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BOEING ENGINEERING & CONSTRUCTION
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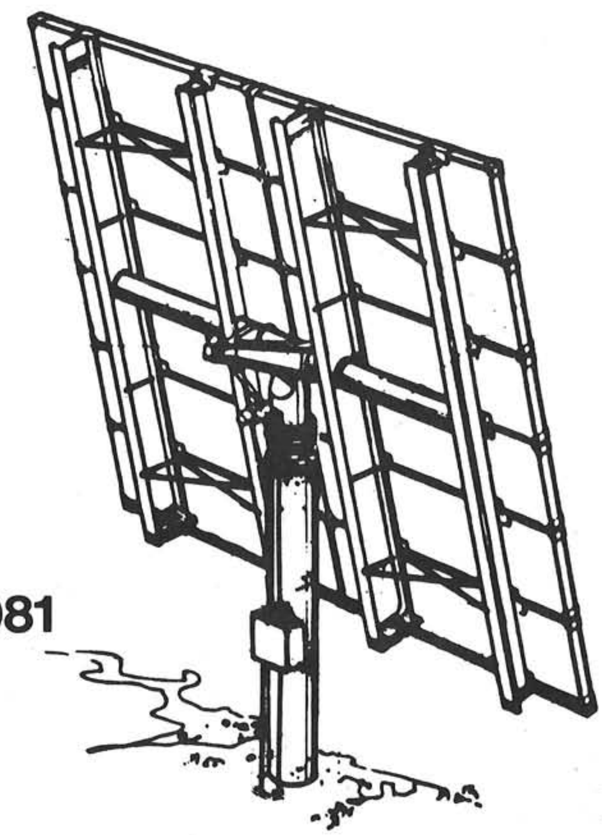
Final Report

Second Generation Heliostat Development for SOLAR CENTRAL RECEIVERS



March 31, 1981

Production Planning and Cost Estimates

Volume II - Appendices A, B, C, F, G, H, W, Y

SECOND GENERATION HELIOSTAT DEVELOPMENT

FINAL REPORT

Volume II

Sections 4.0 - 8.0

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FINAL REPORT
SECOND GENERATION HELIOSTAT DEVELOPMENT FOR SOLAR CENTRAL RECEIVERS

VOLUME II
PRODUCTION PLANNING AND COST ESTIMATES

D.F. PLUMMER

MARCH 31, 1981

BOEING ENGINEERING & CONSTRUCTION
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PREPARED FOR
SANDIA NATIONAL LABORATORIES
LIVERMORE, CALIFORNIA
UNDER CONTRACT 83-2729C

ABSTRACT

Production, transportation, installation, checkout, operation and maintenance of a collector subsystem for a 50 MW/1.5 solar-multiple solar-electric power plant are described. A capital cost estimate for the collector subsystem component manufacturing plant is given. An estimate of the acquisition costs for a collector subsystem installed at a 50 MW/1.5-SM power plant are also provided. Annual operation and maintenance cost estimates are also given. Appendices provide detail plant layouts, production flows and cost information.

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FOREWORD

This volume of the detail design report was prepared to satisfy the requirements of Task 2-E of Sandia Laboratories' Contract 83-2729C. It describes the manufacturing, transportation, installation, operation, maintenance, and cost estimates of a second generation solar energy collector subsystem for thermal-electric-power and industrial process heat plants. The results of subtasks 2.E.2 and 2.E.4 of the contract are reported in this volume. Volume 1 contains the detail design description, trade studies and analyses of the collector subsystem. Because the contract did not provide for detail design of the collector control subsystem, manufacturing plans and cost estimates for that item are only briefly referred to.

The development project for the second generation collector subsystem was performed by the Boeing Engineering and Construction Company (BEC), under the direction of Mr. Roger B. Gillette, Program Manager; the Sandia Technical Manager was Mr. Charles Pignolet.

BEC was assisted in this project by two major subcontractors: Ford Aerospace and Communications Corporation (Western Development Laboratories Division), and Pittsburgh Corning Corporation. Ford designed and fabricated the prototype gimbal-drive assemblies and planned the production capability for the gimbal and frame. Pittsburgh Corning fabricated the prototype reflector facet assemblies, and performed the production planning for the facet.

BEC was also assisted by two electric utilities: Public Service Company of New Mexico, and Arizona Public Service Company. Abbas Akhil (Public Service Company of New Mexico) and Darryl Barnes (Arizona Public Service Company) provided helpful technical advice during the design phase.

PRODUCTION PLANNING AND COST ESTIMATES
FOR
HIGH-VOLUME PRODUCTION OF A
SECOND-GENERATION-HELIOSTAT COLLECTOR SUBSYSTEM

SECTION 1

INTRODUCTION

1.1 General

Sandia Laboratories contract 83-2729C with the Boeing Engineering & Construction Company required a preliminary design of the production, transportation, installation, and maintenance functions for the collector subsystem. In addition, cost estimates for the subsystem were to be prepared based on the preliminary design. The results of these two tasks are summarized in this volume. Volume I summarizes the design and test results for the prototype heliostat design.

1.2 General Market Area

In planning for production of second generation heliostat collector subsystem, Sandia specified that the potential solar power plant market would be in the southwestern United States. Therefore, this plan has been based on initial production to support plants located in that area. All plants are assumed to be new; repowered plants were not considered.

1.3 Collector Field Size

Sandia specified that all planning would be based on a collector field sized for a 50MW solar electric power plant with a solar multiple of 1.5. The number of heliostats required and the field layout was determined by Sandia using BEC-supplied performance data for the heliostat. A Sandia computer code, DELSOL, was used to size and layout the field. All planning for field installation, checkout, etc., is based on this Sandia-developed information.

SECTION 2

Manufacturing, Transportation, Installation, Operations and Maintenance of the Collector Subsystem

To evaluate the production costs for BEC's Second Generation Heliostats, it was necessary to first establish a solar electric plant deployment scenario. This scenario consists of the possible locations for the plants, general plant activation and construction schedules, a preferred assembly concept, and the associated production logistics. Manufacturing, transportation, installation and checkout, and operation and maintenance concepts were then developed which support the deployment scenario.

2.1 Deployment Scenario

Sandia specified that the potential market area for solar-electric power plants was in the 8-state region comprised of California, Nevada, Utah, Colorado, Arizona, New Mexico, Texas and Oklahoma. Within this region a central manufacturing facility (CMF) was to be located. The power plants were to be evenly distributed within a 400 mile radius of the CMF. In order to choose a reasonable location for the CMF, it was first necessary to make some estimate of potential solar-electric plant locations.

2.1.1 Central Manufacturing Plant Location

Potential areas for solar-electric power plants in the 8-state region were reviewed. The major factors considered were insolation availability, topography, highway and rail access, transmission line availability, and nearness to potential load centers. These factors led to the power plant deployment scenario depicted in Figure 2-1. The total number of plants and pertinent comparative statistics are shown in Table 2-1.

Based on the solar-electric-power-plant deployment scenario, CMF locations were considered which would minimize collector subsystem transportation costs from the CMF to the electric plant sites. In addition, candidate CMF locations were required to have adequate labor, land and energy supplies. Phoenix, Arizona was selected as the preferred site. The relation of

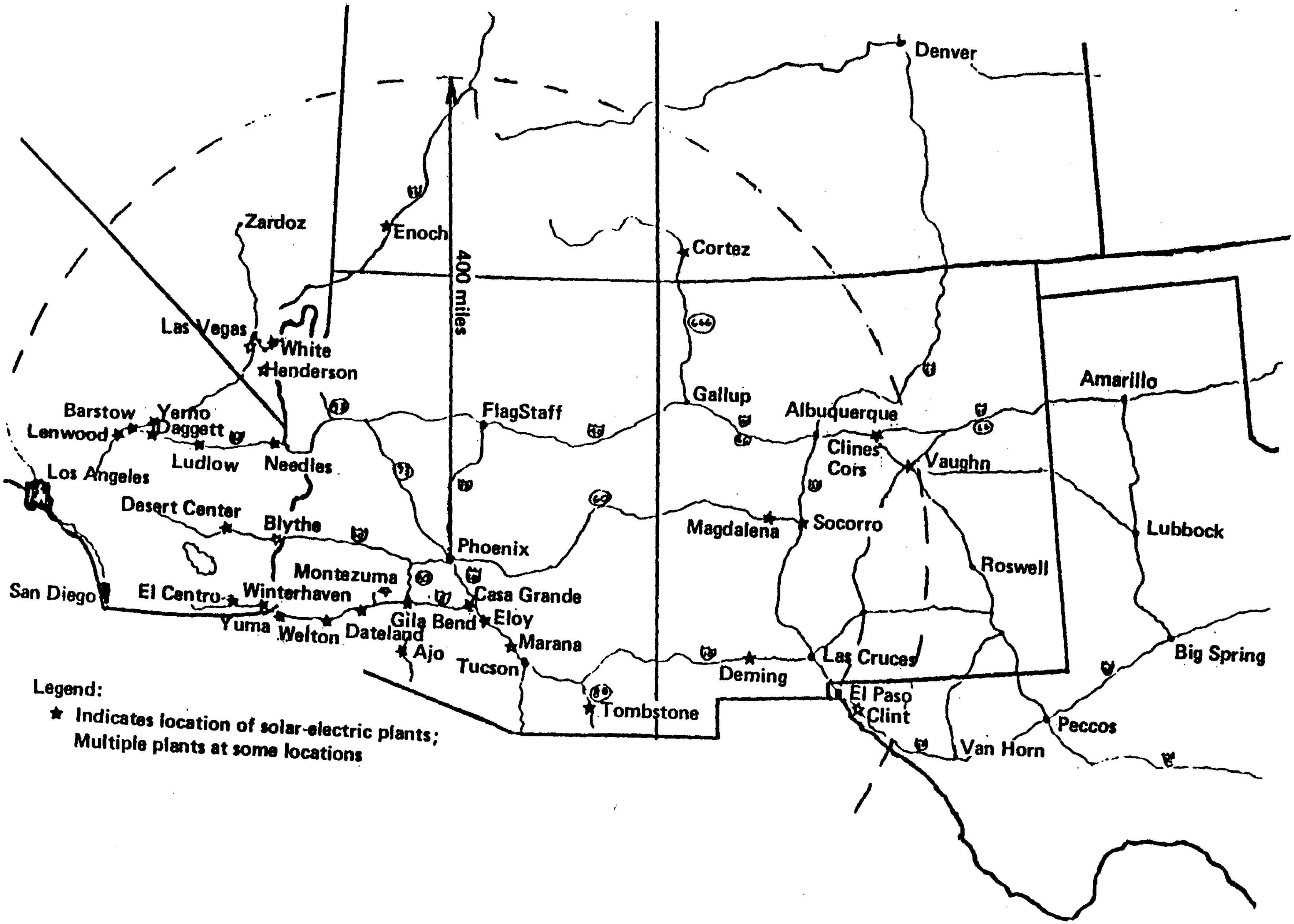

Figure 2-1. Solar-Electric Power Plant Locations

Table 2-1. Solar-Electric Plant Distribution Statistics

	No.	MW (% of total)	Total Area, Miles^2	Area with Insolation ~ 500 L/D* Miles^2	Area with Insolation ~ 500 L/D* Percent
Arizona	36	1800 (46.2%)	113,909	74,041	46.9%
California	16	800 (20.5%)	158,693	31,739	20.1%
Colorado	1	50 (1.3%)	104,247	1,043	0.7%
Nevada	5	250 (6.4%)	110,540	11,054	7.0%
New Mexico	17	850 (21.8%)	121,666	36,500	23.1%
Texas	2	100 (2.6%)	267,338	2,674	1.7%
Utah	1	50 (1.3%)	84,916	849	0.5%
Totals	78	3900	—	157,900	100%

*L/D — Langleys per day

Phoenix to the region's insolation characteristics is shown in Figure 2-2. A general design/construction schedule for the CMF is shown in Figure 2-3.

2.1.2 Solar-Electric Plant Activation/Construction Schedule

Sandia specified that the production planning scenario would be based on a CMF output of 20,000 heliostats the first year (June 1, 1984 through May 31, 1985). Thereafter, production was to be at the rate of 50,000 heliostats per year. Both outputs were to be based on two shifts/day. In addition, each electric plant was to have an output of 50MW with approximately three hours of thermal storage.*

Using BEC-supplied performance data for the heliostat, Sandia determined that 6914 heliostats would be required for a 50MW/SM1.5 plant. Based on this requirement, a general plot plan and construction schedule for the plant were developed; these are shown in Figures 2-4 and 2-5. A detailed collector subsystem construction schedule is shown in Figure 2-6. The plant and subsystem construction schedules are based on reasonable estimates of construction flow times and are compatible with other published information for similar plants: see references 2-1 and 2-2.

Using the construction schedules shown in Figures 2-5 and 2-6, a solar-electric power plant activation schedule was established which was compatible with the Sandia-specified heliostat production rate. As shown in Figure 2-7, approximately 11 plants are being constructed in any one year. This activation rate must be accounted for in the production plan for the collector subsystem.

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*-The collector subsystem was sized for a 50MW electric plant with a solar multiple of 1.5 (approximately 3 hours of storage). Sandia used their DELSOL computer program to size the field.

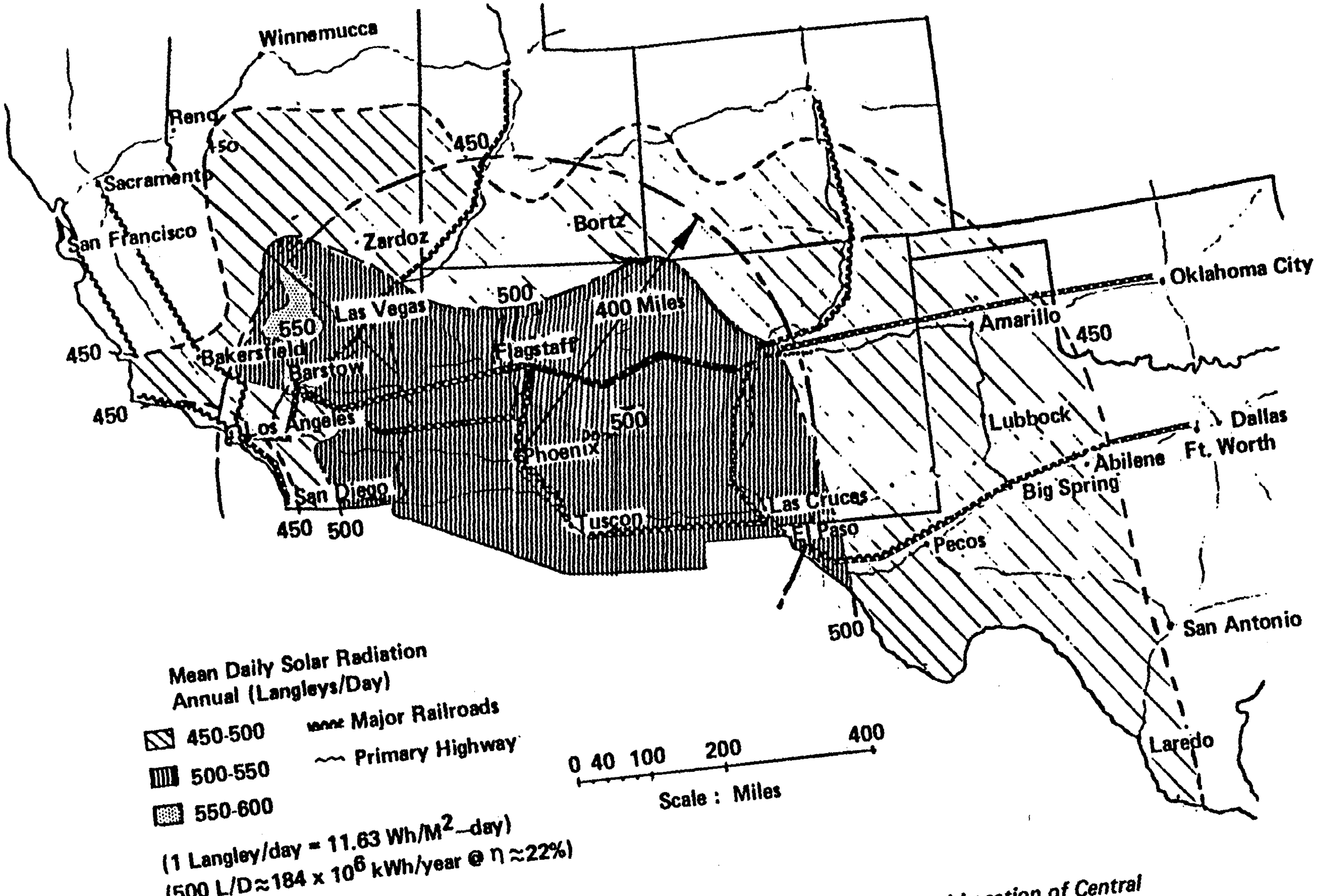
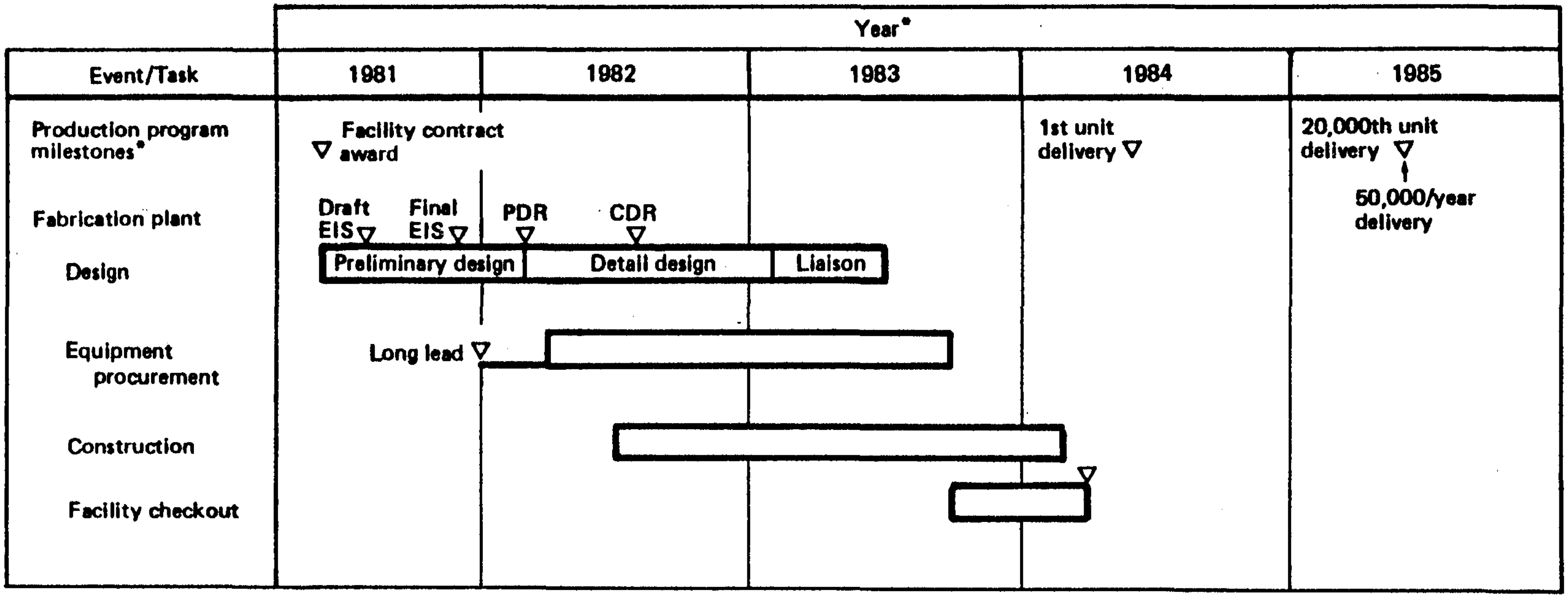


Figure 2-2. Annual Insolation in the Southwestern United States and Location of Central Manufacturing Facility



*Key dates per Sandia letter S.G. Peglow to R.B. Gillette, et al, dated October 8, 1979.

Figure 2-3. Central Manufacturing Facility Design/Construction Schedule

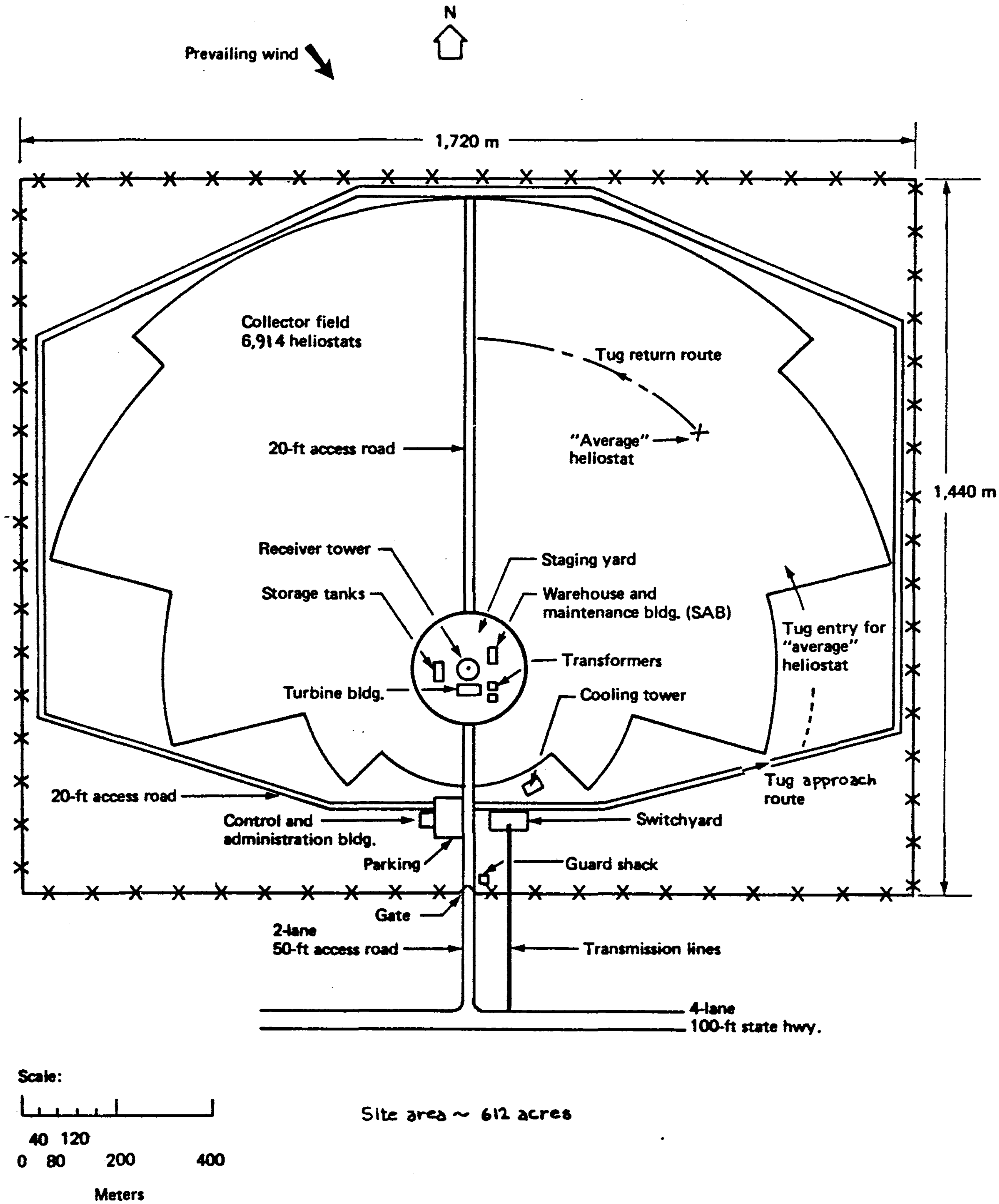
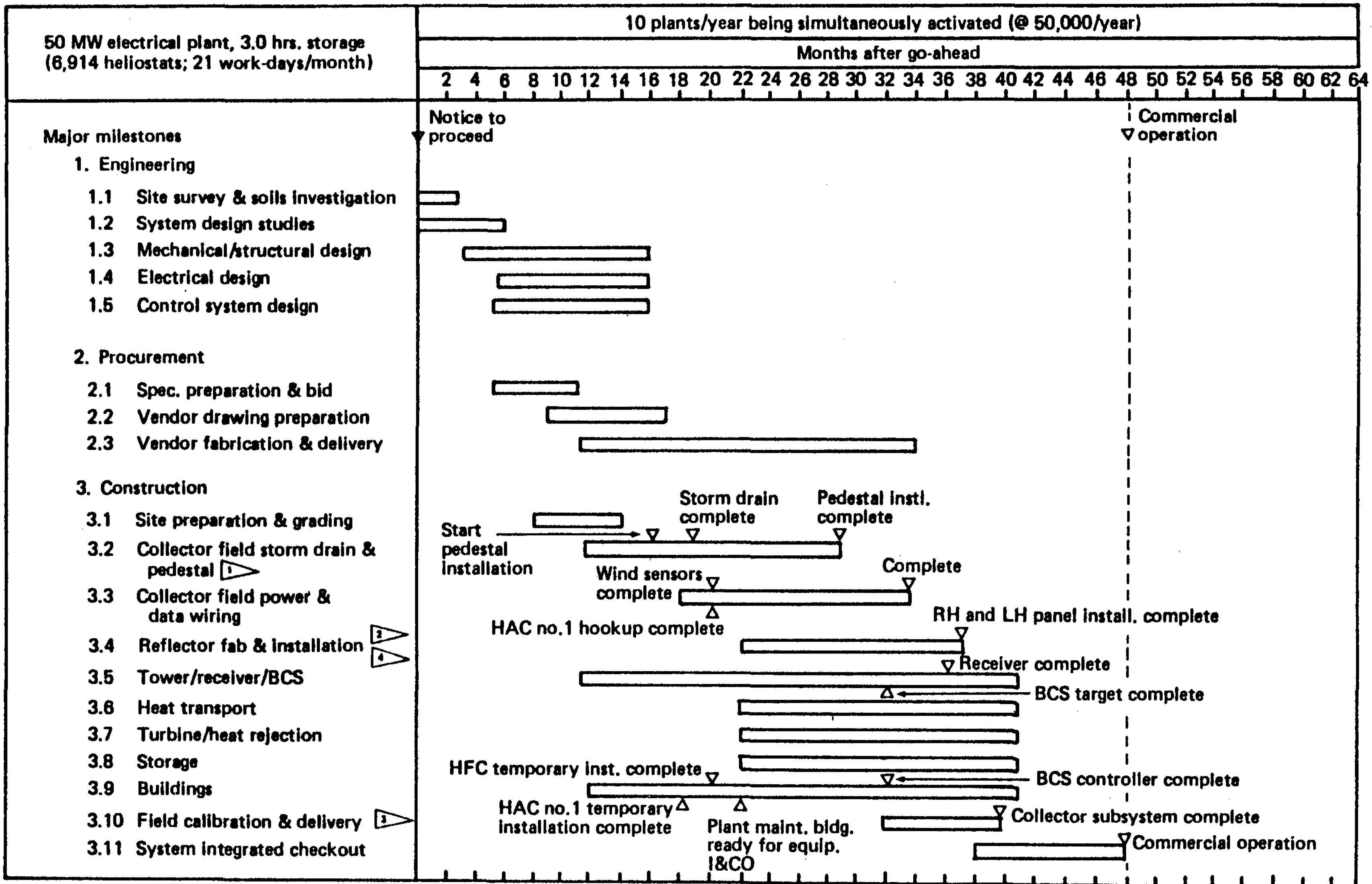


Figure 2-4. 50 MW Solar-Electric Power Plant Plot Plan



1. Assume 1 crew installs 2 pedestal/hr; there are 2 crews: @ 6.6 hrs/day = 26.4 helios/day
2. Assume 1 crew installs 2 helios/hr; there are 2 crews: @ 6.6 hrs/day = 26.4 helios/day
3. Assume 1 crew calib/aligns 1 helios/hr; there are 5 crews: @ 6.6 hrs/day = 33 helios/day
4. Assume 1, 3-man crew can simultaneously clean 2 helios in 10 minutes; @ 6.6 hrs/day = 79.2 helios/day

Figure 2-5. General Solar Electric Plant Construction Schedule

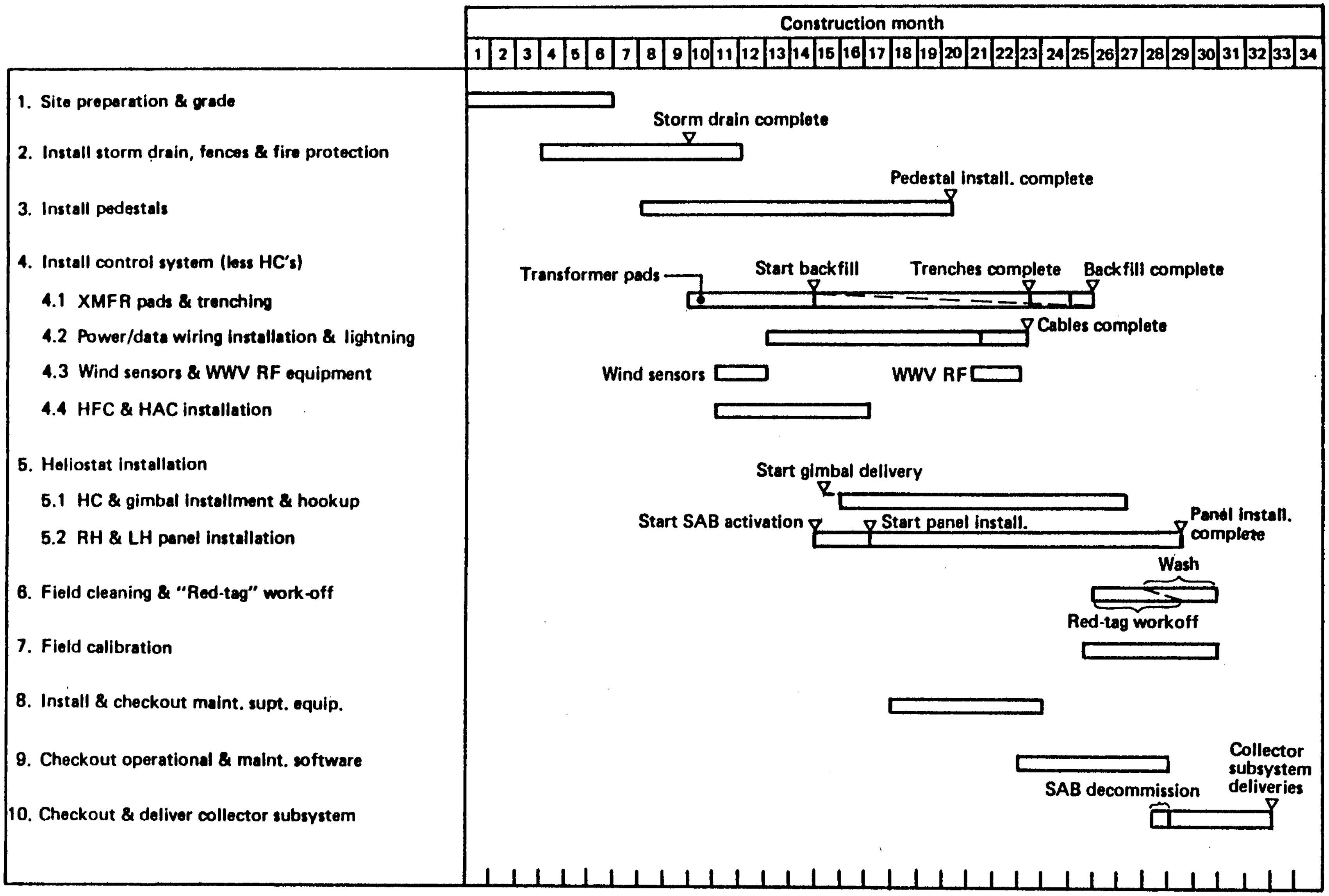


Figure 2-6. Collector Subsystem Construction Schedule

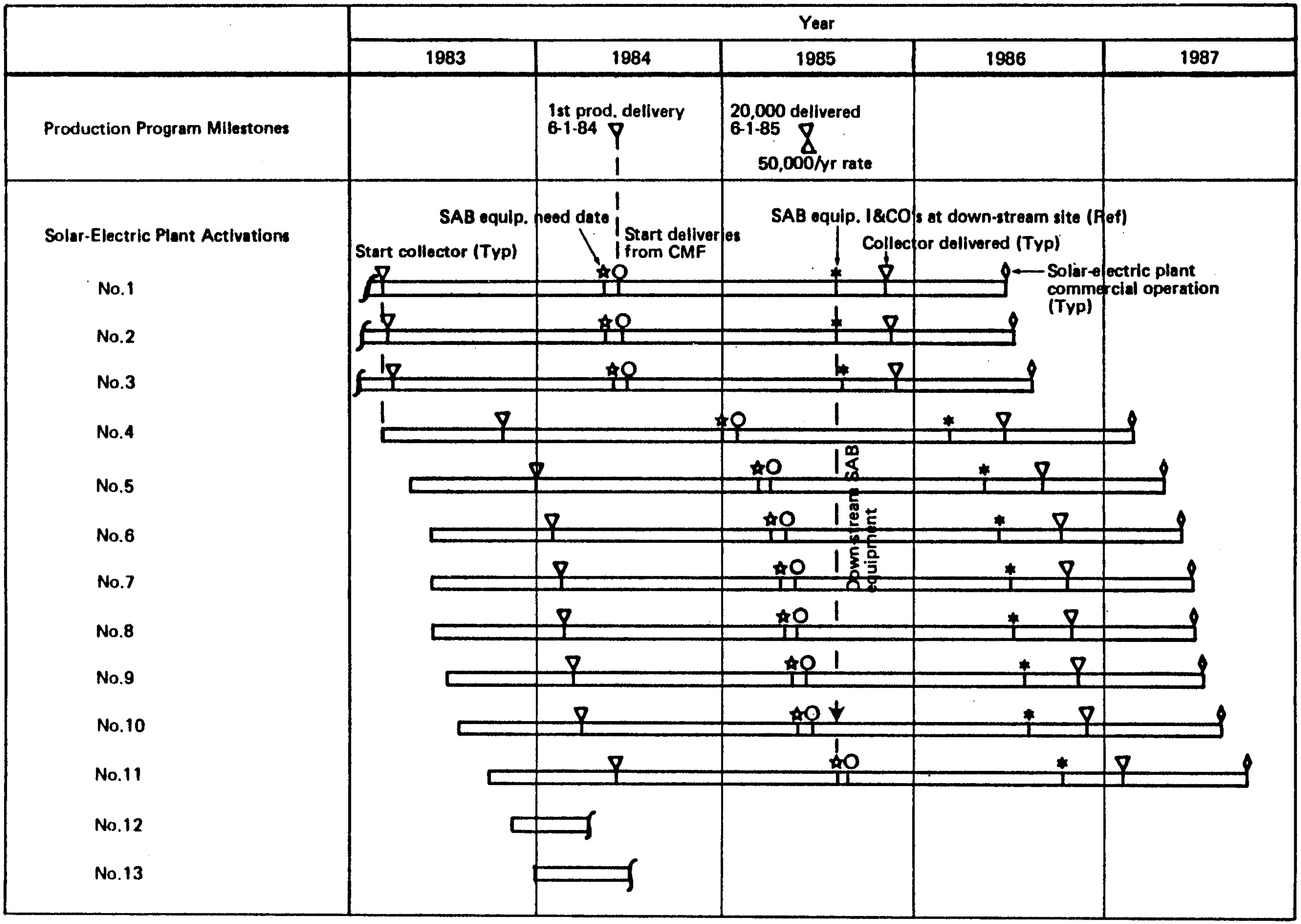


Figure 2-7. Solar-Electric Plant Activation Schedule

2.1.3 Heliostat Final Assembly Concept

Because of its large size (approximately 24.5' x 20'), it is not feasible to assemble and transport the heliostat reflector from the CMF to each plant site. Thus, an alternate assembly concept must be chosen which is compatible with the electric plant construction schedule and the specified production rates. The principal alternatives involved various degrees of on-site assembly using either a pre-engineered high-production-rate facility or the power-plant maintenance and warehouse building*; both are referred to as the site assembly building (SAB).

Several final assembly methods were evaluated on a single-piece and a three-piece torque tube. A complete list of the alternatives is given in Table 2-3, which also gives the incremental costs for each option. Certain options are not feasible and were rejected. The remaining feasible options are compared in Figure 2-8; some of these are illustrated in Figure 2-9.

To determine the preferred option, selection criteria were established and assigned the weights shown in Table 2-4. The feasible options were then scored according to these criteria; the results are shown in Table 2-5. Based on this evaluation, a 3-piece torque tube was selected (option B2) as the preferred design, with the right and left reflector subassemblies being assembled in the SAB (which is temporarily activated within the power-plants' maintenance and warehouse building). The subassemblies are then transported to the field and mounted on the gimbal-drive assembly, which has previously been installed on the pedestal.

---

*For power plants of this size (50MW) it is expected that a maintenance and warehouse building would be provided. Coordination with several utilities resulted in the assumption that a 60' x 100' building would not be unreasonable. For the on-site assembly options, it is planned that this building could be constructed and used on a coordinated basis, so that no facility incremental cost was required.

Table 2-3. Incremental Costs for Alternate Assembly Techniques

Option no	Assembly function at: CMF (Central Manufacturing Facility)	SAB (Site Assembly Building)	Pedestal (6 344 helios)	Type torque tube: 1 Piece	3 Piece	Incremental cost/heliostat for: CMF Capital	CMF Labor	CMF to site transport	SAB Capital ($13,000)	SAB Labor @ $15/hr	Site Transp capital	Site Labor @ $15/hr	Total	Notes
A1			Install gimbal arm, connect H frames to gimbal; install facets on frames		√	X +$10 0	+$10.0	HF ≈ $29.7 GA ≈ $20 9 F ≈ $76.5	0	0	26 RT 1's (4) $6.9	3 men, 3 0 hrs $135.0	$289	1. Assumes gimbal arm installed on separate dispatch 2. CMF capital cost Δ is higher than comparable cost for SAB due to higher production rate, requiring mechanical equipment 3. 4 RT 1's are retained, 22 are down streamed to the 10th site
A2	Assemble gimbal arm and H frame assemblies	Install facets on H-frames	Install gimbal; connect RH and LH reflector assemblies to gimbal		√	X +$10.0	+$10.0	$127.1	$2	2.4 hrs 2 men $72	38 RT 1's (4) $8 4	3 men, 0 64 hrs $28 8	$258 3	1. Assumes gimbal-arm installed on separate dispatch 2. CMF capital-cost Δ (Same as note no.2 in A1) 3. 4 RT-1's are retained; 36 are down-streamed
A3		Install reflector-gimbal assembly on pedestal	Install facets on H frames and assemble, RH and LH reflector assemblies to gimbal		√	X +$10.0	+$10.0	$127.1	(Need 2 SAB's) FSE = $3 0 +SAB = $38*	2 7 hrs 2 men $81	8 RT-1's (1) $4.4	4 men, 0 33 hrs $20.0	$293.5	1. CMF capital-cost Δ (Same as note no 2 in A1) 2. RA 1 trailer cost is ca $16,000/trailer 3. 1 RA-1 is retained; 7 are down-streamed
B1		Assemble H-frame assemblies	Install gimbal; connect RH and LH reflector assemblies to gimbal assembly		√	X	0	GA ~ $19.0 F ~ $76.5 B ~ $18.3 } T_{OB} ~ $4.7 } $23.0	$0.6	1.0 hrs 2 men $30	26 RT 1's (4) $6.9	3 men, 3.0 hrs $135.0	$291.0	1. Need 20 RT-1 carts for frame assemblies and facets to match field assembly rate (Each dispatch is ca 3.4 hrs for assembly at pedestal) 2. SAB cost to assemble H-frame is same as if done at CMF 3. 4 RT-1's are retained, 22 are down-streamed
B2	Fabricate torque tubes, beams braces, gimbal arm assembly	Assemble RH and LH H-frames and install facets	Assemble RH and LH H frames and install facets		√	X	0	$118 5	$2	2 men, 1 hr + 2 men, 2.4hrs $102 0	38 RT 1's (4) $8.4	3 men, 0 64 hrs $28.8	$259 7	1. SAB capital same as A2 2. 4 RT-1's are retained, 34 are down streamed
B3		Assemble RH and LH H frames, install facets connect RH and LH relect assemblies to gimbal assemblies	Connect reflector gimbal assembly to pedestal		√	X	0	$118 5	FSE = $3 0 +$2 SAB @ $38	2 men, 1 hr + 2 men, 2.7 hrs $111	8 RA 1's (1) $4.4	4 men, 0 33 hrs $20.0	$294 9	1. SAB capital same as A3, site capital and labor same as A3 2. 1 RA 1 is retained; 7 are down streamed
C1			Connect frame to gimbal; install facets on frame	√										
C2	Assemble reflector frame assembly	Install facets on frame assembly	Connect reflector assembly to gimbal	√										These options are not feasible due to excessive size of assembled double H frame assembly; an escort would be required for each truck load which would carry 4 helios worth (8 frames)
C3		Install facets on frame; connect reflector assembly to gimbal	Install reflector gimbal assembly on pedestal	√										
D1		Assemble reflector frame	Install gimbal; install frames on gimbal, install facets	√				B ~ $18.3 T_1 ~ $9.0 F ~ $76.5 G ~ $13 0						Beams come direct from Bethlehem Steel in Lackawanna, N.Y., to CMS and are dispatched from Phoenix
D2		Assemble reflector frame, install facets and gimbal	Assemble reflector frame, install facets	√				$116.8						
		Assemble reflector frame, install facets and gimbal	Install reflector; gimbal assembly on pedestal				0	$116 8	$62.1	$60.1	$19.0	$20.0	$278.0	
E	Assemble RH and LH panels		Install gimbal arm assembly; mount RH and LH panels on gimbal-arm		√	+$10.6	+$16.0	$178 2 (Ship) +$15.0 (Crates)		$30	8 RA 1's $4 4	$38.8	$292.0	1. Handling of reflector panel crates 2. 1 RA-1 is retained; 7 are down streamed 3. 78 pipeline crates are required for 10 sites and replaced once

Table 2-3. Incremental Costs for Alternate Assembly Techniques (Continued)

Notes:

T_1	= One-piece torque tube-arm assembly
T_{OB}	= Outboard torque tube
B	= Beams and braces
F	= Facet
HF	= H-frame assembly
GA	= Gimbal-arm assembly
G	= Gimbal assembly (includes elevation drive)
CT	= Center torque-arm assembly
*	= Extra SAB required to meet installation rate: 6,000 ft^2 bldg @ \$40/ft^2 = \$240,000/6,322 = \$38/helio
X	= Baseline Phoenix factory capital cost @ \$50,000/yr as estimated by FMCo.
[1]	= Gimbal-arm installation requires 3 men @ 0.13 hrs

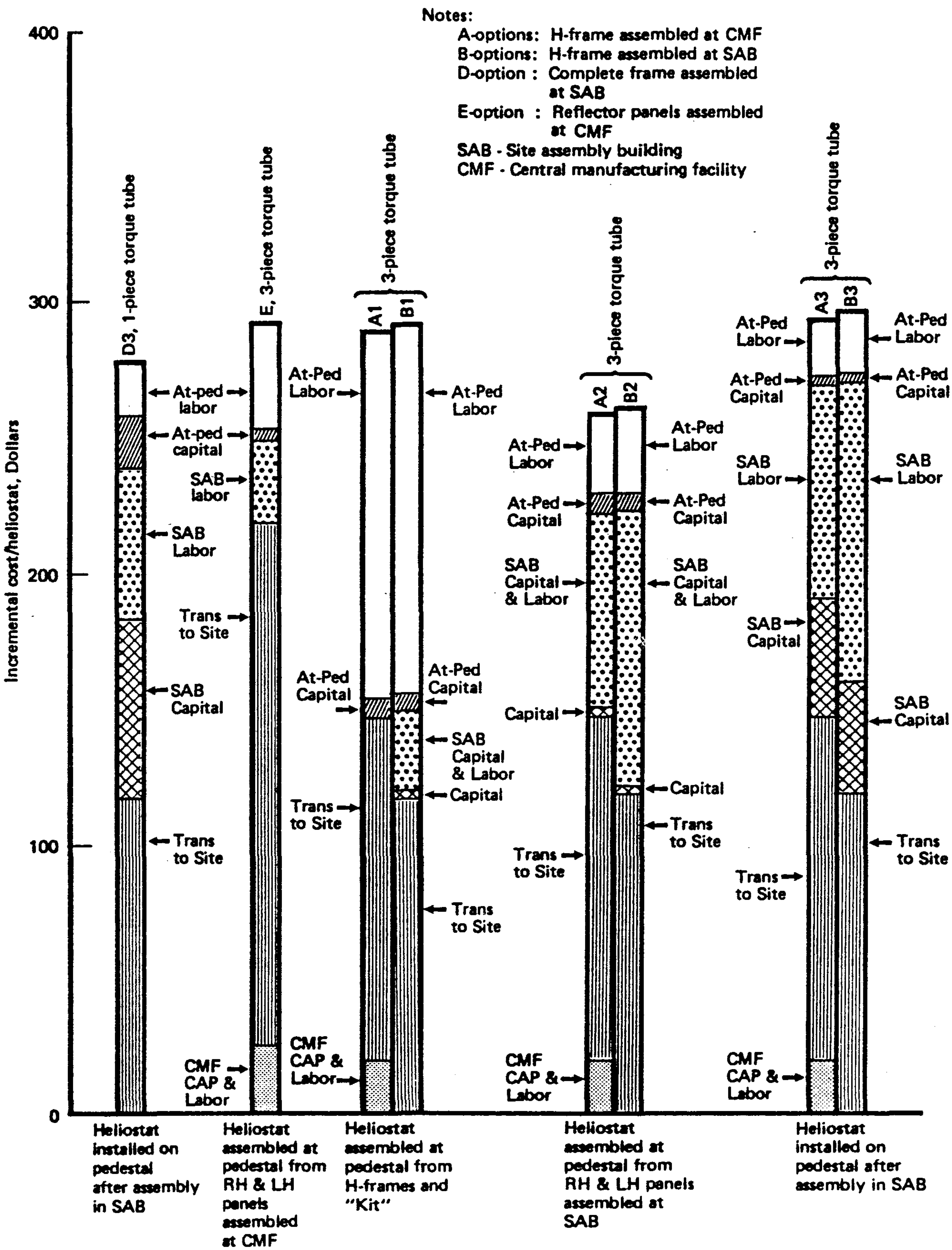


Figure 2-8. Comparison of Incremental Cost Breakdowns for Feasible Final Assembly Methods

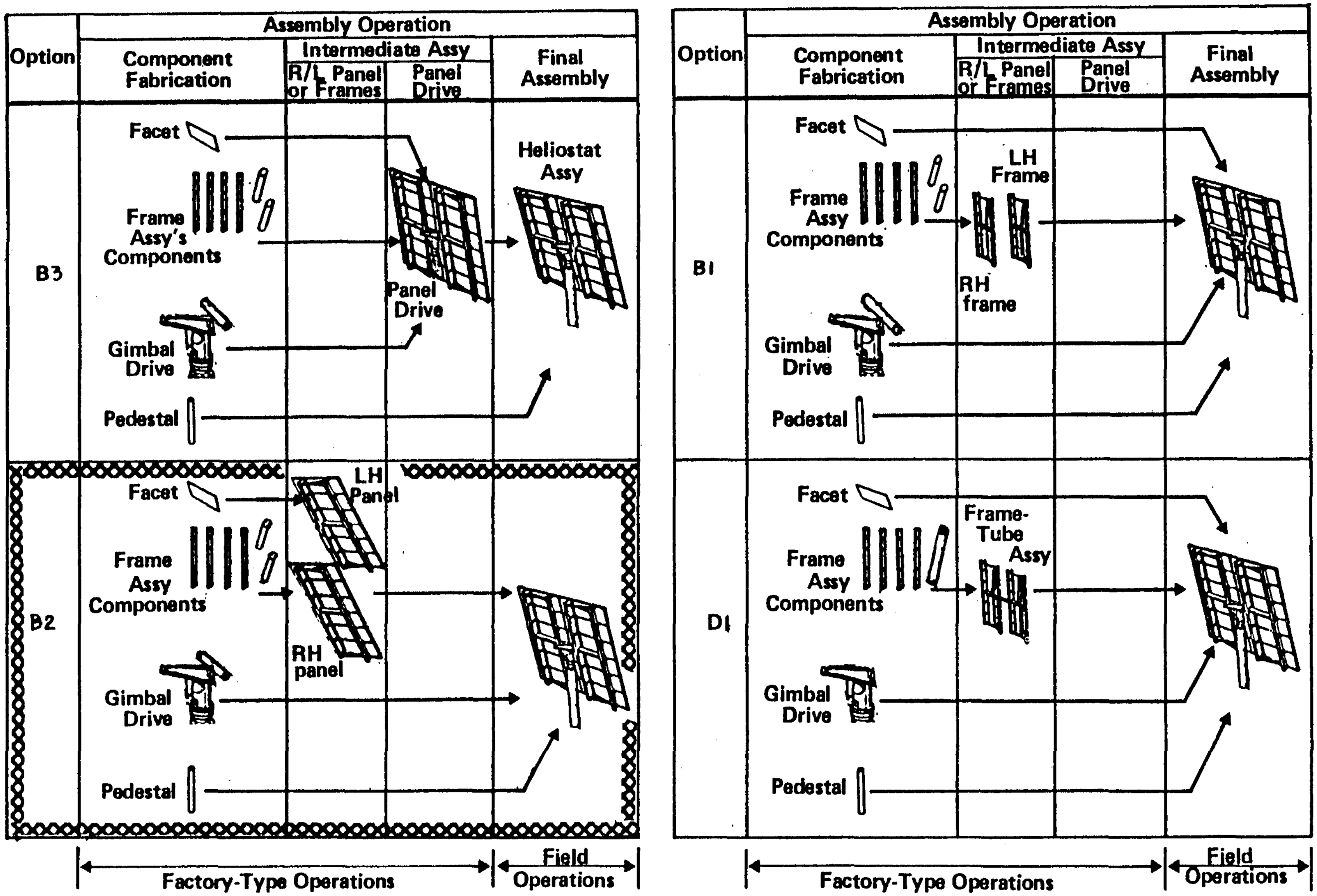


Figure 2-9. Optional Heliostat Assembly Techniques

Table 2-4. Selection Criteria for Assembly Technique

Criteria			Comment or rationale
No.	Description	Weight	
1	Lowest at-pedestal labor costs	4	Weather-caused delays increase costs (thunderstorms in summer, dust and high winds in spring, low temperature in winter; potential damage to heliostat from handling)
2	Lowest site capital costs	2	Reduce investment and logistic management costs (use available power plant buildings, reduce equipment downstreaming costs)
3	Lowest transportation costs	2	Fuel intensive operations sensitive to fuel escalation rates (partly offset by deregulation or trucking and improved fuel economy of trucks)
4	Lowest piece-part unit costs	1	Production rate (50,000/yr) probably ensures approximately equal $/pound cost of different configurations

Table 2-5. Comparison of Alternate Assembly Techniques

Alternative			Score* for criteria no. (Weight of criteria)				Total**	Rank
No.	Heliostat assembly operation at pedestal	Type torque tube	At-pedestal labor 1 (4)	Site capital 2 (2)	Transport 3 (2)	Piece-part 4 (1)		
A1	Assemble heliostat from "kit"	3-P	1	10	2	5	33	6
A2	Assemble heliostat from panels	3-P	6	7	2	5	47	2
A3	None***	3-P	7	2	2	5	41	5
B1	Assemble heliostat from "kit"	3-P	1	9	3	5	33	6
B2	Assemble heliostat from panels	3-P	6	7	3	5	49	1
B3	None***	3-P	7	2	3	5	43	4
D3	None***	1-P	7	1	4	7	45	3
E	Assemble heliostat from panels	3-P	4	10	1	5	43	4

* - Score 1 to 10: 1 = Least preferable, 10 = Most preferable

** - Total is sum of scores times weight of criteria

*** - Entire heliostat is assembled in SAB

2.1.4 Production Logistics

2.1.4.1 Major Plant Locations

Since Phoenix was selected as the location for the CMF, the balance of the production logistics was planned on that basis.

A facet assembly plant (FAP) is required to meet the high production rates. It was concluded that such a facility could be cost-effectively located in Phoenix, and could most efficiently be located adjacent to the gimbal and frame manufacturing plant (GFMP) in order to reduce administrative and other overhead costs. Together, these two plants constitute the central manufacturing facility (CMF).

Because a large amount of cellular glass is required, it is also cost-effective to produce this material in a plant adjacent to the facet plant. However, because the cellular glass is a proprietary product of the Pittsburgh Corning Corporation, the cellular glass plant is considered an entirely separate manufacturing entity. Thus, no benefits (except reduced transportation costs) are credited to the production costs estimates because of the colocation of this plant with the CMF.

2.1.4.2 Raw Materials and Component Part Sources

The major raw material requirements for the collector subsystem are for production of cellular glass. These materials (e.g., soda ash, lime, volcanic ash, etc.) are obtained from various sources throughout the United States and shipped by rail to the cellular glass plant. The necessary natural gas or electricity for the process is available in the Phoenix area.

Sheet fusion glass will be obtained from the Corning Glass Works plant in Blacksburg, Virginia. The front sheets will be silvered by an in-line conventional wet-chemistry process integrated with the fusion glass production.

The beams for the H-frames will be purchased direct from the Bethlehem Steel Corporation, and shipped from Lackawanna, New York. To provide balanced delivery rates, beams will be shipped via rail to each plant site.

Steel castings and other materials for the gimbal drive and tubing for the torque tubes will be obtained from various sources throughout the United States.

Motors and other electrical components for the gimbal-drive will be obtained central and western regions of the United States.

Heliostat field, and array controllers could be manufactured in the Dallas and/or greater Los Angeles areas and shipped direct to the power plant sites.

The overall production logistic concept is depicted in Figure 2-10.

2.2 Manufacturing Plan

The preliminary design of the manufacturing process was based on the production version of the collector subsystem. It is based on a concept of high-volume, low-cost production within the deployment scenario described in paragraph 2.1.

2.2.1 Production Collector Subsystem Design Concept

The production collector subsystem consists of a field of approximately 6900 heliostats. The field is controlled by a computerized, digital electronic system which is, in turn, an integral part of the overall plant control system. Necessary support resources are also included in the collector subsystem. Major elements are shown in Figure 2-11. An individual heliostat is illustrated in Figure 2-12; the field layout is shown in Figure 2-13. Details of the heliostat design are described in Volume I of this report.

2.2.1.1 Reflector Element

The reflector element is composed of twelve glass facets mounted on a galvanized steel frame assembly. The facets are constructed of a 1.5 mm

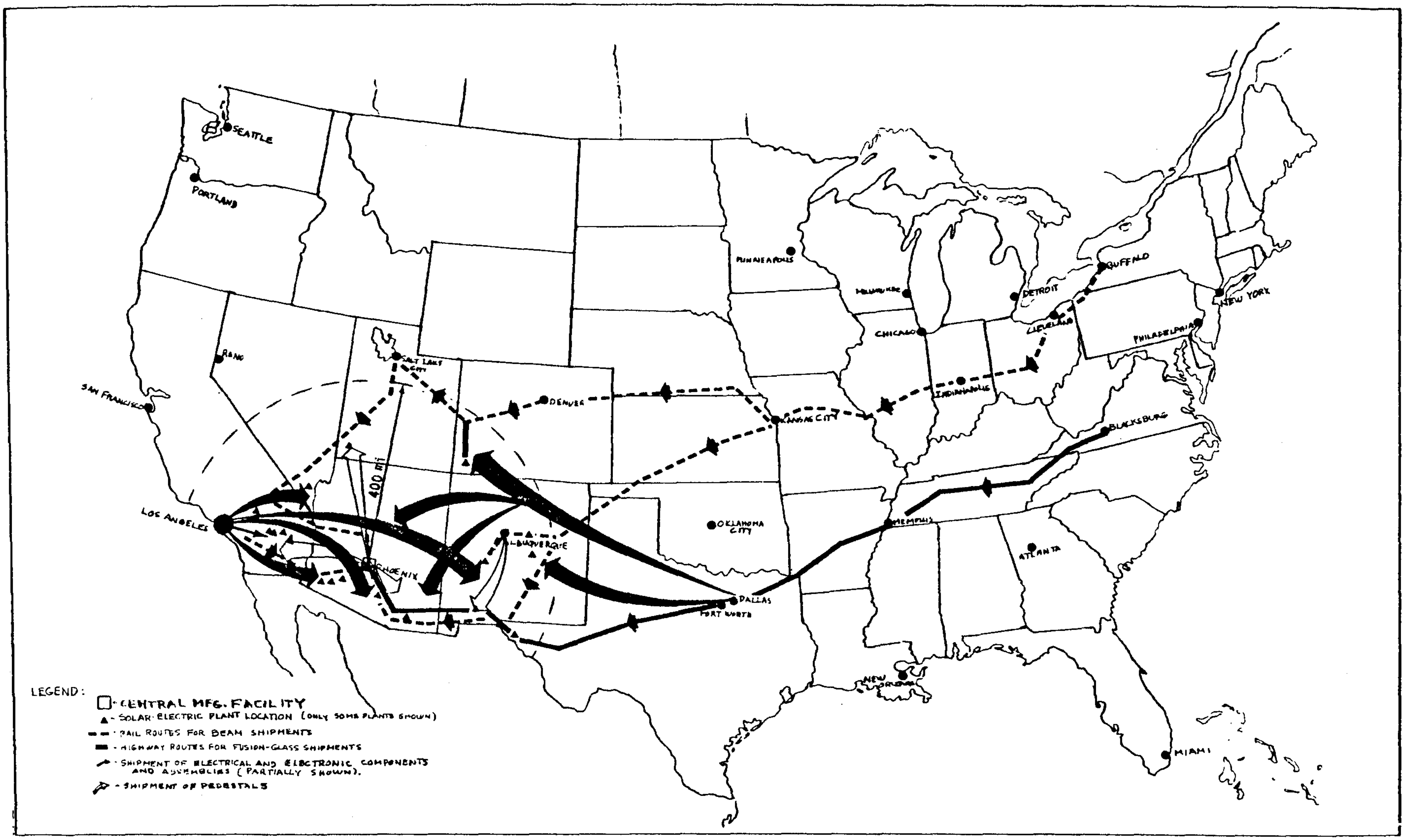


Figure 2-10. Production Logistic Concept

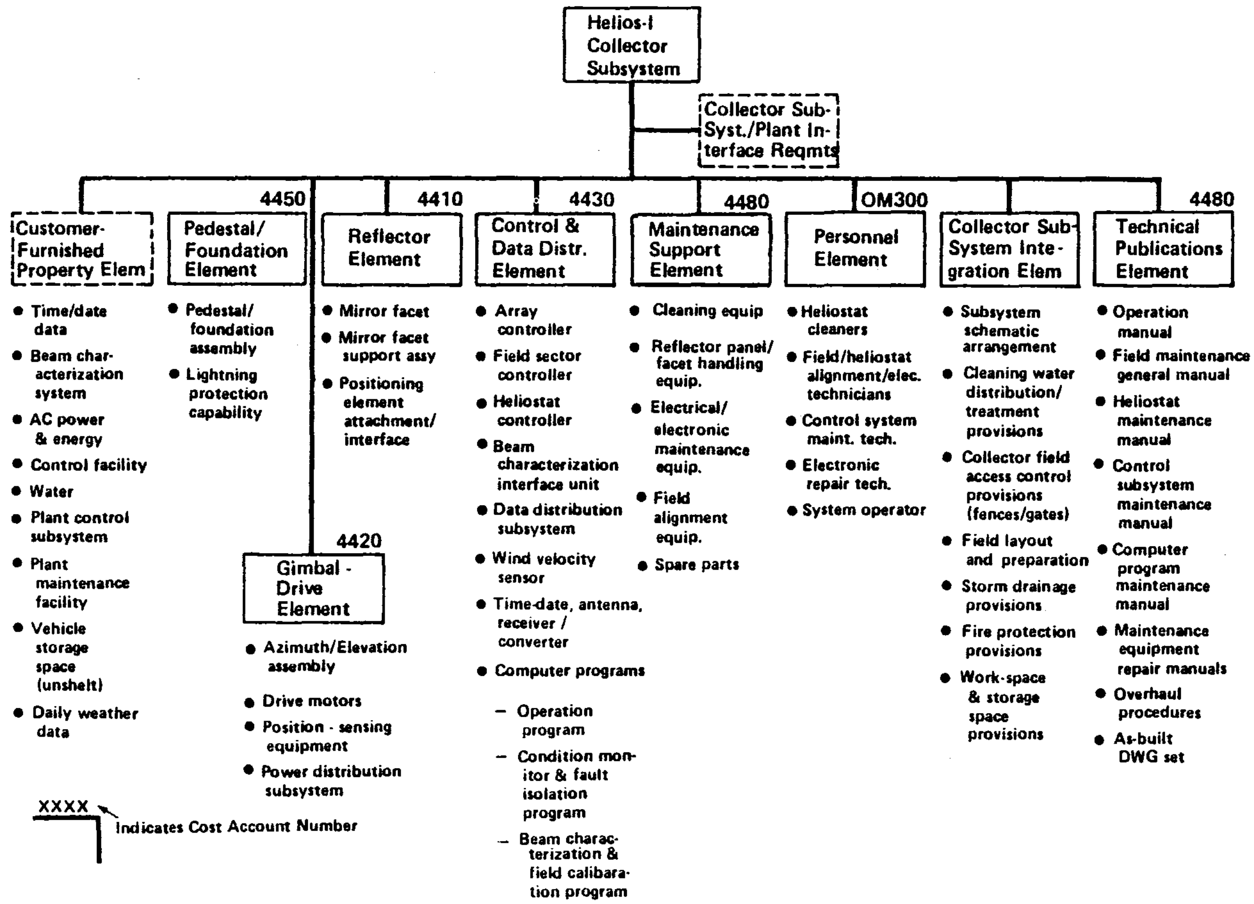


Figure 2-11. Major Elements of The Collector Subsystem

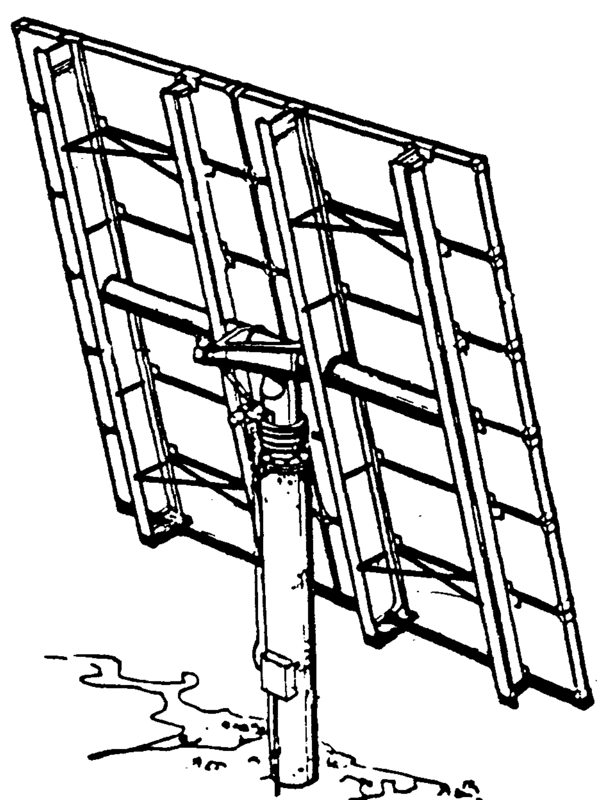


Figure 2-12. Collector Subsystem Heliostat

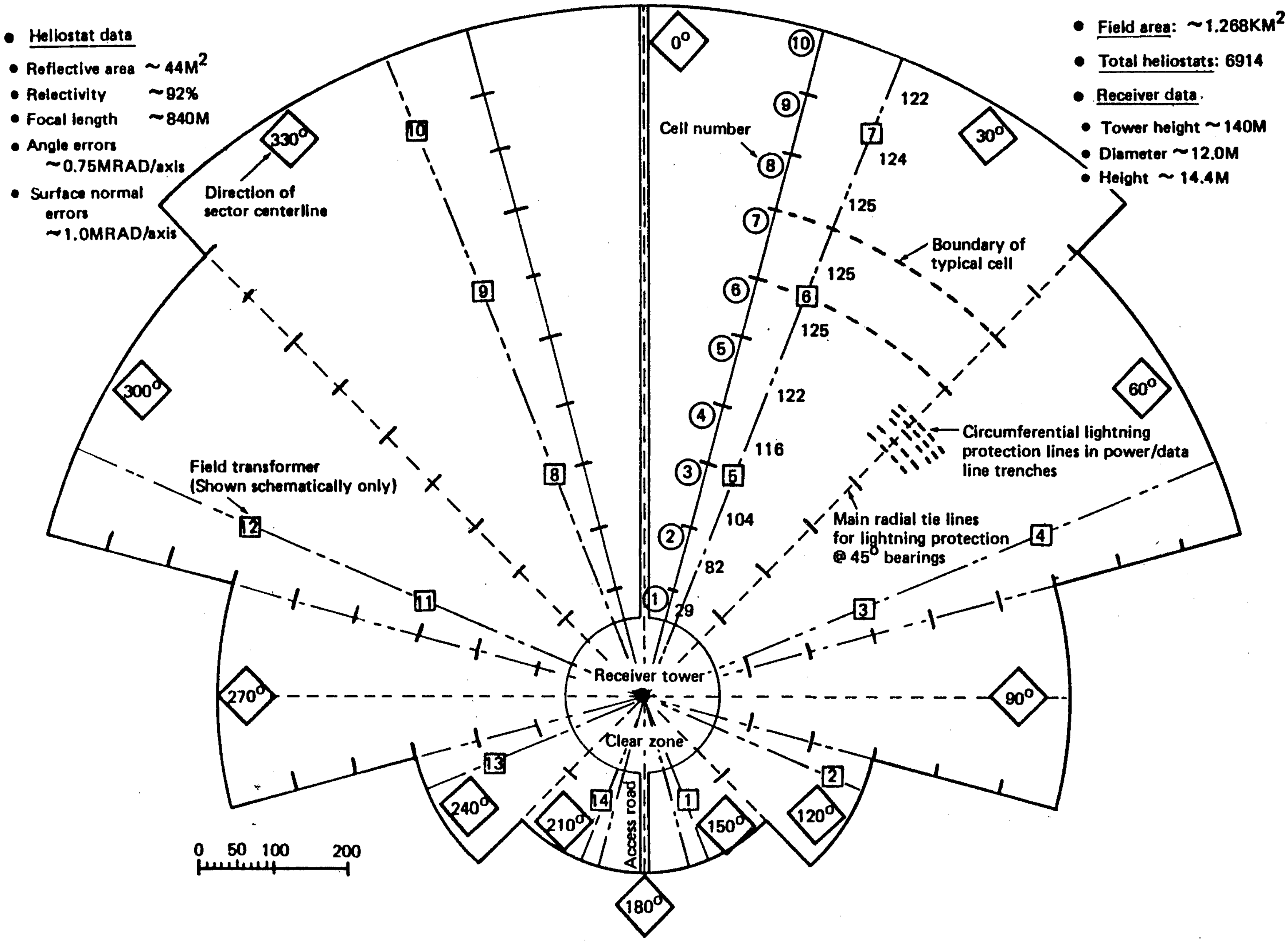


Figure 2-13. Collector Subsystem General Field Layout, 50 MW Solar-Electric Plant

borosilicate glass, back-silvered front skin which is epoxy-bonded to a cellular glass core assembly. The back skin is also 1.5 mm borosilicate glass; it is epoxy bonded to the cellular glass core. The front and back glass skins are Corning 7809 fusion glass. The glass "sandwich" is surrounded by a 24-gage galvanized cap strip attached to the facet edge by an asphalt/ urethane adhesive. The facet assembly is depicted in Figure 2-14.

The twelve facets are mounted on a steel frame assembly which is composed of 2 H-frame assemblies connected to a center section torque tube actuator arm assembly. Each H-frame consists of a center torque tube and two Z-beams with cross braces. Each facet is attached to the frame by four mounting brackets. The frame assemblies are illustrated in Figure 2-15; the mounting brackets in Figure 2-16.

2.2.1.2 Gimbal Drive Element

The gimbal drive element consists of a gimbal assembly, center torque-tube arm assembly, drive motors and sensors, and a power distribution network.

The gimbal assembly consists of a planetary gear azimuth drive assembly, and a linear actuator elevation drive assembly. The azimuth drive is powered by a 1/6th horsepower, 3-phase induction motor, while the elevation drive uses a 1/3rd horsepower, 3-phase induction motor. Necessary reference sensors, limit switches and cabling is also provided. Figure 2-17 illustrates the gimbal drive assembly.

The power distribution network consists of necessary transformers, circuit breakers, switch gear and cabling; it is illustrated schematically in Figure 2-18.

2.2.1.4 Pedestal Foundation Element

The pedestal foundation element consists of a concrete pier assembly and lightning protection provisions.

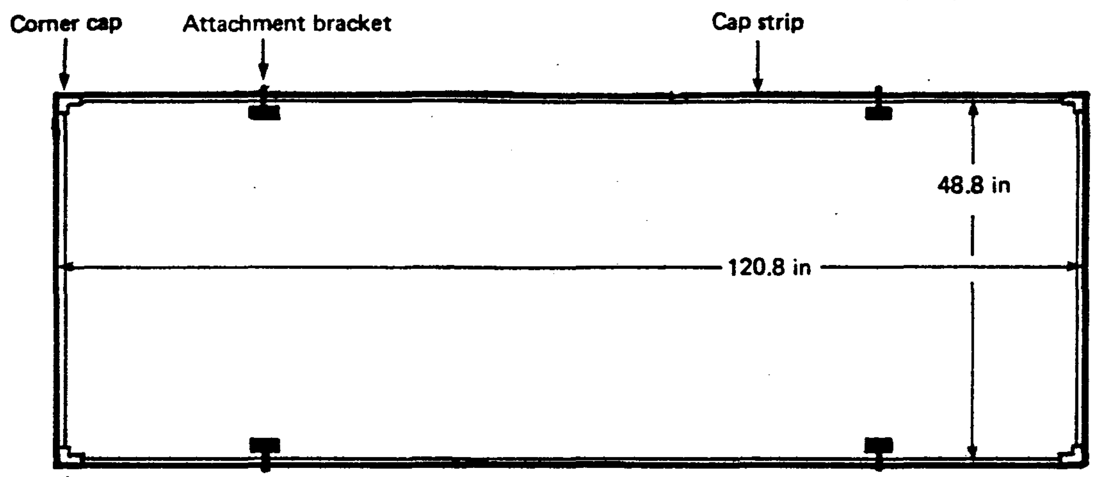


Figure 2-14. Heliostat Facet Assembly

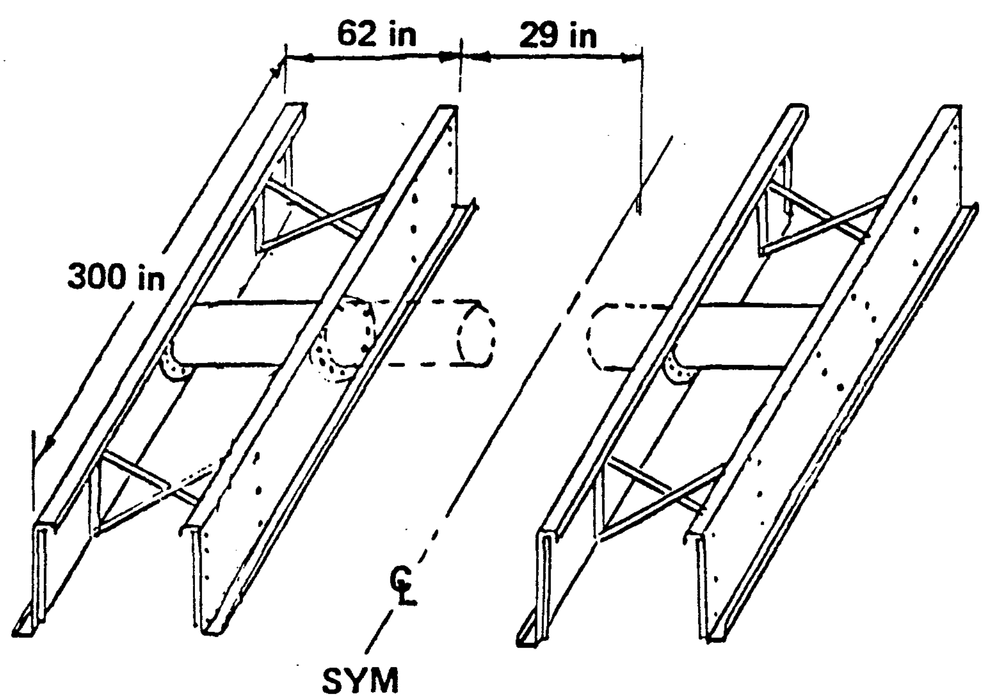


Figure 2-15. Reflector Support Frame Assembly

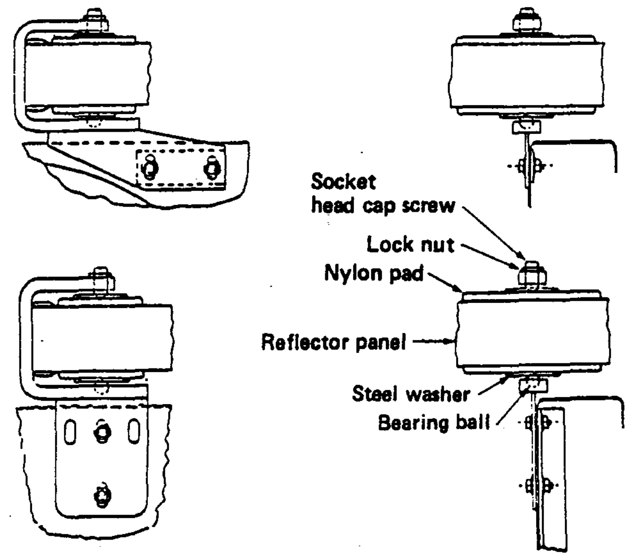


Figure 2-16. Facet Mounting Bracket

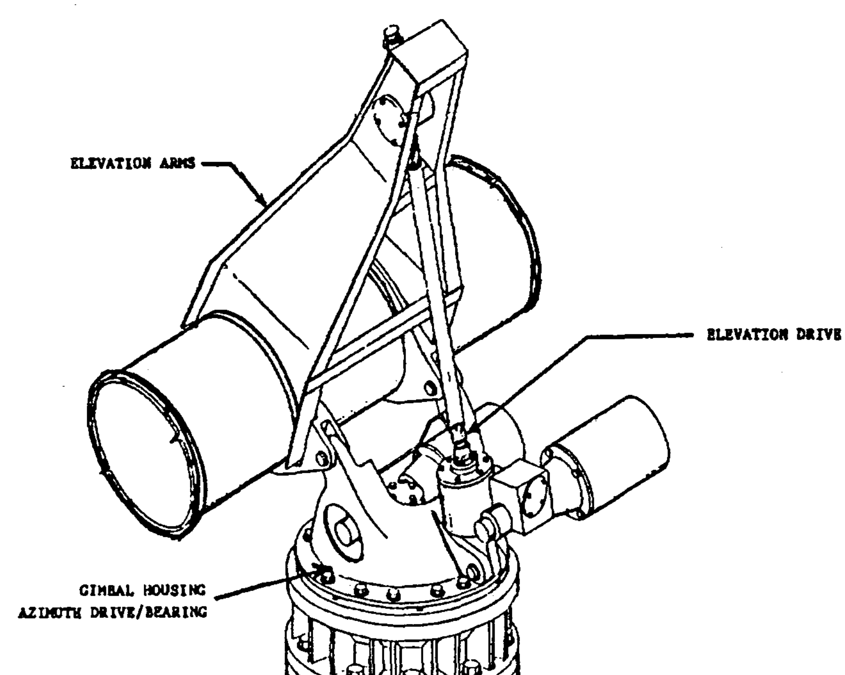


Figure 2-17. Gimbal-Drive Assembly

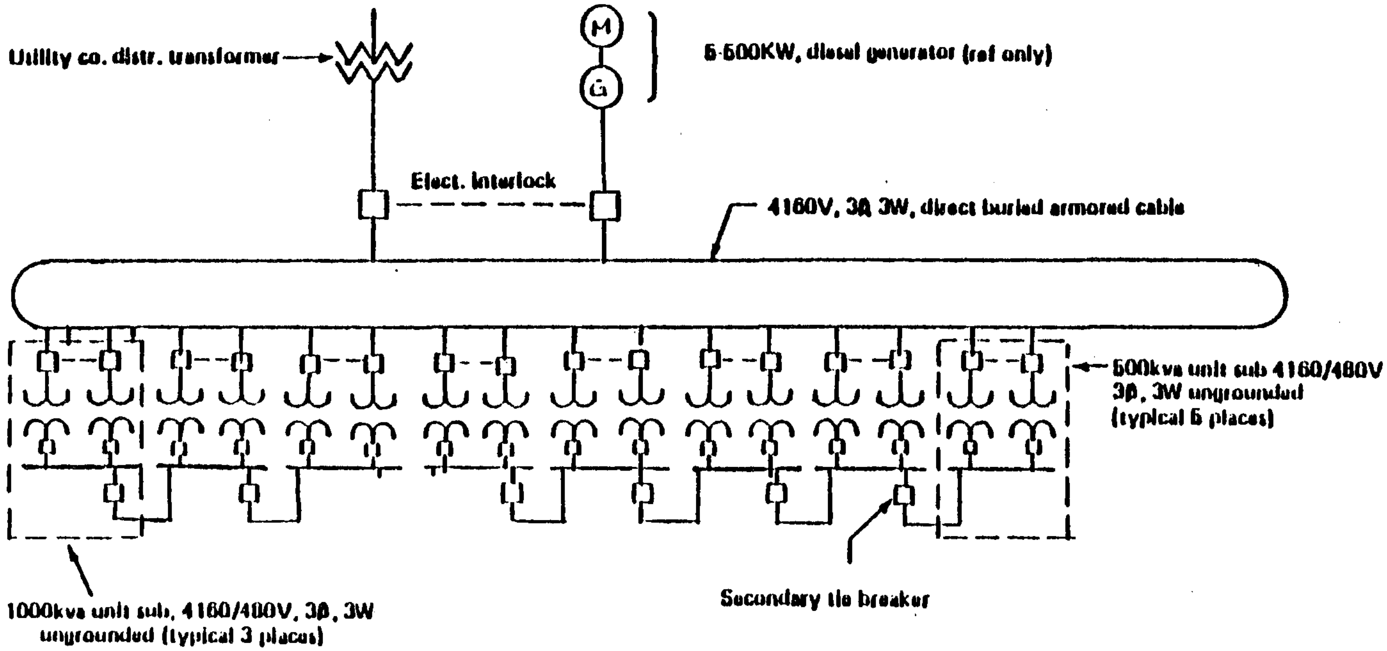


Figure 2-18. Power Distribution Schematic

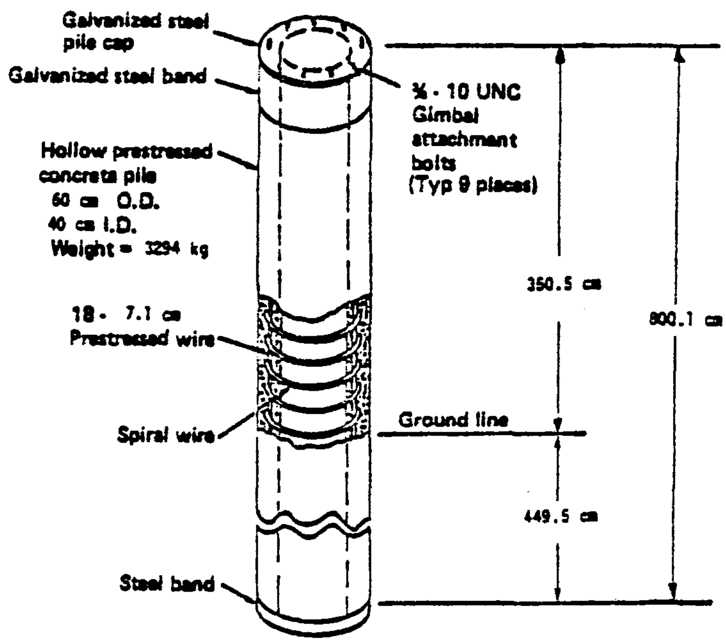


Figure 2-19. Pedestal Assembly

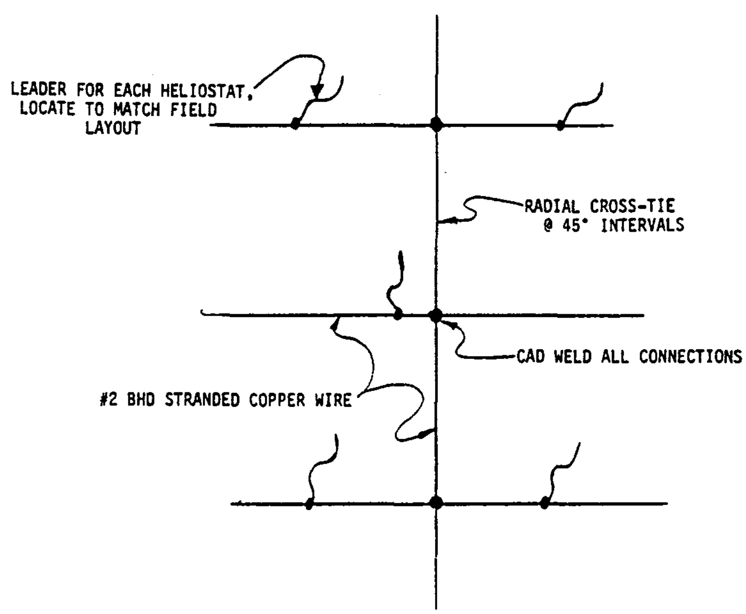


Figure 2-20. Lightning Protection Grid

The pier assembly is a centrifugally cast, prestressed, hollow concrete pile. The pile will be emplaced using conventional pile-driving techniques and machinery. The pier assembly is illustrated in Figure 2-19.

The lightning protection devices consist primarily of a buried grid of stranded copper wire to which each heliostat is grounded; this is illustrated in Figure 2-20. In addition, surge arrestors are provided in the heliostat, field and array controllers.

2.2.1.5 Controls and Data Distribution Element

The control element is composed of array, field-sector and heliostat controllers, operation and maintenance software, and a data distribution network. Although detail design of these components was not developed on this contract, a general schematic is shown in Figure 2-21 to provide visibility on BEC's concept.

2.2.1.6 Support Resources Segment

The support resources segment consists of a maintenance support element, a personnel element, and a technical publications element.

For the most part, the collector subsystem can be maintained with standard electrical, mechanical, and materials handling equipment expected to be available at an intermediate size thermal electric power plant. However, there are several specialized pieces of equipment which may be required; these are identified in Table 2-6.

In addition to the support equipment, an initial (layin) set of spares will be required. These spares will be recommended by the collector subsystem contractor, and selected by the plant owner.

Personnel will be required for the operation and maintenance of the subsystem. A manning summary is shown in Table 2-7.

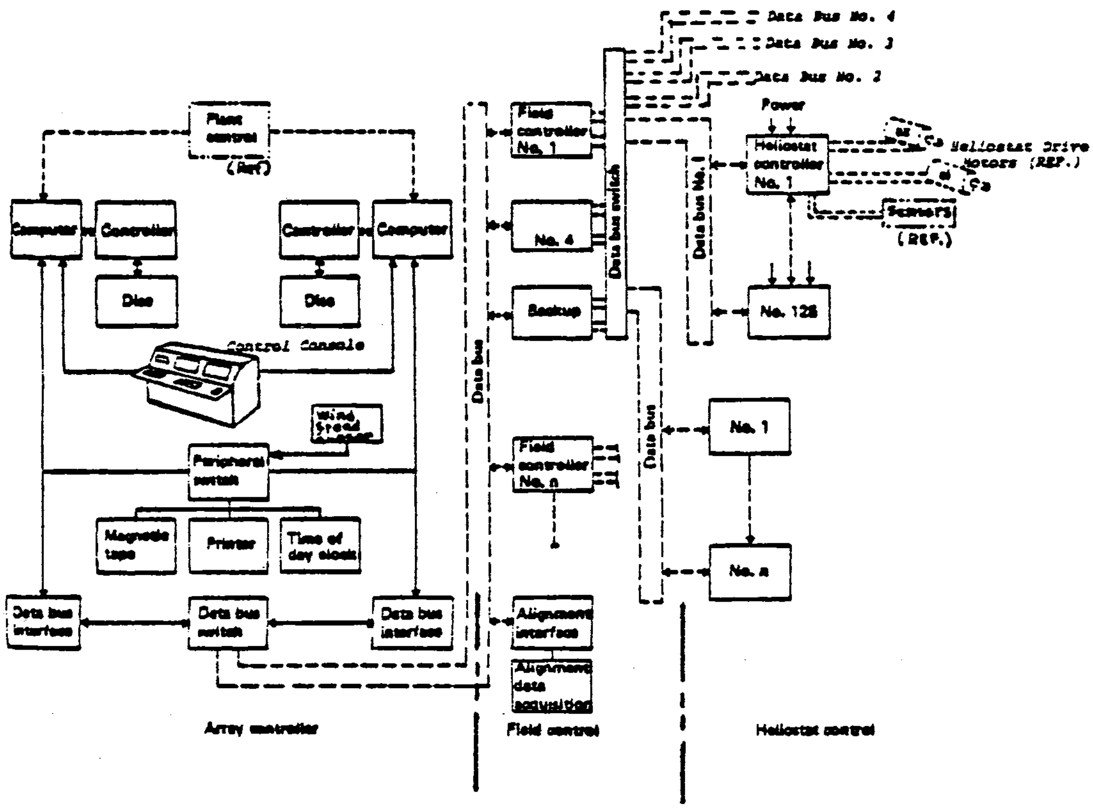


Figure 2-21. Control System Schematic

Table 2-6. Special Support Equipment

REQUIRED FOR	EQUIPMENT NAME OR DESCRIPTION	REMARKS
REFLECTOR ELEMENT	WASHING EQUIPMENT (CAN BE TRUCK-MOUNTED; AUTOMATIC OR MANUAL)	DESIGN AND QUANTITY DEPEND ON WASHING FREQUENCY, WATER RECOVERY, ETC.
	FACET REPLACEMENT FIXTURE	TWO-MAN FIXTURE WITH HANDLES
	REFLECTOR ALIGNMENT TOOL	FOR REPLACEMENT FACET ALIGNMENT
	SLING SET	FOR LIFTING REFECTOR DURING GIMBAL REPLACEMENT
	BEAM CHARACTERIZATION SET (INCLUDES TARGET, SCANNER OPTICS AND ELECTRONIC DATA PROCESSING EQUIPMENT)	FOR ON-GOING HELIOSTAT BEAM ANALYSIS
CONTROL AND POWER ELEMENT	BREAKOUT BOX	FOR HELIOSTAT CONTROLLER TROUBLESHOOTING
	ADAPTER CABLES	FOR FIELD AND ARRAY CONTROLLER TROUBLE-SHOOTING

Table 2-7. Direct Personnel Requirements

	Type	Number Required On		Average Person-Hours Per Month (1)		Remarks
		1st Shift	2nd Shift	Off-Peak	On-Peak	
	Operator	1	1	131.2	183.0	Operation duties performed by plant operator.
MAINTENANCE (2)	Washer, Heliostat	6	4	1760.0		One cleaning crew consists of two washers and one driver.
	Drivers, Heliostat Cleaning Truck	3	2	880.0		
	Technician, Field Maint.	2	0.5	440.0		All are qualified for complete subsystem maintenance.
	Technician, Component Repair	2	-	352.0		One electrical and one mechanical technician.
	Technician, Support Equipment Maintenance	1	-	176.0		Electro-mechanical qualified.

Notes: (1) Operator's time varies according to plant operating strategy (see Section 3). It is assumed the plant operates every day of peak-load months (June - September), but only during the week in off-peak months.

(2) Maintenance personnel work a standard 5-day week throughout the year.

A complete set of as-built drawings will be furnished with the delivered hardware. The necessary operation and maintenance manuals for all equipment will also be provided.

2.2.2 Production Rates

In order to meet the Sandia-specified production rates (20,000 heliostats the first year, 50,000 per year thereafter), the yearly outputs of major components and assemblies were determined. In addition, the expected number of working days per month and year, and general productivity parameters were established. This information is summarized in Tables 2-8 and 2-9.

The output from the integrated production process was allocated to the solar-electric plants according to the delivery rates of heliostat components, and field and plant construction schedules (Figures 2-5, 2-6 and 2-7). This allocation was analyzed in detail for the period June 1984 through December, 1986, to determine manufacturing launch dates (the dates when additional line positions or shifts would be started), and to ensure credible ramp rates for transition to 50,000/year production. An example of the detailed production planning schedule is shown in Figure 2-22.

Sandia required that production planning consider the impact on costs for production rates of 67,500 heliostats/year and 25,000/year from the same CMF. The gross inputs to the process for these rates (see Table 2-8) were evaluated to determine that adequate capacity existed in all major production facilities planned for the 50,000/year rate. The GFMP and FAP will be engineered to support these rates, thus, no problem is anticipated. However, the fusion-glass/mirror and cellular glass production facilities are somewhat unique in that, by their nature, they would normally be operated approximately 8760 hours per year.

Based on coordination with Pittsburgh Corning Corporation (cellular glass production) Corning Glass Works (fusion glass production), and Falconer Glass Industries, Inc. (wet-chemistry silvering), the general plans for glass-material production have been determined. Figures 2-23 and 2-24 show

Table 2-8. Heliostat Production Schedule

Item		Production Year ① * 1984-85	② * 1985-86	③ * 1986-87	④ * 1987-88	⑤ * 1988-89	⑥ * 1989-90	⑦ * 1990-91	⑧ * 1991-92	⑨ * 1992-93	⑩ * 1993-94	⑪ * 1994-95	Alternate Prod. Rates 50% Max rate per year	135% Max rate per year
Production days		253	252	251	253	252	253	253	252	252	253	253	253	253
Yearly output		20,148	50,148	49,949	50,347	50,148	50,347	50,347	50,148	50,148	50,347	50,347	25,174	67,967
Cumulative output		20,148	70,296	120,245	170,592	220,740	271,087	321,434	371,582	421,730	472,077	522,424		
Material requirements****														
Facets (12/helio)		241,776	601,776	599,388	604,164	601,776	604,164	604,164	601,776	601,776	604,164	604,164	302,082	815,622
Beams (4/helio)		80,592	200,592	199,796	201,388	200,592	201,388	201,388	200,592	200,592	201,388	201,388	100,694	271,873
Glass***, ft^2	Sheet/cellular	20,873,328	51,953,328	51,747,164	52,159,492	51,953,328	52,159,492	52,159,492	51,953,328	51,953,328	52,159,492	52,159,492	26,079,746	70,413,812
	Silvered	10,436,664	25,976,664	25,873,582	26,079,746	25,976,664	26,079,746	26,079,746	25,976,664	25,976,664	26,079,746	26,079,746	13,040,132	35,206,906
HC's (1/helio)		20,148	50,148	49,949	50,347	50,148	50,347	50,347	50,148	50,148	50,347	50,347	25,174	67,967
HFC's (14 per plant)		112**	112	112	112	112	112	112	112	112	112	112		
HAC's (1 per plant)		8**	8	8	8	8	8	8	8	8	8	8		
Pedestals		36,922**	50,148	49,949	50,347	50,148	50,347	50,347	50,148	50,148	50,347	50,347	25,174	67,967
Gimbals		20,588**	50,148	49,949	50,347	50,148	50,347	50,347	50,148	50,148	50,347	50,347	25,174	67,967
Production days in	Jun	21	20	21	22	22	22	21	20	22	22	22		
	Jul	21	22	22	21	20	20	21	22	21	21	20		
	Aug	23	22	21	21	23	23	23	22	21	22	23		
	Sept	19	20	20	21	21	20	19	20	21	21	21		
	Oct	23	23	23	22	21	22	23	23	22	21	21		
	Nov	20	19	18	19	20	20	20	19	19	20	20		
	Dec	19	20	21	21	19	19	19	20	21	21	20		
	Jan	22	22	21	20	21	22	22	22	20	20	21		
	Feb	20	20	20	21	20	20	20	20	20	20	20		
	Mar	21	21	22	23	23	22	21	22	23	23	23		
	Apr	22	22	22	21	20	21	22	22	22	21	20		
	May	22	21	20	21	22	22	22	20	20	21	22		
	Total	253	252	251	253	252	253	253	252	252	253	253		

Notes:

*All years run from June 1st through May 31st of the following year, except year 1 , which runs from January 1st, 1984 to May 31st, 1985

**Due to earlier site—need dates

***Frontal area; equal amount of fusion and back-sheet required; sheet area = foam glass in board feet (approximately: See Figure 2-27)

**** Amounts shown account for estimated losses in production, transportation, handling, etc.

Table 2-9. Production Planning Factors

Type of production or item	Times or values for								
	Shift					Productivity measure*		Net hours available	
	Number	Start	Stop	Lunch	Gross hours	Automated	Labor intensive**	Automated	Labor intensive
Factory environment	1st	0730	1600	:40	7.83	90%	87%	7.05	6.81
	2nd	1600	2430	:40	7.83	90%	85%	7.05	6.66
	3rd	2430	0730	:40	6.33	88%	77%	5.57	4.87
Field environment	1st	0700	1530	:40	7.83	84%			6.56
	2nd**	1530	2400	:40	7.83	80%			6.26
	3rd**	2400	0700	:40	6.33	78%			4.94
Personnel "Reliability"	1st	95%							
	2nd	92%							
	3rd	90%							
Number of	Work days	250/year, 21/month (average)							
	Holidays	8 (New Year's; Memorial Day; July 4th, Labor Day; Thanksgiving and day after; Christmas Eve day and Christmas							
Overtime		None							
Standard No. of shifts	Factory	1st and 2nd							
	Field	1st only							
Equipment availability	1st	92%							
	2nd	92%							
	3rd	85% (Includes effect of added wage)							

Notes: * Accounts for equipment breakdown, parts shortages, labor effectiveness, weather (Field environment only), dispatch time, etc.
** Not normally used.
*** Productively measure for labor intensive operations = (Personnel reliability) x (Equipment availability).

Production Planning Schedule

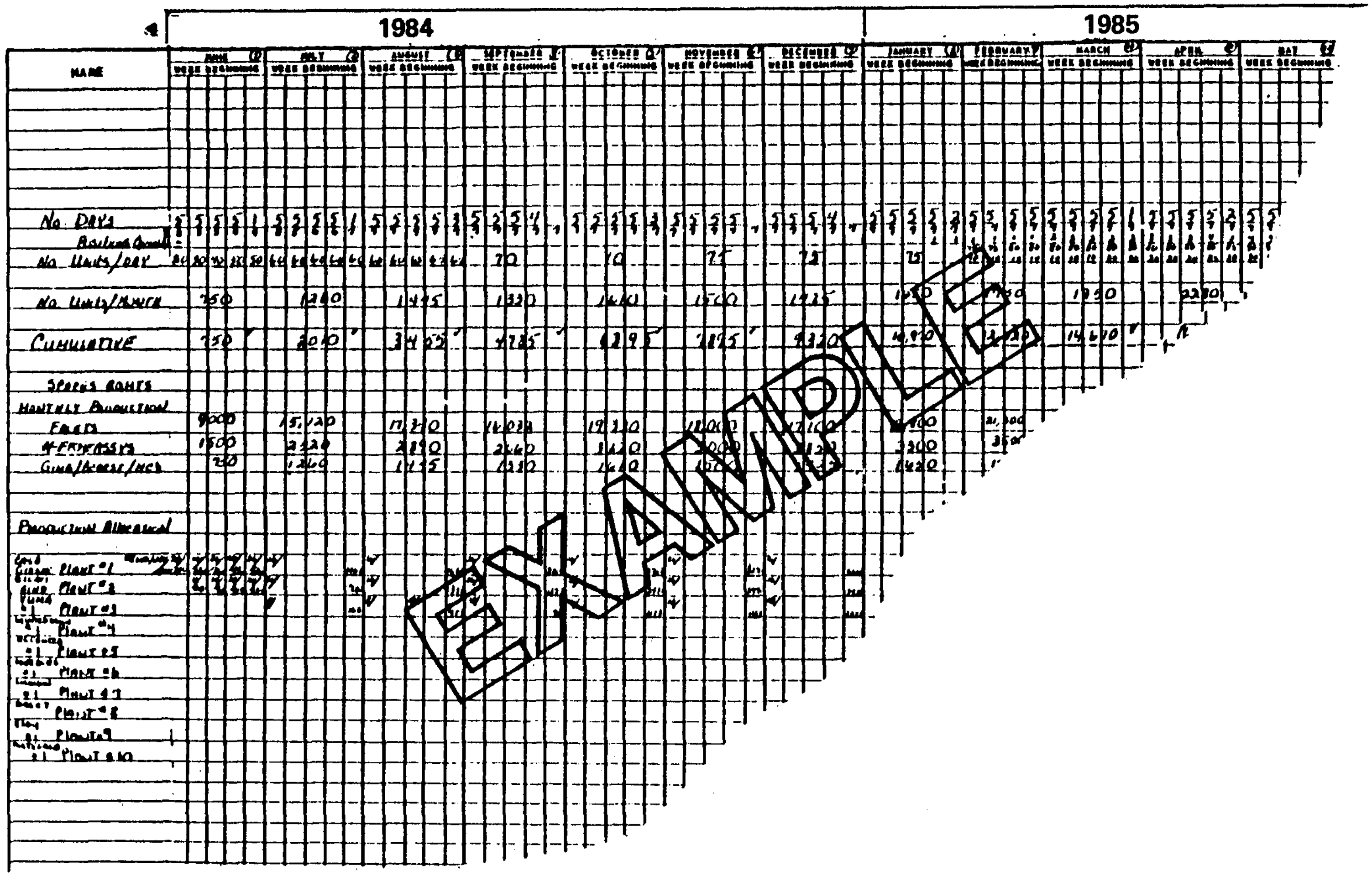
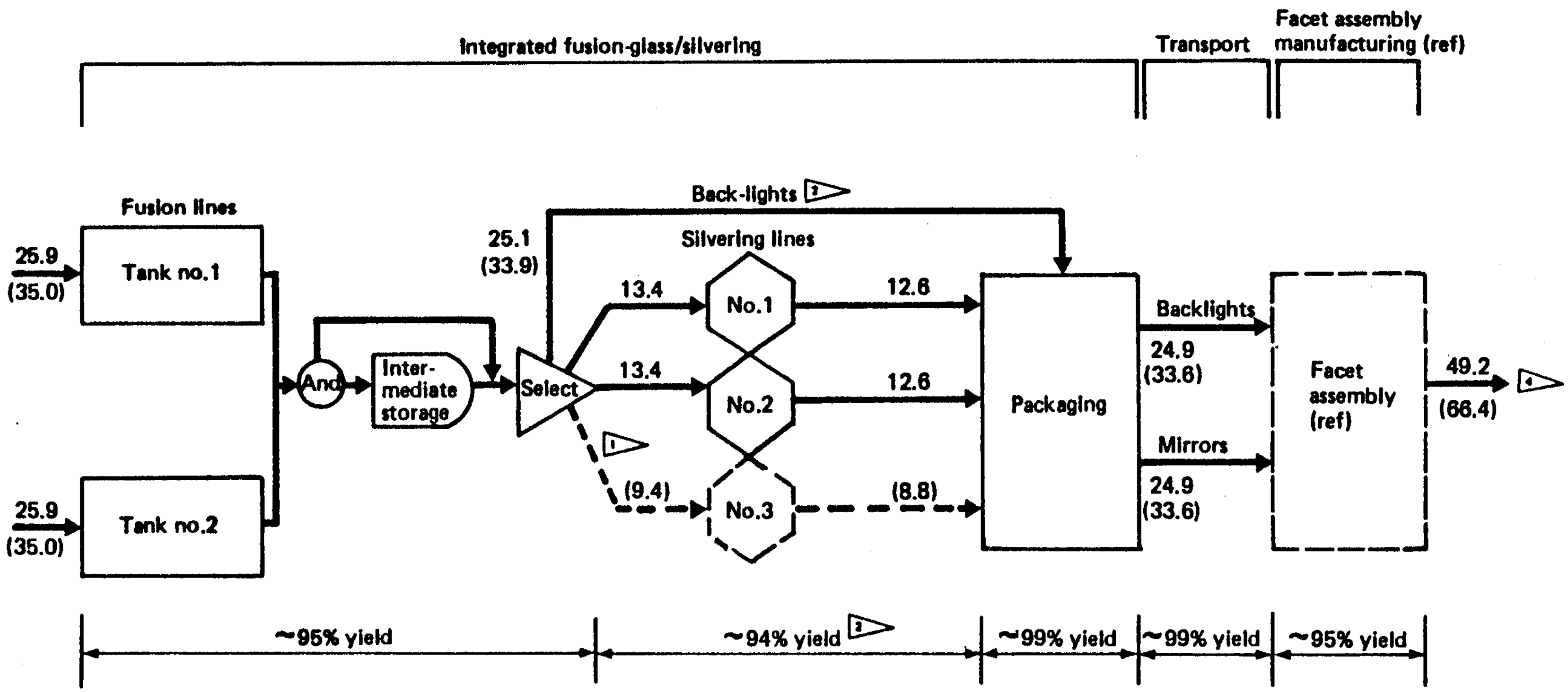


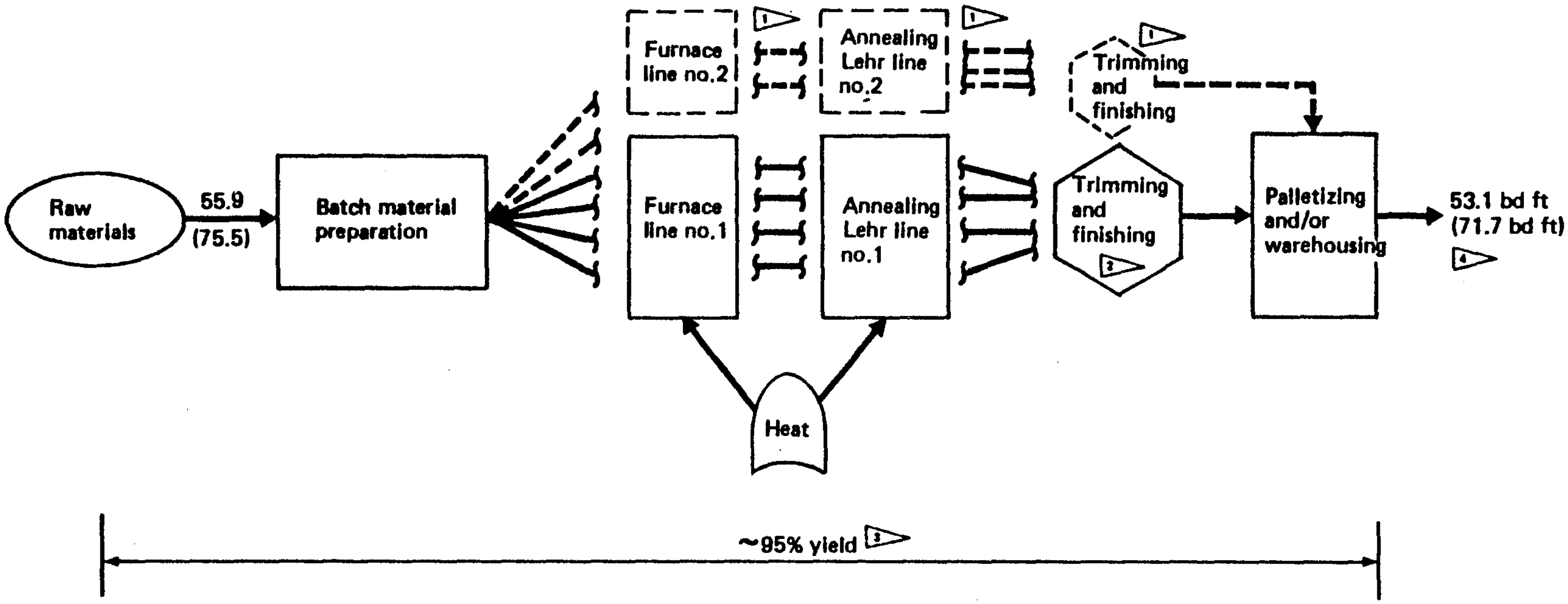
Figure 2-22. Example of Detailed Production Launch Schedule



Notes: Numbers are millions of square feet of glass required for 50,000/year heliostat rate; numbers in parenthesis are areas required for 67,500/year rate.

1. 3rd silvering line used to meet 67,500/year heliostat rate
2. Applies to silvering lines only
3. Yield ~99%
4. Assumes ~98% yield for balance of process

Figure 2-23. Fusion-Glass and Mirror Production Rates Required for Facet Manufacture



Notes:

1. Some additional capacity additions required to meet 67,500/year heliostat rate
2. Ware is trimmed to 19" X 24¼" X 2"
3. Estimated: the production of Foamsil®-75 cellular glass is a proprietary process of the Pittsburgh Corning Corporation
4. Numbers are millions of board feet of cellular glass for 50,000 heliostats/year; numbers in parentheses indicate amounts required for 67,500/year rate

Figure 2-24. Cellular-Glass Production Rate Required for Facet Production schmatically how the required 50,000/year and 67,500/year rates would be achieved. A more detailed description of the cellular glass block production process is given in Appendix A.

Production of electrical and electronic components was not analyzed in detail. However, it is expected that such components will come from various sources, and support of the 50,000/year and 67,500/year rates is not expected to be a problem. Boeing's commercial electronics production facility in the Dallas-Fort Worth area, for example, could supply the heliostat controllers, although additional production facilities would be required.

2.2.3 Manufacturing Concept

The manufacturing processes, facilities, equipment, and tooling have been conceived to support the high production rates required. A key feature of the concept will be a tolerance-cone analysis to identify and control manufacturing tolerances at each step in the fabrication process. The objective of the manufacturing process design will be to repetitively produce components at the high rates required with acceptable producer and consumer risk levels. To achieve this objective, master and other types of tooling will be used to control heliostat mechanical interfaces. Such tooling will provide assurance that reflector panels can be assembled in the SAB with the required degree of accuracy, thus eliminating at-pedestal adjustment of the facets.

2.2.3.1 Central Manufacturing Facility Operations

The heliostat final assembly concept trade (see paragraph 2.1.3) identified the preferred configuration of the torque tube (three-piece design). The balance of the design is relatively insensitive to the preferred final assembly concept. Thus, the CMF is required to produce the gimbal-arm assembly, the torque tubes, cross braces and stiffners, perform galvanizing operations, and manufacture the facet assemblies. Zee-beams for the H-frame assemblies are procured directly from the Bethlehem Steel Corporation, and shipped to each electric plant site.

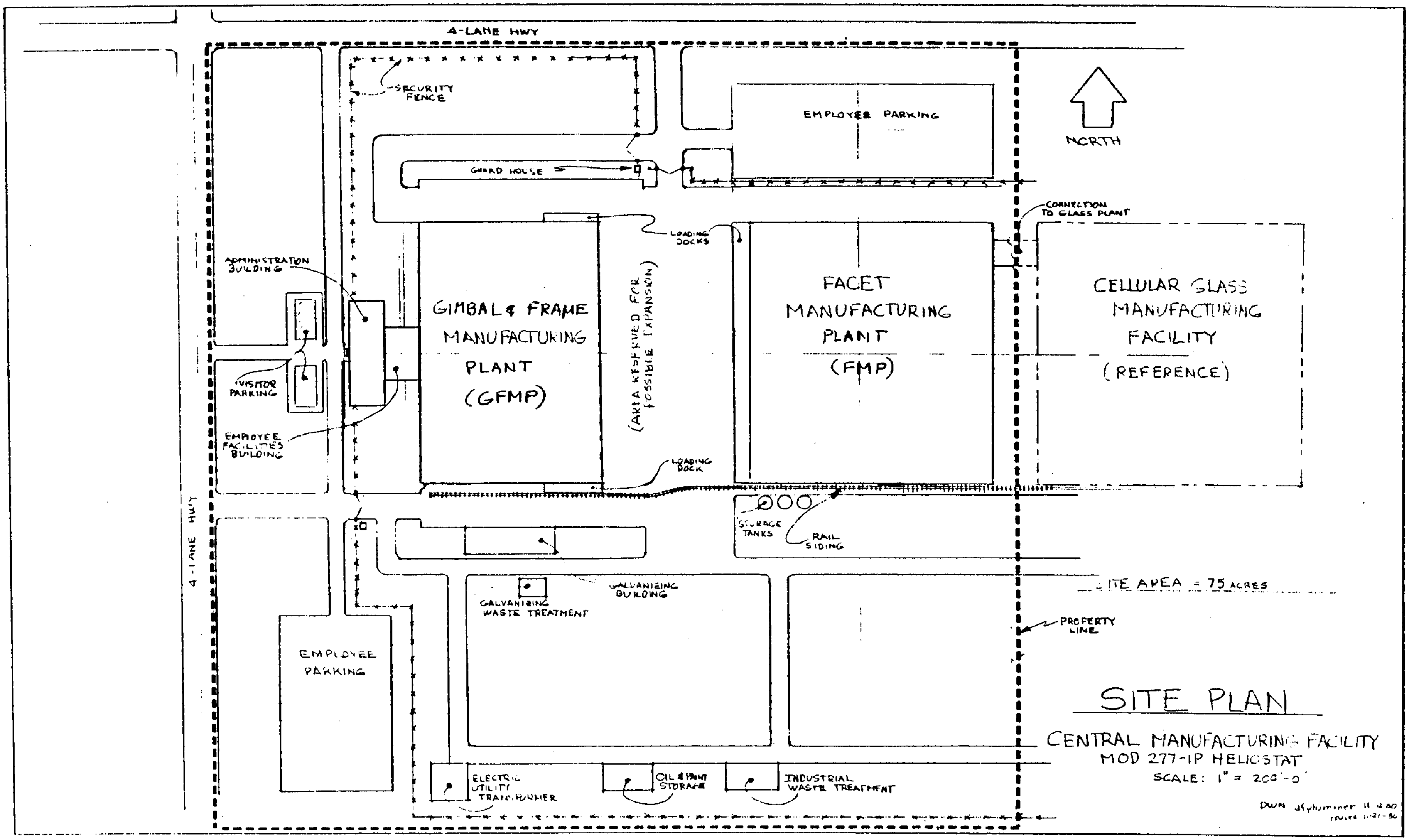


Figure 2-25. Central Manufacturing Facility Site Plan

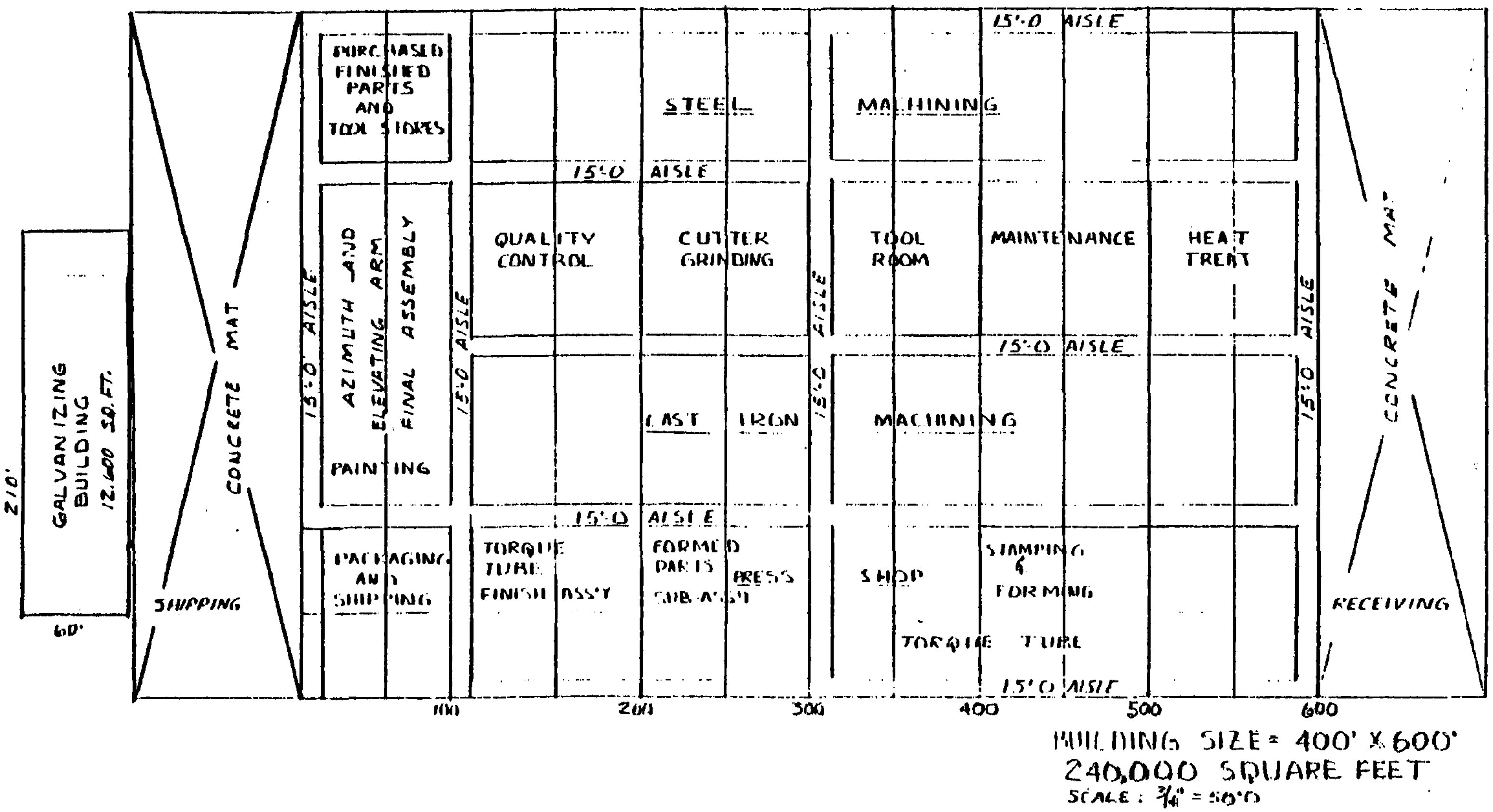


Figure 2-26. Gimbal and Frame Plant Layout

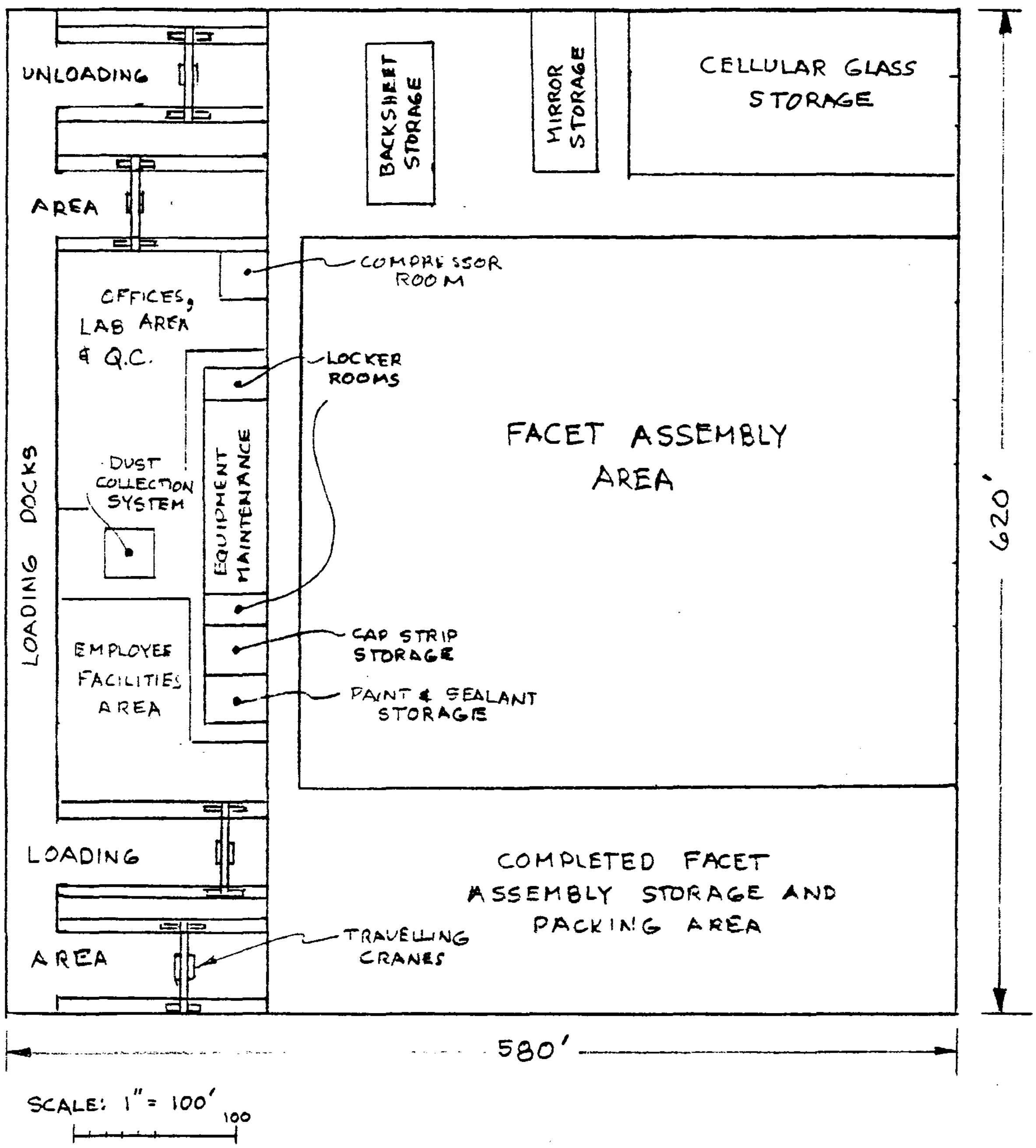


Figure 2-27. Facet Assembly Plant Layout

Consideration of the different manufacturing operations, tooling, and handling equipment required for these components led to the selection of two separate assembly plants, the gimbal and frame manufacturing plant (GFMP), and the facet assembly plant (FAP). As noted in paragraph 2.1.4.1, these two plants are colocated at the CMF in Phoenix. A site plan for the CMF is shown in Figure 2-25; Figures 2-26 and 2-27 show the general arrangements of the GFMP and FAP.

The GFMP and FAP will be built on an industrial site in the greater Phoenix area. The site will be chosen for access by high-capacity roads and rail sidings. An area of approximately 75 acres will be required for the CMF.

a. Gimbal and Frame Manufacturing Plant

The main manufacturing building will have a floor area of 240,000 square feet, constructed with a structural steel framing system, concrete or masonry sill walls, continuous aluminum sash, metal siding to eave, reinforced concrete floor and insulated roof on metal decking. The bay sizes are 50' x 50' with a clear truss height of 18' in the general area and 30' in the high bay area. The building is equipped with all necessary mechanical and electrical services and equipment for the intended manufacturing operations. A complete fire protection system (sprinklers) is included. Air conditioning is provided for the entire GFMP.

Employee facilities for the GFMP will be housed in a single story separate building, adjacent to the manufacturing building and connected to the administration building. It will include locker rooms, showers, toilets, washrooms, cafeteria, medical areas, and a facility training area.

b. Facet Assembly Plant

The facet assembly plant will have an enclosed floor area of 341,000 square feet and will be constructed in a manner similar to the GFMP. Within the FAP will be all necessary warehousing, storage, office space and employee facilities. However, general plant administration (employee wage and salary administration, overall plant control, etc) will be performed from the CMF administration building. The FAP will require extensive conveyor lines, 4 travelling bridge cranes, and light-rail transfer networks. In addition, storage tanks near the rail siding will be required for bulk liquid storage.

c. CMF Administration Building

A single building will be provided for CMF administrative services. This building will be a single-story structure with 10 foot ceilings; it will have all CMF support service personnel (wage and salary administration, general accounting, purchasing, management, etc.). This facility is estimated to require approximately 19,000 square feet of air-conditioned space.

2.2.3.2 Facet Assembly

The facet assembly is produced in an engineered facility specifically designed to achieve the high production rates (approximately 2400/day on a 2-shift, 5-day/week basis) required. A schematic of the production process is shown in Figure 2-28. The make/buy decisions for facet components are described in Appendix B. The layout of the facet assembly building (FAP) (shown schematically in Figure 2-27) is given in greater detail in the drawings in Appendix W.

The facet assembly will be fabricated in the following sequence:

a. Reflective Surface Preparation

The silvered fusion glass lites are received on A-frame shipping frames each weighing 5 tons and holding approximately 270 lites each. These frames are handled using overhead cranes and a wire guided, rubber-tired, computer-controlled, transport system which is designed so that all materials may be moved using the same system.

1. The mirrors are unloaded automatically using the unloader described in paragraph 2.2.5 and placed on a conveyor paint side up.

2. The mirror is advanced through a scrubber which scrubs both sides, rinses with deionized water and dries with a blast of warm air.

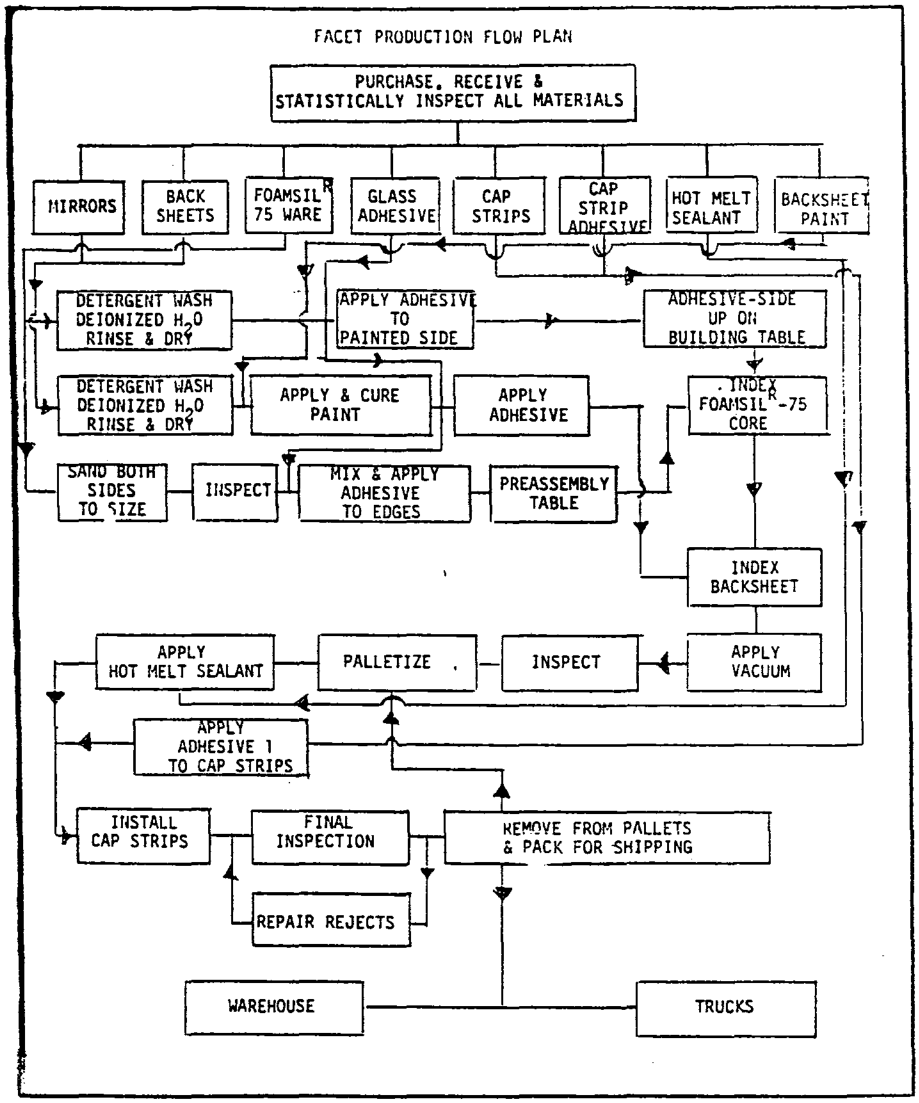


Figure 2-28. Schematic of Facet-Assembly Manufacturing Process

3. The mirror is turned over using a device much like the unloader and the backsheet/facet transfer device (see drawing 4410.1-4)

4. The mirror is inspected for mechanical integrity and rejected if necessary.

5. The mirror is again turned over so as to be paint side up.

6. A two-component epoxy adhesive of short ($<$10 min) cure time is spray applied to the painted side.

7. The mirror with adhesive is conveyed to the mirror transfer and then onto the building table where it is indexed in place using EAR switches and ultrasonic sensing devices (see drawing 4410.1-5).

b. Core Block Preparation

1. The FOAMSIL^{R}-75 core blocks are transported as received from the FOAMSIL^{R}-75 plant to the unloading stations where they are placed on the conveyor.

2. The blocks progress through a roll sander, flipover and another roll sander so as to sand both sides and bring the block within dimensional tolerances.

3. The blocks move through a saw station which saws every 14th block in half so as to make it 9-1/2" x 24-1/4".

4. They now proceed through an adhesive application station where a stripe of fast curing two-component adhesive is applied to two edges (see drawing 4410.1-6).

5. The blocks with adhesive now travel to the crossover conveyor (one for each pre-assembly table). One half of the blocks are turned 180 degrees so that the 19"-direction adhesive stripes of both sides are facing each other.

6. They are placed on the ratcheting pre-assembly table using the vacuum operated placement device (see drawings 4410.1-5 and -7A).

7. The core block placement/indexing device (drawing 4410.1-8) now is lowered over the table with the indexing pins providing positive placement.

8. The compression bars are used to push the blocks together then the vacuum cups are used to hold each block in place.

9. The device then moves to one of four selected tables and places the block core on the adhesive coated side of the mirror using the same index pin/hole setup used on the pre-assembly table.

10. The compression bars and vacuum cups release and the transfer device moves back to its store position.

c. Backsheet Preparation

1. The backsheets arrive in the plant in a manner identical to that in which the mirrors are received. They are loaded onto conveyors and unstacked the same way.

2. The backsheet is scrubbed on both sides, rinsed with deionized water and dried with warm air.

3. It next passes through a roller coating device which delivers 1 mil of photocurable white pigmented urethane coating which is cured by a series of lamps.

4. A second roller coater applies 2 mils of a clear photocurable urethane coating which is cured by lamps on the conveyor line.

5. The painted back lite is now turned over using a device identical to those in use on the mirror line.

6. It runs through an identical adhesive application station, subsequent quality control, and on to the distribution conveyor.

7. The distribution conveyor stops at the appointed location and the backsheet/facet transfer device (drawing 4410.1-9) picks the backsheet off the conveyor and indexes it on the core blocks -adhesive down.

8. The transfer device then returns to its stow position under the backsheet/facet conveyor.

d. Curing and Finishing

1. The vacuum cover moves over the assembled facet, vacuum is applied and the facet is allowed to cure for several minutes.

2. The vacuum cover is removed and the facet is transferred to the backsheet/facet conveyor using the same transfer/placement device used to put the backsheet in place.

3. The facet travels to a flip-over very similar to those used to turn the glass sheets over.

4. The facet now pauses in the optical inspection station where the optical properties are determined and substandard facets are rejected.

5. After scrutiny, the facet moves to a station where padded pins raise the facet and a padded pallet several inches smaller than the facet is moved under it. The pins lower the facet onto the pallet. The pallet is necessary to allow space between the conveyor and the facet for application of the butyl sealant and for the cap strips.

6. The facet now moves into the hot melt butyl applicator section. First, beads are applied along two edges, the panel stops, changes direction by 90 degrees and sealant is applied to the other two edges (see drawing 4410.1-11).

7. The next two stations are where cap strips and corner caps are installed (see drawing).The facet moves into the first station where the cap strips are pressed into place automatically using the devices indicated. The second station installs the corner clips.

8. The completed facet now moves through an inspection station which makes use of electronics to spot defects related to the cap strips on the underside.

9. If defects are located, the facet moves to a repair area for repairing or rejection. If repairable, the repairs are made and the facet is returned to the stream. If no defects are found, the facets move into a surge area capable of holding about 18 minutes production which gives the cap strip adhesive ample time to cure.

10. At the end of the accumulator a flipover device, identical to those used as backsheet/facet transfer devices, removes the facet from its pallet and places it at a crating station. The pallet is rotated 90 degrees and placed on a pallet return conveyor where it returns to point 5 of this section.

11. The shipping crates (drawing 4410.1-12) arrive at the crating station on rails. Only half of the crate is present and it is tilted back about 5 degrees.

12. A device, virtually identical to a glass crate unloader, places the facet in the crate. There are 12 facets per crate.

13. The crate is transported to the facet storage area where the upper half is assembled to it and either shipped via truck or stored.

2.2.3.3 Gimbal Drive Assembly

The gimbal drive assembly is completely manufactured and assembled at the gimbal and frame manufacturing plant (GFMP). Parts and components of the gimbal drive are manufacturered in various areas of the plant, joined into subassemblies, and then enter the gimbal drive final assembly area. Necessary galvanizing and painting operations are performed in separate areas. The complete unit is secured to pallets, and loaded onto trucks for shipment to the electric plant sites. The annual production rate requires a line rate of 13 units per hour (net) which is not high enough to justify extensive automation (transfer-type machining and press lines, automatic transfer between operations, etc.). Make-buy decisions for the gimbal drive and frame components are given in Appendix C; details of the production process are given in reference 2-3.

a. Machining Operations

Machines will be basically stand-alone (either standard or specially designed) automatic cycle production types with parts transferred between machines by using manual roller conveyors or bins and industrial trucks. "Standard" machines include horizontal and vertical lathes and milling machines, grinding machines, drill presses, hones, hobbers, shavers and boring machines.

Special design machines include two, three and four-way precision boring machines as well as multiple station in-line shuttle or rotary index milling and drilling machines. Most operations require special tooling such as part holding fixtures and gages. The majority of the fixtures will be designed for automatic power clamping and manual load and unload. Special tooling also includes multi-spindle heads for drilling, tapping, reaming, boring and milling operations as well as multi-tool boring and facing bars. Gages for the more complex or critical parts include special designed composite electronic gaging that will provide highly accurate functional checking capabilities.

b. Assembly Operations

Assembly operations will include the gimbal-housing /azimuth-drive/bearing assembly and the elevation drive assembly. In general, subassemblies will be performed on off-line manual fixtures using pneumatic nutrunners to secure the bolts. A small conveyor will be used for final assembly of this unit into the azimuth-elevation assembly.

The two drive asemblies will be painted prior to assembly and then be shipped to the power-plant site for mounting on the hèliostat pedestal.

c. Metal Forming Operations

All stampings with the exception of the H-frame beams will be performed in-plant. The parts will be processed by cycle running over two shears and nine presses ranging in capacity from 80 to 500 tons. The cycle running is based on a 30-work-day cycle with sheet steel being purchased for 60 to 90 day runs and sheared to blank size in-plant. The presses are fully loaded for good facility utilization.

The torque tubes will be purchased cutoff with an undersized outer diameter and expanded to size in-plant on a Grotnes tube expander machine.

The rings and adapters will be purchased as mill rolled steel bars and roll formed and welded into a ring on a Grotnes roll former and expanded to size on a Grotnes tube expander.

d. Material Handling

All material will be received and shipped by truck. A five-day float will be stored ahead of the manufacturing and assembly operations. The torque tubes and castings received via flatbed trucks will be unloaded and stored outside. Sheet metal and bar stock will be unloaded and stored inside the building.

Purchased parts (bearings, seals, etc.) will be unloaded at a two-spot depressed dock, and stored inside the building in a stores area. Material will be delivered to the line operations by trailer train and fork trucks.

A five-day float of shipping assemblies (torque tubes, gimbal drives, and small parts) will be stored outside the manufacturing building. All shipping assemblies will be shipped on 40' trailers to the power plant sites.

e. Galvanizing Operations

The galvanizing operation will consist of a series of dip tanks, each 35 feet long by 4 feet wide and 5 feet deep suitably constructed of plate steel with protective lining and a semi-automatic handling system between the tanks. The tanks will include a lip-vent, down draft exhaust system. The exhaust from the galvanizing tank will be vented to a bag house where the zinc particles will be trapped and the cleaned air discharged. The pickling and after-pickling rinse tanks will be exhausted into a filtration system where the acids and water will be separated, cleaned and recycled. The residue will be neutralized before being discharged.

This system will be housed in a laminated wood structure, separate from the main manufacturing building. The laminated wood can better resist the corrosiveness of this operation than the masonry and steel construction of the manufacturing building and its contents.

e. Painting

Castings as received from the supplier foundries will be required to have been cleaned to remove sand, scale, etc., followed by an iron phosphate coating and a dip coat primer paint. The primer paint will be specified to be compatible with the final protective coatings to be applied at the GFMP.

Following final assembly and test, the azimuth-drive/bearing assembly and the elevation drive assembly will be given a manual solvent wipe prior to application of the final protective coatings. The proposed process for these coatings consists of a prime coat of epoxy chromate, followed by a baking cycle, a return through the paint booth for a second application of a topcoat of acrylic urethane color, and then a second baking cycle.

The paint system will consist of the following equipment: Sidedraft "waterwash" spray booth with air make-up system, solvent flash-off enclosure, infra-red paint drying oven, and an overhead monorail conveyor.

2.2.3.4 Pedestal Assembly

The pedestal assembly may be produced by either of two standard manufacturing processes: (1), centrifugal casting of the pre-stressed concrete pile; or (2), conventional split-form casting. Either technique will produce pedestals of the required strength and stiffness, they can be obtained from various sources in the southwestern United States. Producers will be selected to minimize transportation costs.

2.2.3.5 Control Subsystem Components

Although a detail design for the control subsystem was not developed, the general problem of producing the major control components was evaluated. Because each heliostat requires a controller, production of this unit presents the most significant manufacturing problem. Coordination with Boeing's electronic support division confirmed, however, that ample production capacity exists in several areas of the Southwest: The San Jose'-Palo Alto area; the greater Los Angeles and San Diego areas; and the Dallas-Fort Worth area. To ensure a reliable low-cost delivery of the heliostat controllers, it is probable that multiple sources would be used.

Production of the field controllers (approximately 63 are required for each 50MW electric plant), the array controller (one per plant) and associated control/display console equipment can also be obtained from suppliers in the southwestern region of the U.S. No unusual production logistics are anticipated.

2.2.4 Features for Economic Production

There are a number of opportunities for reducing the cost or improving the producibility of various components. These changes can be incorporated in future development. For the gimbal drive and frame assembly, the following changes may reduce costs:

a. Because of the high original expenditures and ongoing costs and environmental problems associated with galvanizing, other protective coatings should be considered as alternatives. One possible substitute is acrylic resin paint which is very durable.

b. The use of existing commercial worm gear drive assemblies or components should be investigated.

c. Investigate possible use of PVC formed components for mounts, covers, etc., for the motor revolution counter and zero reference mounting.

d. Eliminate or reduce quantity of angle steel reinforcements in H-frame assembly by adding stamped ribs or flanged opening reinforcements to beams.

e. Redesign the attachment brackets to incorporate an adjustable feature and eliminate the select fit nylon spacers.

f. Investigate use of electrostatic paint technique for material savings on gimbal and elevation drive final assemblies.

For the facet assembly, the following changes could provide some cost reduction, or improve producibility:

h. Investigate use of lower density cellular glass;

i. Backsheet paint could be reduced in thickness;

j. Incorporate travelling assembly tables in the facet assembly process;

k. Investigate use of lighter gauge cap-strip material.

2.2.5 Special Tools Requiring Development

To produce certain heliostat components at high production rates, some special tooling will be required. For the gimbal drive, frame assembly, pedestal and control system components, standard tooling and fabrication machinery will be adequate. However, for the facet assembly, a number of glass handling and assembly transfer machines will require development:

a. A glass/mirror unstacker consists of a central swivel point with five arms carrying two vacuum pads each. It fastens itself to the sheet, moves it up, out and over, then passes through the rolls of the conveyor simultaneously releasing the vacuum and allowing the sheet to be held off the vacuum pads by the conveyor rolls.

b. Glass-and-facet turnover devices are very similar to the glass/mirror unstackers. The only difference is that they swivel 180 degrees and do not need to move up and down (see drawings 4410.1-4 and 4410.1-5).

c. The block placement device consists of two sets of vacuum-operated lift/transfers which pick up individual blocks of FOAMSIL®-75 ware and places them on the ratcheting pre-assembly table (drawings 4410.1-6 and -7A). The blocks are delivered via belt conveyors with sensors which properly position the blocks for pickup.

d. The core block transfer device (drawing 4410.1-8) pushes the blocks together, and transports them from the pre-assembly table onto the building table. The compression bars are operated using air cylinders. The vacuum pads are then lowered via the electric solenoids and the core is transported en masse.

e. The building table is the central element of the entire facet assembly process (drawing 4410.1-5); it is a fine-finish steel tooling plate mounted on an adjustable table. It contains devices which index the reflective sheet, and help hold the core blocks in place while under vacuum. The building table is also equipped with holes across its surface for use either as air float or vacuum holding of the mirror. Attached to the building table is a vacuum cover that swings into position when the facet is assembled and ready for curing.

f. The backsheet facet transfer device (drawing 4410.1-9) is very similar to the turnover device described above. However, the flipover portion has two sets of vacuum pads (one on either side of the arms) and it is mounted on a carriage which moves from between two building tables to an area under the backsheet/facet conveyor. This latter position is its normal stow position. The device's transfer function is to pick up the painted, adhesive-coated backsheet and place it on the core with the adhesive side down. When the facet is cured, it is moved to the conveyor using the exact reverse of the same process. One transfer device serves two building tables. Index control is by EAR switches and ultrasonic proximity sensors.

g. The hot melt butyl application station (drawing 4410.1-6) consists of two sets of four hot melt bead extrusion tips mounted so that the facet passes through one set getting four beads applied in one direction, changes direction 90 degrees, and has four beads applied in the other direction.

h. The cap strip application section (drawing 4410.1-11) serves to apply the cap strips to the glass 'sandwich'. The edge strips are packaged as a "clip" and are fed one at a time to a roller conveyor (with centering rolls) with the open side up. When a facet is in position, the four edge strips are passed under extrusion heads where they are filled with the cap strip adhesive (two-part urethane-asphalt). They continue into a full-length holder which has a full length lip that engages the edge of the cap strip and flexes it "open"; this provides for clearance of the glass and butyl sealant when the air cylinder presses the edge strip onto the facet. The lip then retracts and releases the edge strip. The air cylinder provides the force to seat the strip onto the facet and to force the adhesive to flow into any voids.

The corner clips are installed in a similar manner. The clips will be fed from bins using standard parts feeders. They will be placed into a holder, filled with adhesive, then applied to the facet at the second station.

2.3 Transportation Plan

Transportation planning for the collector subsystem centered on determining the principal components to be shipped from the CMF (or other major plants) to the solar-electric power plant sites. In addition, the preferred shipping unit configuration (number of components/unit) was determined, and the shipping mode selected.

2.3.1 Shipping Units

A shipping unit is defined as an individual component or group of components which can be conveniently packaged and handled by standard materials-handling equipment, and shipped on existing commercial carriers (truck and train). The configuration, size, and weight of the important shipping units is illustrated in Figure 2-29.

2.3.2 Shipping Modes and Rates

In general, truck-trailer combinations will be used for all shipments except the beams, which will be shipped by rail. The shipping-unit configurations were designed to comply with known ICC constraints on interstate truck shipment.

Shipping rates were determined for the production rates at the CMF, and to match the glass production and silvering rates at the Blacksburg fusion-glass plant. Shipping rates and distances are summarized in Table 2-10. As can be seen, for the 50,000/year standard production rates, the highest number of truck-trailer dispatches per day is for the pedestals (20) and the gimbal-drives (25). Considering an average origin-destination block speed of 35 miles per hour, this would imply round trip times of (on the average) approximately 2 days for these units. A round trip time of 2 days would require a fleet of approximately 40 truck-trailer rigs for the pedestals, and 50 for the gimbal drives. Such fleet sizes suggest that it may be economic to plan production based on producer-owned vehicles; however, for this plan, commercial trucking firms were assumed.

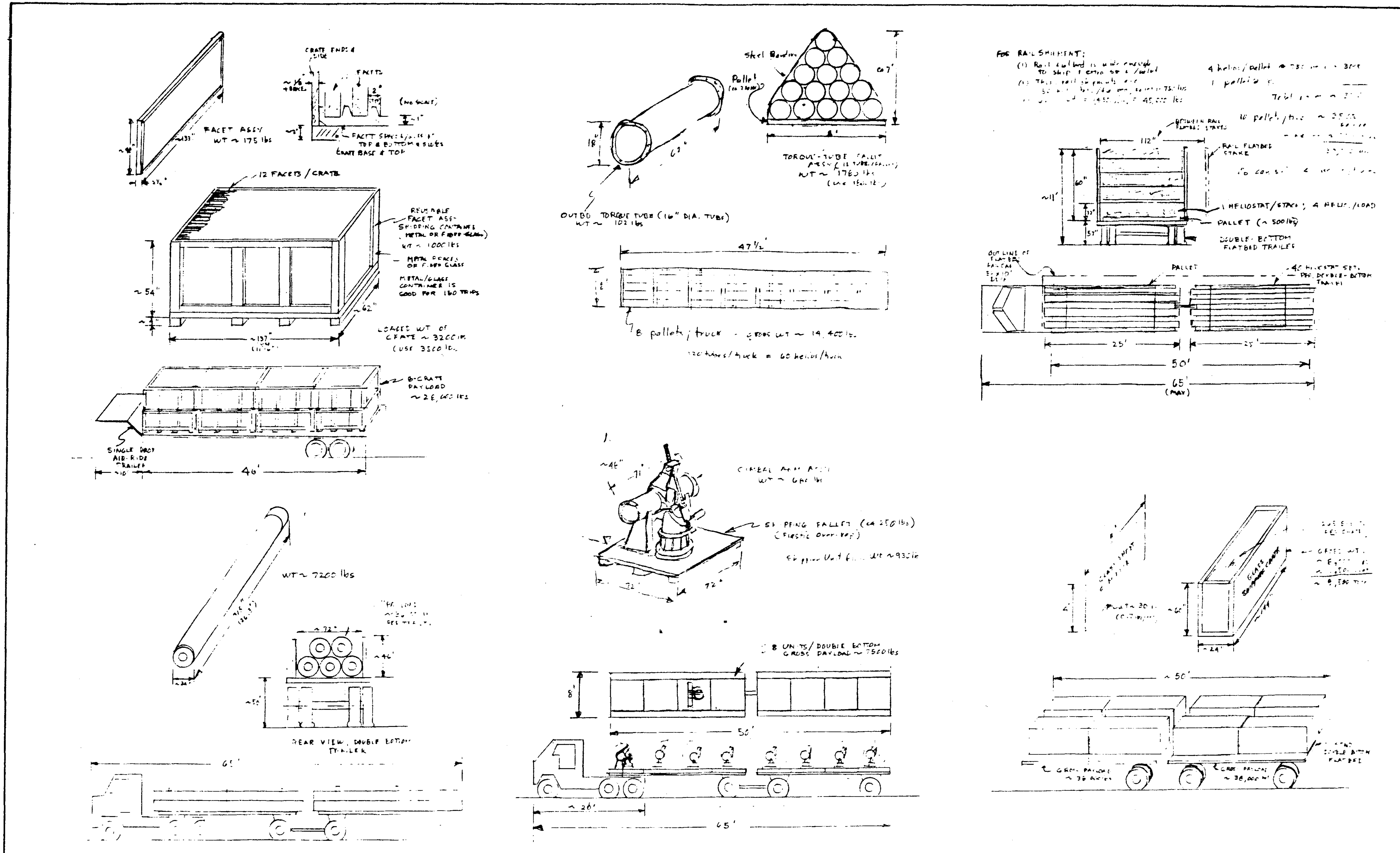
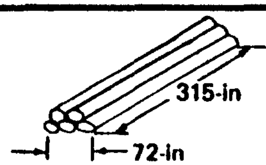
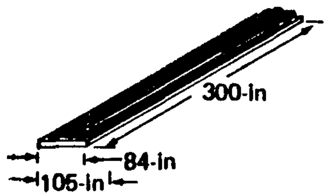
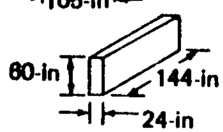
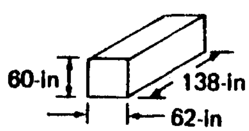


Figure 2-29. Shipping Unit Configurations

Table 2-10. Transportation Mode/Rate Summary

Shipping unit				No. of shipping units per transport mode (No. of heliostat sets/load)	Origin	Destination	Average distances, miles	Approximate no. of unit shipments required/day for yearly production rate of (Truck-trailer dispatches/day) [2]		
Component		Approximate dimensions	Weight, lbs. [1]							
Description	Number per shipping units [3]							25,000	50,000	67,500
Pedestal	5		36,000	2/double-bottom trailers (10)	Phoenix and Albuquerque	Power plant sites	300	20 (10)	40 (20)	54 (27)
Gimbal-drive	1		930	8/double-bottom trailers (8)	Phoenix	Power plant sites	300	99 (13)	198 (25)	267 (34)
Torque tube	15		1,800	8/flatbed-trailer (60)	Phoenix	Power plant sites	300	13 (2)	26 (3.5)	35 (5)
Beams	16		3,500	10/double-bottom trailer (40)	Lackawanna, N.Y.	Power plant sites	2,200	25 (3)	50 (6)	68 (8)
	20 (Rail)		4,500	10/flatbed rail car (50)				20 (2)	40 (4)	54 (5)
Mirror and back sheet	265		9,500	4/double-bottom trailer (530)	Blacksburg, VA	Phoenix	2,800	0.8 (0.2)	1.5 (0.4)	2 (0.5)
Facets	12		3,500	8/single-drop air ride trailer (8)	Phoenix	Power plant sites	300	100 (13)	200 (25)	270 (34)

Notes: [1] Includes shipping pallets and/or crates; all weights approximate
[2] Unit shipments are number required to accomodate production rates shown and to match installation rates at site
[3] All units shipped by truck - trailer unless otherwise indicated

Shipment of the balance of the units evaluated appears to pose no particular problems for existing trucking firms in the United States.*

*Because not all solar-electric plant sites may be accessible by rail, a contingency plan was considered in which beams can be delivered to the SAB by truck-trailer.

2.4 Installation and Checkout

The trade study described in paragraph 2.1.3 confirmed the desirability of assembling the reflector panels at each power plant site. In addition to this activity, the collector field must be graded, drainage provisions added, power and data cables installed, and pedestals pile-driven at surveyed positions. The balance of the control system (field and array controllers) will be installed while heliostat controllers are being installed. Gimbals will then be installed on the pedestals, electrically connected, and operated to obtain pedestal-gimbal vertical axis alignment and zero reference marks. Assembled reflector panels will then be installed, the heliostats washed, and final integrated checkout performed.

2.4.1 Reflector Panel Assembly

The right-hand and left-hand panels are assembled in the site assembly building (SAB), which is housed temporarily in the power plant maintenance/warehouse facility. The layout of the facility is shown in Figure 2-30; Figure 2-31 shows additional details of the panel assembly. After completion of the panel assembly activity, all tooling will be removed, and downstreamed to the next power plant site. The facility will then be converted to its final configuration.

The panels are assembled in temporary support fixtures installed in the SAB. The torque-tube, beams, stiffeners and cross-braces are bolted together in the fixture. Facet alignment templates are then postioned along each beam using tooling holes in the beams; the templates are thermally matched to the beams. The overall indexing of the templates to the beams will be controlled through master tooling to the torque-tube bolt pattern. Facet assemblies are then lowered on to the templates using a pivot jib-hoist (see Figures 2-32 and 2-33). Facet alignment is then established using removable fixtures (part of the template assemblies).

When the panel assembly has been completed, it is inspected and then lifted from the assembly fixture by the SAF hoist and placed on special reflector panel transport trailers (illustrated in Figure 2-34).

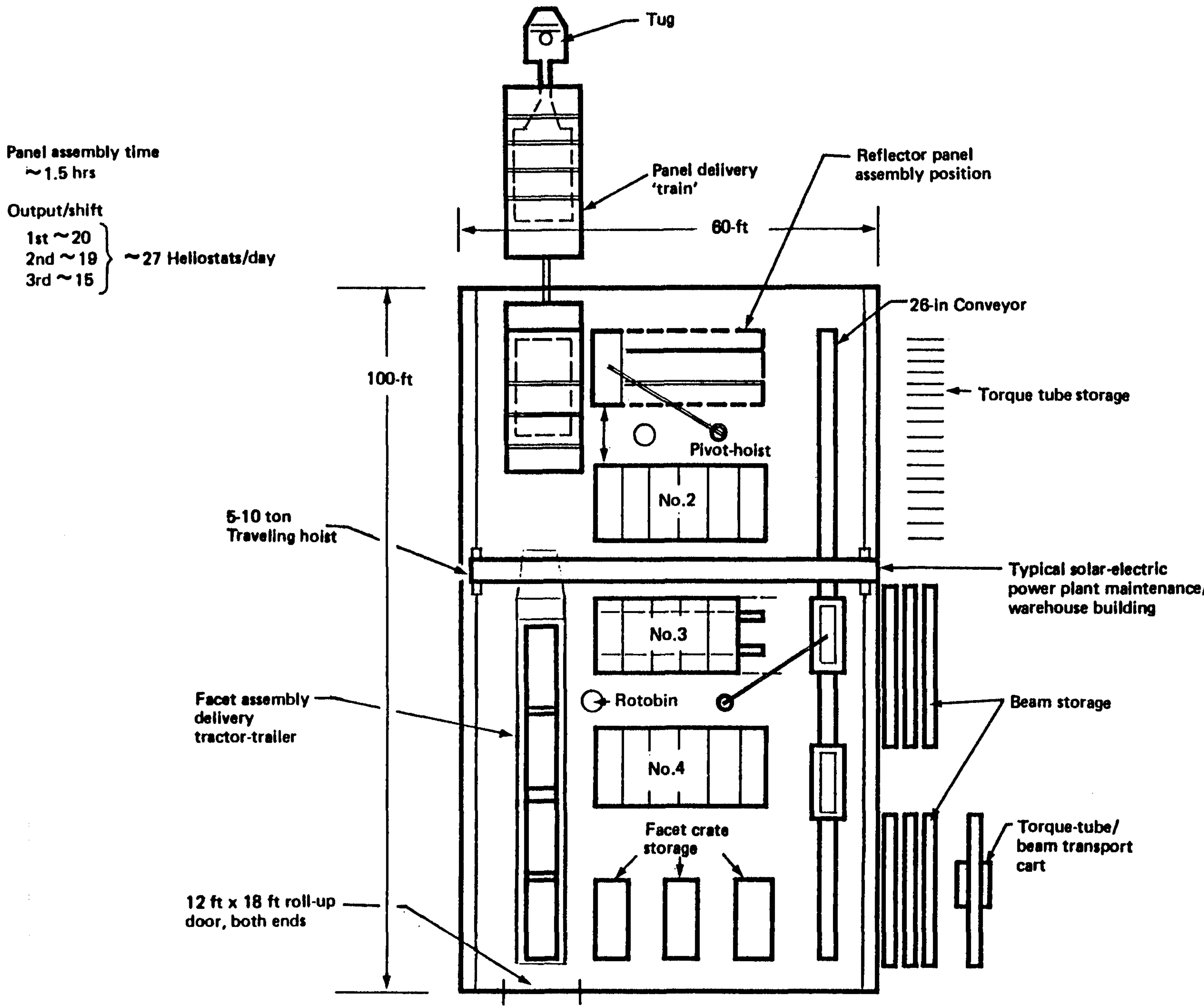


Figure 2-30. Site Assembly Building Layout for Reflector Panel Assembly

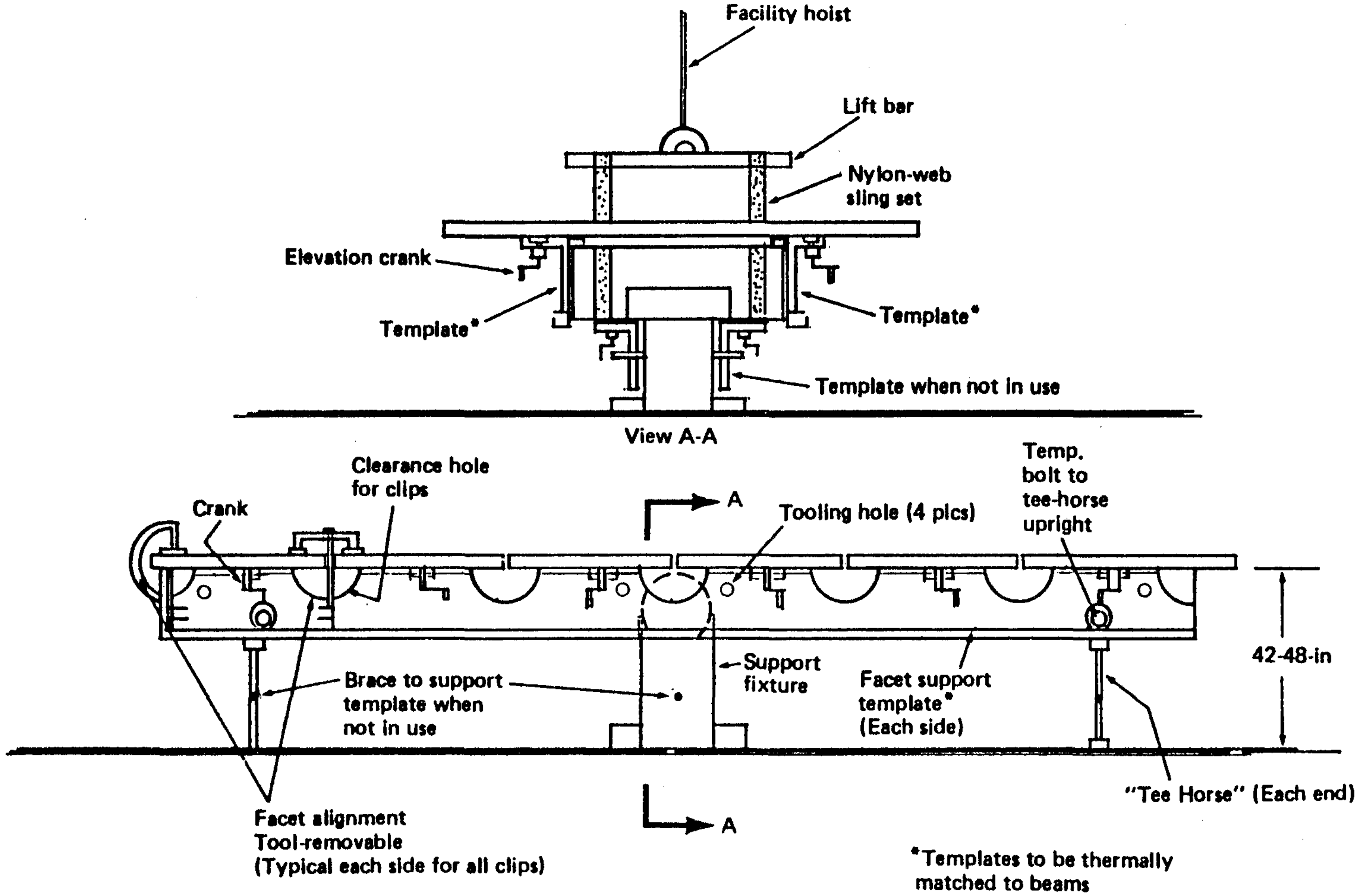


Figure 2-31. RH & LH Reflector Panel Assembly and Facet Alignment in SAB

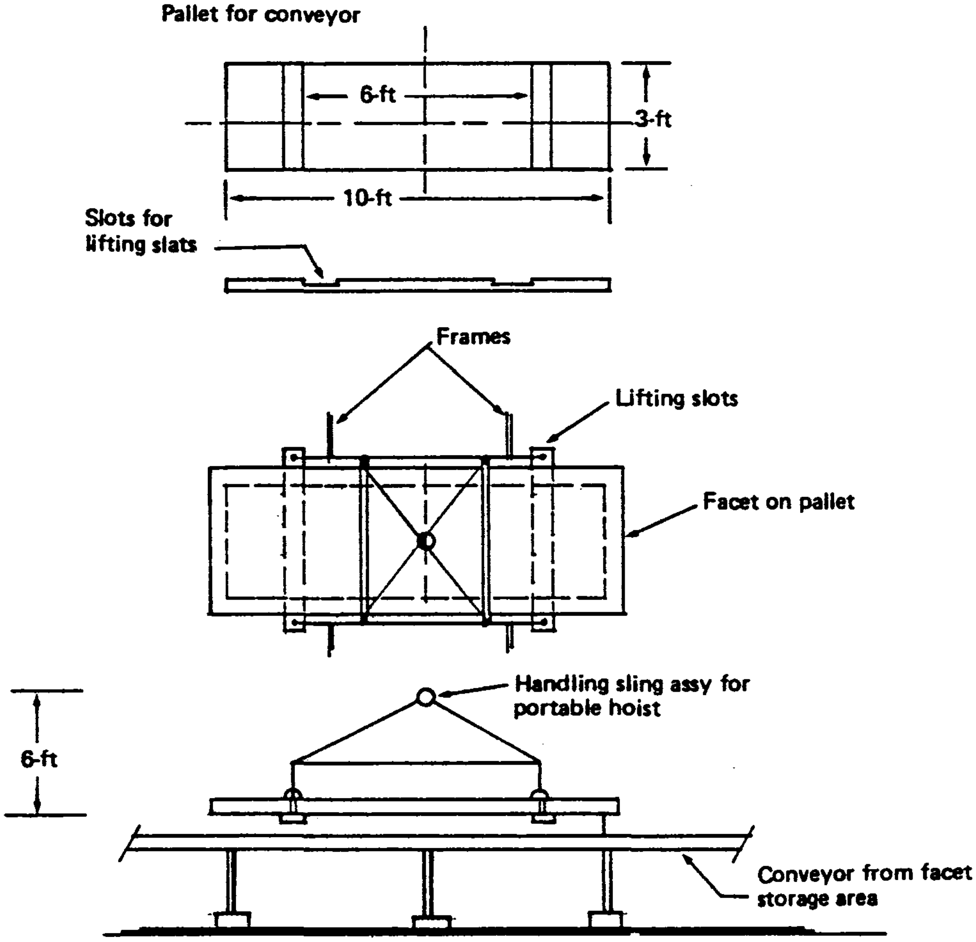


Figure 2-32. Facet Assembly Handling Fixture

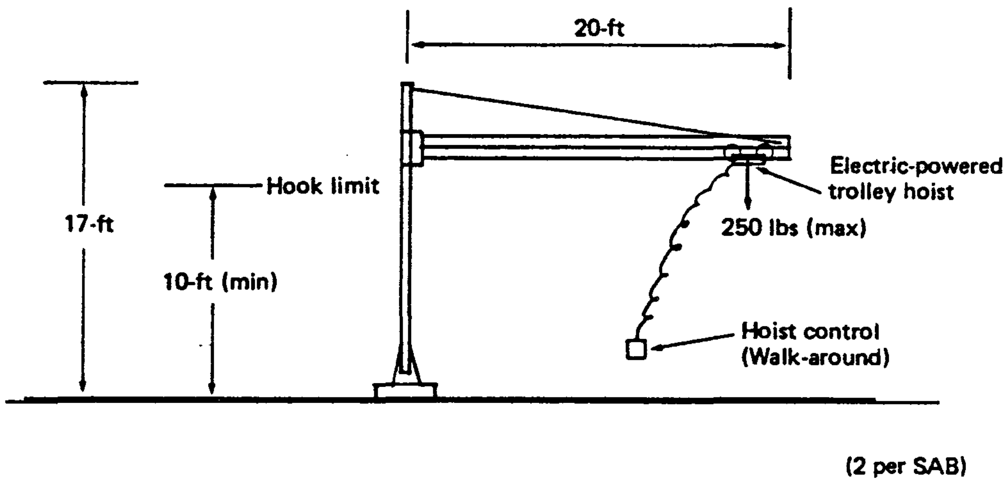
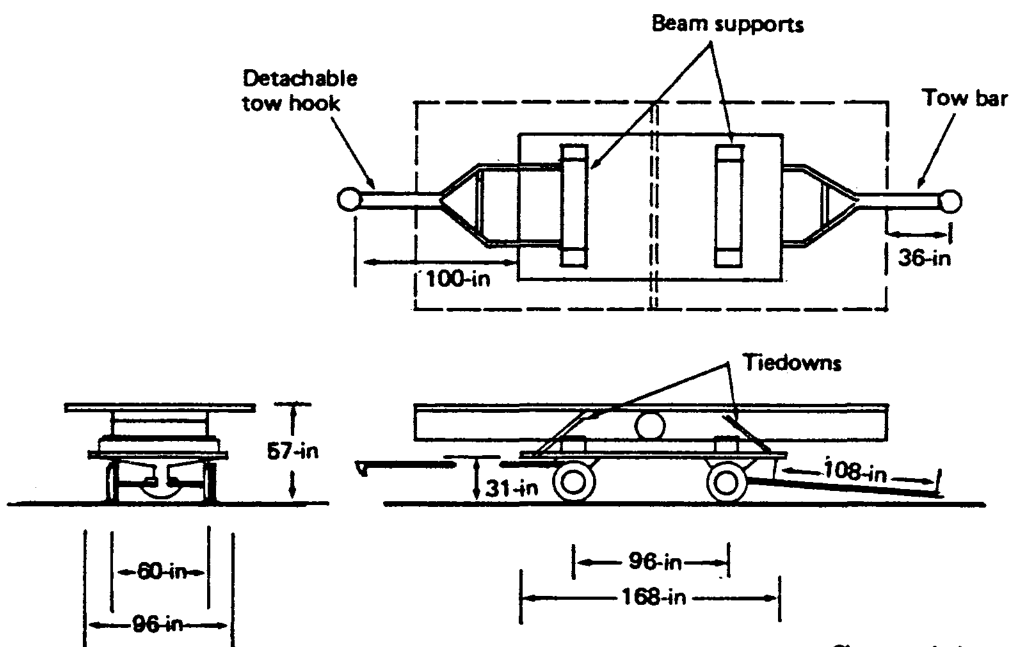


Figure 2-33. Site Assembly Building Pivot Jib Hoist



Characteristics:

1. Steerable front wheels
2. Torsion-spring suspension
3. 3000 lb capacity
4. Pneumatic tires
5. 4-wheel service brakes
6. Estimated price: $6500 - in reasonable quantities
7. Source: Standard MFG. Co., Dallas, Texas.

Figure 2-34. Type RT—1 Panel Transport Trailer

A detailed timeline analysis was conducted of the panel assembly operation to verify the adequacy of the four assembly positions, which is the maximum number feasible for a "standard" power plant maintenance warehouse facility. Assembly of each panel requires approximately 2.7 hours; this necessitates a 3-shift operation to match the planned heliostat installation rate (approximately 26/day).

Since heliostats are not installed on second or third shift, it is necessary to provide storage for the 34 panels produced on these shifts. This is accomplished by using the RT-1 trailer (see Figure 2-34), and staging the loaded trailers in the field, or near the SAB for dispatch the next day. Analysis of the round-trip distance/time for an "average" heliostat showed that a total of 38 RT-1's would be required; they would be towed to the field in pairs by standard tractors. Although the average round-trip times are longer at night (for panels pre-positioned in the field), it was estimated that 2-3 tractors would be sufficient for the trailer towing operations.

2.4.2 Field Preparation

2.4.2.1 Clearing, Grading and Storm-Water Control

Prior to installation of the heliostats, the field must be cleared, then rough-graded for surface storm-water control. The site topography, local weather conditions, and field orientation will be considered in layout of drainage ditches and storm water piping systems.

As field grading and storm water control provisions progress, the location of lightning-protection-, power-and data-line trenches, field transformer pads, and pedestals will be established by conventional surveying techniques. Transformer foundations/vaults will then be installed, and trenching begun.

2.4.2.2 Power, Lighting and Data Cable Installation

Power, data and lightning protection cabling/wiring will be installed in the trenches, and final grading completed as the trenches are covered. Power data and lightning ground cable stubs will be left at each pedestal location and at field transformer locations.

2.4.2.3 Pedestal Installation

For the production scenario, soil conditions suitable for pile-driving were assumed. The pedestals will be installed at their staked positions using conventional pile-driving techniques. (Depending on actual soil conditions, it may be necessary to predrill or water jet some locations; water settlement of soil around some pedestals may also be required.)

2.4.2.4 Field Transformer Installation and Final Field Survey

Following pedestal installation, field transformers will be installed. In addition, the actual latitude and longitude of pedestals will be accurately surveyed. This completes the initial field preparation, and installation of gimbals and reflector panels can now begin.

2.4.3 Control Subsystem Installation

Because a detail design was not developed for the control subsystem, its installation can only be described in a general way. This description is included to provide continuity to the collector subsystem installation concept.

2.4.3.1 Field and Array Controllers

In the BEC concept the field (HFC) and array controllers (HAC) would be designed for installation in the power-plant control room building. The array controller would probably be installed in the main control room, with field controllers installed in a separate room nearby. The only special provisions for these items are normal electronic-equipment temperature and humidity environmental control.

2.4.3.2 Heliostat Controllers

The heliostat controllers are attached to the pedestal by two bolts which are screwed into threaded fittings which have been fabricated into the pedestal assemblies. After the controllers are mounted, the installation is completed by connecting the power and data lines, and attaching the lightning protection ground.

2.4.4 Gimbal Installation

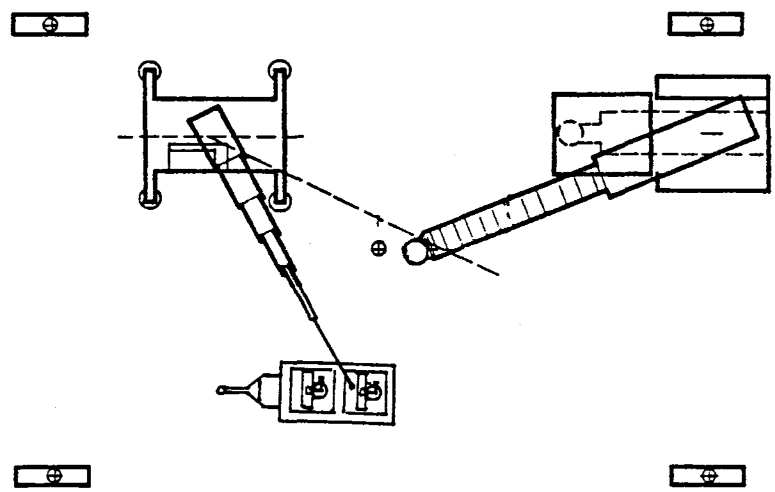
The gimbal is installed on the pedestal using standard construction equipment as illustrated in Figure 2-35. Two gimbals are transported to the field on an RT-1 trailer. The gimbal is hoisted on to the pedestal and guided into position by a workman in the lineman's-truck basket. The gimbal hold-down nuts are then torqued to the prescribed value. Index markings on the gimbal and pedestal bolt ring aid in proper orientation. After the nuts are torqued, the gimbal electrical connections are completed, and a brief "aliveness" test is run using control switches on the heliostat controller.

After confirmation that the gimbal operates properly, the installation crew will mount a zero-reference/level (ZRL) template on the gimbal and connect the electronic level's output cable to an input connector on the controller. The orientation of the ZRL template to the gimbal will be controlled by the gimbal torque-tube bolt pattern. The relationship between the template and tube bolt patterns will be controlled through master tooling.

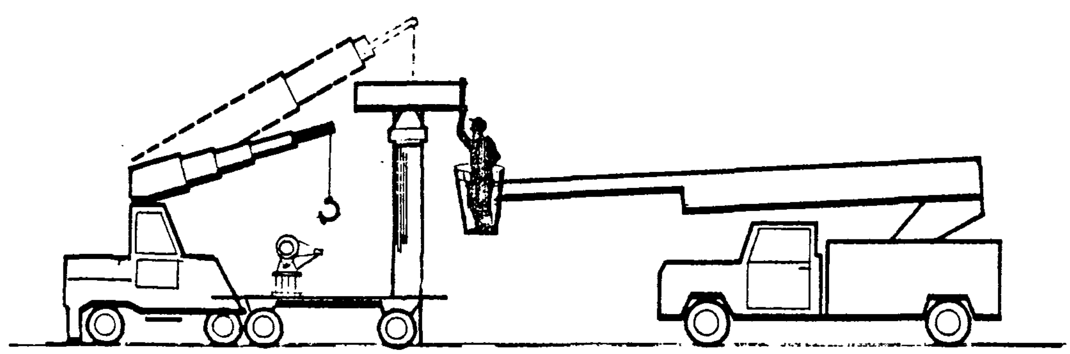
The installation crew will then communicate their position via radio to a system technician in the control room. He will be advised that the gimbal is ready for vertical axis orientation measurement and zero-reference mark calibration.

Using the ZRL template's electronic level, the heliostat gimbal will be rotated 360° and the vertical axis orientation determined and recorded by a special software program. With this measurement completed, the azimuth and elevation zero reference marks can then be determined.

First, the torque tube will be oriented so that, if a reflector were installed it would be in a vertical position. Then the gimbal is commanded to the seek-reference mode; the elevation zero reference is thus established and recorded. Similarly, using the ZRL template's telescope, the proper



a) Plan view



b) Side view

Figure 2-35. Mounting Gimbal at Pedestal azimuthal orientation of the gimbal is established by alignment with a designated target on the receiver tower. The seek-reference mode is then activated and the azimuth zero reference determined and recorded.

2.4.5 Reflector Installation

As noted in paragraph 2.4.1, the right- and left-hand reflectors are assembled in the SAB, then transported to the field on RT-1 trailers. Using the same type of handling equipment as that used for gimbal installation, the reflectors will be positioned and fastened to the gimbal center torque tube. This assembly is facilitated by the captivated bolts in the inboard flanges of the torque tube frame interface, illustrated in Figure 2-15. Torquing of nuts at the torque tube joint will be performed by powered precision torque wrenches. The installation technique is illustrated in Figure 2-36.

2.4.6 Field Cleaning, Calibration and Checkout

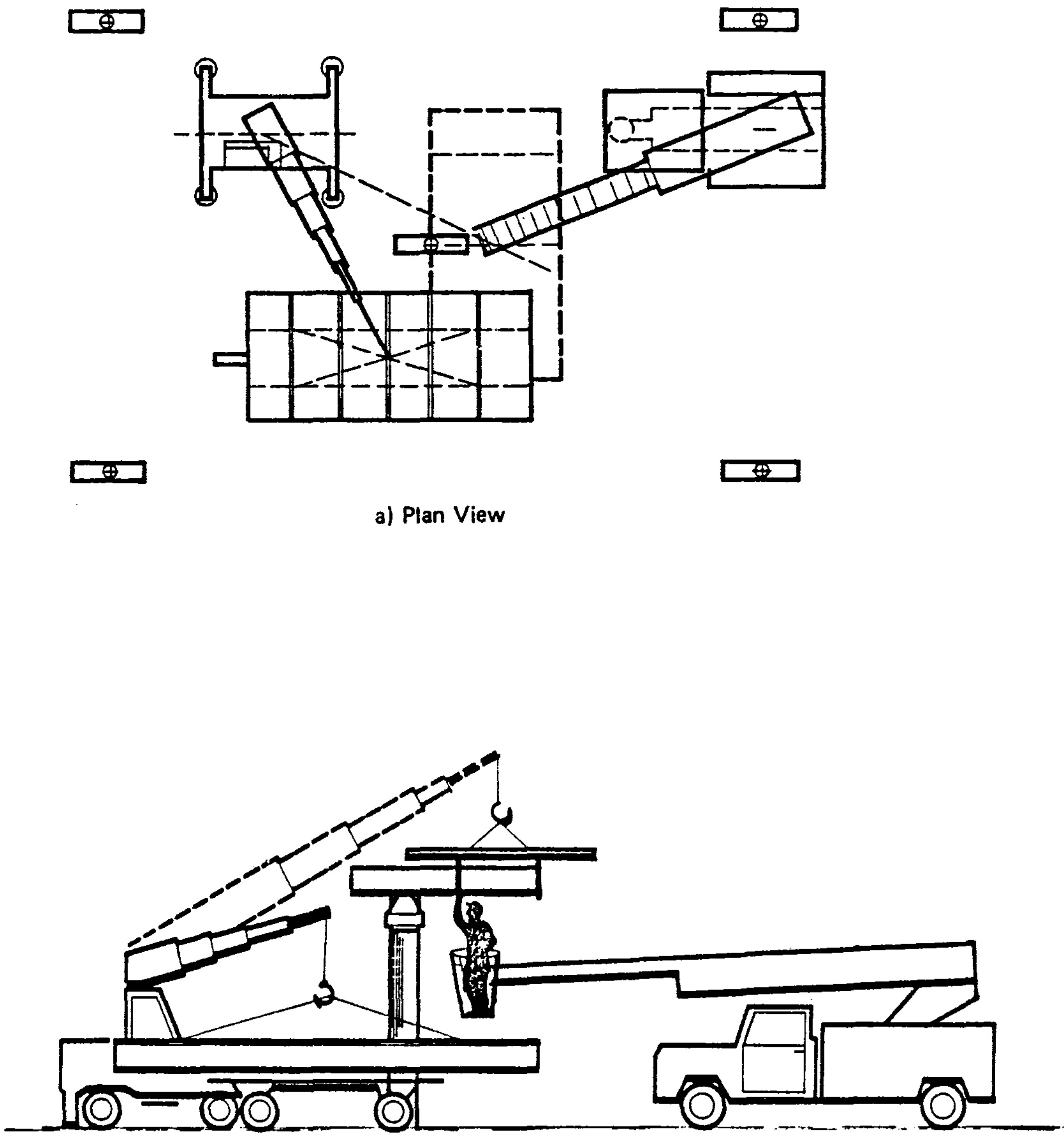
2.4.6.1 Field Cleaning

Construction activities may generate considerable airborne dust. Depending on the time of year when reflector panels are installed, the local rainfall patterns, and other weather factors (winds, thunderstorm activity, etc.) it may be necessary to clean the mirrors before beginning final subsystem integrated checkout. The cleaning equipment and techniques planned for normal field maintenance can be used for this purpose.

2.4.6.2 Collector Subsystem Calibration and Checkout

When all subsystem elements have been installed, and the field cleaned (if necessary), the final calibration and checkout of the entire subsystem will be performed. This will require an operable beam characterization system.

To gain assurance that the assembled collector subsystem will perform properly, and complete delivery to the system owner, several types of verifications will be performed. First, a series of subsystem checkouts will be accomplished



a) Plan View

b) Side View

Figure 2-36. Reflector Panel Installation at Pedestal under the direction of the array operator. The checkout will consist of automatic self-tests of the control and power-distributor elements under software control. These tests will verify that the system has been properly configured, and can be operated within design limits.

Second, a series of physical inspections will be accomplished to verify that all required elements have been installed or delivered. The availability of all required technical publications and data will be verified. The status of operator and maintenance personnel training will also be reviewed.

Third, a random-sample verification of heliostat beam quality will be performed using the owner-furnished beam characterization system. The size and selection of the sample will be coordinated with the power-plant owner. Standard statistical quality control techniques will be used to ensure that image quality and beam control characteristics are within acceptable limits.

Finally, a functional checkout of the entire collector subsystem will be performed. This checkout will consist of demonstrating all operational modes under direction of the array operator while visually observing the behavior of the field. Depending on the construction status of receiver, storage and turbine subsystems, it may not be possible to illuminate the receiver at full power. In this case, the ability of the field to focus and remain on the standby region around the receiver will be used to verify proper operation in the steering mode. All other operational modes will also be demonstrated (power-up, standby, overnight and high-wind stow). Successful completion of these demonstrations will complete the functional checkout of the system and it will be delivered to the power-plant owner or his prime contractor, as provided by contract.

2.4.7 Dust Control Provisions

Under some circumstances, it may be desirable to treat the heliostat field to reduce generation of wind-blown particulates. The method of treatment (vegetative, chemical surface stabilizers, etc) will depend on local weather conditions, site topography and soil characteristics, natural flora, etc. It is assumed that some sort of treatment will have long-term beneficial effects on ownership costs. However, because of the many unknowns, including the power-plant owner's specific requirements and objectives, this issue was not explored further.

2.5 Operations and Maintenance concept

2.5.1 Operation Concept

It was assumed that the power plant would be used as a cycling plant serving a summer-peaking load. This suggested that the plant would operate 5 days per week October through May, and 7 days per week June through September. Figure 2-37 shows typical operating profiles; expected operating hours are summarized in Table 2-11.

The collector subsystem is expected to be operated from the power plant control room. Because many of the control tasks are mechanized and aided by computer equipment, the collector operator will normally be performing supervisory and monitoring duties.

Stowage protocol for the heliostats is summarized in Table 2-12.

2.5.2 Maintenance Concept

The maintenance concept for collector subsystem is based on scheduled and unscheduled maintenance of the various elements and components.

2.5.2.1 Scheduled Maintenance

Scheduled maintenance consists primarily of periodic cleaning of the mirrors. To evaluate the impact of various cleaning schedules, the frequency of cleaning was varied and the resulting average reflectivity determined based on several degradation rates; this relationship is illustrated in Figure 2-38. The impact of average reflectivity on field size was evaluated with the Sandia DEL-SOL computer code; the result is shown in Figure 2-39.

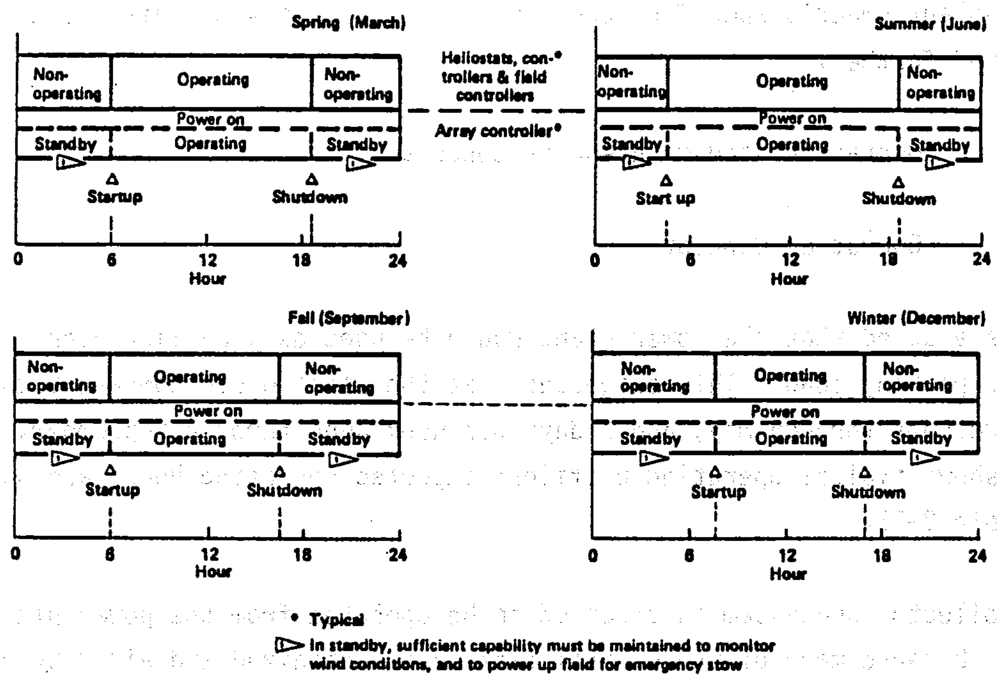


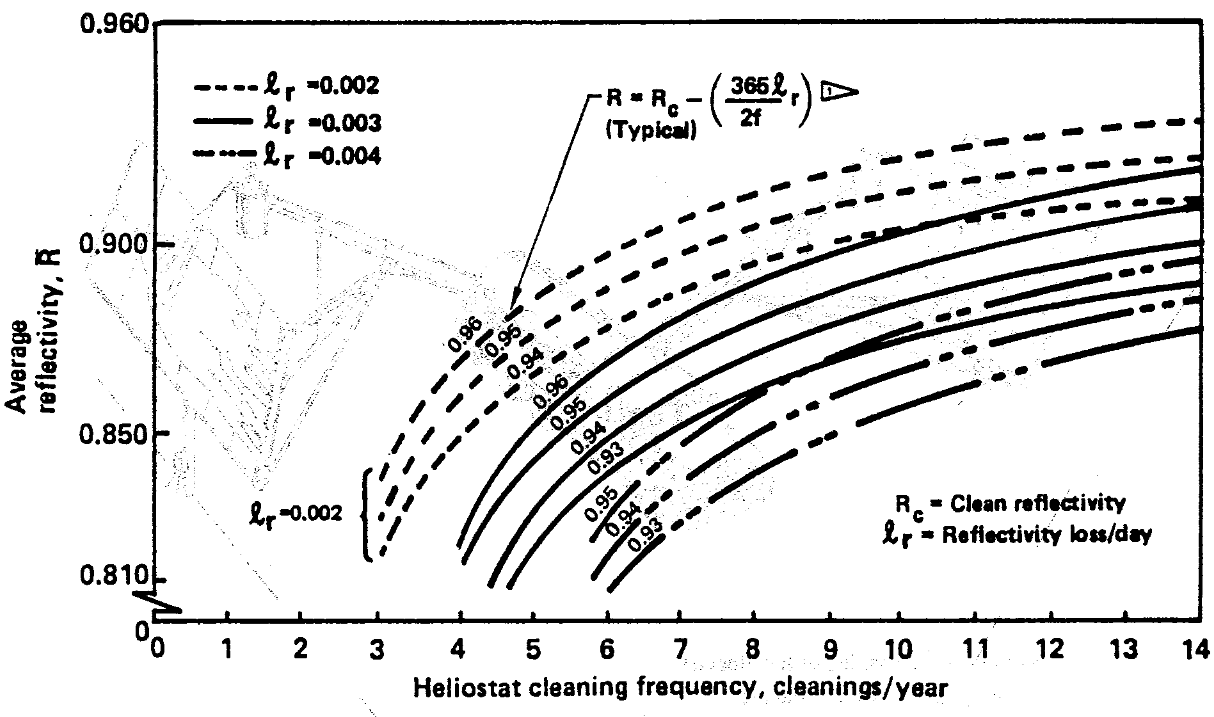
Figure 2-37. Typical Seasonal Operating Profiles

Table 2-11. Expected Values for Yearly Operating and Non-Operating Hours

Helios element	Average (expected-value) hours per year	
	Operating	Non-operating
Pedestal	8760	–
Gimbal-drive	3985	4775
Reflector	3985	4775
Controls		
Heliostat controller	8760	–
Field controller	3985	4775
Array controller	8760	–
Data distribution	3985	4775
Power distribution	3985	4775
Wind sensor	8760	–
Time-date receiver	8760	–
Maintenance		
MSE	3875	4885

Table 2-12. Heliostat Stowage Protocol

Condition	Stow position		Considerations
	Elevation	Azimuth	
Overnight stow	Near vertical	For next-day ops	• Minimize dirt buildup • Minimize non-op power & energy required
High wind stow	Horizontal	Any	• Minimize damage from airborne material • Structural limitations
Cleaning position	Near vertical	As required for cleaning tech.	• Minimize cleaning time



Source: Eason, E.D., "The Cost and Value of Cleaning Heliostats", Sandia Laboratories, Livermore, CA, mimeo; June, 1979; p.8

Figure 2-38. Average Reflectivity versus Heliostat Cleaning Frequency

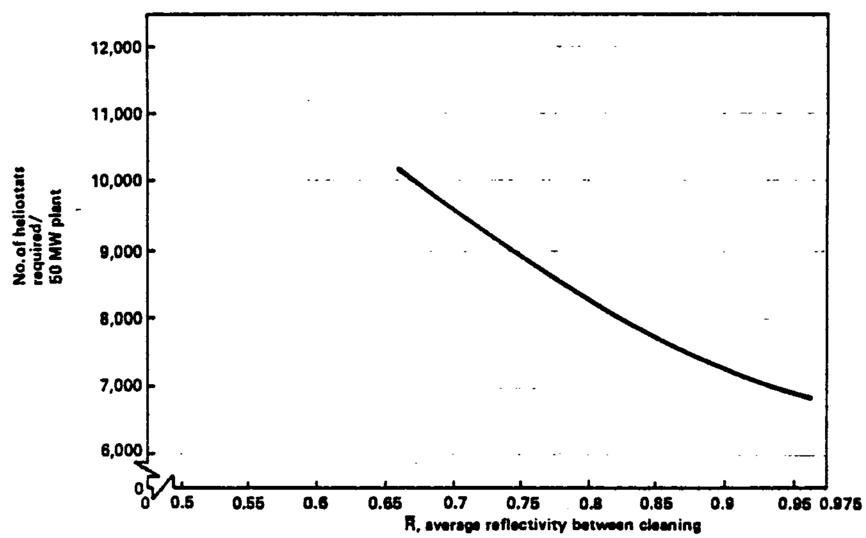
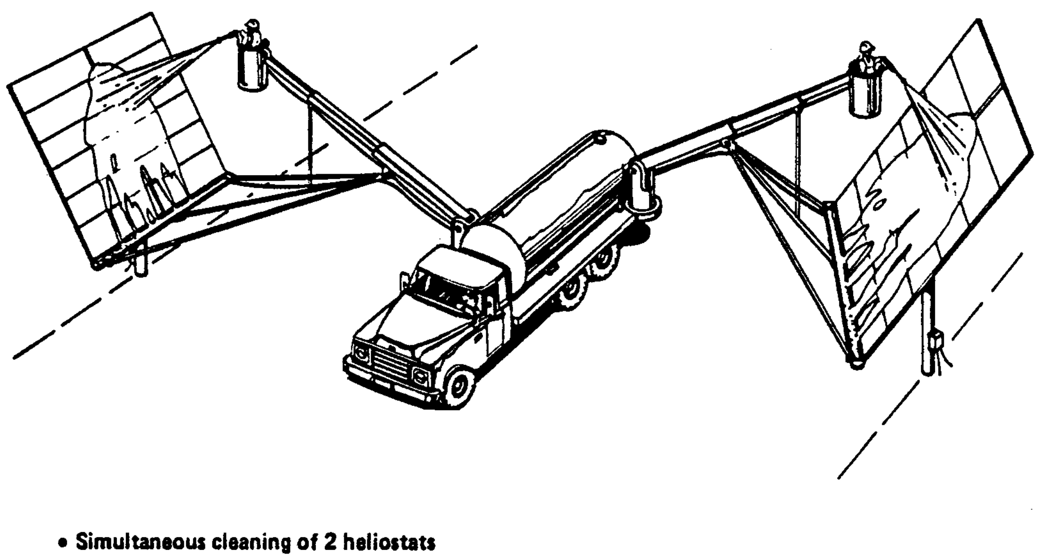


Figure 2-39. Heliostat Field Size versus Average Reflectivity



- Simultaneous cleaning of 2 heliostats
- Cleaning time ~ 10 min./helios
  (Includes positioning, pro-rata refills, etc.)
- Standard truck/booms/tankage/pumps
- Approximate cost ~ $75,000/truck
- 75% water recovery

Figure 2-40. Heliostat Cleaning Concept

To determine the preferred cleaning frequency, a "clean" reflectivity of 0.94 and a degradation rate of 0.3% per day were assumed. A cleaning concept was also assumed and priced; the basic technique is illustrated in Figure 2-40. The approximate cleaning costs for various cleaning rates and cleaning crew/equipment sizes is shown in Figure 2-41.

Based on the concept illustrated in Figure 2-40, the expected busbar electricity cost for the power plant was determined using the DELSOL code. The results are shown in Figure 2-42. As can be seen, the preferred cleaning frequency (based on the assumptions noted above), is about 8 times per year. This rate could be achieved by 5 crews with 3 cleaning trucks (3 crews on day shift, 2 at night). The resulting average reflectivity for the 0.3% degradation rate would be about 0.872, resulting in a field size of approximately 7500 heliostats. This field size and cleaning frequency results in the lowest busbar energy costs.

The foregoing illustrates how scheduled cleaning analysis can be approached. But because no environmental conditions were specified by Sandia, the impact on field size (of an average reflectivity of 0.872) was not incorporated into the collector subsystem production field size. However, for pricing purposes, the cleaning frequency and equipment/crew requirements noted above were used. It is probable that actual cleaning frequency will be determined empirically based on environmental conditions encountered at the power plant site.

2.5.2.2 Unscheduled Maintenance

The unscheduled maintenance concept for the collector subsystem is based on the automatic fault detection, isolation and annunciation capability which would be provided by the control element. In this concept the control subsystem would constantly monitor the condition of the various (active) components of the collector, including its own components. Failures would be detected by fault monitoring hardware and software, and isolated to the major collector element (controls, power, heliostat, etc.). To the extent feasible, fault isolation algorithms would identify the failure and announce a suggested repair sequence to the operator. Failures requiring dispatch of maintenance resources would be

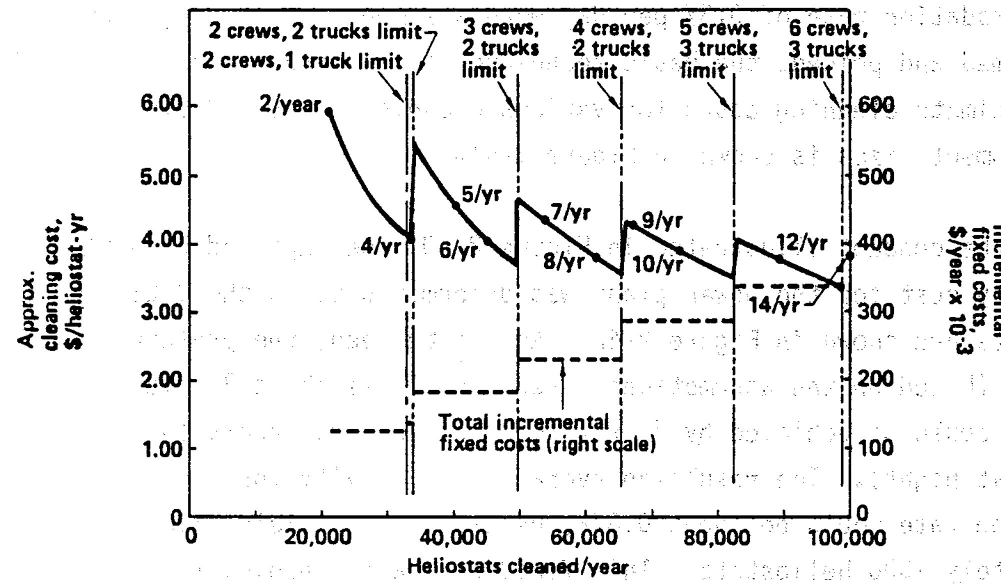
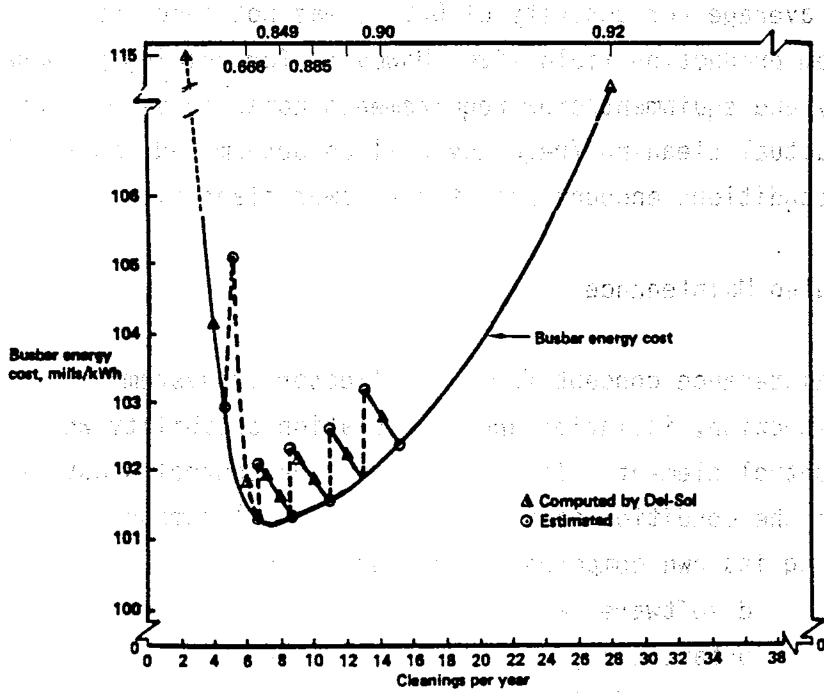


Figure 2-41. Cleaning Costs Based on Various Crew/Equipment Sizes



Source: Del-Sol runs (F. Mahony, 12-3/12-7-79)

Figure 2-42. Busbar Energy Costs versus Cleaning Frequency forwarded to the maintenance supervisor. Certain failures could be deferred, based on maintenance crew workload, or scheduled to coincide with power-plant maintenance.

Conservative Failure rates and repair times were based on available information or engineering estimates and are shown in Table 2-13; they were used to estimate maintenance manhours required. Sufficient maintenance personnel were then determined to achieve the desired collector subsystem availability (design goal of 90%).

Table 2-13. Collector Subsystem Reliability and Maintainability Figures of Merit

ELEMENT OR COMPONENT	NUMBER PER SUBSYSTEM	ESTIMATED UNIT VALUES MTBF, HOURS	FAILURE RATE x 10^6	(1) MTTR HOURS
Ped.-Foundation Ele.	1	-	-	10.00
Pedestal Assy.	6,400	876,000	1.14	10.00
Lightning Prot. Sys.	1	150,000	6.67	50.00
Gim.-Drive Ele.	1	-	-	8.95
Gimbal Assy.	6,400	28,725	34.81	3.07
Azimuth Gear Box	6,400	100,000	10.00	60.00
Elevation Drive	6,400	150,000	6.67	30.00
Motors (3)	12,800	200,000	5.00	8.00
Wiring & Switches	6,400	150,000	6.67	8.00
Structure	6,400	675,000	1.48	25.00
Pwer Distribution	1	2,700	371.19	9.39
Substations	5	200,000	5.00	16.00
Power Cable Net	1	350,000	2.86	40.00
Swithc Boxes	50	150,000	6.67	10.00
Misc. Components	1	100,000	10.00	20.00
Reflector Element	1	26,900	37.20	5.71
Facet Assy. (4)	76,800	750,000	1.33	NR (2)
Frame Assy.	6,400	500,000	2.00	24.00
Bracket Assy.	307,200	2,500,000	0.40	NR (2)
Cont.& Dat. Dis. Ele.	1	-	-	2.55
Array Controller	1	20,000	50.00	24.00
Field Sector Cont.	16	25,000	40.00	16.00
Heliostat Controller	6,400	25,000	40.00	16.00
BCS Interace Unit	1	20,000	50.00	48.00
Data Dist. System	1	150,000	6.67	24.00
Wind Vel. Sensor	1	50,000	20.00	16.00
Time-Date Recvr.	1	50,000	20.00	16.00
Computer Programs	1	500,000	2.00	100.00
Mainten. Support Ele.	1	-	-	47.69
Cleaning Equip.	3	10,000	100.00	40.00
Facet Handlg. Fixt.	2	100,000	10.00	8.00
Reflect. Aling. Fixt.	2	100,000	10.00	8.00
BCS Set	1	50,000	20.00	48.00
Misc. Elec. Repr. Equp.	1	100,000	10.00	500.00
Personnel Elem.	1	-	-	13.80
Operator	2	50,000	20.00	8.00
Cleaners	15	30,000	33.33	16.00
Repair Tech.	6	40,000	25.00	8.00

Notes: (1) Includes active repair time only, but incudes delay times, e.g., overnight waits.

(2) "NR" - Not repairable

(3) Approx. fail rate from CRTF: 4.93 x 10^{-6}

(4) Approx. CRTF fail rate: 0.4 x $.0^{-6}$

SECTION 3

PRODUCTION COST ESTIMATES

3.1 Ground Rules and Cost Breakdown Structure

3.1.1 Ground Rules

Cost and price estimates for the collector subsystem have been developed for the production plan described in Section 2. Estimates are given for:

a. The central manufacturing facility, and the site activation building equipment;

b. Production costs and prices for the collector subsystem as a function of cumulative production of 520,000 heliostats; and

c. Collector subsystem yearly operating and maintenance costs.

The cost estimates are expressed in constant 1980, second-quarter dollars. The estimates are for heliostats delivered and installed at a 50MW power plant. All incremental costs which are expected to be incurred after 31st December, 1980, have been accounted for. The production of heliostats from the CMF is to start on 1st June, 1984, with an initial production rate of 20,000 units the first year. The production rate is to be increased to 50,000 per year by 1st June, 1985. Normal production from the CMF is to be two 8-hour shifts. Production at the 50,000 per year rate is to continue for 10 years, with the CMF assumed to continue production thereafter.

In addition to the 50,000-per-year estimates, costs and prices have also been estimated for production at 25,000 and 67,500 per year rates from the CMF.

Operation and maintenance costs are based on a 50MW power plant as described in Section 2.

3.1.2 Cost Breakdown Structure

Sandia specified a cost breakdown structure for the collector subsystem; it is illustrated in Figure 3-1. This cost structure was expanded as required to account for all elements of the collector subsystem.

No cost breakdown structure was specified for the CMF and SAB tooling, but they have been segregated according to normal accounting practices.

3.2 Manufacturing Facility Costs

The costs for the central manufacturing facility are summarized in Table 3-1. Both acquisition and operating costs are given. Details of the cost estimate are contained in Appendix F. Costs for the SAB are summarized in Table 3-2.

3.3 Collector Subsystem Installed Costs versus Cumulative Production

The installed costs and prices for the collector subsystem as a function of cumulative production of 520,000 units are summarized in Table 3-3, and illustrated in Figure 3-2. As can be seen, the collector subsystem unit price varies from \$8,793 to \$6,263; these values correspond to \$200/m^2 and \$142/m^2, respectively. Details of these costs are shown in Appendix G.

3.4 Collector Subsystem Costs versus Production Rate

The variation of collector subsystem cost as a function of heliostat production rate is shown in Figure 3-3. As can be seen, prices may vary from \$6,884 to \$6,353 per heliostat for the 25,000- , 50,000- and 67,500-per year rates; a cost summary is given in Appendix Y.

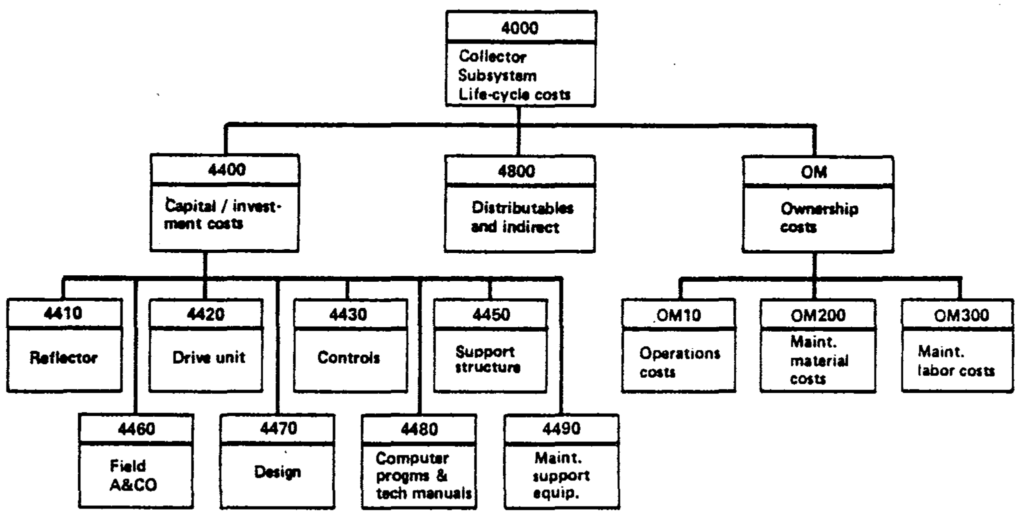


Figure 3-1. Collector Subsystem Life Cycle Cost Breakdown Structure

Table 3-1. Central Manufacturing Facility Cost Estimate

COST ELEMENT	AMOUNT AND UNIT COST		TOTALS
LAND	75 Acres @ $32,000/Acre		$2,400,000
SITE IMPROVEMENTS	GFMP: $2,100,000 FAP: $1,344,000		3,444,000
BUILDINGS	GFMP:		
	Mfg. Building @	$10,100,000	
	Galv. Building @	750,000	
	Utility Bldg. @	200,000	
	Oil & Paint Bldg. @	25,000	
	Indust. Waste @	1,250,000	
	Employee Facil. @	750,000	
	Subtotal	13,075,000	
	FAP:		
	Mfg. Building @	$ 6,372,000	
	Paint Storage @	25,000	
	Cap-strip Stor. @	25,000	
	Employee Facil. @	96,000	
	QC & Supv. Facil. @	29,000	
	Maint. Shops @	170,000	
	Warehouse Off. @	10,000	
	Loading Docks @	60,000	
	Compressor Bldg. @	17,000	
	Subtotal	6,804,000	
	ADMINISTRATION BLDG.	$ 1,323,000	
	GUARD HOUSES	25,000	
	Buildings Total	$21,227,000	$21,227,000
UTILITY SUBSTATION	1 SUBSTATION	750,000	750,000
FURNISHINGS & EQUIP	General Equipment (Air Conditioning, Furnishings, etc.)		
	1 Set	$ 2,337,000	
	Process Equipment & Tools		See Detail
	Peculiar Tooling @	51,953,250	
	General Purpose Tools @	21,536,300	
	Total	$75,826,550	75,826,550
A&E FEES, PERMITS, ETC. @ 4% OF TOTAL CONSTRUCTION (ITEMS 3,6,30,32)			3,912,140
FACILITY TURNOVER AND ACCEPTANCE (ALLOWANCE)			250,000
		CMF TOTAL	$107,809,690

OPERATING COSTS PER YEAR

GFMP	$403,725*
FAP	315,625*
Total	$719,350

* - Note: Portions of these costs are accounted as variable costs; see Appendix F for details.

Table 3-2. SAB Cost Estimate

COST ELEMENT	AMOUNT AND UNIT COST		TOTALS FOR ONE SAB
Land	(Part of Power Plant Site)		-
Site Improvements	(Part of Power Plant Site)		-
Buildings	(Standard Cent. Rcvr. Pwr. Plant Maint. & Warehouse)		-
Tools & Equipment	H-Frame Assy Fixtures 4 @ $5000 =	20,000	
	Jib-Joists 2 @ $750	1,500	
	Conveyor Line 80' @ 200/10 ft Sect	1,600	
	Facet Pallets 10 @ $250	2,500	
	Template/Alignment Fixtures, 4 sets @ 2000	8,000	
	Beam Transport Carts 4 @ $250	1,000	
	Misc. Tools 4 Sets @ $500	2,000	
	Misc. Slings 4 Sets @ $300	1,200	
	Conting. Allowance @ $5000	5,000	
	total	$42,800	$42,800
Transport Equip.	1. 2 RT-1 Trailers (For Panels) 2 RT-1's for Gimbals @ 6500	26,000	These items are maintenance support equipment delivered to plant owner (Class 4496)
	2. Pro-Rata Share of Downstream RT-1's: $\frac{(10)(36)(6500)}{520,000}$ (6914) = $31,100		$31,100
Vehicles	Lineman's Truck, Drot Crane, Tractors		These items are M.S.E. See Class 4496
Office Equip.	(Allowance) @ $2500		$2500
		SAB Total	$76,400

OPERATING COSTS/YEAR

Equipment Rental	$43,200
Utilities	
Phones: $50/Month =	600
Power/Light: $100/Month	1200
Misc. Allowance	1000
	$2800

Table 3-3. Collector Subsystem Acquisition Cost Summary

COLLECTOR SUBSYSTEM MANUFACTURING
COMPANY COST/PRICE SUMMARY (CONSTANT 1980 $'s)
PRODUCTION FISCAL YEAR

NOTE: Fiscal Years Run From June 1 to May 31
1 Heliostat = $44 m^2$

COST COMPONENT	1984 1st YEAR	1985 2nd YEAR	1986 3rd YEAR	1987 4th YEAR	1988 5th YEAR	1989 6th YEAR	1990 7th YEAR	1991 8th YEAR	1992 9th YEAR	1993 10th YEAR	1994 11th YEAR	TOTAL	PER HELIOSTAT Per m^2	Per Unit
UNITS PRODUCED	20,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	520,000		
VARIABLE COSTS														
EQUIP. RENTAL	86,400	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	4,406,400	0.19	8.47
COLLECTOR SUBS. VAR. COST	117,857,342	294,643,354	297,643,354	294,643,354	294,643,354	294,643,354	294,643,354	294,643,354	294,643,354	294,643,354	294,643,354	3,064,290,882	133.93	5892.87
WARRANTY SERVICE	265,200	663,000	663,000	663,000	563,000	663,000	663,000	663,000	663,000	663,000	663,000	6,895,200	0.30	13.26
POWER, UTILITIES & FACIL. MAINT.	178,050	278,050	278,050	278,050	278,050	278,050	278,050	278,050	278,050	278,050	278,050	2,958,550	0.13	5.69
ECONOMIC PROFIT	11,389,792	11,389,792	11,389,792	11,389,792	11,389,792	7,678,864	7,678,864	7,678,864	7,678,864	7,678,864	7,678,864	103,022,144	4.50	198.12
TOTAL VARIABLE COSTS	129,776,784	307,406,196	307,406,196	307,406,196	307,406,196	303,695,268	303,695,268	303,695,268	303,695,268	303,695,268	303,695,268	3,181,573,176	139.05	6118.41
FIXED COSTS														
CENTRAL MFG. PLANT														
PLANT DESIGN & CONST. FEES	3,912,140	-	-	-	-							3,912,140	0.17	7.52
PLANT TURNOVER/ ACCEPT	250,000	-	-	-	-							250,000	0.01	0.48
PROCESS DESIGN	6,227,870	-	-	-	-							6,227,870	0.27	11.98
PLANT STARTUP	13,755,100	-	-	-	-							13,755,100	0.60	26.45
DEPRECIATION	15,095,250	13,677,870	12,255,852	10,839,607	9,423,725	8,000,844	6,587,962	5,170,080	3,751,700	2,334,318	916,436	88,053,644	3.85	169.33
TAXES	2,312,365	2,312,365	2,312,365	2,312,365	2,312,365	2,312,365	2,312,365	2,312,365	2,312,365	2,312,365	2,312,365	25,436,015	1.11	48.92
SITE ASSEMBLY BLDG	-	-	-	-	-									
PROCESS DESIGN	188,270	-	-	-	-							188,270	0.01	0.36
EQUIPT. DEPRECIATION	138,908	125,018	111,127	98,237	83,345	69,455	55,563	41,673	27,782	13,892	-	765,000	0.03	1.47
SITE ACTIVATION/DOWNSTRM	114,800	330,000	330,000	330,000	330,000	330,000	330,000	330,000	330,000	330,000	330,000	3,414,800	0.15	6.57
INSURANCE	709,450	711,980	711,980	711,980	711,980	711,980	711,980	711,980	711,980	711,980	711,980	7,829,250	0.34	15.06
DESIGN CHANGE ADMIN.	165,000	165,000	165,000	165,000	165,000	165,000	165,000	165,000	165,000	165,000	165,000	1,815,000	0.08	3.49
GEN & ADMIN. OVERHEAD	3,214,880	5,046,680	5,046,680	5,046,680	5,046,680	5,046,680	5,046,680	5,046,680	5,046,680	5,046,680	5,046,680	53,681,680	2.35	103.23
TOTAL FIXED COSTS	46,084,033	22,368,913	20,933,004	19,503,869	18,373,095	16,636,324	15,209,550	13,177,778	12,345,507	10,914,235	9,482,661	205,328,769	8.97	394.86
TOTAL COSTS	175,860,817	329,775,109	328,339,200	326,910,065	325,479,291	320,331,592	318,904,818	317,473,046	316,040,775	314,609,503	313,177,729	3,386,901,945	$148.03	$6,513.27

Notes: 2 Sites Activated in 1st Year, 10/Year Thereafter

Table 3-3. Collector Subsystem Acquisition Cost Summary, continued

COST ACCOUNT	QTY/ SYSTEM	DESCRIPTION	UNIT COST	ECONOMIC PROFIT RATE,%	TOTAL PRICE
4410	6914	REFLECTOR ASSY	$2124.37	3.2	15,157,907
4420	6914	DRIVE UNIT	1602.55	3.2	11,434,592
4425	1	ELECTRIC POWER	NOT PRICED		
4430	1	CONTROL SUBSYSTEM	NOT PRICED		
4441	1	LAND	469,950.00	3.2	484,988
4451	6914	PEDESTAL	618.00	3.2	4,409,588
4453	1	LIGHTNING PROTECTION	281,342.00	3.2	290,345
4460	1	FIELD ASSY & CHECKOUT	5,092,817.00	6	5,398,386
4470	1	DESIGN AND ENGINEERING	200,000.00	10	220,000
4490	1	MAINT. SUPPORT EQUIP.	400,500.00	3.2	413,316
4820	1	SPARE PARTS	32,375.00	3.2	33,411
4830	1	A&E SERVICES	757,782.00	6	803,249
4840	1	CONSTRUCTION MGMT	112,898.00	6	119,672
4850	1	PLANT STARTUP & CHECKOUT	270,742.00	6	286,987
4860	1	CONTINGENCY	1,690,848.00	-	1,690,848
				TOTAL	$40,743,283
					$5892.87/ HELIOSTAT
Other Variable Costs:		(Equip. Rental & Warranty Service + Economic Profit + Utilities):			225.54
All Fixed Costs:		$394.86/HELIOSTAT			394.86
					$6513.27 =
					$148.03/m^2

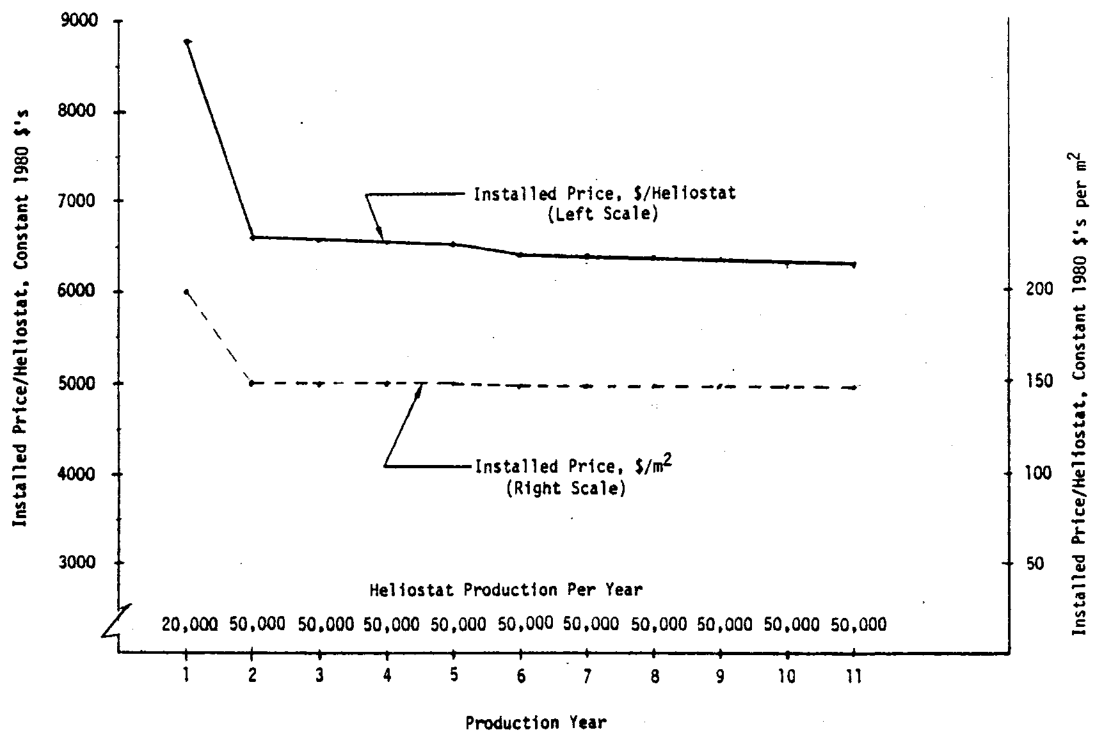


Figure 3-2. Collector Subsystem Price vs. Cumulative Production

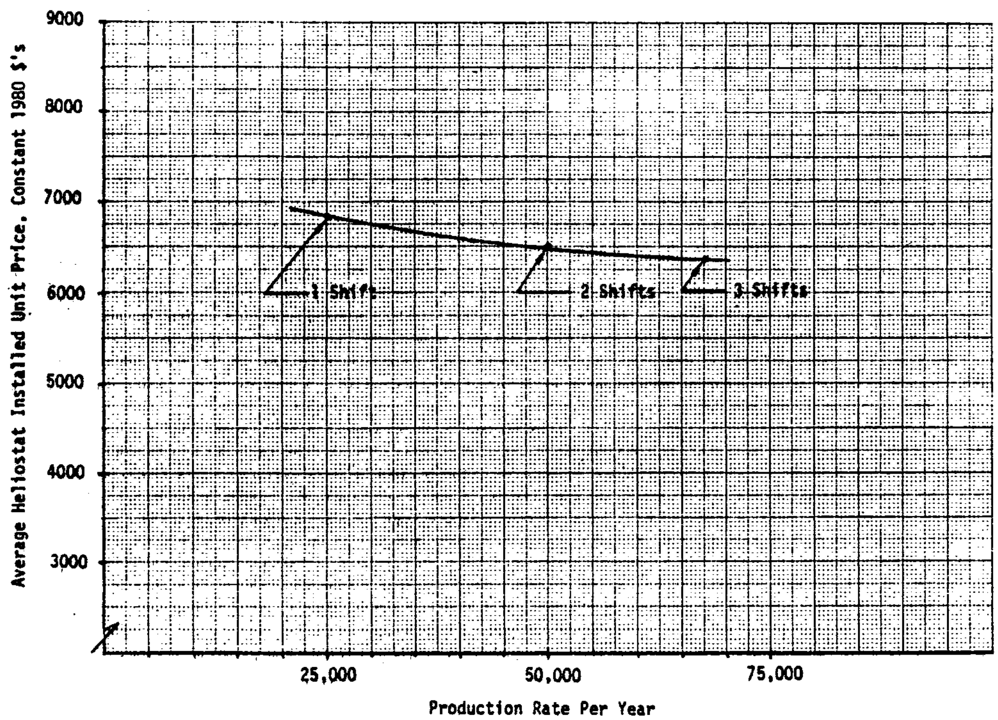


Figure 3-3. Average Heliostat Installed Price At Different Production Rates From The CMF

3.5 Collector Subsystem Operations and Maintenance Costs for a 50MW Electric Plant

3.5.1 One Year Operation and Maintenance Cost

Table 3-4 summarizes the expected operation and maintenance costs for one year of ownership at a 50MW power plant. These costs are based on the operating hours, failure and repair rates given in paragraph 2.5. Details of the costs are given in Appendix H.

3.5.2 Operation and Maintenance Cost Variation Over the Power Plant 30-Year Life

The principal variables in collector subsystem O&M costs are the expected amount of operation and the variation in weather conditions. Although both of these parameters would cause O&M costs to vary, they cannot be predicted. It is anticipated that the operating electric utility will generate expected O&M yearly budgets as they gain experience with the system. No attempt has been made to generate specific estimates, but (disregarding inflationary effects), an average annual variation of $\pm$ 10% of the costs shown in Table 3-4 might be reasonable.

3.6 Potential Cost Reduction

It is possible that certain changes can be made to the Collector Subsystem to reduce costs. The type of changes and their estimated cost impact are summarized in Table 3-5.

Table 3-4. Collector Subsystem Operation and Maintenance Costs

ACCOUNT NO.	DESCRIPTION		1980 $'s/YEAR
OM 10	OPERATIONS		
OM 10.1	COLLECTOR FIELD OPERATORS		$ 78,760
OM 10.2	ELECTRICAL POWER*		22,520
		OM 10	$ 101,280
OM 200	MAINTENANCE MATERIALS		
OM 210	REPLENISHMENT SPARES		$ 98,000
OM 220	REPAIR MATERIALS		5,000
		OM 200	$ 103,000
OM 300	MAINTENANCE LABOR		
OM 310	SCHEDULED MAINTENANCE		$431,950
OM 320	UNSCHEDULED MAINTENANCE		123,780
		OM 300	$760,730
		OM TOTAL	$ 760,090

*While Power Plant Is Not Operating

Table 3-5. Potential Cost Reduction Items

ITEM	JUSTIFICATION	COST REDUCTION $/m² [1]
• Reduce pedestal diameter from 23-5/8" to 18" OD	• Lateral stiffness measured at 3 to 10 times > design value	2.40
• Reduce gimbal diameter to 18" OD	• Maintain compatibility with pedestal	7.30
• Change from Foamsil to Foamglas core in reflector facets	• Lower cost • Commercial availability • Favorable JPL experience	2.20
• Reduce cost of silvering from 5.38 to 3.87 $/m² (0.50 to 0.36 $/ft²)	• Battelle report [2] indicates lower cost	1.50
• Reduce cost of drive motors	• Reduce spec/requirements • Develop competitive suppliers	1.70
	TOTAL	$ 15.10/m²

[1] Based on 44 m² nominal reflector area

[2] Heliostat Mirror Survey and Analysis, M.A. Lind et.al., Battelle Report PNL-3194/UC-62, September, 1979

REFERENCES

REFERENCES

Section 2

2-1. ______ .Technical and Economic Assessment of Solar Hybrid Repowering, SAN/1608-4-2, Stearns-Roger Inc., And Public Service Co. of New Mexico Albuquerque, New Mexico, September, 1978, Appendix, Construction Schedule

2-2. ______ .Combined Cycle Solar Central Receiver Hybrid Power System Study, Bechtel National, Inc., San Francisco, California, November, 1979, Volume II, p. 5-151.

2.3. ______ .Second Generation Heliostat Manufacturing Study, WDL-TR8958, Ford Motor Co., Dearborn, Michigan, and Ford Aerospace & Communications Corp., Palo Alto, California, October 31, 1980.

APPENDIX A

General Description of Cellular Glass Block Manufacturing Process

Appendix A

Cellular Glass Block Manufacturing Process

1.1 This appendix provides an overview of the FOAMSILR-75 ware manufacturing process which is owned/patented by Pittsburgh Corning Corporation.

1.2 Process Description (see Figure A-1).

1.2.1 Materials are received and stored either in silos or in their shipping containers ready for use in the mixing area.

1.2.2 Materials are automatically fed into continuous ball mills which deliver "ground batch" to a storage silo.

1.2.3 Ground batch is automatically fed onto a belt which carries it through a sintering furnace where volatile materials are removed to form a "klinker".

1.2.4 The klinker is ground and sized (and reground if necessary) and fed into a final batch storage silo.

1.2.5 Stainless steel mold pans are filled with the final batch and automatically fed into a cellulating furnace where the foaming operation takes place.

.2.6 When the pans emerge from the cellulating furnaces, the molds are stripped and the "buns" placed in the annealing lehr where they are cooled under controlled conditions to room temperature.

1.2.7 After annealing, the buns are trimmed on all six sides to 19" x 24-1/4" x 2" thick, palletized on special pallets and either warehoused or sent via conveyor to the facet plant.

`.2.8 Quality checks will be made of glass density, modulus, water vapor permeability and visual appearance on a sampling basis.

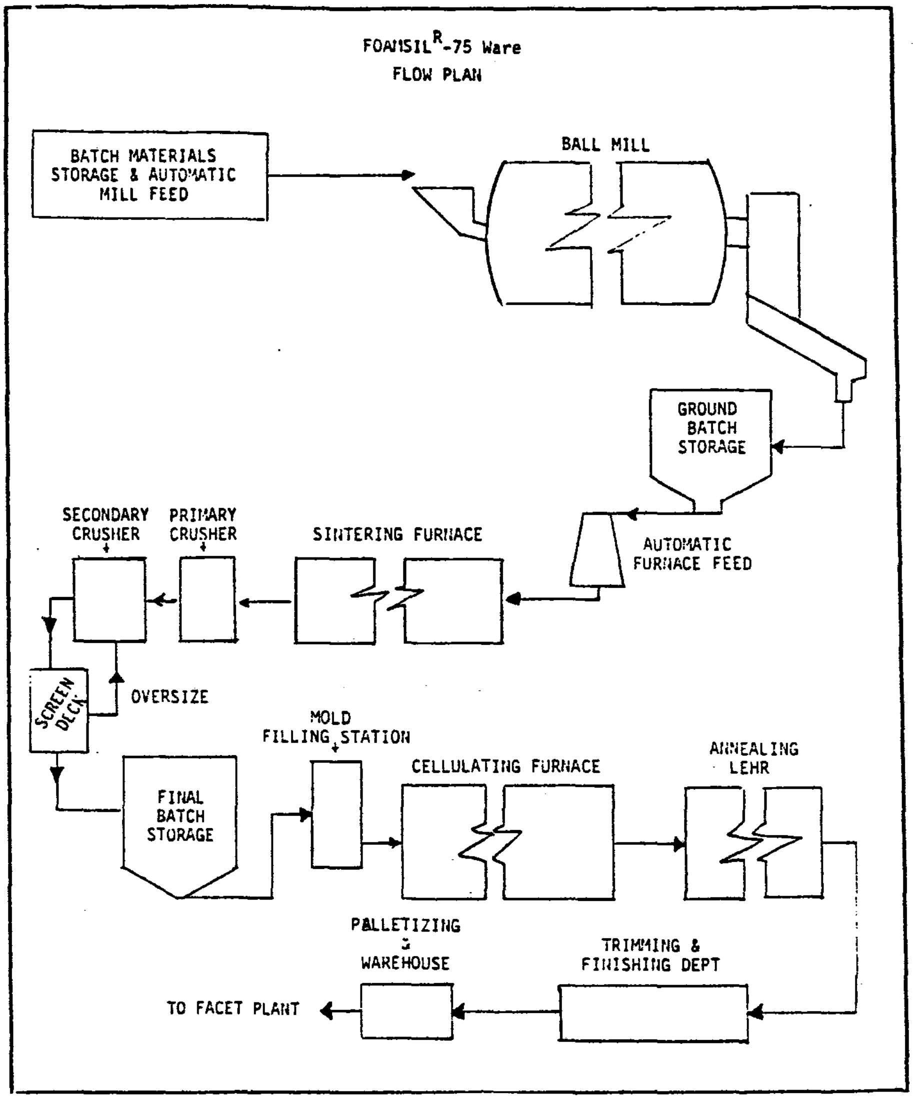


Figure A-1. Schematic of Cellular Glass Production Process permeability and visual appearance on a sampling basis.

APPENDIX B

Make/Buy Decisions for Production Facet Assembly

Appendix B

Make/Buy Decisions for Facet Assembly

1.1 Component Materials - Make/Buy Decisions

Amounts necessary for 50,000 heliostat units per year were analyzed to determine the preferred source.

1.1.1 Fusion Glass, Clear 48" x 120" x 0.060"

Buy - Technology is property of Corning Glass Works. To supply the quantities in question, Corning Glass Works would expand its facilities in Blacksburg, Virginia rather than establish a plant in the Southwest.

1.1.2 Fusion Glass, Silvered 48" x 120" x 0.060"

Buy - As in 2.1.1, the fusion glass would be purchased from Corning Glass Works and silvered on an in-line silvering facility at Blacksburg. Silvering in-line with the glass making process will provide a high quality reflective surface due to reduced contamination of the surface to be silvered.

1.1.3 FOAMSILR-75 Ware 19" x 24-1/4" x 2"

Buy - Purchase from FOAMSILR-75 plant situated adjacent to the facet assembly plant with "through the wall" delivery. All materials involved in the production of FOAMSIL-75 ware are to be purchased. Technology owned by Pittsburgh Corning Corporation.

1.1.4 Epoxy Adhesive (2-component)

Buy - Well established large plant operations in a number of locations by several companies are capable of supplying this quantity of material (Shell, Dow, Henkel, Ciba-Geigy, Devcon).

1.1.5 Hot Melt Butyl Sealant

Buy - Commerically available in this quantity from several companies, including the Norton Company and H. B. Fuller Company.

1.1.6 Cap Strip Adhesive

Buy - Urethane modified asphalt is available from Pittsburgh Corning Corporation, Flintkote, and others.

1.1.7 Cap Strips

Buy - Available locally from sheetmetal shops. Business could be farmed out to a large number of contractors. Purchase primed and painted.

1.1.8 Corner Caps

Buy - To be manufactured on punch press equipment. Available from large stamping companies. Purchase primed and painted.

1.1.9 Paint - Backsheets

Buy - Photocurable 100% solids urethane. Available from several sources, e.g., Hughson Chemicals, Dupont, Ameron, Mobay. Application is 1 mil of white and 2 mils of clear.

1.2 All materials are to be shipped to the plant in the Phoenix, Arizona area via rail or truck. All glass will be shipped via open top truck. Adhesives are to be received from rail tank cars. The paint and hot melt butyl may be shipped either by rail or truck and the cap strips and corner caps should arrive by truck.

1.3 All make/buy decisions and shipping requirements are unaffected by the production rate.

APPENDIX C

Make/Buy Decisions for Production Gimbal Drive and Frame Components

Appendix C

Make/Buy Decisions for Gimbal Drive and Frame Components

1.1 All major castings will be purchased outside and machined in - plant to provide control of the critical components and achieve total manufacturing costs that are probably lower than obtainable from outside machine shops at these volumes.

1.2 All major non-standard components and assembly for the planetary drive/bearing assembly are sourced in-plant.

1.3 Final assembly of the azimuth and elevation worm drive units is also sourced in-plant with the worm gearing purchased outside, and the acme thread S.S. shaft sourced in-plant because of difficulties in locating sources with sufficient capacity.

1.4 The torque tube will be purchased outside cut to length. In-plant, the outer diameter will be expanded to the close tolerance size required in the ring fit areas.

1.5 The flanges and rings to be welded to the tube in-plant will be purchased as form extruded sections in approximately 100" lengths. In-plant the material will be cut to length, ring rolled, end welded and expanded to I.D. size to fit the torque tube O.D. This method utilizes available capacity at the steel supplier for extruded mill sections and provides for good utilization of ring rolling, etc., equipment in-plant.

1.6 The beams for the H-frame assembly will be purchased finished, made from pre-galvanized steel (galvalume process) and shipped direct to the power-plant sites.

1.7 Miscellaneous stampings are sourced in-plant with presses fully loaded.

1.8 Various miscellaneous machined parts and weldments are sourced in-plant. These include pins, brackets, spacers, adapters, etc., which could be cycle run over common equipment to obtain good utilization. These parts should be reviewed for sourcing in actual production by obtaining quotes from small local outside suppliers who may have available time on existing equipment.

APPENDIX F

Central Manufacturing Plant and Site

Assembly Building Detail Costs

Table F-1. CMF Design/Construction Cash Flow

ITEM	AMOUNT INCURRED IN 1st YEAR	2nd YEAR	3rd YEAR	4th YEAR	5th YEAR
DESIGN					
GFMP	989,400 19.4%	2,519,400 49.4%	1,591,200 31.7%		
FAP	-	963,201 85.4%	164,669 14.6		
SAB	-	-	188,270 100%		
ACTIVATION					
GFMP	-	-	3,393,750 25%	10,181,250 75%	
FAP	-	-	36,020 20%	144,080 80%	
CONSTRUCTION					
LAND	2,400,000	-	-	-	
SITE INPROV.	1,722,000	1,722,000	-	-	
BUILDINGS	4,245,400 20%	10,613,500 50%	5,306,750 25%	1,061,350 5%	
SUBSTATION	750,000 100%	-	-	-	
FURNISHINGS & EPUIP.	3,791,328 5%	30,330,620 40%	30,330,620 40%	11,373,983 15%	
A&E PERMITS	782,428 20%	1,173,642 30%	1,564,856 40%	391,214 10%	
FACILITY TURNOVER	-	-	-	250,000	
CASH FLOW	14,680,696	47,322,363	42,576,135	23,401,877	127,981,071
INTEREST @ 6%					TOTALS
1st YRS	880,842	880,842	880,842	880,842	3,523,367
2nd YRS	-	2,839,341	2,839,341	2,839,341	8,518,025
3rd YRS	-	-	2,554,568	2,554,568	5,109,136
4th YRS	-	-	-	1,404,113	1,404,113
				TOTAL	$18,554,641

Table F-2. CMF and SAB Design and Startup Costs

ITEM/DESCRIPTION	ESTIMATED COST	REMARKS
GFMP		
PROCESS DESIGN & DEVELOPMENT	5,100,000	
PREACTIVATION & LAUNCH	13,575,000	
FAP		
PROCESS DESIGN & DEVELOPMENT	1,127,870	
PREACTIVATION & LAUNCH	180,100	
SAB		
PROCESS DESIGN & DEVELOPMENT	188,270	
PREACTIVATION & STARTUP/SITE	32,400	1ST 2 SITES
	13,000	All Other Sites
TEARDOWN & MOVE/SITE	25,000	1ST 2 SITES
	20,000	All Other Sites

Table F-3. Gimbal and Frame Plant Process and Installed Equipment, and Operating Costs

ITEM		AMOUNT
1. PROCESS EQUIPMENT:		
1.1 Peculiar Vendor Tooling		$ 822,150
1.2 Process Machines	"Peculiar Equip"	29,749,700
1.3 Tools & Gauges		7,188,900
1.4 Production Support	"General Equip"	14,347,400
	Sub Total	$ 52,108,150
2. INSTALLED EQUIPMENT (AIR CONDITIONING, ETC.; SEE NOTE BELOW)		
2.1 Furniture, Kitchen & Lockers		$ 600,000
2.2 Air Conditioning Equipment		900,000
	Sub Total	$ 1,500,000
3. OPERATING COSTS:		
3.1 General Utilities (Phones, Water, Waste Disposal		$ 50,000/YR
3.2 Air Conditioning:		
15,000 kWH/Day @ $0.03/kWH for 250 days =		$112,500
7500 kWH/Day @ 0.03/kWH for 115 days =		25,875
	Sub Total	$138,375/YR
3.3 Lighting & Machinery:		
14,000 kWH/Day @ 0.03/kWH for 250 days =		$105,000
3,000 kWH/Day @ 0.03/kWH for 115 days =		10,350
	Sub Total	$115,350
4. MISCELLANEOUS EXPENSES (ALLOWANCE) REPAIRS, PAINTING, ETC.		$150,000

NOTE: "Installed Equip. Costs" Include Allowance For Furniture, Etc., For CMF Administration Bldg.

Table F-4. Facet Assembly Plant Furnishings, Installed Equipment and Operating Costs

ITEM			AMOUNT
1. PROCESS EQUIPMENT			
Process Equip			$15,231,400
Glass Ship. Crates	"Peculiar Equip"		450,000
Facet Ship. Crates			5,700,000
		Total	$21,381,400
2. INSTALLED EQUIPMENT (AIR CONDITIONS, ETC.; SEE NOTE BELOW)			
Air Conditioning			737,000
Furniture & Fixtures			100,000
		Total	$ 837,000

3. OPERATING COSTS/YEAR OR UNIT

Generating Utilities @ $30.00 - 600,000 = $0.05/Facet

Air Conditioning Power:

12,960 kWH/Day @ 3 /kWH for 250 Days = 97,200
for 250 Days = 97,200

6,500 kWH/Day @ $0.03 for 115 Days = 22,425
Subtotal $119,625

Lighting & Machinery Power:

12,000 kWH/Day @ 3 /kWH for 250 Days = $90,000
2400 Facets

= $0.15/Facet

2000 kWH/Day @ 3 /kWH for 115 Days = 6,900
Subtotal $ 96,900

4. MISCELLANEOUS EXPENSES (ALLOWANCE)
REPAIRS, PAINTING, ETC. =$ 100,000

NOTE: "Installed Equipment Costs" Include Allowance For Furniture, Etc., In CMF Administration Bldg.

Table F-5. CMF Operating Expense Allocation

	Variable Costs	Amount/Year Accounted For In Fixed Costs
1. Gimbal & Frame		
Gen. Utilities	50,000	
Air Conditioning		$138,375
Lighting & Machine Power	105,000	10,350
Misc. Expense	150,000	
	$305,000	$148,725
2. Facet Assembly Plant		
Gen. Utilities	30,000	
Air Conditioning	97,200	22,425
Lighting & Machine Power	90,000	100,000
	$217,200	$129,325
	Total	$278,050
3. 1st Year Expense		$178,050

Table F-6. SAB Furnishings, Equipment and Operating Costs

ITEM	AMOUNT PER SAB	TOTAL FOR 10 SITES
PROCESS EQUIPMENT (PER SITE)		
Peculiar Tools, Jigs & Fixtures	$42,800	$428,000
Special Transport Equipment	31,100	311,000
		$739,000
OFFICE EQUIPMENT (DESKS, ETC.)		
(Allowance)	$2500	$25,000
OPERATING COSTS/YEAR		
Equipment Rental	$43,200	$432,000
Utilities		
Phones: $50/Month =	600	
Power/Light: $100/Month	1200	
Misc. Allowance	1000	
	$2800	$ 28,000

Table F-7. Production Tooling Equipment Costs

A. Peculiar Tooling

ITEM	APPLICABLE TO	DESCRIPTION	TOTAL COST
1	4410.2	Beam Tooling, Vendor	$250,000
2	4410.3	Bracket Pad Tooling, Vendor	18,000
3	4410	SAB Tooling, 10 SAB's @ $42,800 H-frame assy fixture 4 @ 5000 Jib hoist 2 @ 750 Conveyor line, 80 ft. @ 200/10' Facet pallets, 10 @ $250 Templates for facet alignment, 4 sets of 2 ea. @ 2000/set Beam transport costs, 4 @ $250 Misc. tools, 4 sets @ $500 Sling sets, 4 sets @ $300 Misc. Allowance, 1 @ $5000	428,000
4	4420.3	Gimbal Assembly fixtures at CMF (15 fixtures)	250,000
5	4420.3	Gimbal Component handling slings, 1 set, CMF	5,000
6	4410.2.06	Outboard torque-tube flange tooling, CMF	60,000
7	4423.2	Elevation motor tools; vendor	900
8	4420.1.3	Misc. tools, gimbal, CMF components at CMF 531442.25 gasket tool, 1 @ $150 531442.09 magnet holder tool, 1 @ $3000 531442.12 magnet holder tool, 1 @ $2500	5,700
9	4410	Site trailers, Type RT-1; 10 sites @ 68,400 6 trailers per site @ 6500 = $39,000 pro-rata share of downstream unit $\frac{(10)(34)(6500)}{(520,000)}$ (6914) = $29,400	684,000

Table F-7. Continued

ITEM	APPLICABLE TO	DESCRIPTION	TOTAL COST
10	4496	Tow tractors, for RT-1 Trailers, 2 ea. purchase @ $7500; 1 yr rental for 5 tractors at $2400/year per tractor = $12,000	$120,000 rental (nondepreciable)
11	4496	Lineman's truck at SAB 1 ea. purchase @ $50,000; rental of 1 truck for 1 year @ $1000/month	$120,000 rental (nondepreciable)
12	4496	Drott Crane at SAB 1 ea purchase @ $55,000 rental of 1 crane for 1 year @ 1600/month	$192,000 rental (non depreciable)
13	4420.4.3	Vendor tooling for rings	30,000
14	4420.4.5	Vendor tooling for swivel extender ring	13,400
15	4421	Azimuth drive tooling for: (at CMF)	100,600

Worm gear @	$15,900
H.S. cover @	6,700
H.S. worm @	5,000
S.S. worm @	5,000
H.S. gasket @	150
S.S. gasket @	150
Base @	15,000
Cover @	10,100
Planet Gear @	5,800
Planet Frame@	4,575
Primary gear@	2,205
Second ring gear	1,518
H.S. Pinon @	7,000
Base gasket @	300
Cover gasket @	300
Motor adapter @	9,600
Gimbal housing @	11,200
Total	$100,598

Note: These items are MSE and delivered to plant owner under class 4496

Table F-7. Continued

ITEM	APPLICABLE TO	DESCRIPTION	TOTAL COST
16	4422	Elevation drive tooling for: (at CMF)	$88,550

Housing @	$17,400
Attachment housing @	17,400
H.S. cap closed @	4,800
S.S. cover @	8,400
Motor adapter @	9,600
S.S. cover gasket @	150
Center gasket @	150
Attachment housing gasket @	150
H.S. worm @	10,000
H.S. worm gear @	5,000
S.S. worm @	10,500
S.S. gear @	5,000
Total	$ 88,550

Peculiar Tooling Totals

To GMF	SAB: Items 3,9,10,11,12	$2,237,000
	CMF: Items 1,2,4-8,13,14,15,16	822,150
	Equipment Rental (From Items 10,11,12)	432,000/year
		$3,059,150
	+	432,000/year rental

B. PROCESS MACHINERY, TOOLS & GAUGES, AND PRODUCTION SUPPORT EQUIPMENT FOR GFMP

(See Table B1 for Details)

GFMP PROCESS MACHINERY TOOLS AND GAUGES TOTALS

Process Machinery	$29,749,700
Tools & Gauges	7,188,900
Production Support	14,347,400
Total	$51,286,000

Table B-1. GFMP Machinery and Tooling Equipment

I - MANUFACTURING PLANT	Part Number	Quantity Required Per Unit	Process Machinery (000)	Tools & Gauges (000)	Production Support Equipment (000)	Total (000)	Remarks
Gimbal/Azimuth/Bearing Drive Assembly	D-651133-18	1	$ 0	$ 354.0	$ 175.0	$ 529.0	
Worm Gear Housing	790234	1	929.1	306.0	207.7	1,442.8	
H. S. Cap	800240	1	215.8	38.5	142.0	396.3	
S. S. Cover	800241	1	211.5	74.0	74.0	359.5	
S. S. Shaft Spacer-Short	835235	1	0	8.0	0	8.0	
S. S. Shaft Spacer-Long	834236	1	0	10.0	0	10.0	
H. S. Housing Bushing	835234	1	90.7	18.0	49.7	158.4	
Base Housing	926610	1	713.0	145.0	184.0	1,042.0	
Cover - Housing	926220	1	747.0	237.0	251.0	1,235.0	
Planet Gear	936140	3	3,183.0	438.5	551.0	4,172.5	
Planetary Frame	926310	1	706.0	384.5	147.0	1,237.5	
Primary Ring Gear	935710	1	2,134.0	605.2	362.0	3,101.2	
Secondary Ring Gear	936440	1	1,958.0	988.0	467.0	3,413.0	
Friction Ring	926360	6	19.5	12.5	20.7	52.7	
Journal Pin	926361	3	11.3	11.0	6.5	28.8	
Ball Retaining Bolt	926913	1	9.2	3.0	5.0	17.2	
Gimbal Housing	531146	1	733.0	210.0	215.0	1,158.0	
Elevation Drive Assembly	D651140-18A	1	0	59.0	45.5	104.5	
Housing	D651140-22	1	1,607.0	665.0	234.0	2,506.0	
Attachment Housing	C651140-46	1	855.0	339.0	177.0	1,371.0	
Attachment Housing Cover	A5510-L	1	55.0	16.5	27.5	99.0	
Inter Cover - H.S. Cap Closed	4485	1	98.5	28.0	25.0	151.5	
S. S. Cover	B651140-20	1	99.0	32.5	19.0	150.5	
H. S. Cap Open	A651140-45A	1	171.0	50.0	18.5	239.5	
Motor Adapter	7922	1	132.5	67.0	50.5	250.0	
S. S. Spacer	A651140-21A	1	72.0	42.0	17.5	131.5	
S. S. Shaft Spacer Washer	A651140-44A	1	71.0	18.0	36.5	125.5	
Upper Stop Collar	A651140-43	1	73.0	10.0	41.5	124.5	
Lower Stop Collar	A651140-48	1	90.1	35.5	87.5	213.1	
S. S. Shaft	B651140-23	1	10,385.0	662.0	665.0	11,712.0	
Torque Tube Assembly	SK-6130-002	1	34.7	164.4	*	199.1	
Torque Tube	SK-6130-002-2	1	721.0	133.0	*	854.0	
Flange-Outboard	SK-6130-002-3	2	133.6	91.6	*	225.2	
Flange-Inboard	SK-6130-002-	2	0	0	0	-	Included in Flange-Outboard
Adapter Ring	431439A	2	401.7	15.9	*	417.6	
Arm Assembly Torque Tube Act.	531147	1	21.9	20.6	*	42.5	
Arm Actuation	531147-1	2	311.6	122.9		434.5	
Brace-Cross	531147-2	2	0	11.0	*	11.0	
Brace-Cross	531147-3	2	0	5.8	*	5.8	
Cap-End	531147-4	1	35.9	9.4		45.3	

*Included under Press Shop General

Table B1, continued

	Part Number	Quantity Required Per Unit	Process Machinery (000)	Tools & Gauges (000)	Production Support Equipment (000)	Total (000)	Remarks
Torque Tube & Act. Arm Assembly	(new added)	1	$ 4.5	$ 45.5	$ *	$ 50.0	
Swivel Ext.-Ring Adapter	(new added)	2	562.0	292.0	87.0	941.0	
H-Frame Assembly	277-1020	2	-	-	-	-	Included in Heliostat Ass'y on Utility Sites
Reinf. Angle	277-1020-4	8		5.4	*	5.4	
Reinf. Angle	277-1020-12	16	46.1	4.3	*	50.4	
Reinf. Bar	277-1020-8	4	172.5	6.8	*	179.3	
Strut	277-1020-5	8	56.0	2.4	*	58.4	
Assembly Attach. Brkt.	277-10119	48	119.0	82.0	*	201.0	
Bracket Attach. Plate	277-10119-14	24	80.0	6.4	*	86.4	
Bracket Attach. Plate	277-10119-13	8	83.1	7.0	*	90.1	
Bracket Attach. Plate	277-10119-17	16	115.9	20.7	*	136.6	
Attachment-Bracket	277-10119-18	48	220.7	34.2	*	254.9	
Doubler B/U Plate	277-10119-19	48	41.1	4.4	*	45.5	
Adapter-El. Dr. Trunnion	531442-01	2	405.0	83.4	101.0	589.4	
Adapter-Motor Rev. Cntr.-Az.	531442-02	1	73.9	3.2	*	77.1	
Sleeve-Motor Rev. Cntr.-Az.& El.	531442-03	2	199.5	47.0	125.2	371.7	
Adapter-Motor Rev. Cntr.-El.	531442-04	1	0	4.8	*	4.8	
Cover-Motor Rev. Cntr.-Az. & El.	531442-05	2	0	4.3	*	4.3	
Mount-PC Board -Az. & El.	531442-06	2	34.3	5.3	*	39.6	
Adjuster-PC Board-Az. & El,	531442-08	2	9.2	1.2	2.5	12.9	
Magnet Holder-Rev. Cntr.-Az. & El.	531442-09	2	28.4	9.6	61.0	99.0	
Mount-Zero Ref., Az.	531442-10	1	0	1.5	*	1.5	
Holder-Zero Ref., Az.	531442-11	2	66.9	2.4	33.8	103.1	
Magnet Holder-Zero Ref. Az. & El.	531442-12	2	0	1.7	0	1.7	
Mount-Zero Ref.-El.	531442-13	1	87.3	13.2	0	100.5	
Bracket Magnet Holder-El.	531442-14	1	3.1	6.7	*	9.8	
Bracket Magnet Holder-Az.	531442-15	1	208.9	9.5	*	218.4	
Pin-El. Bearing	531442-16	2	77.1	23.0	38.0	138.1	
Pin-El. Act. Mount Pivot	531442-17	1	0	10.0	0	10.0	
Bracket-Az. Cable Wrap	531442-24	1	24.6	8.7	*	33.3	
Tool Room					1,767.2	1,767.2	
Cutter Grind					1,233.2	1,233.2	
Maintenance					1,340.0	1,340.0	
Quality Control Layout & Lab's					1,719.7	1,719.7	
Washing-Cleaning Equipment					449.9	449.9	
Heat Treat General					408.3	408.3	
Press Shop General					592.0	592.0	
Galvanizing System					1,250.0	1,250.0	
Paint System					330.0	330.0	
Material Handling					506.0	506.0	
Sub-Total - Manufacturing Plant			$29,749.7	$7,188.9	$14,347.4	$51,286.0	

*Included under Press Shop General

Table F-8. Components of Economic Profit

COMPONENTS OF ECONOMIC PROFIT

AMOUNT TO BE RECOVERED IN

ITEM	1984 1st	1985 2nd	1986 3rd	1987 4th	1988 5th	1989 6th	1990 7th	1991 8th	1992 9th	1993 10th	1994 11th	TOTALS
RETURN ON LABOR & MATERIALS @ 3.2%	See Balance Sheet - Included in Unit prices											-
RETURN OF INTEREST ON INVESTMENT	3,710,928	3,710,928	3,710,928	3,710,928	3,710,928	-						18,554,641
RETURN ON INVESTMENT OF $127,981,071 @ 6%	7,678,864	7,678,864	7,678,864	7,678,864	7,678,864	7,678,864	7,678,864	7,678,864	7,678,864	7,678,864	7,678,864	84,467,507
RETURN OF CAPITAL (DEPRECIATION)	See Balance Sheet											
TOTAL ECONOMIC PROFIT	11,389,742	11,389,742	11,389,742	11,389,742	11,389,742	7,678,864	7,678,864	7,678,864	7,678,864	7,678,864	7,678,864	$103,022,148
												$198.2/heliostat
												$4.50/$m^2$

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APPENDIX G

Detail Cost Estimate

for Collector Subsystem

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT

JOB NO MOD277-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE 12-17-80 REV 2-6-81

SHEET 1 OF 4

6914 HELIOSTATS
44 m²

4410 REFLECTOR ASSY, RIGHT HAND AND LEFT HAND

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL PER HELIOST
4410.1	FACET ASSY										
	4410.1.01 FACET MATERIAL	12	$108.61	$1303.32							$1303.32
	4410.1.02 ASSEMBLY LABOR	12	—	—	—	—	$2.22	$1.28			42.00
	4410.1.03 MAINTENANCE MAT'L	12	0.42	5.04							5.04
	4410.1.04 DIRECT UTILITIES	12	0.36	4.32							4.32
							12	FACET ASSYS FOB CMF			$1354.68
	4410.1.99 TRANSPORTATION OF FACETS	1	76.50	76.50			12	FACET ASSY'S TRANSPORTATION			76.50
				SUB TOTAL			12	FACET ASSY'S DEL'D TO SITE			$1431.18
4410.2	FRAME ASSY, RH and LH	2	(SEE DETAILS BELOW)								
	4410.2.01 SUPPORT BEAM (277-10122-5 & -6)	4	—	—	—	—	—	—	$63.40	$253.60	$253.60
	4410.2.02 STRUT (CROSS-BRACES) (277-10120-5)	8	1.17	9.36	—	—	0.22	0.76			10.34
	4410.2.03 REINFORCING BAR (277-10120-8)	4	0.53	2.12	—	—	2.36	8.27			12.75
	4410.2.04 REINFORCING ANGLE (277-10120-12)	16	0.33	5.32	—	—	0.49	1.70			7.51
	4410.2.05 REINFORCING ANGLE (277-10120-9)	8	0.29	2.32	—	—	0.27	0.95			3.54
	4410.2.06 TORQUE TUBE ASSY, RH&LH	2	—	—	—	—	0.75	2.00			2.75
	4410.2.06.01 TORQUE TUBE, 62"	2	27.94	55.88	—	—	0.86	2.00	—	—	58.74
	4410.2.06.02 FLANGE, OUTBD	2	10.87	21.74	—	—	1.58	5.54	—	—	28.86
	4410.2.06.03 FLANGE INBD	2	10.87	21.74	—	—	1.15	4.03	—	—	26.92

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT
JOB NO MOD277-1P
PREPARED BY D.F. Plummer CHECKED BY: DATE 1-29-81
SHEET 2 OF 4

6914 HELIOSTATS
44 m^2

4410 REFLECTOR, CONTINUED

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL PER HELIOSTAT
4410.2	FRAME ASSY, continued										
	4410.2.07 TRANSPORT BEAMS FROM MANUFACTURER'S PLANT TO SITE: RAIL TRANSPORT FROM LACKAWANNA, N.Y.									$70/HELIO	$70.00
	4410.2.08 TRANSPORT TORQUE TUBES FROM CMF TO SITE: TRUCK TRANSPORT									4.70/HELIO	4.70
	4410.2.09 TRANSPORT BEAM STRUTS, BARS & ANGLES FROM CMF TO SITE: TRUCK TRANSPORT									2.50/HELIO	2.50
	4410.2.10 ASSEMBLE H-FRAMES AT SAB										
	4410.2.10.1 ASSEMBLY HARDWARE	1 SET	$7.77	7.77							7.77
	4410.2.10.2 ASSEMBLY LABOR				2.13	4.25	34.00	INCLUDED IN CMF COSTS			34.00
				SUBTOTAL, H-FRAMES ASSEMBLED AT SAB							$524.44
4410.3	MIRROR-FACET ATTACHMENT BRACKET										
	4410.3.01 277-10119 ASSEMBLY	48					0.65	2.27			2.92
	4410.3.02 27-10119-27 (SIMILAR TO -14) PLATE	8	0.06	0.48			0.57	2.00			3.05
	4410.3.03 27-10119-26 (RR PLACES -13 & -17) PLATE	40	0.15	6.00			2.50	5.00			13.50
	4410.3.04 27-10119-29 (REPLACES -16) NYLON PAD	96							0.16	15.36	15.36
	4410.3.05 27-10119-25 (SIMILAR TO -16) BRACKET	48	0.44	21.12			1.78	6.23			29.13
	4410.3.06 JAM NUT, 1/2-20UNF-2A	48	0.015	0.72							0.72
	4410.3.07 STEEL BALL, 0.500 DIA STL	48	0.05	2.40							2.40
	4410.3.08 WASHER 277-10119-30	96	0.05	4.80							4.80
	4410.3.09 SET SCREW 277-10119-28	48	0.10	4.80							4.80
				SUBTOTAL, 48 BRACKET ASSEMBLIES							$76.68

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT

JOB NO MOD277-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE 2-2-81

SHEET 3 OF 4

6914 HELIOSTATS
$44 m^2$

4410 REFLECTOR, CONTINUED

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
4410.4	MISCELLANEOUS ASSEMBLY FASTENERS (BRACKET ASSY TO FRAMES)										
	NUTS, BOLTS, WASHERS,	1 SET	—	$ 5.00							$ 5.00
4410.5	ASSEMBLY LABOR, RH & LH. REFLECTOR ASSYS										
	4410.5.1 POSITION TEMPLATES TO BEAMS	4			0.14	0.56	4.48				4.48
	4410.5.2 LOAD FACETS ON FRAMES (INCLUDES MOUNTING BRACKETS TO FACET)	12			0.26	3.20	25.60				25.60
	4410.5.3 CANT FACETS AND TORQUE BRACKET NUTS	12			0.067	1.60	12.80				12.80
	4410.5.4 REMOVE TEMPLATES INSPECT ASSEMBLY, INSTALL SLING & TRANSFER TO RT-TRLR	2			0.333	0.667	5.33				5.33
			4410.5	SUBTOTAL RH & LH REFLECTOR ASSEMBLED							$ 48.21
4410.6	TRANSPORT RH & LH REFLECTORS TO PEDESTAL										
	4410.6 AVERAGE TRANSPORT ROUNDTRIP TIME FOR DELIVERY (2 REFLECTORS PER TRIP)	1 UNIT			0.33	0.33	2.67				2.67
4410.7	ASSEMBLE RH & LH REFL. PANELS TO GIMBAL-DRIVE AT PEDESTAL	1 UNIT			1.55	1.55	12.40				12.40
4410.8	GALVANIZING AND REWORK FOR REFLECTOR [illegible] COMPONENTS (SEE BACKUP SHEET)	1 UNIT		12.00			2.62	9.17			23.79
				SUBTOTAL RH & LH REFL. PANELS INSTALLED							$ 38.86

4410 REFLECTOR, CONTINUED

Cost Code 4410.8 Galvanizing and Rework Costs for Reflector Panel Assys

Item	Description	Total Cost/Helio
1	Galvanizing, labor & material	17.18 ✓
2	Tear down and repair	6.61 ✓
	Total	$ 23.79 ✓

Breakout of Costs:

	Material	Direct Labor	Var. Burden
1	12.00	1.15	4.03
2		1.47	5.14

DDP 2/4/81

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT

JOB NO MOD277-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE 2-4-81 REVISED 2-6-81 SHEET 4 OF 4

6914 HELIOSTATS
$44 m^2$

4410 REFLECTOR ASSY, RH & LH, SUMMARY

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
			Unit Price	Amount	Unit M.H.	Total M.H.	Total Direct	Total Variable Burden	Unit Price	Amount	
4410	RH & LH REFLECTORS ASSEMBLED AND INSTALLED AT PEDESTAL										
	4410.1, FACET ASSY	12	$166.05								$1431.18
	4410.2, H-FRAME ASSY	2	263.46								524.44
	4410.3 ATTACHMENT BRKT	48	1.60								76.68
	4410.4 ASSEMBLY HARDWARE	1 SET	5.00								5.00
	4410.5 ASSEMBLY LABOR	2	26.61								48.21
	4410.6 ON-SITE TRANSPORT	1	11.07								2.67
	4410.7 ASSEMBLY LABOR	1	12.40								12.40
	4410.8 GALVANIZING & REWORK	1	23.79								23.79
					4410 TOTAL						$2124.37

COST ESTIMATE SUMMARY | **BE&C ENGINEERS INC.** A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT

JOB NO MOD277-1P

PREPARED BY D.F. Plummer CHECKED BY: ______ DATE 2-4-81 SHEET 1 OF 9

6914 HELIOSTATS
44 m²

4420 DRIVE UNIT

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
4420.1	DRIVE UNIT ASSEMBLY AT CMF										
	4420.1.1 ASSEMBLE ELEVATION DRIVE TO AZIMUTH AT CMF	1			0.08	0.08	$0.30	$0.60			$0.90
	4420.1.2 ASSEMBLE CENTER TORQUE TUBE TO AZ-EL ASSY AT CMF	1			0.18	0.18	1.33	2.60			3.93
	4420.1.4 OPERATIONAL CHECKOUT OF ASSEMBLED DRIVE	1			0.10	0.10	0.75	1.50			2.25
	4420.1.5 ASSEMBLY PARTS DRIVE UNIT (SEE ATTACHED LIST)	1 SET		$30.94	–	1.83	13.73	48.06		$101.72	194.45
					4420.1 SUBTOTAL						$201.53
4420.2	TRANSPORT/INSTALL DRIVE UNIT	1 UNIT									
	4420.2.1 TRANSPORT DRIVE UNIT TO SITE									20.90	20.90
	4420.2.2 TRANSPORT DRIVE UNIT TO PED.	(4 GIMBALS/DISPATCH: 1/2 REFLECTOR TRANS. COST)									
					0.17	0.17	1.32				1.32
	4420.2.2 INSTALL DRIVE UNIT ON PED		9 NUTS/WASH. @ $0.15	1.35	0.26	0.26	2.08				2.08
					4420.2 SUBTOTAL						$24.30
4420.3	CORROSION PROTECTION & REWORK (SEE ATTACHED SHEET)	1 UNIT		17.97		1.51	11.31	39.62			$68.91

4420.1.3 Assembly Parts for Gimbal

Item	Description	Cost
1	Electrical Wiring	$45.00
2	Lubricating oil	6.16
3	Parts set, drive unit (see attached list)	143.29

4420.1.5 Assembly Parts Set, Drive Unit

Part Nomenclature	Part Number	Quantity	Sourcing	Total Material Cost	Total Purchased Parts Cost	Direct Labor Cost	Variable Burden Cost	Total Variable Cost
Bracket-As. Cable Wrap	531442-24	1	Make	$ 2.97*	$	$ .79*	$ 2.77*	$ 6.53*
Gasket	531442-25	2	Purchase		.018	-	-	.018
Retaining Ring	5100-100I	6	Purchase		.48	-	-	.48
Screw-Cap Hex. Hd. 1/4-20 UNC x 3/4	531436-33	8	Purchase		.296	-	-	.296
Washer-Flat 1/4	531436-34	19	Purchase		.027	-	-	.027
Washer-Lock Spring, 1/4	531436-35	19	Purchase		.228	-	-	.228
Screw-Cap Hex. Hd. 3/8-16 UNC x 7/8	531436-36	10	Purchase		.360	-	-	.360
Washer-Flat 3/8	531436-37	18	Purchase		.029	-	-	.029
Washer-Lock Spring 3/8	531436-38	18	Purchase		.324	-	-	.324
Screw-Cap Hex. Hd. 3/8-16 UNC	531436-39	8	Purchase		.352	-	-	.352
Nut-Hex 3/8 - 16 UNC	531436-40	8	Purchase		.184	-	-	.184
Thrust Washer, Cad Plated	014UU	4	Purchase		.048	-	-	.048
Bushing	GF1620-16	3	Purchase		.54	-	-	.54
Permatex, Form-A-Gasket No. 2	7472A2	A/R	Purchase		.20	-	-	.20
Screw-Cap Hex. Hd. 1/4-20 UNC x 7/8	531436-44	8	Purchase		.304	-	-	.304
Screw-Mach. Pan Hd. #10-32 UNFx5/8	531436-45	16	Purchase		.432	-	-	.432
Washer-Flat #10	531436-46	16	Purchase		.022	-	-	.022
Washer-Lock Spring #10	531436-47	16	Purchase		.208	-	-	.208
Socket Hd. Screw #10-32 UNF x 1/4	531436-48	2	Purchase		.052	-	-	.052
Screw-Mach. Pan Hd. #4-40 UNC x 3/8	531436-49	4	Purchase		.010	-	-	.010
/ Washer-Flat #4	531436-50	4	Purchase		.006	-	-	.006
Washer-Lock, Spring #4	531436-51	4	Purchase		.044	-	-	.044
Nut, Hex. Jam 1/4-28 UNF-2B	531436-52	1	Purchase		.04	-	-	.04
Retaining Ring-Beryllium Copper	500-18 C	2	Purchase		.52	-	-	.52
Spring Compression, Stainless Steel	LC-0426-5	2	Purchase		.74	-	-	.74
Dowel Pin 1/8 Dia. x 1 1/4 Lg. S.S.	531436-55	2	Purchase		.04	-	-	.04
Grommet-Cable Tie	TYO-34H	2	Purchase		.10	-	-	.10
Screw Cap, Hex Hd 1/4-20 UNCx1 3/4	531436-57	3	Purchase		.078	-	-	.078
Nut-Hex. Hd. 1/4-20 UNC	531436-58	3	Purchase		.06	-	-	.06
Nut-Hex. Jam 3/4-16 UNF 2B	531436-59	4	Purchase		.60	-	-	.60
Cord Grip	2521	2	Purchase		3.52*	-	-	3.52*
Cord Grip	2632	2	Purchase		5.00*	-	-	5.00*
Hall Effect-Digital Switch	5315516	2	Purchase		2.00	-	-	2.00
Screw Mach. Pan Hd. #4-40 x 1/4	531436-63	2	Purchase		.048	-	-	.048
Washer-Flat #4	531436-64	2	Purchase		.003	-	-	.003
Washer-Lock Spring #4	531436-65	2	Purchase		.046	-	-	.046
Adapter-Elev. Drive Trunnion	531442-01	2	Make	21.40		1.64	5.73	28.77
Adapter-Motor Rev. Counter, Az.	531442-02	1	Make	.23*		.14*	.48*	.85*
Sleeve -Motor Rev. Counter, Az & El	531442-03	2	Make	1.22*		2.57*	9.00*	12.79*
Adapter-Motor Rev. Counter, El.	531442-04	1	Make	.29*		.24*	.86*	1.39*
Cover -Motor Rev. Counter, Az & El	531442-05	2	Make	.86*		.73*	2.56*	4.15*
Mount-PC Board, Az. & El.	531442-06	2	Make	.14		1.32	4.63	6.09
PC Board-M'tr. Rev. Counter, Az & El	531442-07	2	Purchase		22.00	-		22.00
Adjuster-PC Board, Az. & El.	531442-08	2	Make	.14*		.34*	1.18*	1.66*
Magnet Holder-Rev. Counter Az & El	531442-09	2	Purchase		[illegible]	-	-	7.00
Mount, Zero Ref., Az.	531442-10	1	Make	.73*		1.03*	3.60*	5.36*
Holder, Zero Ref., Az. & El.	531442-11	2	Make	.19*		1.25*	4.37*	5.81*
Magnet Holder, Zero Ref. Az. & El.	531442-12	2	Purchase		4.60	-	-	4.60
Mount, Zero Ref., El.	531442-13	1	Make	.61*		1.86*	6.51*	8.98*
Bracket Magnet Holder, Zero Ref. El	531442-14	1	Make	.43*		.68*	2.39*	3.50*
Bracket Magnet Holder, Zero Ref. Az	531442-15	1	Make	.22*		.46*	1.61*	2.29*
Pin-El., Bearing	531442-16	2	Make	1.02		.46	1.58	3.06
Pin-El., Actuator Mount Pivot	531442-17	1	Make	.49		.22	.79	1.50
			Totals	30.94 ✓	50.56 ✓	13.73 ✓	48.06 ✓	$ 143.29

4420 DRIVE UNIT

Cost Code 4420.3, Drive Unit Rework, Corrosion Protection, and Handling At CMF

Item	Description	Total Cost/Unit
1	Galvanize Gimbal/arm assy	17.18
2.	Heat treat gimbal-drive components	10.36
3	Paint gimbal/arm assy	21.55
4	Repair and rework	19.82
	Total	$68.91

Breakout of Costs

	Material	Direct Labor	Var. Burden
1	12.00	1.15	4.03
2		2.30	8.06
3	5.97	3.46	12.12
4		4.40	15.41

COST ESTIMATE SUMMARY — **BE&C ENGINEERS INC.** A BOEING SUBSIDIARY

PROJECT: 2ND GENERATION HELIOSTAT
JOB NO: MOD272-1P

PREPARED BY: D.F. Plummer CHECKED BY: DATE: 2-5-81 SHEET 5 OF 9

6914 HELIOSTATS
$44 m^2$

4420 DRIVE UNIT

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
4420.4	CENTER TORQUE-ARM ASSY										
	4420.4.1 TORQUE TUBE ASSEMBLY LABOR	1			—	0.75	$5.63	$11.25			$16.88
	4420.4.2 TORQUE TUBE	1	$32.00	$32.00	.	—	0.50	1.00			33.50
	4420.4.3 FLANGE, OUTBOARD	2	10.87	21.74		—	1.15	4.03			25.77
	4420.4.4 ADAPTER RINGS, EL. ARM	2	10.87	21.74		-	1.15	4.03			25.77
	4420.4.5 53147 ELEVATION ARM ASSY	1	—	39.44	—	0.47	3.49	12.25			55.18
	4420.4.6 GALVANIZING	(INCLUDED IN		4420.3)							—
	4420.4.7 REPAIR & REWORK	(INCLUDED IN		4420.3)							—
						4420.4 SUBTOTAL					$157.10
4421	AZIMUTH DRIVE ASSY			395.81	—	—	36.54	128.99	—	171.09	732.43
	(FOR DETAILS, SEE ATTACHED SHEET)										
4422	ELEVATION DRIVE ASSY			70.07	-	-	19.01	67.63	—	112.30	269.01
	(FOR DETAILS, SEE ATTACHED SHEET)										

4421 AZIMUTH DRIVE

Part Nomenclature	Part Number	Item Number	Quantity	Sourcing	Total Material Cost	Total Purchased Parts Cost	Direct Labor Cost	Variable Burden Cost	Total Variable Cost
Azimuth Drive Assembly	D-651133-18		1	Assembly			$7.63	$26.70	$34.33
Worm Gear Housing	790234	1	1	Make	$10.58		2.01	9.82	23.21
H. S. Cap	800240	2	1	Make	.795		1.65	5.78	8.225
S. S. Cover	800241	3	1	Make	2.58		1.24	4.35	8.17
H. S. Worm	860990	4	1	Purchase		$19.48	-	-	19.48
S. S. Shaft	830234	5	1	Make	1.091		3.73	13.07	17.891
S. S. Worm Gear	900990	6	1	Purchase		11.18	-	-	11.18
S S. Shaft Spacer-Short	835235	7	1	Make	.039		.29	1.02	1.349
S S. Shaft Spacer-Long	835236	8	1	Make	.039		.30	1.04	1.379
H. S. Housing Bushing	835234	9	1	Make	.197		.37	1.28	1.847
H. S. Cap Gasket	815486	10	1	Purchase		.046	-	-	.046
S. S. Cover Gasket	815487	11	1	Purchase		.025	-	-	.025
Encoder Sft. Ball Brg. (MRC 3822)	20303	12	1	Purchase		3.63	-	-	3.63
H. S. Ball Bearing (MRC 2034)	20118	13	2	Purchase		5.38	-	-	5.38
S. S. Ball Bearing (MRC 2065)	20207	15	1	Purchase		4.02	-	-	4.02
Spiralox Retaining Ring (RST-66)	10271	16	1	Purchase		.028	-	-	.028
Truarc Retaining Ring (N-5000-156)	10139	17	1	Purchase		.072	-	-	.072
Truarc Support Washer (5900-66)	10275	18	1	Purchase		.069	-	-	.069
H. S. Seal (CR 6630 CRW 1)	30172	19	3	Purchase		1.98	-	-	1.98
H. S. Seal (CR 6660 CRW 1)	30173	20	1	Purchase		.71	-	-	.71
S. S. Seal (CR 11610 CRW 1)	30174	21	4	Purchase		3.12	-	-	3.12
Alemite Grease Fitting (1684 B)	13746	22	1	Purchase		.897	-	-	.897
Base	926610	23	1	Make	93.15*		1.07	3.74	97.96*
Cover	926220	24	1	Make	63.48*		1.76	6.14	71.38*
Planet Gear	936140	25	3	Make	30.12		4.86	17.01	51.99
Planetary Frame	936310	26	1	Make	36.85		.73	2.55	40.13
Primary Ring Gear	936710	27	1	Make	58.64*		3.03	10.60	72.27*
Secondary Ring Gear	936440	28	1	Make	36.64		2.99	10.47	50.10
Friction Ring	926360	29	6	Make	.236		.31	1.10	1.646
H. S. Pinion	936060	30	1	Purchase		16.28	-	-	16.28
Journal Pin	926361	31	3	Make	.306		1.12	3.93	5.356
Base Gasket	926911	33	1	Purchase		1.43	-	-	1.43
Cover Gasket	926910	34	1	Purchase		1.43	-	-	1.43
Ball-Load	926914	35	66	Purchase		2.97	-	-	2.970
Ball Spacer	926915	36	66	Purchase		2.97	-	-	2.970
Ball Retaining Bolt	926913	37	1	Make	.14		.15	.51	.80
Torrington Needle Bearing(NJ101812)	20304	38	6	Purchase		15.30	-	-	15.30
Locknut	176	39	1	Purchase		.123	-	-	.123
Dowty "O" Ring (No. 200-908)	50170	40	1	Purchase		.028	-	-	.028
C/A Axial Clamp Ser.No. 524363	30171	41	1	Purchase		69.37*	-	-	69.37*
3/16 x 1 Spirol Pin	10531	42	12	Purchase		.814	-	-	.814
1/4 x 20 x .75 lg. Hex. Hd. Bolt	11702	43	4	Purchase		.147	-	-	.147
1/4 x 20 x 1 3/8 Hex. Hd. Bolt	11703	44	4	Purchase		.157	-	-	.157
3/8 x 16 x 1.75 lg. Hex. Hd. Bolt	11743	45	4	Purchase		.176	-	-	.176
1/2 - 13 x 2 lg. Hex. Hd. Bolt	12323	46	4	Purchase		$ .312	$ -	$ -	$ .312
1/2 - 13 x 1 1/2 lg. Hex. Hd. Bolt	11786	47	18	Purchase		1.152	-	-	1.152
1/4 - 20 x 5/8 lg. Hex. Hd. Bolt	11701	48	2	Purchase		.022	-	-	.022
1/8 x 1/8 x 3/4 Pinion Key	15008	49	1	Purchase		.023	-	-	.023
1/4 x 1/4 / 5/8 Gear Key	15231	50	1	Purchase		.031	-	-	.031
3/8 Pipe Plug	11141	51	1	Purchase		.035	-	-	.035
1/8 Pipe Plug	11104	52	3	Purchase		.12	-	-	.12
1/4 Lockwasher	13213	53	14	Purchase		.17	-	-	.17
3/8 Lockwasher	13230	54	4	Purchase		.06	-	-	.06
1/2 Lockwasher	13250	55	30	Purchase		.48	-	-	.48
L-050 Lovejoy Coupling	100000	56	1	Purchase		1.40	-	-	1.40
Motor Adapter (Use 651140-18 Det.7)	805000	57	1	Make	$ 5.73		1.11	5.00	11.84
1/4 - 20 x 3/4 Lg. Soc. Hd. Screws	12242	58	4	Purchase		.104	-	-	.104
1/8 x 1/8 x 1/2 Coupling Key	15009	59	1	Purchase		.034	-	-	.034
1/4 Pipe Plug	11122	60	2	Purchase		.12	-	-	.12
1/2 - 13 x 3 3/4 Lg. Hex. Hd. Bolts	11776	61	12	Purchase		1.632	-	-	1.632
Spacer	835237	62	4	Purchase		.68	-	-	.68
Spacer	835238	63	12	Purchase		2.88	-	-	2.88
Gimbal Housing	531146		1	Make	55.20		1.39	4.88	61.47
				TOTALS	$ 395.81	$ 171.09	$ 36.54	$ 128.99	$ 732.43

4421 AZIMUTH DRIVE

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4422 ELEVATION DRIVE

Part Nomenclature	Part Number	Item Number	Quantity	Sourcing	Total Material Cost	Total Purchased Parts Cost	Direct Labor Cost	Variable Burden Cost	Total Variable Cost
Elevation Drive Assembly	D651140-18		1	Assembly			4.10	14.35	18.45
Housing	D651140-22	1	1	Make	11.96		4.01	14.03	30.00
Attachment Housing	C-651140-46	2	1	Make	6.90		2.22	7.78	16.90
Attachment Housing Cover	5510	3	1	Make	.404		.07	.23	.704
H. S. Cap Closed	4485	4	1	Make	.35		.38	1.34	2.07
S. S. Cover - No print	B-651140-20	5	1	Make	3.82		.85	2.97	7.64
H. S. Cap	A-651140-45	6	1	Make	.334		.75	2.61	3.694
Motor Adapter	7922	7	1	Make	5.73		1.11	5.00	11.84
S. S. Shaft	B-651140-23	8	1	Make	36.38		2.79	9.77	48.94
S. S. Spacer	A-651140-21	9	1	Make	.070		.30	1.05	1.42
S. S. Shaft Washer	A-651140-44	10	1	Make	.034		.24	.86	1.134
S. S. Timkin Cone (No. 43125)	20308	11	1	Purchase		3.774	-	-	3.774
S. S Timkin Cup (No. 43312)	20509	12	1	Purchase		1.714	-	-	1.714
S. S. Timkin Cone (No. 27881)	20310	13	1	Purchase		3.069	-	-	3.069
S. S. Timkin Cup (No. 27820)	20077	14	1	Purchase		1.821	-	-	1.821
Int. Timkin Cone (No. 05062)	3370	15	2	Purchase		3.886	-	-	3.886
Int. Timkin Cup (No. 04185)	3371	16	2	Purchase		1.744	-	-	1.744
H. S. Timkin Cone (No. A6062)	3336	17	2	Purchase		4.168	-	-	4.168
H. S. Timkin Cup (No. A6151)	3337	18	2	Purchase		1.712	-	-	1.712
S. S. Cover Gasket	A-651140-24	19	1	Purchase		.045	-	-	.045
Inter Gasket	4487	20	2	Purchase		.022	-	-	.022
H. S. Cap Gasket	4370	21	2	Purchase		.016	-	-	.016
Attachment Housing Gasket	5521	22	1	Purchase		.022	-	-	.022
H. S. Seal Garlock 63 x 51	3301	23	4	Purchase		3.04	-	-	3.04
S. S. Seal C/R 14939 CRWA1	30026	24	2	Purchase		1.78	-	-	1.78
S. S. Seal Enclosure Cap	B-651140-47	25	1	Purchase		12.00*	-	-	12.00*
Worm Drive Power Clamp	52200	26	1	Purchase	$	$ .76*	$ -	$ -	$ .76*
Upper Stop Collar	A-651140-43	27	1	Make	.957		.32	1.11	2.387
Lower Stop Collar	A-651140-48	28	1	Make	3.134		1.87	6.53	11.534
Elev. Actuator Nut	B-651140-42	29	1	Purchase		17.09	-	-	17.09
3-16 x 3/16 x 1 H. S. Gear Key	10002	30	1	Purchase		.085	-	-	.085
3/8 x 3/8 x 1 1/4 S. S. Gear Key	15420	31	1	Purchase		.096	-	-	.096
3/64 x 1 Spirol Pin	10500	32	1	Purchase		.036	-	-	.036
1/8 Sq. Hd. Pipe Plug	11211	34	4	Purchase		.144	-	-	.144
1/4 Sq. Hd. Pipe Plug	11212	35	3	Purchase		.203	-	-	.203
Spiron Pin 1/8 x 1	10520	33	2	Purchase		.072	-	-	.072
3/8 Sw. H.d Pipe Plug	11213	36	1	Purchase		.070	-	-	.070
Alemite (No. 1610-B1)	13701	37	1	Purchase		.196	-	-	.196
Alemite (No. 1625)	13704	38	1	Purchase		.618	-	-	.618
Lovejoy Coupling (No. L-070)	100035	39	1	Purchase		3.75	-	-	3.75
1/8 x 1/8 x 3/4 Coupling Key	15008	40	1	Purchase		.035	-	-	.035
1/4 - 20 x 5/8 Lg. Hex. Hd. Bolt	11874	41	8	Purchase		.080	-	-	.080
1/4 - 20 x 7/8 Lg. Hex. Hd. Bolt	11873	42	4	Purchase		.150	-	-	.150
1/4 x 20 x 1 Lg. Hex. Hd. Bolt	11875	43	8	Purchase		.315	-	-	.315
1/4 - 20 x 1 1/4 Lg. Soc. Hd. Cap Screw	11876	44	4	Purchase		.104	-	-	.104
3/8 - 16 x 1 Lg. Hex. Hd. Bolt	11871	45	6	Purchase		.240	-	-	.240
5/4 - 16 x 1 1/2 Lg. Nylock Hex. Hd. Bolt	11824	46	1	Purchase		.063	-	-	.063
3/4 - 16 x 2 Lg. Nylock Hex. Hd. Bolt	11877	47	1	Purchase		.054	-	-	.054
1/4 Lockwasher	13336	48	20	Purchase		.24	-	-	.24
3/8 Lockwasher	13337	49	6	Purchase		.096	-	-	.096
H. S. Worm	C-651140-29-13	50	1	Purchase		17.61	-	-	17.61
H. S. Worm Gear	651140-50	51	1	Purchase		8.32	-	-	8.32
S. S. Worm	651140-41	52	1	Purchase		13.10	-	-	13.10
S. S. Gear	651140-34	53	1	Purchase		9.96			9.96
				TOTALS	$70.07	$112.30	$19.01	$67.63	$269.01

4422 ELEVATION DRIVE

SHT 2 of 9

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT

JOB NO MOD277-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE

SHEET 8 OF 9

6914 HELIOSTATS
44m²

4420 DRIVE UNIT, CONTINUED

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
			Unit Price	Amount	Unit M.H.	Total M.H.	Total Direct	Total Variable Burden	Unit Price	Amount	
4423	MOTORS										
	4423.1 AZIMUTH MOTOR	1							$66.65		$66.65
	4423.2 ELEVATION MOTOR	1							82.62		82.62
						4423 SUBTOTAL					$149.27

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT

JOB NO MOD277-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE

SHEET 9 OF 9

6914 HELIOSTATS
44 m^2

4420 DRIVE UNIT SUMMARY

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
			Unit Price	Amount	Unit M.H.	Total M.H.	Total Direct	Total Variable Burden	Unit Price	Amount	
4420	DRIVE UNIT ASSEMBLED AND INSTALLED AT PEDESTAL										
	4420.1 DRIVE UNIT ASSEMBLY	1	201.53								201.53
	4420.2 DRIVE UNIT TRANSPORT	1	24.30								24.30
	4420.3 CORROSION PROTECTION	1	68.91								68.91
	4420.4 CENTER TORQUE ARM	1	157.10								157.10
	4421 AZIMUTH DRIVE	1	723.43								723.43
	4422 ELEVATION DRIVE	1	269.01								269.01
	4423 MOTORS	2	—	149.27							149.27
							4420 TOTAL				$1602.55

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT

JOB NO MOD277-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE 2-6-81 SHEET 1 OF 1

6914 HELIOSTATS
44 m^2

4440 FOUNDATION AND SITE

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
			Unit Price	Amount	Unit M.H.	Total M.H.	Total Direct	Total Variable Burden	Unit Price	Amount	
1.1.11	COLLECTOR FIELD LAND	313.3 ACRES	$1500	$469,950							$469,950
						4440 TOTAL					$469,950

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COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT
JOB NO MOD272-1P
PREPARED BY D.F. Plummer CHECKED BY: DATE 2-6-81 SHEET 1 OF 1

6914 HELIOSTATS
44 m^2

4450 HELIOSTAT SUPPORT

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
4451	PEDESTAL, DELIVERED TO SITE	6914							$618	$4,272,852	$4,272,852
	SOURCE: HYDRO CONDUIT CORP. QUOTE OF 11-14-80										
4453	LIGHTNING PROTECTION PROVISIONS										
	4453.1 COUNTERPOISE NETWORK										
	4453.1.1 COPPER GRID WIRE, #2 BHD (4.17 lbs/ft)	450,000 LF, 108,000 lbs	$1.95/lb	$210,600							210,600
	4453.1.2 WELD TIES EACH PED.	6914	$3.00/wld	$20,742							20,742
	4453.1.3 CABLE INSTALLATION	(INSTALLED WITH POWER CABLES)									
	4453.2 LIGHTNING RODS (ALLOWANCE)	1 UNIT	$50,000	$50,000							50,000
	4453.3 PEDESTAL-TO-COUNTERPOISE CONNECTIONS (INCLUDED IN CLASS 4467)										
					4450 TOTAL						$4,554,194

1 ACRE = 43,560 ft²

COST ESTIMATE SUMMARY		BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2nd [illegible]

JOB NO [illegible]-1P

PREPARED BY R.E. Plummer CHECKED BY: DATE 2-12-81 SHEET 1 OF 4

6914 HELIOSTATS 4 in²

4460 FIELD ASSEMBLY, CHECKOUT & INTEGRATION

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
4460.1.1	MOBILIZE & SET UP (ALLOWANCE)	1 UNIT								$50,000	$50,000
4460.1.2	INITIAL SITE SURVEY	314 ACRES	$40/ACRE	$12,560							12,560
4461	CLEAR, GRUB & GRADE										
	CLEAR & GRUB	314 ACRES	$1675	$525,950							525,950
	GRADE (ASSUME LEVEL SITE, AVG. 1ft/ft² MOVEMENT)	507,000 C.Y.	$1.51	$765,570							765,570
4462	STORM DRAINAGE PROVISIONS	(ALLOWANCE)									500,000
4463	FIRE PROTECTION PROVISIONS	(ALLOWANCE)									500,000
4464	ACCESS PROVISIONS										
	4464.1 CHAIN-LINK FENCE (INSTALLED)	20,700 LF	$9.25/LF	$191,475							191,475
	4464.2 ACCESS GATE (FURNISHED	BY POWER	PLANT	OWNER							—

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2nd [illegible]

JOB NO [illegible]-1P

PREPARED BY [illegible] CHECKED BY: DATE 2-12-81 SHEET 2 OF 4

6914 HELIOSTATS
4.1 m²

4460, FIELD A&CO, CONTINUED

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
4465	INTEGRATION EQUIPMENT										
	4465.1 CLEANING FLUID PROCESSING/SUPPLY PLANT INCLUDES WATER SUPPLY/TREATMENT (ALLOWANCE)										$250,000
4466	CONTROL SYSTEM COMPONENT INSTALLATION IN POWER-PLANT CONTROL BUILDING (NOT PRICED)										—
4467 & 4468	(SEE SHTS 3&4)										
4469	HELIOST REFERENCE MARK SETTING & FINAL SURVEY										
	4469.1 USING ZERO REFERENCE LEVEL, DETERMINE HELIOSTAT AZIMUTH & ELEVATION ZERO REFERENC MARKS. THIS ACTIVITY PERFORMED IN CONJUNCTION WITH CONTROL OPERATOR: ESTIMATE 2 MEN AT PEDESTAL FOR 1/2 HOUR, PLUS 1/4 HOUR OF CONTROL OPERATOR'S TIME/HELIOSTAT ($8.00/HR LABOR)										
		6914			1.25	8643	$69,144	(INCLUDED IN CMF)			$69,144
	4469.2 PERFORM FINAL PEDESTAL SURVEY TO DETERMINE LATITUDE & LONGITUDE, 0.25 HRS/HELIOSTAT (AVERAGE) @ $8.00 HR										
		6914			0.25	17285	$13,828	(INCLUDED IN CMF)			$13,828

COST ESTIMATE SUMMARY | **BE&C ENGINEERS INC.** A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT

JOB NO M02277-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE 2-6-81

SHEET 3 OF 4

6914 HELIOSTATS
4.1 m²

4460 FIELD ASSY & CHECKOUT, CONTINUED

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
4467	PEDESTAL INSTALLATION (PILE DRIVING)	6914									
	PILE-DRIVING @ $12/LINEAL FOOT OF PILE (NOT DRIVEN LENGTH): 26.25' x $12 x 6914 =									$2,177,910	$2,177,910

COST ESTIMATE SUMMARY | **BE&C ENGINEERS INC.** A BOEING SUBSIDIARY

PROJECT 2nd [illegible]

JOB NO [illegible]2277-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE 2-12-81

SHEET 4 OF 4

6914 HELIOSTATS
4-11m²

4460 FIELD A&CO, CONTINUED

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
4468	ELECTRICAL/LIGHTNING CONN. AT PED.										
4468.1	CONNECT ELECTRICAL & LIGHTING-PROTECTION CONNECTIONS (DATA, POWER & LIGHTNING)										
		6914			0.15	1037	$16.05/HR	$6.50/HR			$23,387
4468.2	OPERATE GIMBAL & VERIFY OPERABILITY										
		6914			0.083	576	$16.05	$6.50			$12,993
				4460 TOTAL							$5,092,817

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT
JOB NO MOD272-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE 2-12-81 SHEET 1 OF

6914 HELIOSTATS
$44 m^2$

4470 DESIGN AND ENGINEERING

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
4471	FIELD DESIGN										
	SITE SPECIFIC DESIGN/LAYOUT FOR SOIL CONDITIONS, TOPOGRAPHY, LATITUDE & LONGITUDE: (ALLOWANCE)										$150,000
4472	SOFTWARE ADAPTATION FOR PLANT-SPECIFIC TURBINE/RECEIVER DESIGN: (ALLOWANCE)										$50,000
	4470 TOTAL										$200,000

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT

JOB NO MOD272-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE 2-12-81 SHEET 1 OF 1

6914 HELIOSTATS
44 m^2

1480 COMPUTER PROGRAMS AND TECHNICAL MANUALS

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
			Unit Price	Amount	Unit M.H.	Total M.H.	Total Direct	Total Variable Burden	Unit Price	Amount	
[illegible]	TAPE PROGRAMS	3 ea	$500	$1500							$1500
[illegible]	TECHNICAL MANUALS										
	OPERATOR'S MANUAL	: 1	@ $500								500
	SYSTEM MAINTENANCE MANUAL	: 1	@ $500								500
	ELECTRONIC SYSTEM MAINTENANCE MANUAL	:		1 @ $500							500
	ELECTRONIC EQUIPMENT REPAIR MANUALS			: 5 @ $500							2500
	MISC. OEM/OVERHAUL MANUALS :	10 ea		@ $300							3000
148							4480 TOTAL				$8500

NOTE: ABOVE PRICES ARE FOR REPRODUCTION & HANDLING COST ONLY — PREPARATION COSTS NOT INCLUDED.

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT
JOB NO MOD272-1P
PREPARED BY D.F. Plummer CHECKED BY: DATE 2-12-81
SHEET 1 OF 3

6914 HELIOSTATS
44 m²

4490 MAINTENANCE SUPPORT EQUIPMENT

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
			Unit Price	Amount	Unit M.H.	Total M.H.	Total Direct	Total Variable Burden	Unit Price	Amount	
4491	HELIOSTAT CLEANING EQUIPMENT										
	HELIOSTAT WASHING TRUCK	3 ea							$75,000	$225,000	$225,000
4492	REFLECTOR MAINT. EQUIP.										
	4492.1 FACET SLING	2 ea							500	1000	1000
	4492.2 REFLECTOR HANDLING SLING	2 ea							1500	3000	3000
4493	DRIVE UNIT MAINT. EQUIP.										
	4493.1 GIMBAL/TORQUE-ARM SLING	3 ea							500	1500	1500
	4493.2 GEAR-BOX REPAIR TOOLS	1 SET							2500	2500	2500
	4493.3 ACTUATOR REPAIR TOOLS	1 SET							1000	1000	1000
	4493.4 ELECTRICAL MAINT. EQUIP	1 SET							5000	5000	5000
4494	CONTROL SYSTEM MAINT. EQUIP.										
	(NOT PRICED)										
4495	FIELD CALIBRATION & ALIGNMENT EQUIP.										
	4495.1 ZERO REFERENCE LEVEL	1 ea							5000	5000	5000
	4495.2 WIND VELOCITY SENSOR REPAIR EQUIP	1 SET							1500	1500	1500
	4495.3 TIME/DATE RECEIVER MAINT. EQUIP.	1 SET							1500	1500	1500
				SHEET SUB-TOTAL							$247,000

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT

JOB NO M03772-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE 2-10-81 SHEET 2 OF 3

6914 HELIOSTATS
$41 m^2$

4490 MAINTENANCE SUPPORT EQUIPMENT, CONTINUED

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
4496	VEHICLES										
4496.1	TRAILER, TYPE RT-1	4							$6500	$26,000	$26,000
	2 TRAILERS FOR GIMBALS										
	2 TRAILERS FOR FACETS										
4496.2	TOW TRACTOR, GENERAL	2							$7500	$15,000	15,000
4496.3	LINEMAN'S TRUCK WITH	1							$50,000	$50,000	50,000
	EXTENDABLE ARM & BASKET										
4496.4	DROTT CRANE	1							$55,000	$55,000	$55,000
					4496 TOTAL						$146,000

COST ESTIMATE SUMMARY	**BE&C ENGINEERS INC.** A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT
JOB NO MOD277-1P
PREPARED BY D.F. Plummer CHECKED BY: DATE 2-12-81 SHEET 3 OF 3

6914 HELIOSTATS
44 m²

4490 MAINTENANCE SUPPORT EQUIPMENT, CONTINUED

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
4497	MAINT. EQUIPMENT FOR HELIOSTAT CLEANING EQUIPMENT										
	(ALLOWANCE)	1 SET							$ 7500	$ 7500	$ 7500
				4490 TOTAL							$ 400,500

151

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT
JOB NO MOD272-1P
PREPARED BY D.F. Plummer CHECKED BY: .... DATE 2-12-81
SHEET 1 OF 3

6914 HELIOSTATS
44 m^2

4800 DISTRIBUTABLES AND INDIRECT

Item No.	DESCRIPTION	Quantity & Unit	Unit Price	Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
4810	TEMP. FACILITIES	— NONE									—
4820	SPARE PARTS, INITIAL	LAYIN SET									
	4421 REFLECTOR SYSTEM	1 SET									
	5 FACETS	5	$1500	$7500							$7500
	4422 DRIVE UNIT SYSTEM										
	MOTORS	25	$75	$1875							1875
	MISC. REPAIR PARTS	1 SET	$5000	$5000							5000
	4423 CONTROL SYSTEM										
	(NOT PRICED)										
	4424 HELIOSTAT SUPPORT SYS.	1 SET	$3000	$3000							3000
	4425 MAINT. SUPPORT EQUIP.	1 SET	$15,000	$15,000							15,000
									4820 SUB	TOTAL	$32,375
4830	A&E SERVICES (FIELD CONSTRUCTION)	1 UNIT	$757,782	$757,782		(SEE DETAILS)					757,782
4840	CONSTRUCTION MGMT (FIELD CONSTRUCTION)	1 UNIT	$112,898	$112,898		(SEE DETAIL)					112,898
4850	PLANT START UP & CHECKOUT										
	4851 INITIAL FIELD CAL & CHKOUT	1 UNT	$250,000	$250,000							250,000
	4852 INITIAL FIELD CLEANING	6914	$3.00	$20,742							20,742
4860	CONTINGENCY @ X% OF DIRECT	(SEE DETAIL)									1,690,848
[illegible]	AFDC (INCLUDED IN NET PROFIT)										
							4800 TOTAL				$2,864,645

DIRECT COST SUMMARY & CONTINGENCY

CLASS	UNIT COST $	AMOUNT $	CONTINGENCY RATE & AMT $
4410	2125	14,692,250	3% 440,678
4420	1603	11,083,142	1% 110,832
4425	1,472,465	1,472,465	10% 147,246
4440	469,950	469,950	1% 4700
4450	4,554,194	4,554,194	5% 227,709
4460	5,078,989	5,078,989	10% 507,899
4470	500,000	500,000	20% 100,000
4490	400,500	400,500	10% 40,050
4820	32,375	32,375	10% 3238
4830	757,782	757,782	10% 75,778
4840	112,898	112,898	5% 5,645
4850	270,742	270,742	10% 27,074
			$ 1,690,848

A&E SERVICES & CONSTRUCTION MANAGEMENT COSTS

ITEM		COST		
4830 A&E SERVICES – 12% OF ON-SITE CONSTRUCTION COSTS:				
4441 LAND		$469,950	(SOURCE: MIKE SELIVANOFF, BEC ENGINEERS)	
4453. LIGHTNING PROTECTION PROV.		281,342		
4460 FIELD ASSY & CHKOUT		5,092,817		
4470 FIELD DESIGN		200,000		
4850 PLANT STARTUP & CHKOUT		270,742		
	TOTAL	$6,314,851	@ 12% =	$757,782

ITEM		COST		
4840 CONSTRUCTION MANAGEMENT – 2% OF AT-SITE COSTS				
4453 LIGHTNING PROTECTION PROV.		$281,342	(SOURCE: MIKE SELIVANOFF, BEC ENGINEERS)	
4460 FIELD ASSY & CHECKOUT		5,092,817		
4850 PLANT STARTUP & CHECKOUT		270,742		
	TOTAL	$5,644,901	@ 2% =	$112,898

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APPENDIX H

Detail Cost Estimate

for Ownership Costs

COST ESTIMATE SUMMARY | **BE&C ENGINEERS INC.** A BOEING SUBSIDIARY

PROJECT 2nd Generation Heliostat

JOB NO M22272-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE 2-9-81 SHEET 1 OF 1

6914 HELIOSTATS
$4.1 m^2$

OM OPERATIONS AND MAINTENANCE SUMMARY

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS		LABOR				SUB-CONTRACT		TOTAL PER YEAR
			Unit Price	Amount	Unit M.H.	Total M.H.	Total Direct	Total Variable Burden	Unit Price	Amount	
	OM 10 OPERATIONS										$101,280
	OM 200 MAINTENANCE MATERIALS										103,080
	OM 300 MAINTENANCE LABOR										555,730
							OM TOTAL/YEAR				$760,090
157											

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2nd [illegible] HELIOSTATS
JOB NO [illegible]-1P
PREPARED BY D.F. Plummer CHECKED BY: DATE 2-9-81 SHEET 1 OF 6

6914 HELIOSTATS
44 m^2

OM 10 OPERATIONS

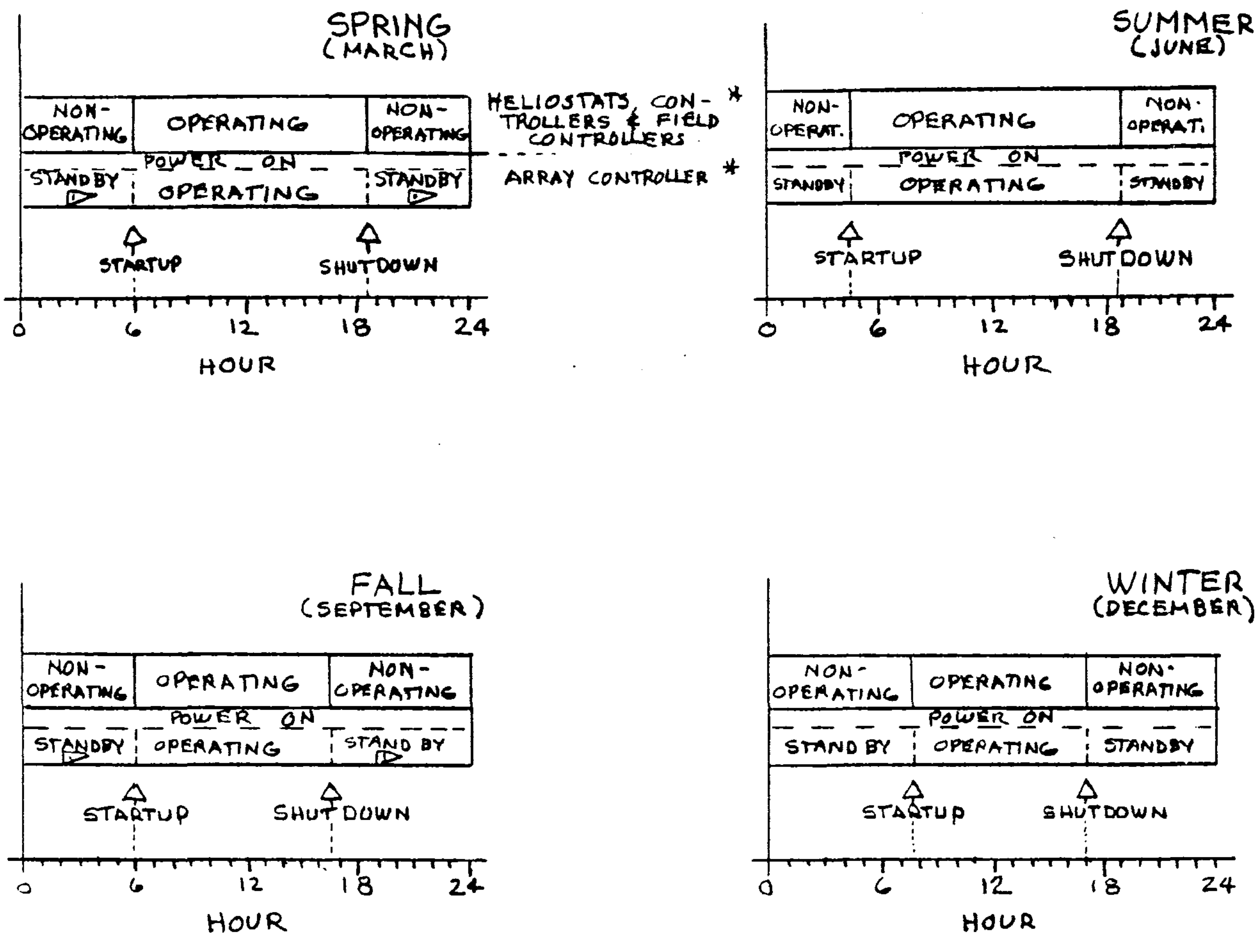
Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
OM 10	OPERATIONS										
	OM 10.1 FIELD CONTROL OPERATORS:										$78,760
	2 OPERATORS REQUIRED 7 MONTHS/YEAR @ $2917.00/MONTH/OPERATOR = $40,838										
	1 OPERATOR REQUIRED 1 MONTH/YEAR @ $2917/MONTH/OPERATOR = $2917 (INCLUDES FRINGE BENEFITS)										
	3 OPERATORS REQUIRED 4 MONTH/YEAR @ $2917/MONTH/OPERATOR = $35,004										
	OM 10.2 SYSTEM ELECTRICAL POWER										
158	a. DURING NORMAL OPERATING CONDITIONS, ELECTRIC POWER IS OBTAINED FROM THE MAIN GENERATOR; THIS ELECTRICITY IS ASSUMED TO BE "COSTLESS"										
	b. DURING NON OPERATING CONDITIONS, POWER IS REQUIRED FOR CERTAIN COMPONENTS; SEE ATTACHED DETAILS.										
	TOTAL POWER COSTS: 563,100 KWH/YEAR @ $0.04/KWH =										$22,520
	OM 10 TOTAL										$101,280

TABLE XI. SHIFT TIMES FOR SYSTEM OPERATORS, 2ND GEN. HELIOSTAT

	MONTH	GEN. ST.	GEN. STOP	1ST SHIFT START	1ST SHIFT STOP	2ND SHIFT START	2ND SHIFT STOP	NO. OF OPERATORS REQUIRED	REMARKS
1	JANUARY	[illegible]	1800	0700	1530	1500	2330	2	
2	FEBRUARY	0730	1800	0630	1500	1430	2300	2	
3	MARCH	0700	1900	0600	1430	1400	2230	2	
4	APRIL	0630	2000	0530	1400	1330	2200	2	
5	MAY	0600	2100	0500	1330	1300	2130	2	
6	PEAK { JUNE	0530	2100	0500	1330	1300	2130	3	3 OPERATORS REQUIRED TO SUPPORT 7-DAY/WEEK OPERATION
7	JULY	[illegible]	2000	0500	1330	1300	2130	3	
8	AUGUST	0600	2100	0530	1400	1330	2200	3	
9	SEPTEMBER }	0700	1900	0600	1430	1400	2230	3	
10	OCTOBER	0730	1800	0630	1500	1430	2300	2	
11	NOVEMBER	0800	1700	0700	1530	1500	2330	2	
12	DECEMBER	0830	1700	0730	1730	—	—	1	SINGLE OPERATOR WORKS OVERTIME

SOURCE: DERIVED FROM FIGURE X.1

FIGURE X.1. TYPICAL OPERATION PROFILES
50 MW ELECTRIC CYCLING PLANT
(BASED ON 1976 BARSTOW INSOLATION)



* - TYPICAL

▷ - IN STANDBY, SUFFICIENT CAPABILITY MUST BE MAINTAINED TO MONITOR WIND CONDITIONS, AND TO POWER UP FIELD FOR EMERGENCY STOW.

	Initials	Date
Prepared By	dfp	2/3/9
Approved By		

TABLE X2. 2ND GENERATION OPERATING ELECTRIC POWER REQUIREMENTS

ITEM	(1) AVERAGE POWER KW PER UNIT	(2)	(3) EXPECTED COINCIDENT POWER, KW	(4) OPERATING HOURS/MONTH FROM MAIN GEN	(5) FROM AUX PWR	(6) REMARKS
HELIOSTAT MOTORS	0.39 KW		53.9			ASSUME 2% OF HELIOSTATS MOVE AT ONCE
HELIOSTAT CONTROLLER	0.010 KW		69.1			CONTROLLERS OPERATE AT ALL TIMES EXCEPT WEEK ENDS OF NON-PEAK MO'S.
FIELD & ARRAY CONTROLLERS	5.0 KW		5.0			OPERATES 24 HRS/DAY, 365 DAYS/YR
WIND & TDS	0.4 KW		0.4			OPERATES 24 HRS/DAY, 365 DAYS/YR

ELECTRIC POWER/ENERGY REQUIRED FOR:

(a) STARTUP/DAY

674 KW FOR 1 HR ≈ 674 KWHRS (MOTORS)
69.1 KW FOR 1.5 HRS ≈ 104 KWHRS (HEL CONT)
5.0 KW FOR 1.5 HRS ≈ 8 KWHR (FC&AC)
TOTAL/DAY = 786 KWH/DAY
TOTAL/YR = 286,890 KWH/YEAR

ASSUME 25% OF HELIOS ARE MOVED AT ONCE FOR 15 MINUTES

(b) NIGHTIME OPERATIONS

FIELD & ARRAY CONTROLLERS (FROM TABLE 8)
= 24,550 KWH/YEAR

HELIOSTAT CONTROLLERS
(69.1 KW)(3642)
= 251,662 KWH/YEAR

TOTAL NON-OPERATING ENERGY = 563,100 KWH/YEAR

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2nd [illegible]
JOB NO [illegible]-1P
PREPARED BY D.F. Plummer CHECKED BY: DATE 2-9-81 SHEET 1 OF 1

6914 HELIOSTATS
41 m^2

OM 200 MAINTENANCE MATERIALS

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
OM210	REPLENISHMENT SPARES ALLOWANCE (PERCENTAGE OF ACQUISITION COST)										
OM210.4	4450. PEDESTAL/FOUNDATION (0.1%)			$3950							$3950
OM210.1	4410. REFLECTOR ELEMENT (10 FACETS/YEAR)			$15,000							$15,000
OM210.2	4420. GIMBAL DRIVE										
	4420.1, GIMBAL 4420.3, 4421, 4422, 4423 (0.5%)			$49,130							$49,130
	4425, ELEC. POWER DIST.			$10,000							$10,000
OM210.3	4430 CONTROL SYSTEM			$10,000							$10,000
OM210.5	4480 MAINTENANCE SUPPORT ELEMENT			$10,000							$10,000
							OM210 TOTAL				$98,080
OM220	REPAIR MATERIALS (ALLOWANCE; INCLUDES CLEANING FLUID, MISC. REPAIR PARTS, ETC.)										$5,000
OM230	OTHER										—
							OM 200 TOTAL				$103,080

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION HELIOSTAT

JOB NO MOD277-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE 2-9-81 SHEET 1 OF 4

6414 HELIOSTATS
$44 m^2$

OM 300 MAINTENANCE LABOR

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
OM310	SCHEDULED MAINTENANCE										
	OM310.1, HELIOSTAT CLEANING										
	CLEANING FREQUENCY REQUIRED TO ACHIEVE 0.92 AVG REFLECTIVITY										
	IS 6-8/YEAR. THIS REQUIRES A TOTAL OF 5 CLEANING										
	CREWS (3 ON 1ST SHIFT, 2 ON 2ND SHIFT). EACH CREW										
	CONSISTS OF 1 DRIVER AND 2 CLEANING TECHNICIANS;										
	5 DRIVERS @ $1420/MONTH/DRIVER x1.42 = $2016/MO. } INCLUDES FRINGE BENEFITS										$120,984
163	10 WASHERS @ $1420/MONTH/WASHER x1.42 = $2016/MO										241,968
	OM310.2, DRIVE-UNIT INSPECTION & OM310.4, MAINT. SUPPORT EQUIP. GEN. SCHEDULED MAINT										
	1383 INSPECTIONS/YEAR @ 0.5 HRS/INSPECTION = 691.5 HRS (INSPECTION REQUIRED EVERY 5 YEARS)										
	GENERAL SCHEDULED MAINT. ON VEHICLES, WASHING EQUIPMENT, ECT @ 691.5 HRS										
	1 FIELD MAINTENANCE TECHNICIAN @ $2900/MONTH (INCLUDES FRINGE BENEFITS)										$34,800
	OM310.3, FIELD ALIGNMENT OF HELIOSTAT & GENERAL CAL-CERT OF INSTRUMENTS, ETC										
	1/2 FIELD MAINTENANCE TECHNICIAN @ $2900/MONTH (INCLUDES FRINGE BENEFITS)										$17,400
	OM310.4, MISCELLANEOUS MAINTENANCE (WEED CONTROL, ETC.)										
	1/2 GENERAL MAINTENANCE PERSON FROM POWER PLANT @ $2800/MONTH (INCLUDES FRINGE)										16,800
							OM 310 TOTAL				$431,950

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2nd GENERATION HELIOSTAT
JOB NO M02272-1P
PREPARED BY D.F. Plummer CHECKED BY: DATE 2/9/81 SHEET 2 OF 4

6914 HELIOSTATS
44 m^2

OM 300 MAINTENANCE LABOR, CONTINUED

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
[illegible]	UNSCHEDULED MAINTENANCE										
	OM 320.1 REFLECTOR UNIT										
	10 FACET REPLACEMENTS/YEAR @ 4 HRS =				8	80/YR					
	OM 320.2 DRIVE UNIT										
	OPERATE: (3985 HRS/YR)(6914 # UNITS)(20.0×10^{-6}) ≈ 551 FAILURES/YR } TOTAL = 617 FAILURES										
	NON OPERATE: (4775)(6914)(2.0×10^{-6}) ≈ 66 FAILURES/YR										
	21 DRIVE-UNIT FAILURES: 125 REPLACEMENTS @ 12 HRS; 300 REPAIRS @ 4 HRS; 192 REPAIRS @ 1 HR } (2 MEN) AVG REPAIR TIME = 4.7 HRS										
					—	4392/YR					
	POWER DISTRIBUTION: 14 XFMRS @ 31.1×10^{-6}; 10 SWTCGEAR @ 125×10^{-6}; 25 CIRCUIT BRKS @ 152×10^{-6}; 125 KM WIRE @ 285×10^{-6}										
	OPERATE: (3985)(1966×10^{-6}) ≈ 8 FAILURES/YEAR										
	NON OPERATE: (4775)(197×10^{-6}) ≈ 1 FAILURES/YEAR										
	9 FAILURES @ 16 HRS/FAILURE				16	144/YR					
	OM 320.3 CONTROL SUBSYSTEM										
	HELIOSTAT CONTROLLER:										
	OPERATE: (1126)(6914)(8.0×10^{-6}) ≈ 395 FAILURES/YEAR } 404 FAILURES										
	NON OPERATE: (1632)(6914)(0.8×10^{-6}) ≈ 9 FAILURES/YEAR										
	404 FAILURES @ 1 HRS/FAILURE				1	404/YR					
	ARRAY/FIELD CONTROLLERS: 10 FAILURES/YR @ 5 HRS				5	50/YR					
	DATA DISTRIBUTION: 20 FAILURES/YR @ 8 HRS				8	160/YR					

COST ESTIMATE SUMMARY	BE&C ENGINEERS INC. A BOEING SUBSIDIARY

PROJECT 2ND GENERATION [illegible]

JOB NO M02272-1P

PREPARED BY D.F. Plummer CHECKED BY: DATE 2-9-81

SHEET 3 OF 4

6914 HELIOSTATS
44 m^2

OM300 MAINTENANCE LABOR, CONTINUED

Item No.	DESCRIPTION	Quantity & Unit	MATERIALS Unit Price	MATERIALS Amount	LABOR Unit M.H.	LABOR Total M.H.	LABOR Total Direct	LABOR Total Variable Burden	SUB-CONTRACT Unit Price	SUB-CONTRACT Amount	TOTAL
[illegible]	UNSCHEDULED MAINT., CONTINUED										
	OM320.3 CONTROL SUBSYSTEM, CONTINUED										
	TIME/DATE RCVR, WIND SENSORS, & BCS INTERFACE UNIT										
	10 FAILURES/YR @ 4 HRS/FAILURE				4	40	160/YR				
	TOTAL MAINTENANCE MANHOURS/YR = 5390 ÷ 2008 MH/PERSON•YEAR = 2.684										
	THEREFOR, 2.684 MAINTENANCE TECHNICIANS ARE REQUIRED										
	2.684 TECHNICIANS @ $2800/MONTH (INCLUDES FRINGE BENEFITS)										$90,180
	OM320.4 MAINTENANCE SUPPORT EQUIPMENT & COMPONENT REPAIR										
	1 TECHNICIAN @ $2800/MONTH (INCLUDES FRINGE BENEFITS)										$33,600
	OM 320 TOTAL										$123,780
	OM 300 TOTAL										$555,730

TABLE 3. EXPECTED-VALUE USAGE HOURS BY ELEMENT, HELIOS I COLLECTOR AT 50 MW ELECTRIC CYCLING PLANT

HELIOS I ELEMENT	AVERAGE (EXPECTED-VALUE) HOURS PER YEAR ①		
	OPERATING ②	NON-OPERATING ②	OTHER ②
PEDESTAL	—	—	8760
DRIVE UNIT	3985	4775	
REFLECTOR	8760		
CONTROLS			
HELIOSTAT CONTROLLER	7128	1632	DOES NOT OPERATE WEEKENDS OF NON-PEAK MONTHS
FIELD CONTROLLER	3985	4775	
ARRAY CONTROLLER	8760	—	
DATA DISTRIBUTION	3985	4775	
POWER DISTRIBUTION	3985	4775	
WIND SENSOR	8760	—	
MAINTENANCE			
MSE	3875 ④	4885	

NOTES:

① HOURS PER YEAR PERFORMING EQUIPMENT DESIGN FUNCTION THROUGHOUT EACH DIURNAL CYCLE.

② SEE SK-A10772-102 FOR APPLICABLE ENVIRONMENTAL CRITERIA.

③ PORTIONS OF THE ARRAY CONTROLLER MUST OPERATE CONTINUOUSLY TO PERFORM WIND MONITOR FUNCTION.

④ TO BE FURTHER BROKEN OUT FOR MAJOR ITEMS OF MSE (MAINTENANSE SUPPORT EQUIPMENT).

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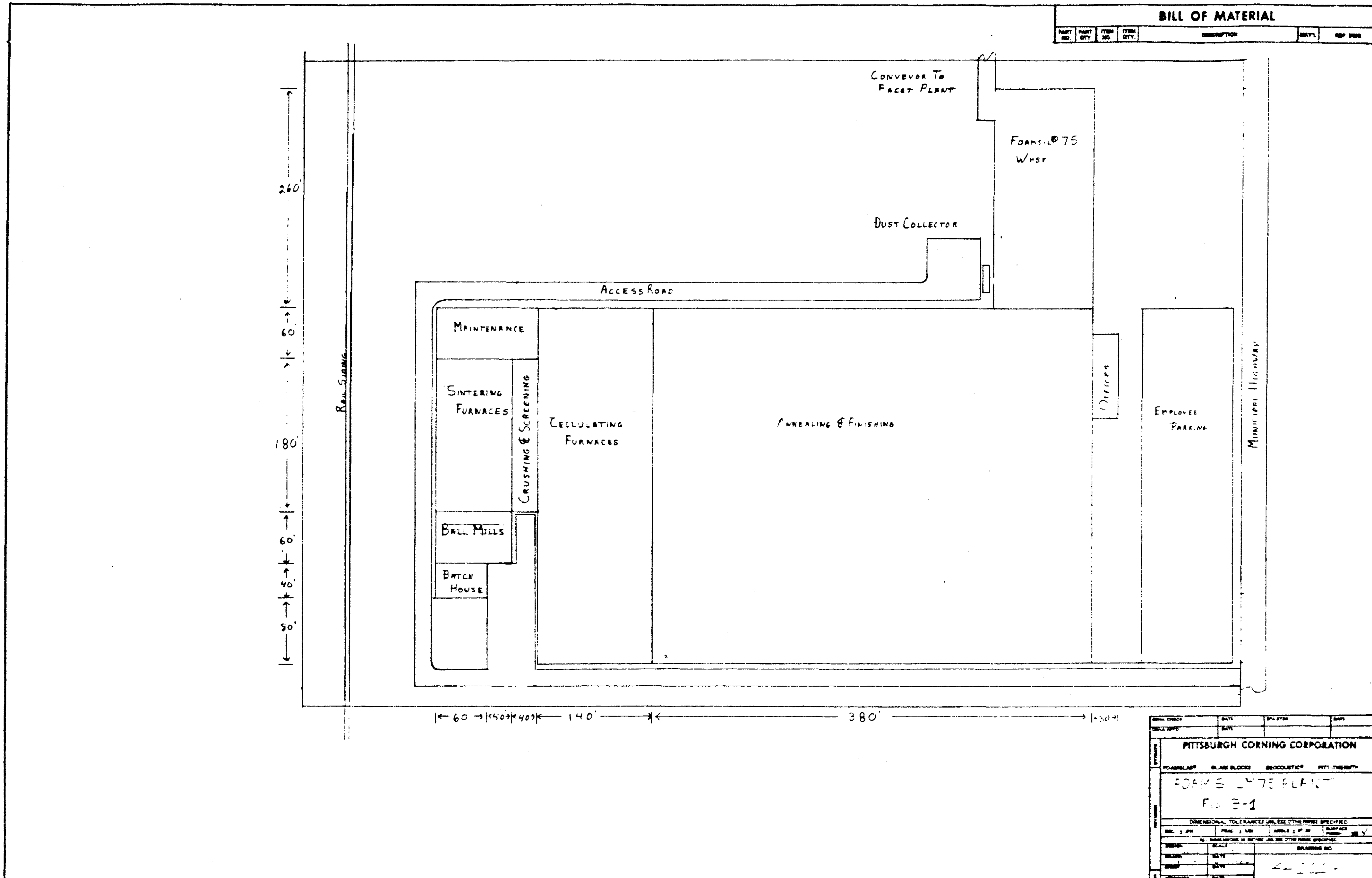
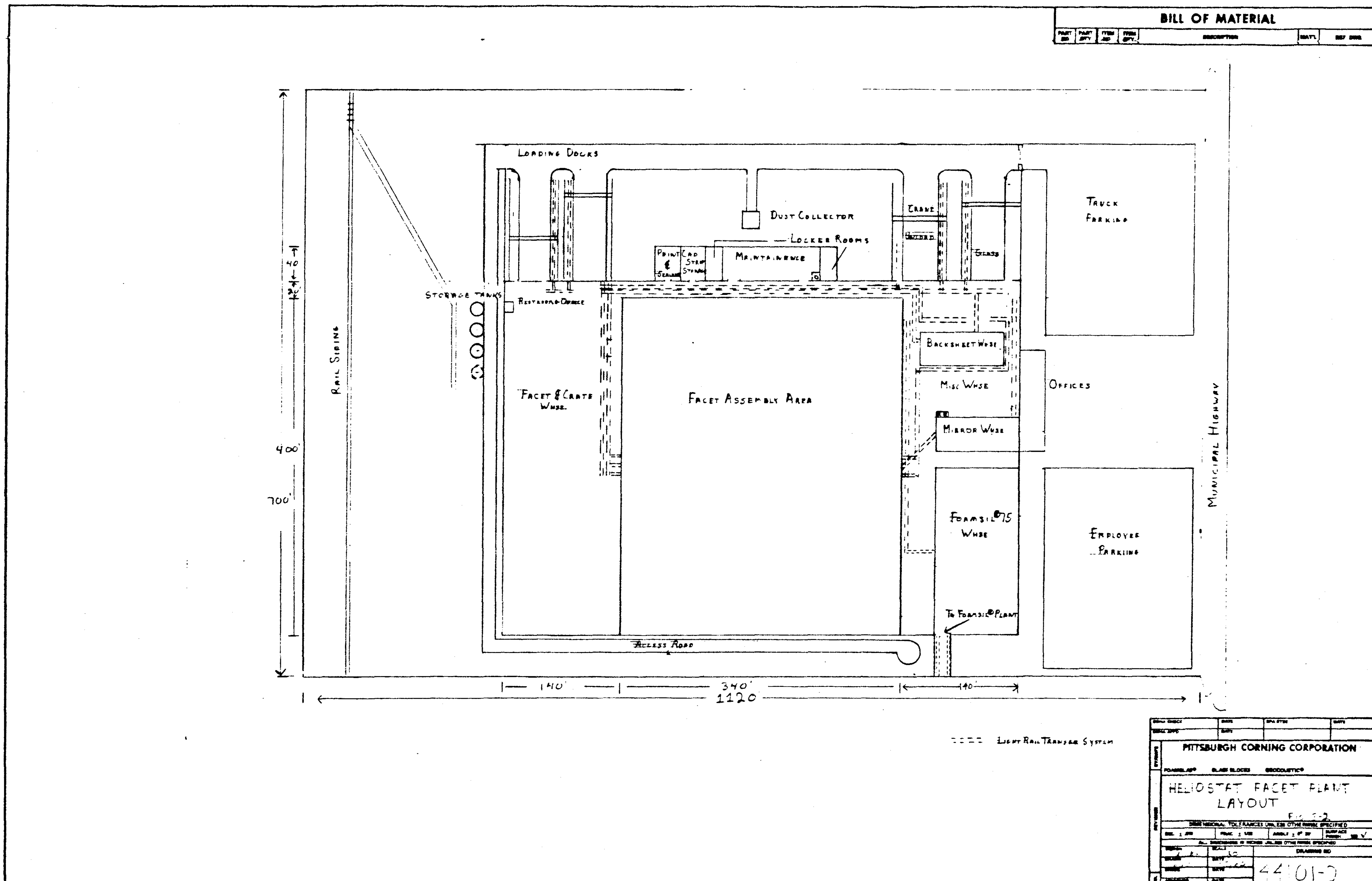
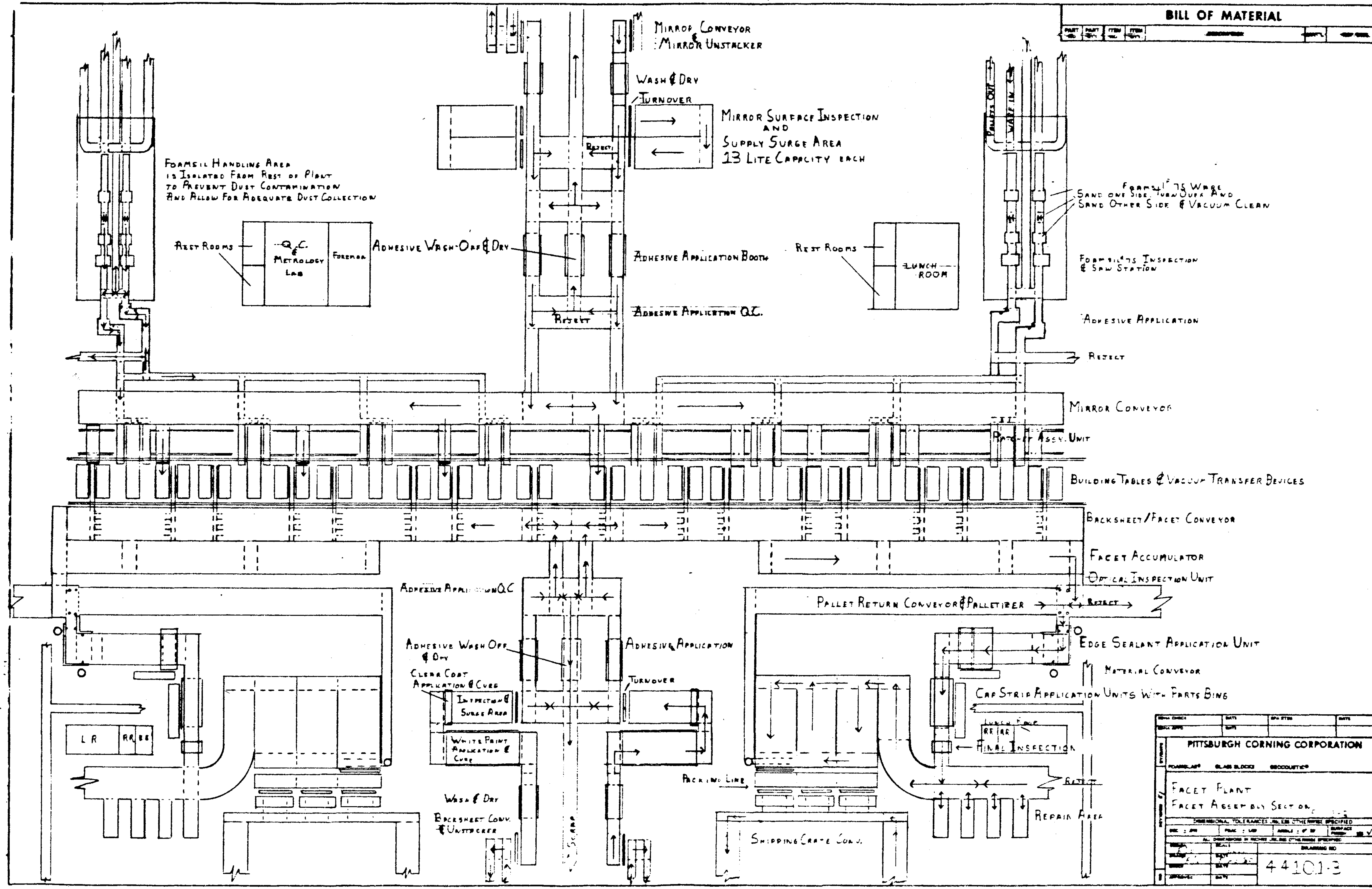
APPENDIX W

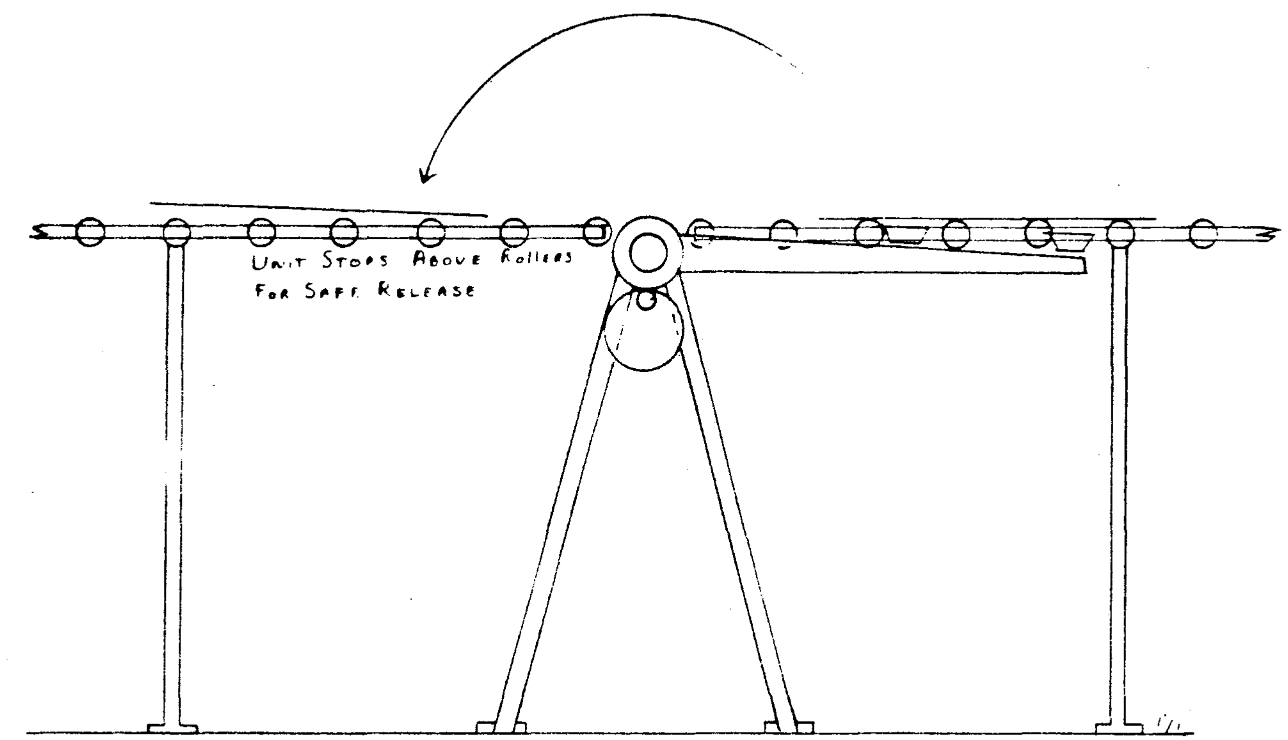
Drawings of Facet Assembly Tooling

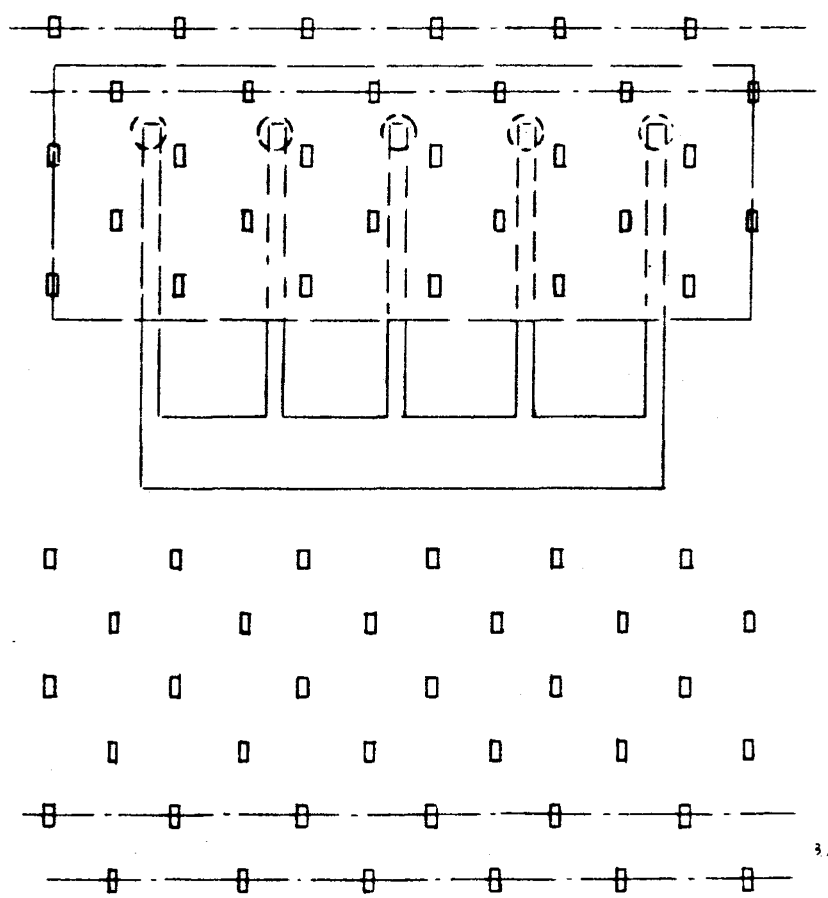

BILL OF MATERIAL
Conveyor To
Facet Plant
Foamsil® 75
Whse
Dust Collector
Access Road
Maintenance
Sintering
Furnaces
Crushing & Screening
Cellulating
Furnaces
Annealing & Finishing
Offices
Employee
Parking
Municipal Highway
Rail Siding
Ball Mills
Batch
House
260'
60'
180'
60'
40'
50'
60
140'
380'
PITTSBURGH CORNING CORPORATION


BILL OF MATERIAL
LOADING DOCKS
DUST COLLECTOR
LOCKER ROOMS
MAINTAINENCE
PAINT & SEALANT
CAP STRIP STORAGE
CRANE
GLASS
TRUCK PARKING
STORAGE TANKS
RAIL SIDING
FACET & CRATE WHSE.
FACET ASSEMBLY AREA
BACKSHEET WHSE
MISC WHSE
OFFICES
MIRROR WHSE
FOAMSIL®75 WHSE
EMPLOYEE PARKING
MUNICIPAL HIGHWAY
TO FOAMSIL® PLANT
ACCESS ROAD
40
400'
700'
140'
340'
140'
1120'
LIGHT RAIL TRANSFER SYSTEM
PITTSBURGH CORNING CORPORATION
HELIOSTAT FACET PLANT LAYOUT
44101-2


BILL OF MATERIAL
Mirror Conveyor & Mirror Unstacker
Wash & Dry
Turnover
Mirror Surface Inspection and Supply Surge Area 13 Lite Capacity each
Reject
Formsil Handling Area is Isolated From Rest of Plant to Prevent Dust Contamination And Allow For Adequate Dust Collection
Rest Rooms
Q.C. & Metrology Lab
Foreman
Adhesive Wash-Off & Dry
Adhesive Application Booth
Adhesive Application Q.C.
Reject
Rest Rooms
Lunch Room
Wares In
Pallets Out
Sand one Side, Turn Over And Sand Other Side & Vacuum Clean
Adhesive Application
Reject
Mirror Conveyor
Building Tables & Vacuum Transfer Devices
Backsheet/Facet Conveyor
Facet Accumulator
Optical Inspection Unit
Adhesive Application Q.C
Pallet Return Conveyor & Palletizer
Reject
Edge Sealant Application Unit
Adhesive Wash Off & Dry
Adhesive Application
Clear Coat Application & Cure
Inspection & Surge Area
Turnover
Material Conveyor
Cap Strip Application Units With Parts Bins
White Paint Application & Cure
Final Inspection
L R
Packing Line
Reject
Wash & Dry
Backsheet Conv. & Unstacker
Scrap
Shipping Crate Conv.
Repair Area
PITTSBURGH CORNING CORPORATION
Facet Plant
Facet Assembly Section
44101-3

BILL OF MATERIAL





PITTSBURGH CORNING CORPORATION

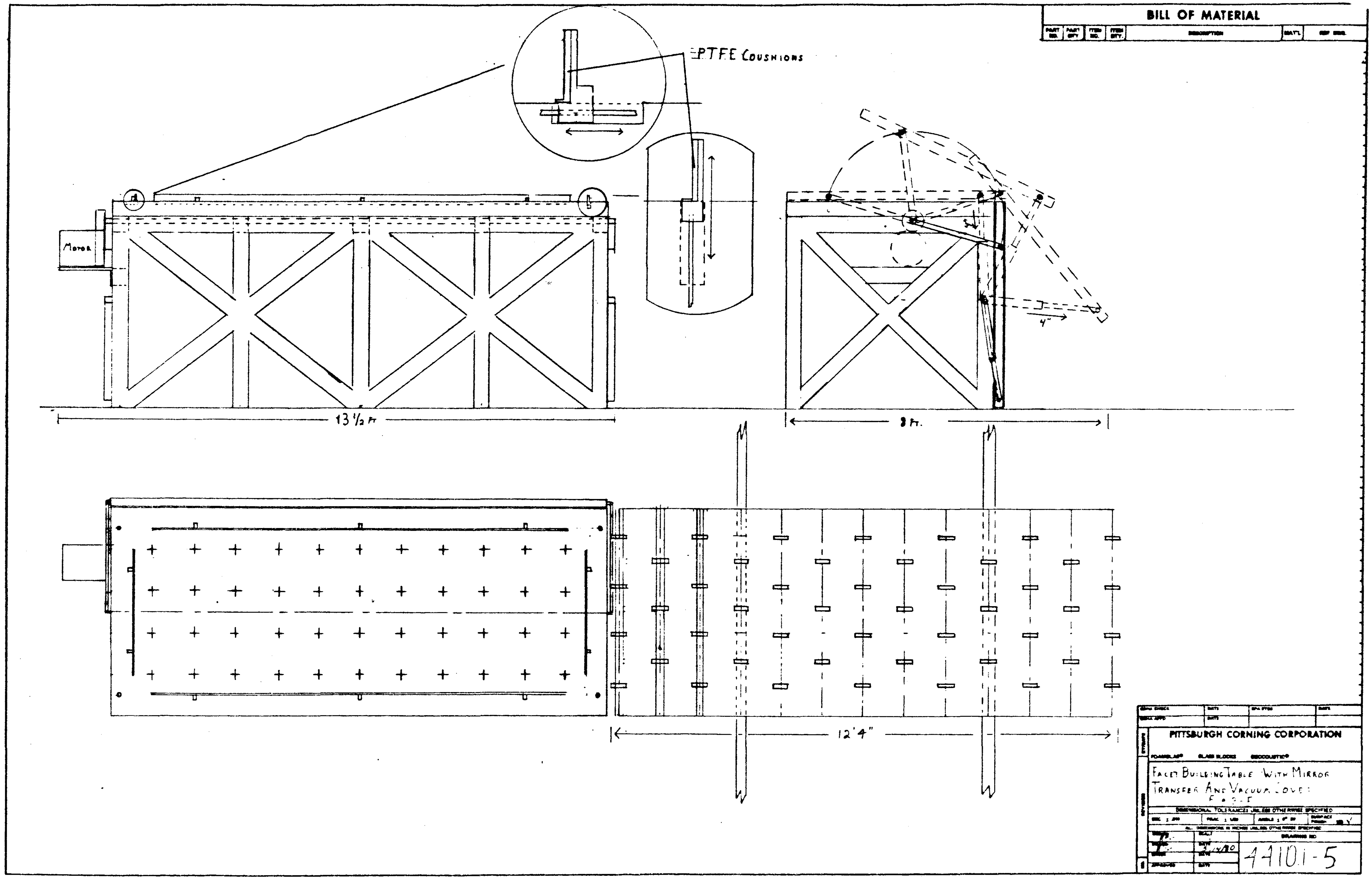
FOAMGLAS® GLASS BLOCKS GEOCOUSTIC®

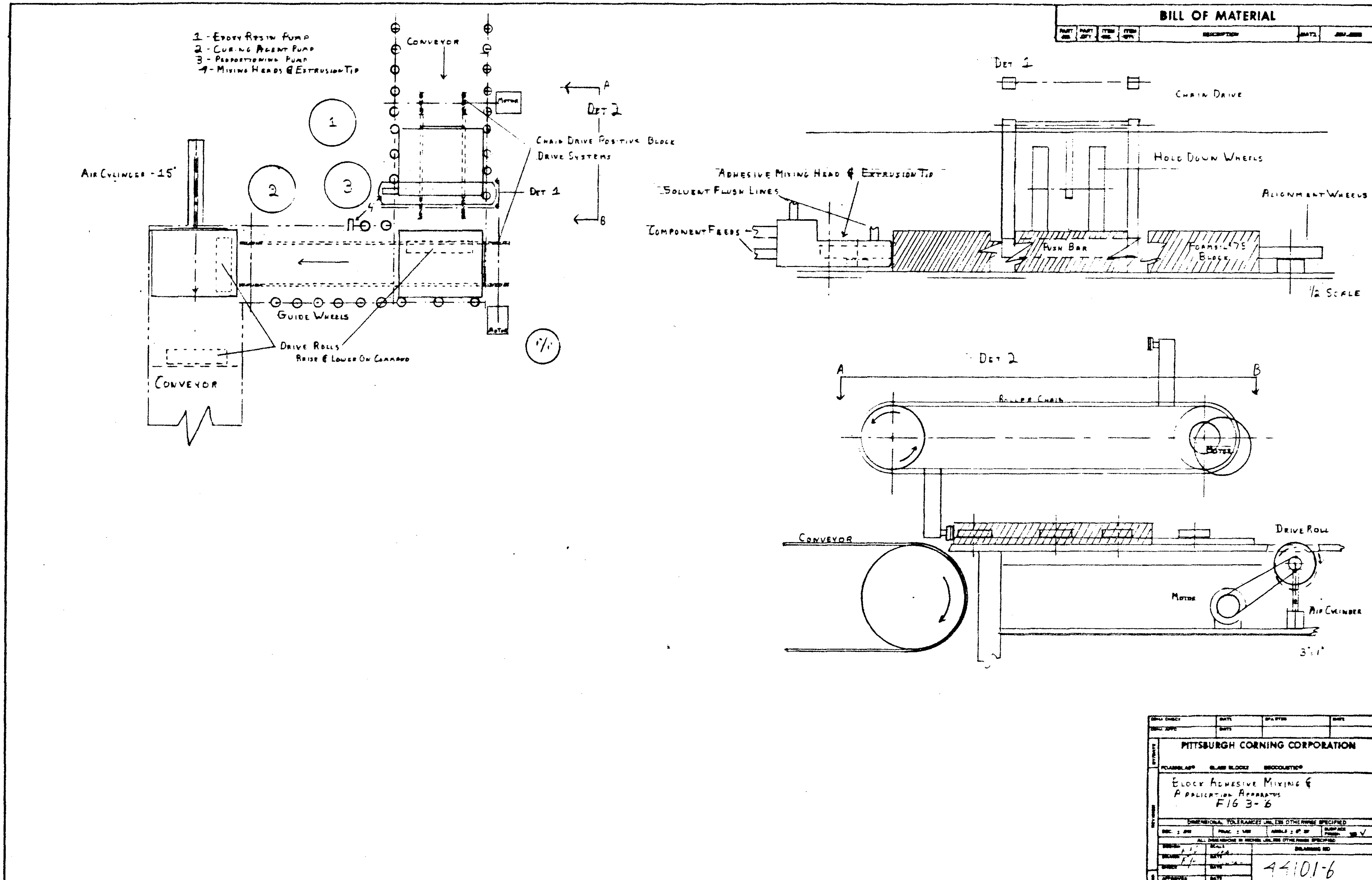
TURNOVER

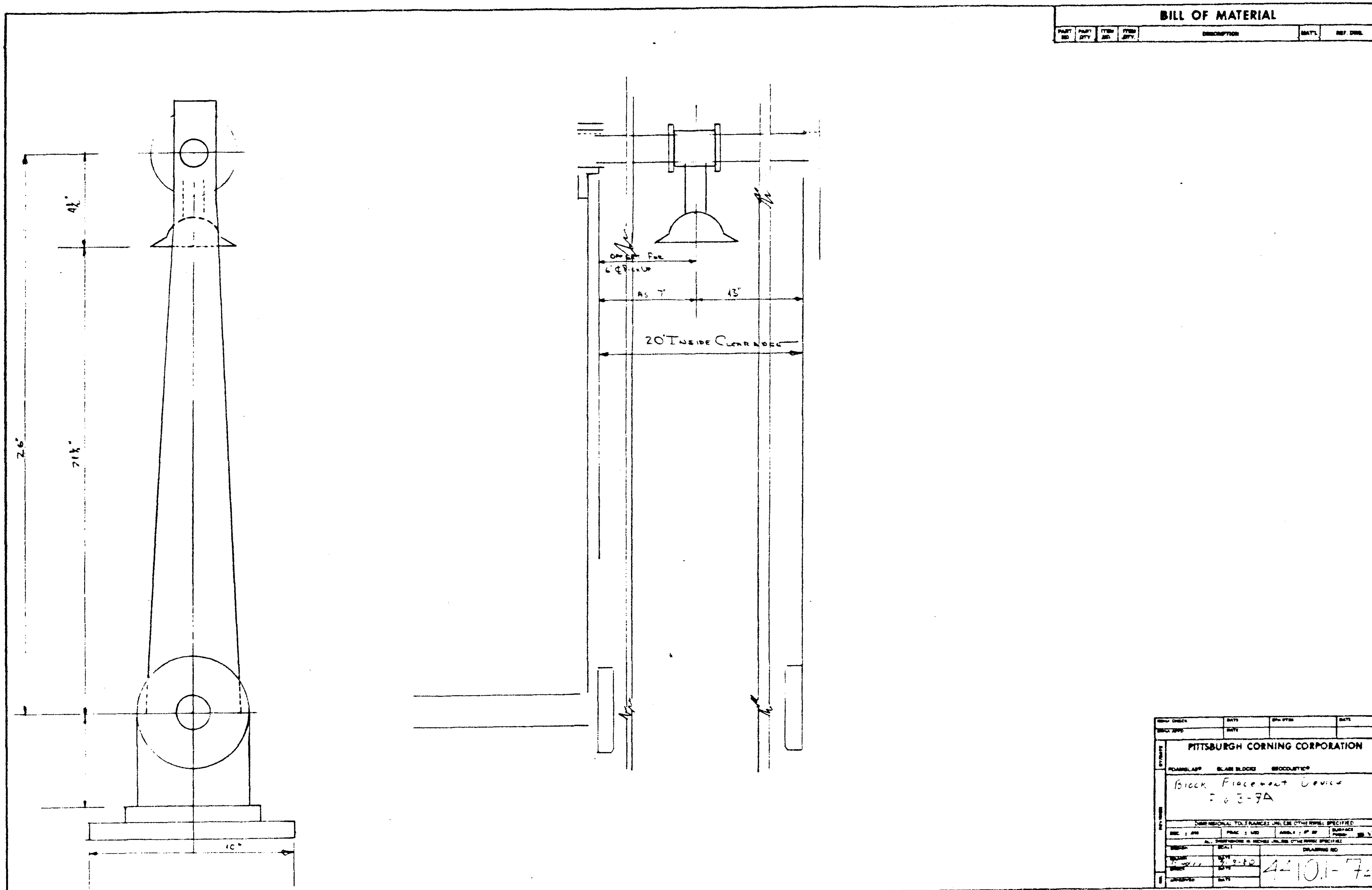
FIG 3-4

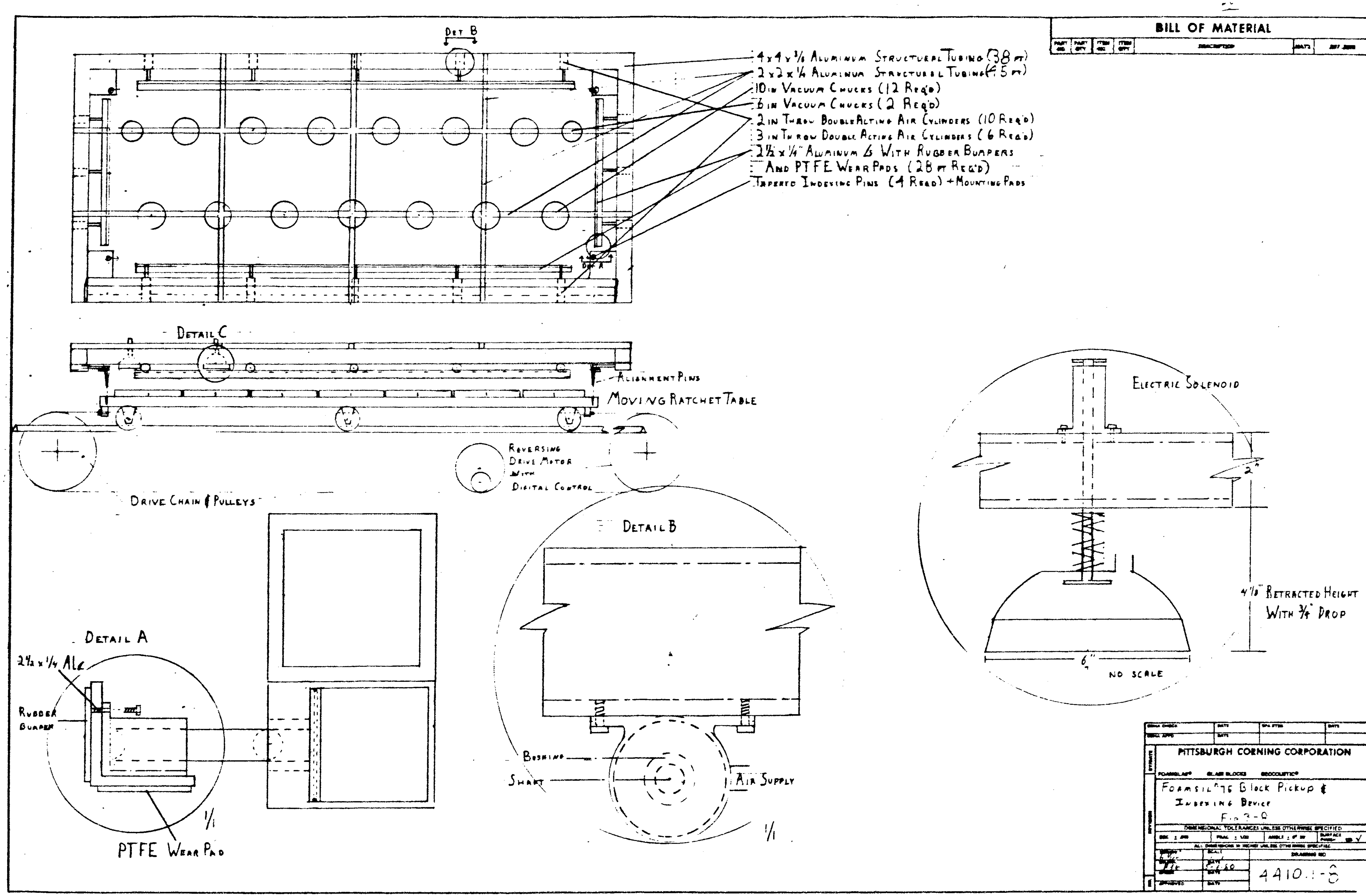
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

DRAWING NO 44101-4

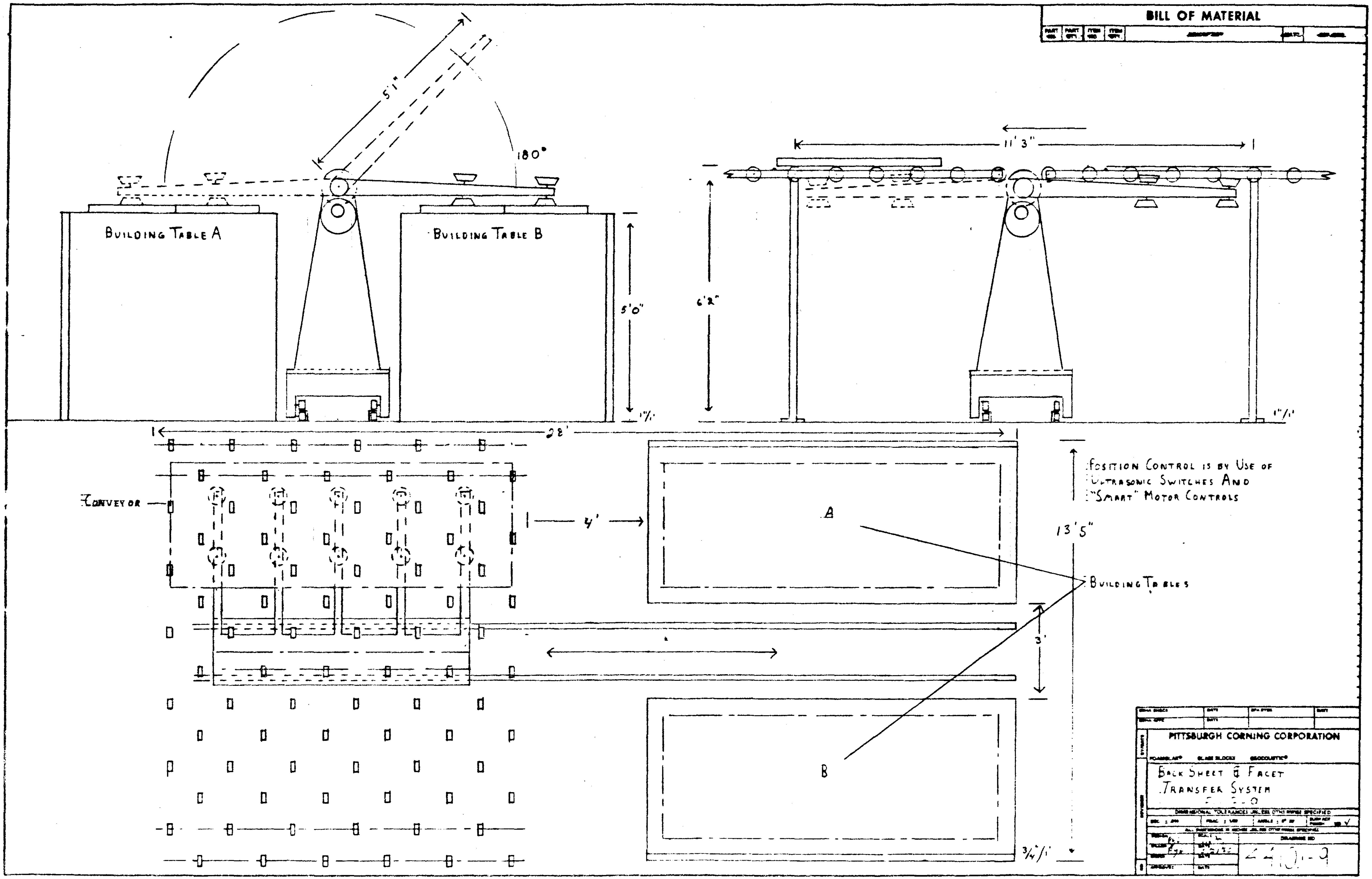

BILL OF MATERIAL
PTFE Coushions
Motor
13 ½ Ft
8 Ft.
4"
12'4"
PITTSBURGH CORNING CORPORATION
Facet Building Table With Mirror
Transfer And Vacuum Cover
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
DRAWING NO
44101-5

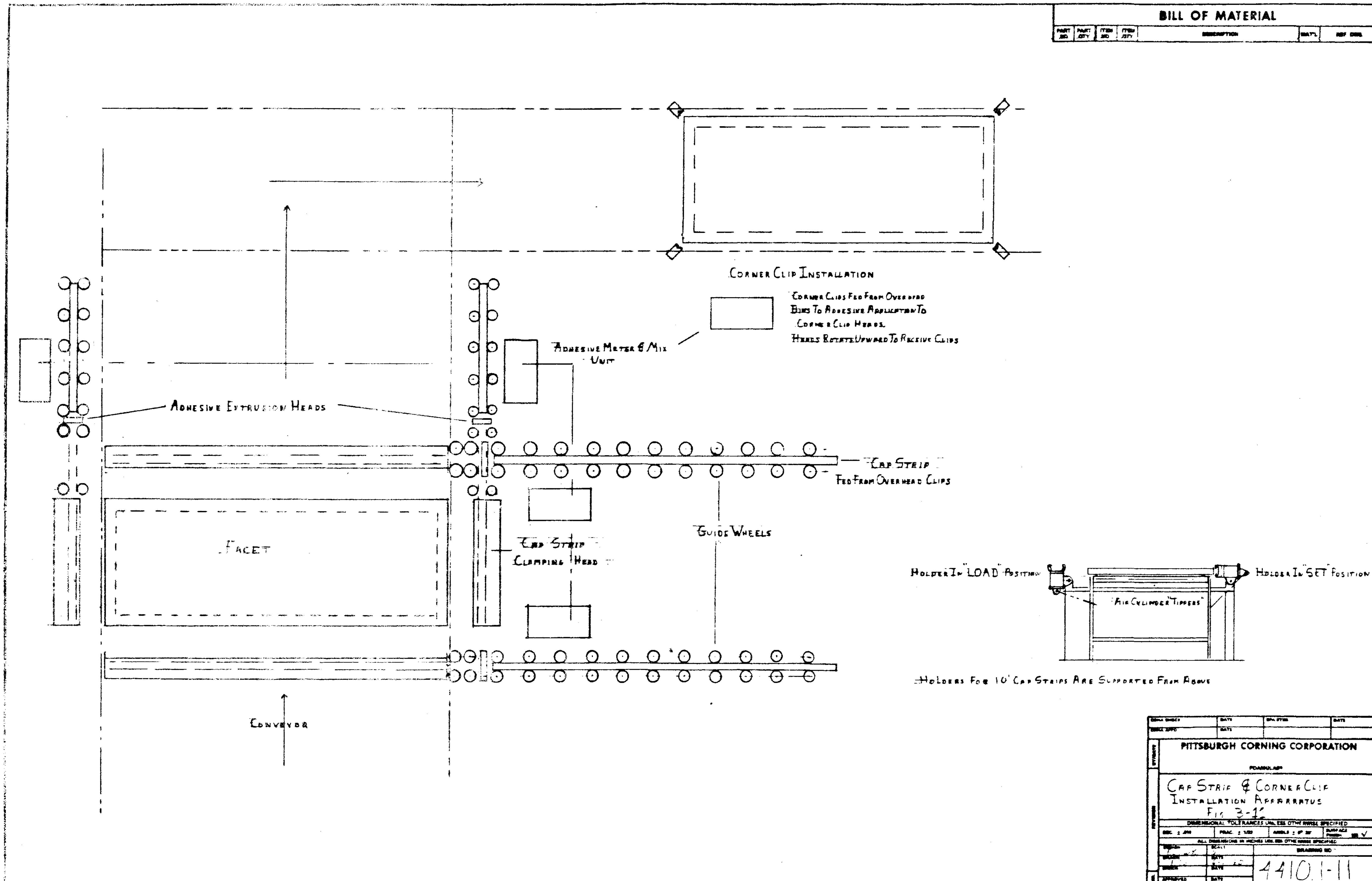

BILL OF MATERIAL
1 - Epoxy Resin Pump
2 - Curing Agent Pump
3 - Proportioning Pump
4 - Mixing Heads & Extrusion Tip
Conveyor
Motor
Det 2
A
B
Chain Drive Positive Block
Drive Systems
Det 1
Air Cylinder - 15"
Guide Wheels
Drive Rolls
Raise & Lower On Command
Conveyor
Det 1
Chain Drive
Hold Down Wheels
Adhesive Mixing Head & Extrusion Tip
Solvent Flush Lines
Alignment Wheels
Component Feeds
Push Bar
Foamglas Block
1/2 Scale
Det 2
Roller Chain
Motor
Drive Roll
Conveyor
Motor
Air Cylinder
PITTSBURGH CORNING CORPORATION
Block Adhesive Mixing &
Application Apparatus
FIG 3-6
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED
DRAWING NO
44101-6

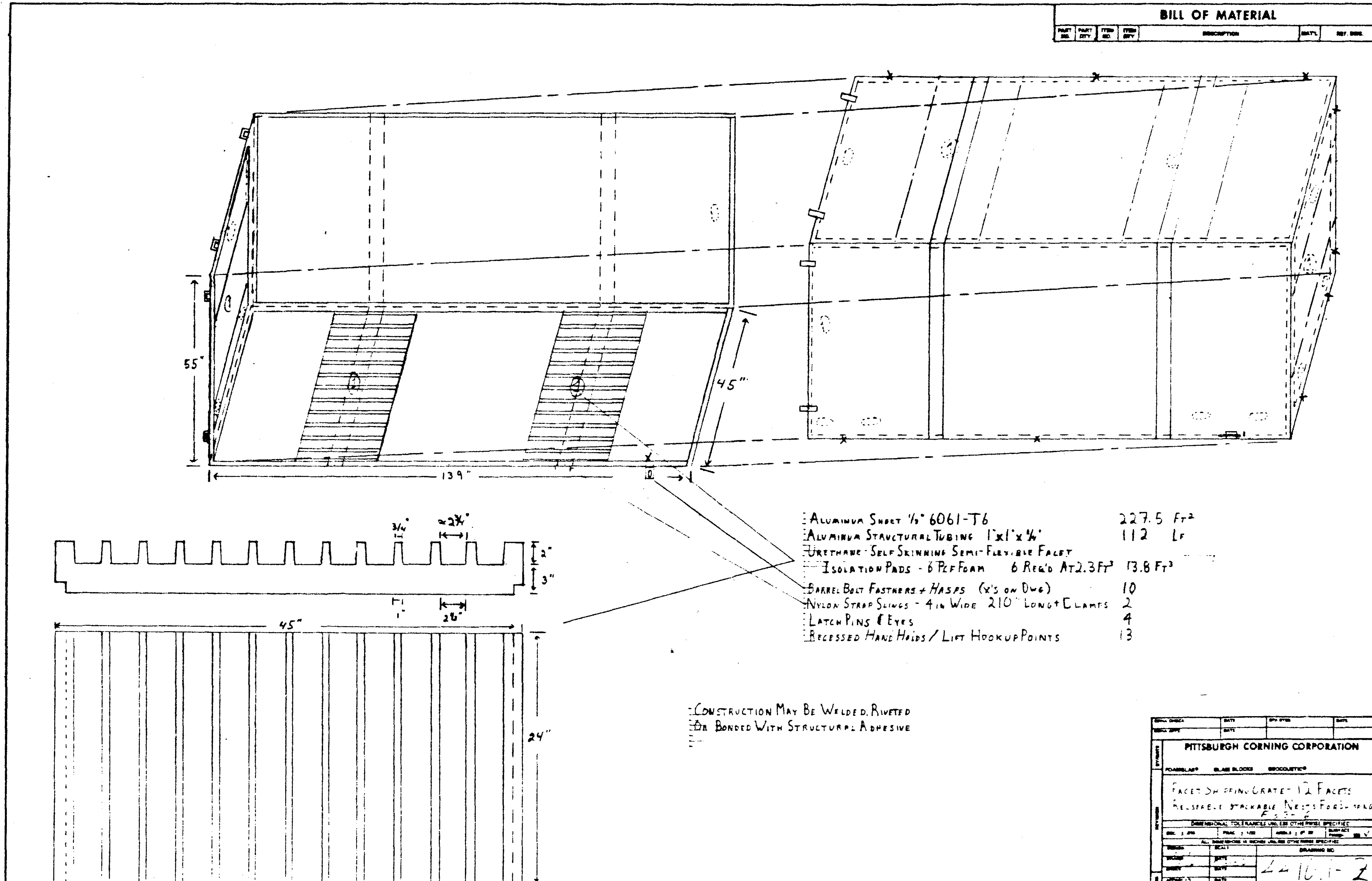

BILL OF MATERIAL
DESCRIPTION
20" Inside Clearance
13"
PITTSBURGH CORNING CORPORATION
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
DRAWING NO



BILL OF MATERIAL
DET B
4x4x¼ Aluminum Structural Tubing (38 ft)
2x2x¼ Aluminum Structural Tubing (45 ft)
10in Vacuum Chucks (12 Req'd)
6in Vacuum Chucks (2 Req'd)
2in Throw Double Acting Air Cylinders (10 Req'd)
3in Throw Double Acting Air Cylinders (6 Req'd)
2½x¼" Aluminum ∠ With Rubber Bumpers
And PTFE Wear Pads (28 ft Req'd)
Tapered Indexing Pins (4 Req'd) + Mounting Pads
DET A
Detail C
Alignment Pins
Moving Ratchet Table
Reversing Drive Motor With Digital Control
Drive Chain & Pulleys
Electric Solenoid
2"
4⅛" Retracted Height With ¾" Drop
6"
NO SCALE
Detail B
Bushing
Shaft
Air Supply
1/1
Detail A
2½x¼ Al∠
Rubber Bumper
PTFE Wear Pad
1/1
PITTSBURGH CORNING CORPORATION
Formsil 75 Block Pickup & Indexing Device
Fig 3-9
4410.1-8


BILL OF MATERIAL
5' 1"
180°
BUILDING TABLE A
BUILDING TABLE B
5'0"
1"/1'
11' 3"
6'2"
1"/1'
28'
CONVEYOR
4'
POSITION CONTROL IS BY USE OF
ULTRASONIC SWITCHES AND
"SMART" MOTOR CONTROLS
A
13' 5"
BUILDING TABLES
3'
B
3/4"/1'
PITTSBURGH CORNING CORPORATION
BACK SHEET & FACET
TRANSFER SYSTEM


BILL OF MATERIAL
Corner Clip Installation
Corner Clips Fed From Overhead
Bins To Adhesive Application To
Corner Clip Heads.
Heads Rotate Upward To Receive Clips
Adhesive Meter & Mix Unit
Adhesive Extrusion Heads
Cap Strip
Fed From Overhead Clips
Facet
Cap Strip Clamping Head
Guide Wheels
Holder In "LOAD" Position
Holder In "SET" Position
"Air Cylinder" Tippers"
Holders For 10' Cap Strips Are Supported From Above
Conveyor
PITTSBURGH CORNING CORPORATION
Cap Strip & Corner Clip Installation Apparatus
Fig 3-12
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED
DRAWING NO.
4410.1-11


BILL OF MATERIAL
55"
139"
45"
3/4"
≈2¾"
2"
3"
1"
2¾"
45"
24"
Aluminum Sheet ⅛" 6061-T6 227.5 Ft²
Aluminum Structural Tubing 1"x1"x¼" 112 Lf
Urethane - Self Skinning Semi-Flexible Facet
Isolation Pads - 6 Pcf Foam 6 Req'd At 2.3 Ft³ 13.8 Ft³
Barrel Bolt Fastners + Hasps (x's on Dwg) 10
Nylon Strap Slings - 4 in Wide 210" Long + Clamps 2
Latch Pins & Eyes 4
Recessed Hand Holds / Lift Hookup Points 13
Construction May Be Welded, Riveted
Or Bonded With Structural Adhesive
PITTSBURGH CORNING CORPORATION
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED
DRAWING NO.

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APPENDIX Y

Cost Summary for Alternate

Production Rates

Table Y-1. Summary of Costs at 25,000 and 67,500 per Year Rates

Item	Approximate Unit Cost at		Production Rate of	
	25,000	Remarks	67,500	Remarks
Variable Costs				
Equip. Rental	$ 8.64	5 sites/yr	$ 8.32	13 sites/yr
Subsys. Var. Costs	5,892.87		5,892.87	
Warranty Serv.	10.61		9.82	
Power/Utilities	6.95	1 shft only	9.48	3 shifts
Economic Profit	307.15	Assume 10th yr	113.76	Assume 10th year
TOTAL VARIABLE COSTS	$6,226.22		$6,034.25	
FIXED COSTS				
CMF Design, Strup, etc.	$ 92.87	260,000 Total Prod.	$ 34.74	695,000 Total Prod.
Depreciation	338.67	260,000 Total Prod.	$ 126.70	695,000 Total Prod.
Taxes	92.49	Per unit/yr	34.26	Per unit/yr
Sab Design	0.72	260,000 Total Prod.	0.27	695,000 Total Prod.
Sab Equip. Depreciation	2.94	260,000 Total Prod.	1.10	695,000 Total Prod.
Site Activat./Dwnstrm	11.48	5 sites/yr	11.05	13 sites/yr
Insurance	14.00		10.81	
Design Change Admin.	4.00		2.59	
Gen. & Admin. Overhead	100.93		97.20	
TOTAL FIXED COSTS	$ 657.65		$ 318.72	
TOTAL COST	$6,883.87		$6,352.97	
	$ 156/m^2		$ 144/m^2	

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