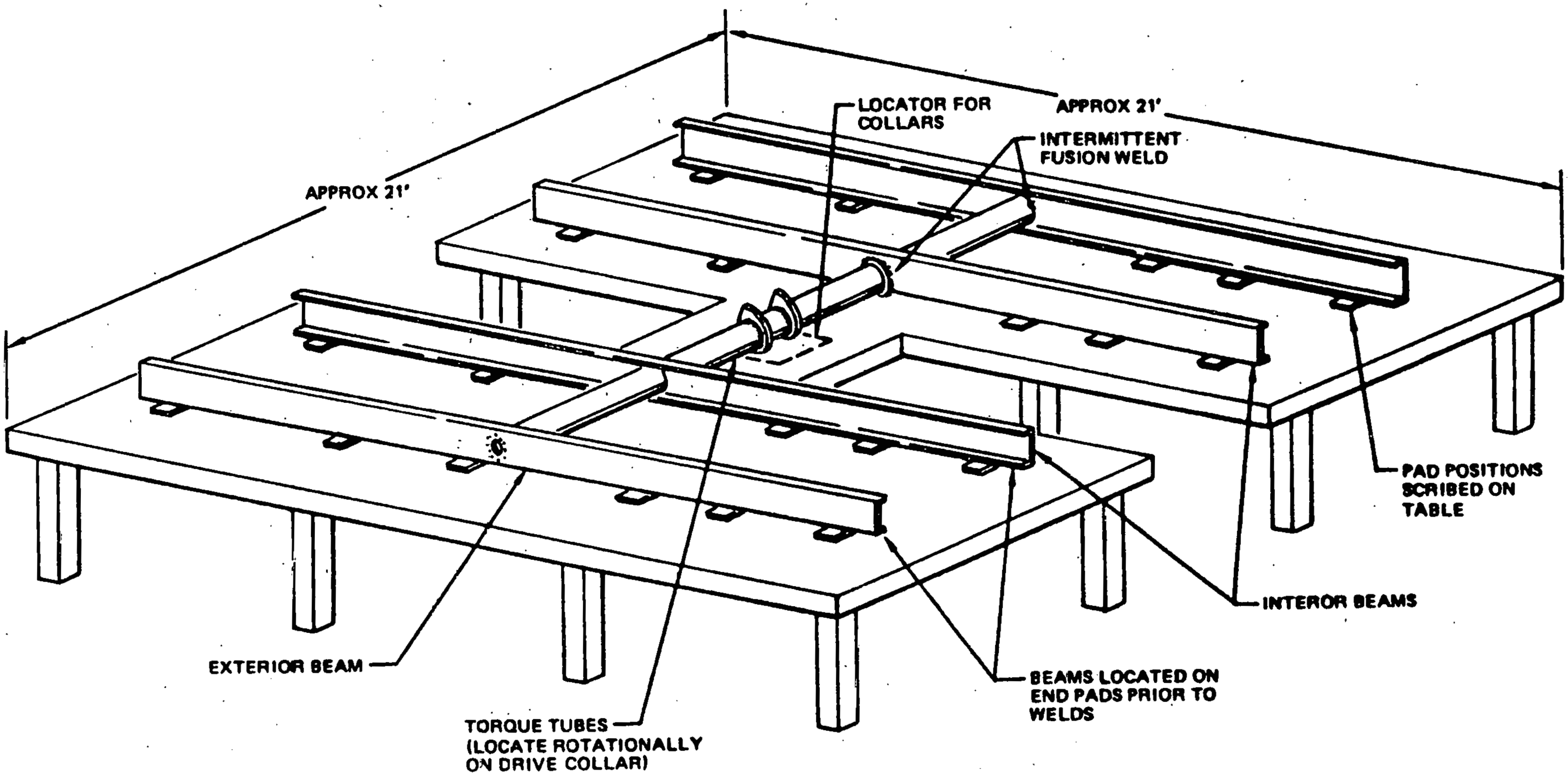


Figure A-12. Site Plant, Beam/Torque Tube Assembly Station (Typical)

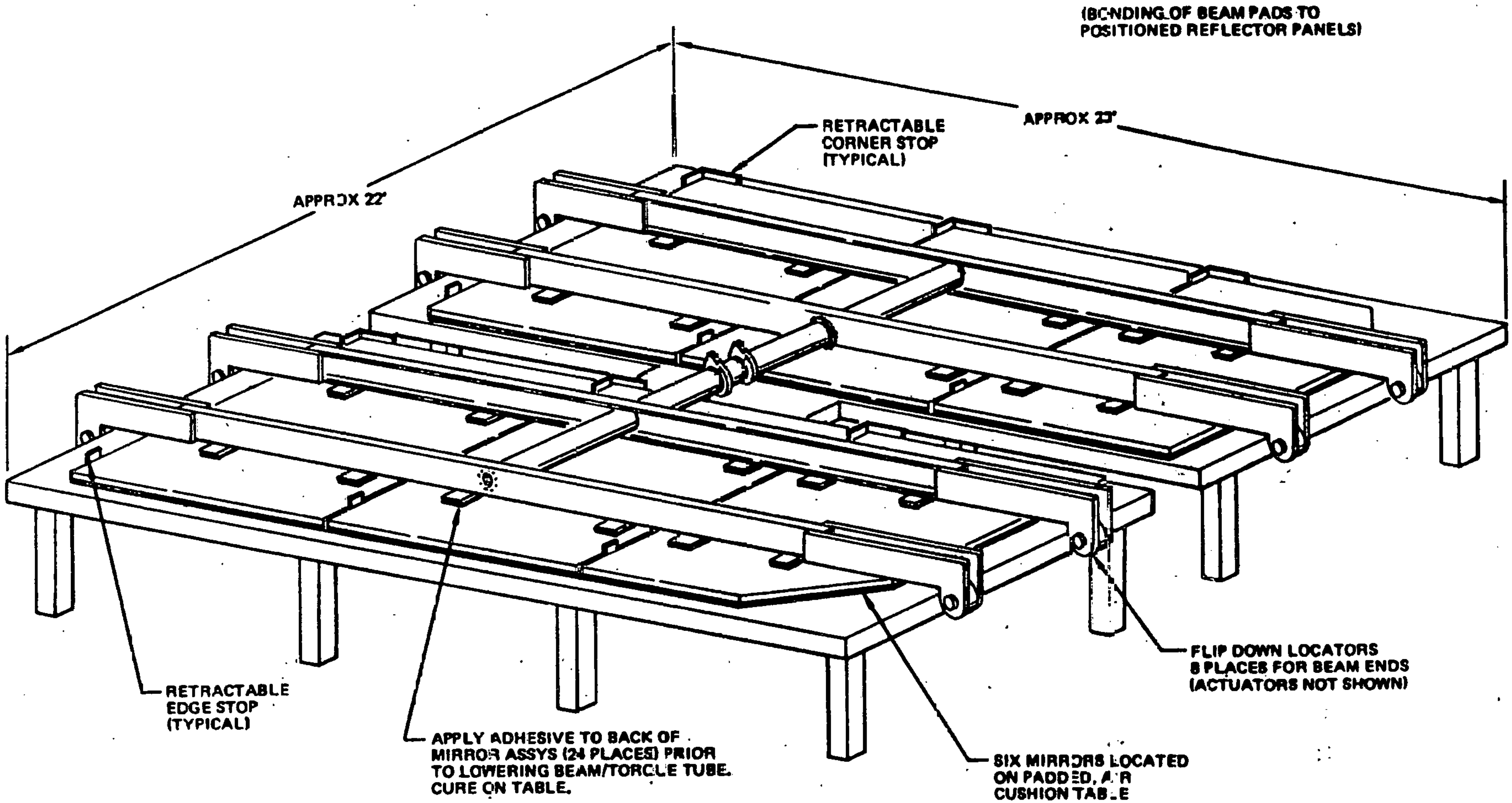


Figure A-13. Site Plant, Array Assembly Station (Typical)

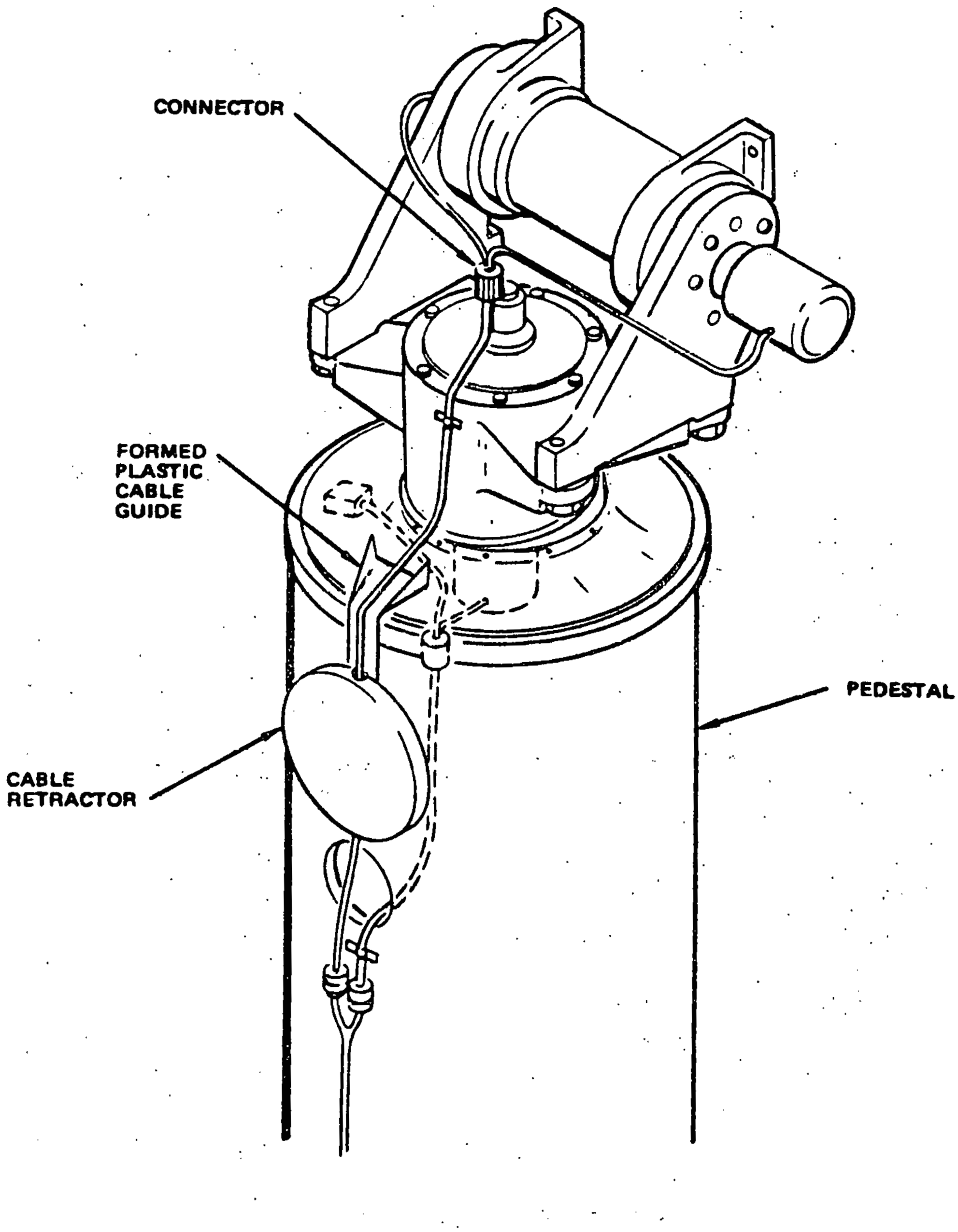


Figure A-14. Elevation Drive Motor Power and Control Wiring

- Assembly and sealing of the drive rain shields, and
- Transport of the subassembly to the final assembly station.

A. 1. 2. 4 Assembly of the Reflective Array and Supports to the Drive and Pedestal. The last operation within the Site Plant occurs at six final assembly stations. Three additional crews at these six stations perform the final steps in the heliostat assembly process. These are:

- Obtain, transport and rotate a reflective array and structure from one of the array assembly work tables and position it over a pedestal and drive subassembly at the final assembly station.
- Mate the torque tube collars with the elevation drive mounting feet and mount the array to the drive.
- Mount the sensor reflector and its supports.
- Touch up painting of the completed heliostat.
- Transport of the heliostat to a holding position for movement to the site on a special vehicle.

None of the activities in the Site Plant require special fabricating or assembly equipment.

The preceding section has discussed the manufacturing, concepts and processes envisioned in the 'steady state' or the Nth commercial plant, with yearly production capacity of 60,000 or more heliostats. The first commercial plant, with a capacity of approximately 21,000 heliostats per year, would incorporate some of the automated techniques of the Nth plant where these prove cost effective and retain some of the pilot plant processes where increased automation is not cost effective. For instance, automatic welding of the pedestal back and top plate would be similar to if not identical to the Nth plant process.

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