

5105-23
Solar Thermal Power Systems Project
Parabolic Dish Power Systems
Module Development

Cost Analysis of the Omnium-G System 7500 in Selected Annual Production Volumes

C. A. Blake



May 1980

Prepared for
U.S. Department of Energy
Through an agreement with
National Aeronautics and Space Administration
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SECTION I

INTRODUCTION

The objective of this study was to develop accurate cost numbers for the Omnium-G System 7500* in annual production quantities of 25, 100, 25,000 and 100,000 units. The results of the study are to serve as a "baseline" to which the cost of other point-focusing distributed receiver systems can be compared. All costs are expressed in 1979 dollars.

The information contained herein is for a complete Omnium-G System 7500 which is rated at 7.5 kW electrical and 30,000 BTU thermal (nominal). These performance figures were supplied by the Omnium-G Company.

The Omnium-G System 7500 concentrator** (Figure 1-1) is a parabolic dish, six meters in diameter, composed of 18 mirrored petal segments. This assembly is articulated in elevation and azimuth enabling it to track the sun from horizon to horizon. The mirrored segments are fabricated from electrochemically polished aluminum bonded to a polyurethane foam substrate.

The concentrator focuses the rays of the sun onto a receiver that is 3.9 meters in front of the center of the mirror. This receiver acts as a heat exchanger by boiling water contained within a helical tube thus producing steam. The steam ultimately powers a steam engine generator which produces electricity.

* Solar-powered electrical plant manufactured by the Omnium-G Company, Anaheim, California.

**The term concentrator includes the reflector, supports, and foundation of the System 7500.

SECTION II

SYSTEM COMPONENTS

The basic components and sub-units of the total system were classified as follows:

- A. RECEIVER
- B. REFLECTOR
 - 1. Backup Structure
 - 2. Reflective Surface (Petals)
- C. BASE STRUCTURE
 - 1. Support
 - 2. Enclosure
 - 3. Transport Line
 - 4. Azimuth Control and Trolleys
 - 5. Elevation Mechanism
- D. SENSORS AND CONTROLS
- E. STEAM ENGINE
- F. PREHEATER
- G. CONDENSER
- H. HOTWELL
- J. POWER CART

A description of each system component is provided in the corresponding subsection.

A. RECEIVER

The receiver (converter) consists of an outer body composed of #316 stainless steel, and an inner container of stainless steel and Inconel materials. The balance of the receiver is composed of insulation, #304 and #316 stainless steel tubing, a temperature probe, stainless steel fittings and 75 lbs. of pure aluminum.

At the present time the manufacturing is accomplished with standard machine shop equipment, power sheet metal shears, automatic cutting torches, small power tools and tungsten inert gas (T.I.G.) welding.

B. REFLECTOR

1. Backup Structure

The reflector is supported by a backup structure which is composed of polygonal supports, yoke assemblies and converter support legs. The entire backup structure is fabricated by using standard shop practices: electric hack saw, milling machine, T.I.G. welding, etc. Assembly is by heliarc welding and the use of standard fasteners.

a. Polygonal Supports. The three regular nine-sided polygons are composed of:

- (1) An outer ring of: #6063 aluminum alloy tubing having a 3.00 in. outside diameter x .049 in. wall. Fabrication is by welding.
- (2) An inner ring whose fabrication is similar to the outer ring.
- (3) A truss ring whose fabrication is similar to the outer ring.
- (4) Struts (27 required) of: #6063 aluminum alloy tubing having a 1.5 in. outside diameter x .049 in. wall. Fabrication is by welding.

b. Yoke Assembly. This is a heavy box assembly, welded and fabricated from heavy plate #6061 aluminum alloy, which is then welded to the inner ring. The entire backup structure pivots about a shaft which is connected to this assembly. More detail will be provided in discussion of the elevation mechanism.

c. Converter Support Leg. Four receiver support legs are clamped 90° apart around the outer ring of the backup structure. These hold the receiver at the focal point of the mirrors. The legs are a welded assembly, consisting of aluminum tubing, channel, plate and sheet metal. No special tooling or fixtures are required.

2. Reflective Surface (Petals)

Eighteen mirror segments or petals comprise the reflective surface of the concentrator.

Each petal consists of three mirror segments of electro-chemically polished aluminum (Alzak) bonded to a polyurethane foam substrate. This is accomplished by placing the mirror segments face down in a mold, applying the polyurethane foam to the back surface of the mirrors and allowing it to foam in situ. When the foam substrate hardens, the mirror assembly is removed from the mold and is permitted to complete the cure cycle. Mounting cleats are installed and a conformal coating is applied to the cured foam substrate.

Two strut mounting assemblies are required per petal. These consist of a purchased tie rod end, a muffler clamp and a welded bracket.

C. BASE STRUCTURE

The base structure consists of a cantilever support with decking, and a base enclosure with an azimuth track.

1. Support

The cantilever support is made from standard structural steel channel, an "H" beam, heavy plates and sheet metal. No special tooling is required for fabrication other than a welding fixture. The support is a completely welded structure.

2. Enclosure

The base enclosure is made from a 10 foot section of Kaiser aluminum culvert stock and an azimuth track fabricated from heavy plate which is installed on the upper lip. No special tooling is required other than some simple fixtures.

3. Transport Line

The transport lines conduct the steam from the receiver to the engine and then return the spent steam, by way of a condenser, to the receiver for conversion into high energy steam. The transport lines are fabricated in four sections of #304 stainless steel. A feed and return line surrounded by insulation is contained in a stainless steel sleeve. The overall length is approximately 27 feet. No special tooling is required. The general construction is by welding and the use of standard fasteners.

4. Azimuth Control and Trolleys

Two trolley assemblies are situated on the front edge of the support structure with their flanged wheels resting on the azimuth track. They are driven by means of two D.C. motors connected by chains and sprockets to the wheels. The general assembly is fabricated from heavy steel plate with purchased parts augmenting the assembly. Fabrication is by means of welding and the use of standard fasteners.

5. Elevation Mechanism

The elevation mechanism is located between the yoke assemblies of the backup structure. It is connected to the yoke by means of two bearing end plates with bolt patterns that correspond to those on each side of the yoke. This complete assembly is pivoted by a tube within a tube; the outer tube being welded to the cantilevered support arm. The inside diameter of the outer tube and the outside diameter of the inner tube act as bearings allowing the entire structure to tilt up and down. The actuation is accomplished by means of a D.C. motor and a gear reduction box situated on a platform atop the cantilever arm. The output shaft of the gear box is connected to one side of the yoke by an adjustable drag link. The fabrication is accomplished with standard machine shop equipment. Assembly is welded and uses standard fasteners.

D. SENSORS AND CONTROLS

Electronic and electromechanical sensors and controls are used to accomplish the following:

- (1) Elevation above and below sun
- (2) Azimuth left and right of sun
- (3) Heat exchanger temperature sensing
- (4) Battery charging
- (5) Speed servo controls
- (6) Clock memory for sun tracking
- (7) Photo cells for sun sensing
- (8) Electronic circuitry operations
 - (a) Amplifiers
 - (b) Sensors
 - (c) Drivers

(9) Miscellaneous electromechanical operations

(a) Relays

(b) Switches

(c) Indicators

The electronic circuitry is on printed circuit boards, held in caged racks with edge connecting receptacles accomplishing the functional wiring. The balance of the circuitry is contained in a National Electrical Manufacturers Association box, except for such items as limit switches, sensors, etc. that must be located at the source of their function.

E. STEAM ENGINE

The engine is a two-cylinder, sleeve-valve, actuated device driven by steam, which is produced by a point-focusing solar thermal source.

A six unit pilot run of the engine is currently being produced. These are 100% machined from aluminum raw stock, employing standard machine shop equipment and practices. Some rudimentary castings could be justified as the quantity approaches 100 per year. As production nears 25,000 per year, more sophisticated castings and second operations would be in order. At an annual rate of 100,000 units, a fully automated approach with complete foundry facility could be justified with a substantial product cost reduction.

F. PREHEATER

The preheater consists of a jacket through which spent steam flows prior to entering the condenser. A copper tube passes through this condenser carrying water pumped from the reservoir to the receiver.

G. CONDENSER

The condenser reduces spent steam to water which is deposited in a reservoir to be recycled to the receiver. It is a stainless steel construction consisting of an outer jacket and internal tubes supported by header plates.

The condenser is presently being fabricated by hand using standard shop tools and a welded construction. In larger quantities, a straightforward sheet metal shop approach adjusted to quantity requirements would be the best approach.

H. HOTWELL

A "hotwell" is provided to make hot water available. This consists of an 800-gallon corrugated, galvanized steel tank, externally coated with approximately four inches of polyurethane foam insulation. The water is heated by means of a copper tube heat exchanger connected to an engine exhaust steam line. The hotwell has a self-contained pump, solenoid valves and a radiator that can move water or dump heat as required.

At present the tank is purchased and the components and insulation are assembled in-house. For quantities up to 100,000/year, it would be a simple matter to create a total in-house capability by establishing a conventional sheet metal shop.

I. POWER CART

The power cart is a weldment consisting of a reservoir tank upon which is mounted the power generating components. This power cart includes the steam engine, preheater and condenser. Also included are the generator, D.C. sustainer motor, oiler, pump, magnetic clutch and miscellaneous controls.

The alternator is driven by the sustainer motor on battery power until sufficient pressure head is built up for the steam engine to take over. At this point, a magnetic clutch is engaged allowing the engine to drive the alternator. The sustainer motor then operates as a D.C. generator for battery charging and other functions.

Other required items are: a positive displacement pump to supply water to the receiver, an automatic oiler for engine lubrication, and miscellaneous plumbing and controls.

SECTION III

COSTING METHODOLOGY

Each part, assembly, and subassembly was identified and documented, as little information of this nature was available from the manufacturer. This necessitated visiting the facility and examining the various components, taking measurements, making pertinent notes and sketches, and then preparing the necessary dimensioned drawings. These drawings were used to prepare parts lists which identify the component parts, their basic breakdown and general sequence of assembly. The raw material and purchased parts were then identified and itemized. These were costed for a production run of 25 per year by examining the manufacturers' purchasing records and extracting the actual costs of the parts. This information was transferred to the parts lists. Appendixes A through E contain the detail drawings, costs and parts lists employed in this study's evaluation of the Omnium-G System 7500.

Capital equipment and tooling costs were not estimated. Labor costs were calculated based upon direct observation of parts manufacture. A figure of \$10.00 per hour was applied as direct labor. The basic information provided by the Omnium-G Company reflects costs at a present production rate of approximately 25 units per year.

An in-depth investigation was undertaken to determine price reductions for annual quantities up to 100,000 units. Dramatic decreases can be realized with the greater quantities. For example, aluminum used at the present production rate (approximately 25 units per year) is purchased as needed through retail dealers. As the volume increases, quantity discounts are minimal from this source. At higher production levels, one may purchase wholesale lots at considerable savings. Again, as volume increases, it is more profitable to purchase directly from the mill. Although there is little difference between the price of tubing, plate, or sheet at this point, a price differential would exist for various alloys. For example, small quantities of tubing might cost over \$3.00 per lb. from a dealer, but this price could decrease to less than \$1.20 per lb. when purchased from a mill.

SECTION IV

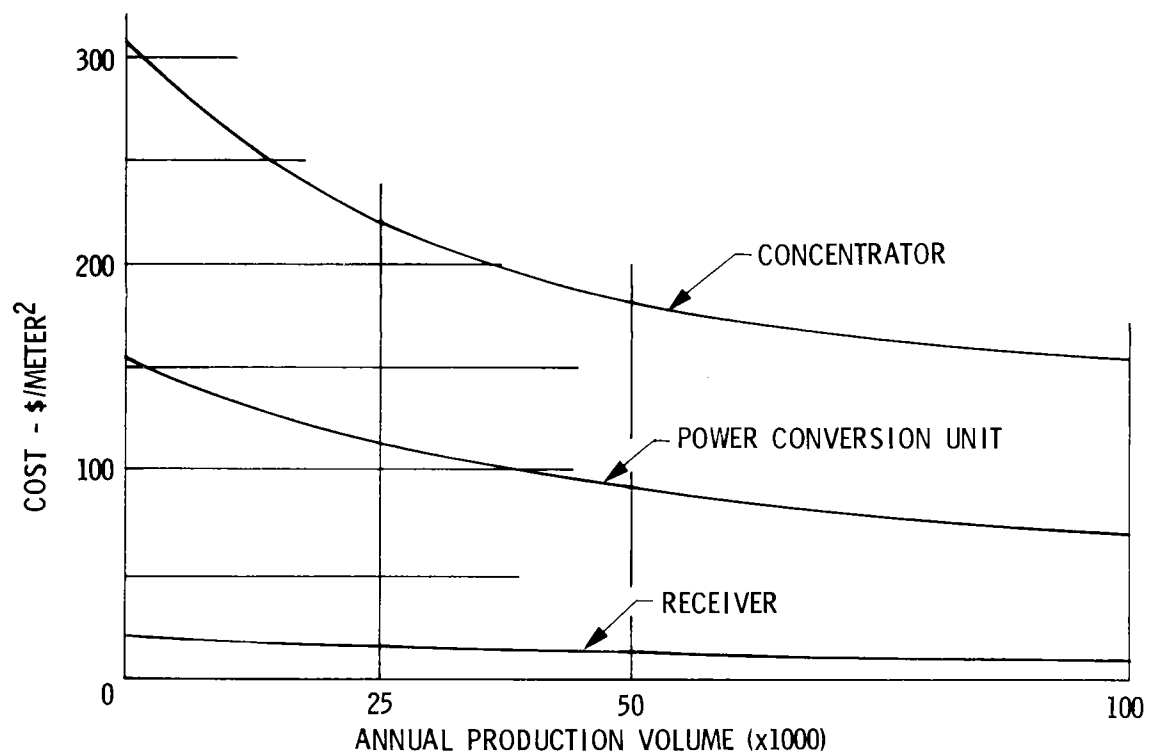
RESULTS

The cost results reported in this study reflect annual production quantities of 25, 100, 25,000 and 100,000 units. All costs are expressed in 1979 dollars.

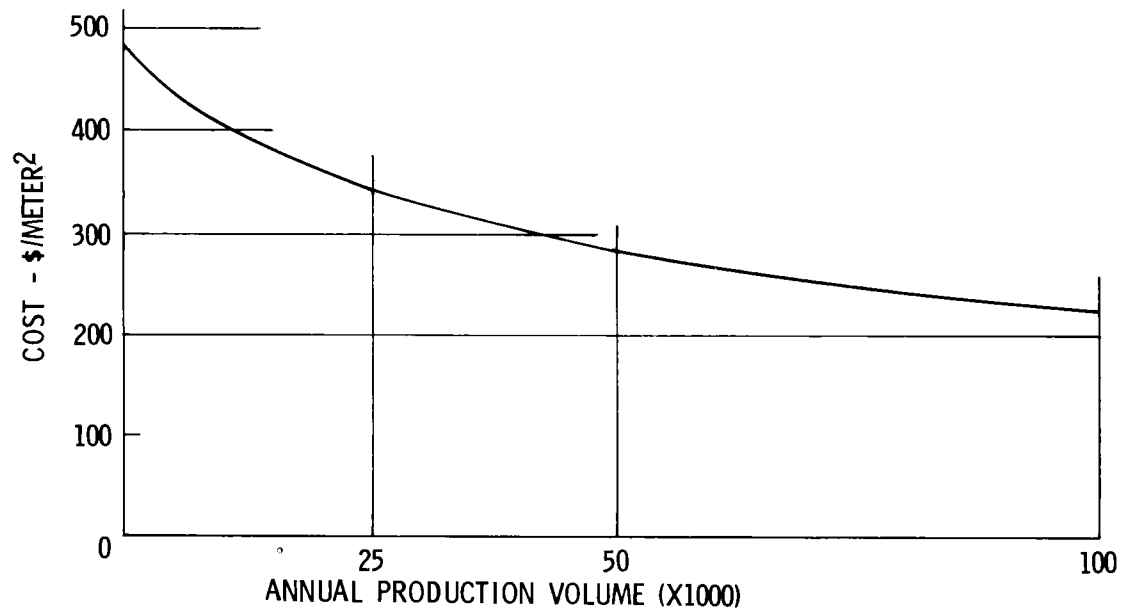
Table 4-1 presents the cost of a complete Omnium-G System 7500 reduced to basic labor and material. The curves in Figure 4-1 represent the cost of each of the major components (concentrator, power conversion unit and receiver) of the Omnium-G System 7500 in dollars per square meter of concentrator area. The cost of a complete Omnium-G System 7500 in dollars per square meter of concentrator area is shown by the curve in Figure 4-2. Figure 4-3 is a bar chart illustrating the cost of a complete Omnium-G System 7500 as a function of production volume.

Table 4-1. Production Quantities and Costs Per Unit

SUB-ASSEMBLY	25 Units		100 Units		25,000 Units		100,000 Units	
	Material	Labor	Material	Labor	Material	Labor	Material	Labor
Receiver Assembly	391.27	120.50	378.57	114.50	291.20	80.15	213.55	45.80
Backup Structure	476.57	171.10	379.17	162.50	270.63	113.80	155.56	65.00
Petal Assembly	3,066.84	78.00	2,877.63	75.00	2,100.60	30.00	1,540.29	13.40
Receiver Strut	169.24	17.90	166.00	17.00	126.46	12.00	93.08	6.80
Cantilever Support	842.78	151.60	743.98	144.00	565.24	100.80	420.38	57.60
Elevator Mechanism	601.37	44.70	586.14	42.50	451.03	29.75	330.35	17.00
Azimuth & Trolley Assembly	746.18	93.20	642.96	88.50	494.69	62.00	362.70	35.40
Yoke Assembly	175.34	73.70	170.95	70.00	119.67	49.00	70.14	28.00
Base Assembly	336.61	82.60	326.29	78.50	252.46	55.00	198.89	31.40
Electrical	288.50	85.80	288.50	81.50	216.38	57.10	156.68	32.60
Foundation	550.05	766.20	550.05	727.85	385.04	673.25	220.02	545.89
Steam Engine	123.15	335.50	123.13	318.70	92.34	218.30	73.88	127.50
Condenser	41.85	23.00	41.85	21.80	31.39	15.26	25.11	8.70
Preheater	20.40	11.60	20.40	11.00	15.30	7.70	12.24	4.40
Hotwell	797.96	30.50	797.96	29.00	638.37	20.40	478.77	11.60
Power Cart	2,396.89	73.70	2,396.89	70.00	1,797.66	49.00	958.75	28.00
Transport	438.77	39.30	438.77	37.33	329.08	13.63	223.77	5.98
TOTALS	11,463.75	2,199.90	10,929.24	2,089.68	8,177.54	1,587.14	5,534.16	1,065.07
GRAND TOTALS (MATERIALS + LABOR)	\$13,663.65		\$13,018.92		\$9,764.68		\$6,599.23	



NOTE: COSTS ARE IN 1979 DOLLARS
 Figure 4-1. Component Cost per Meter² of Concentrator Area



NOTE: COSTS ARE IN 1979 DOLLARS
 Figure 4-2. System Cost per Meter² of Concentrator Area

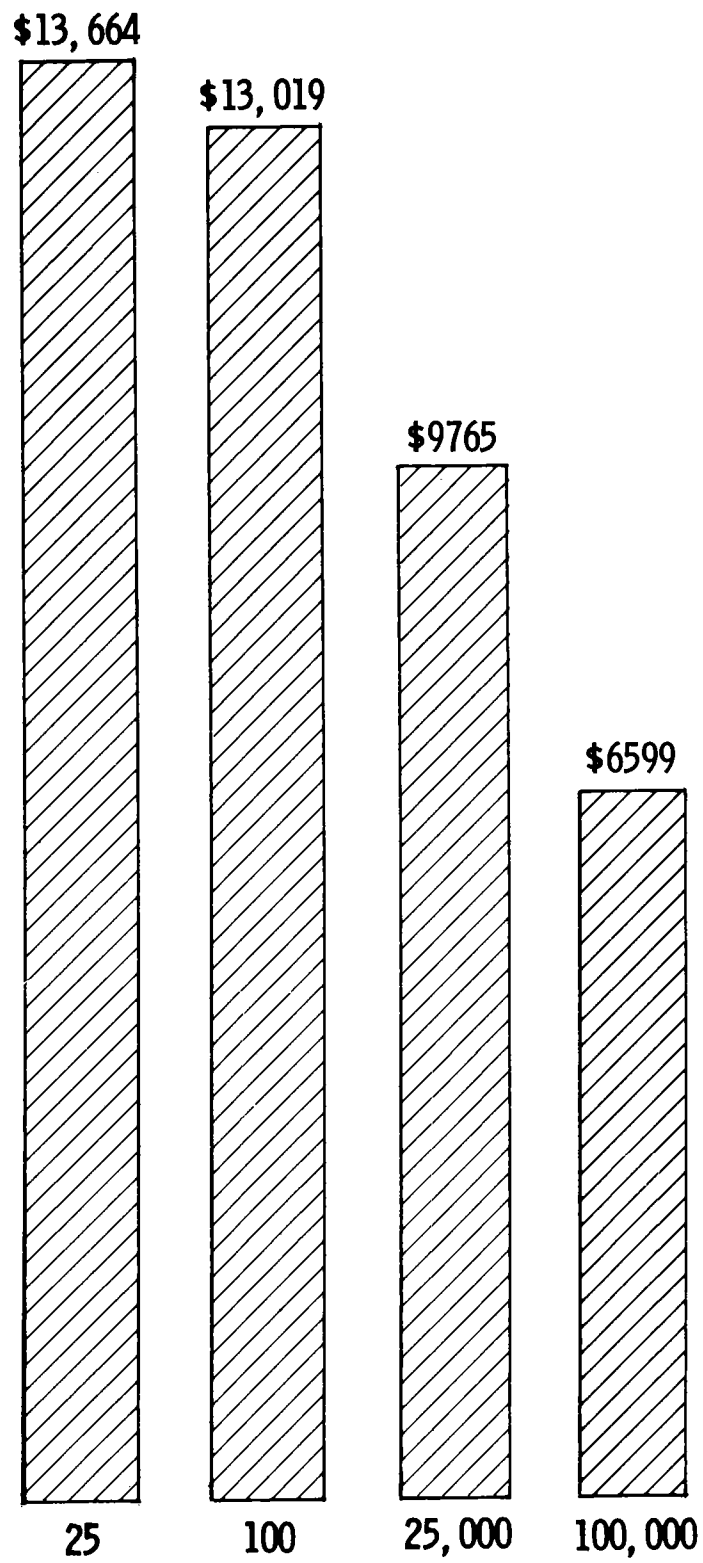
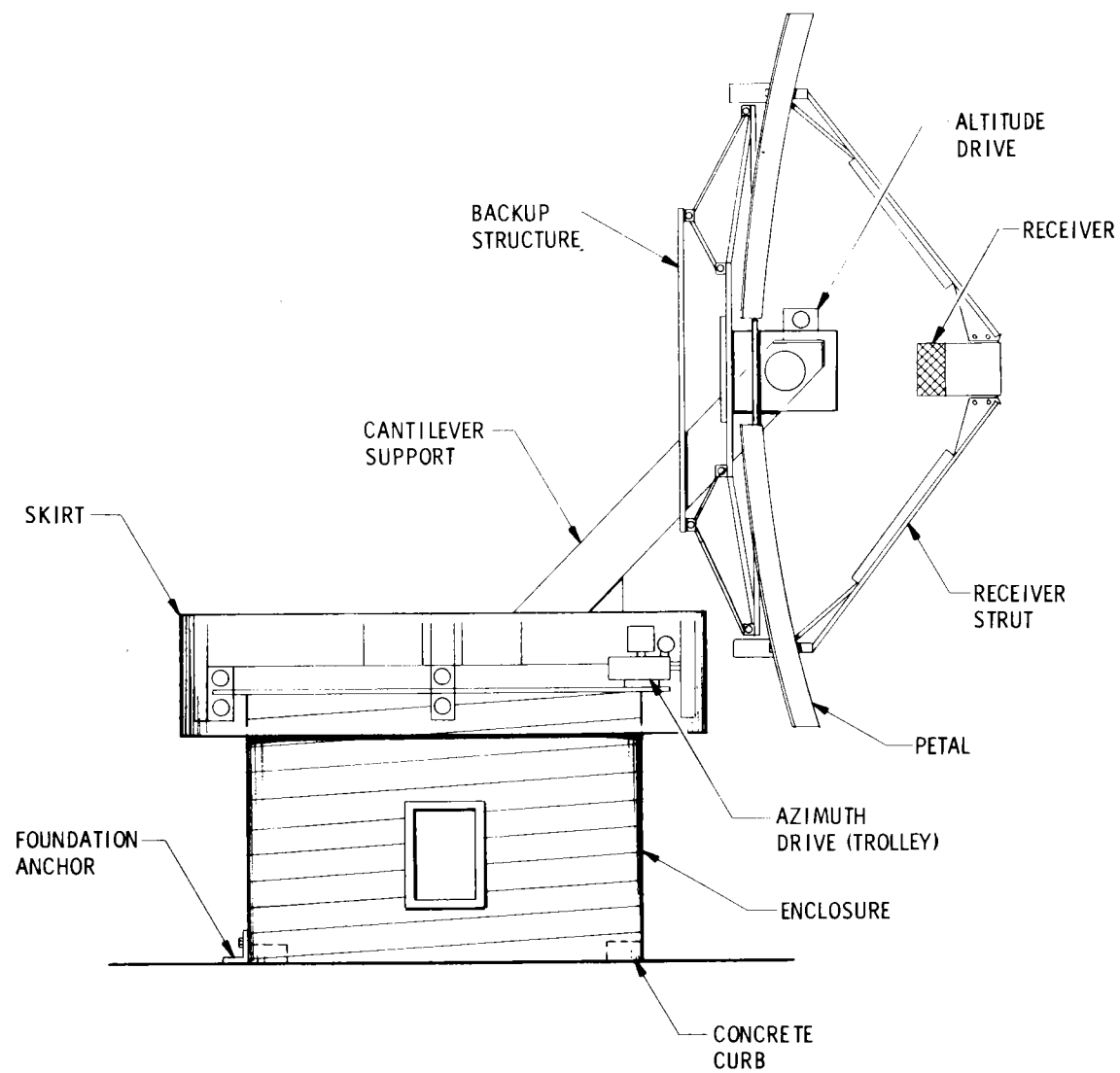


Figure 4-3. Cost as a Function of Annual Production Volume



f/d = .65

Figure A-1. Omnium-G System 7500

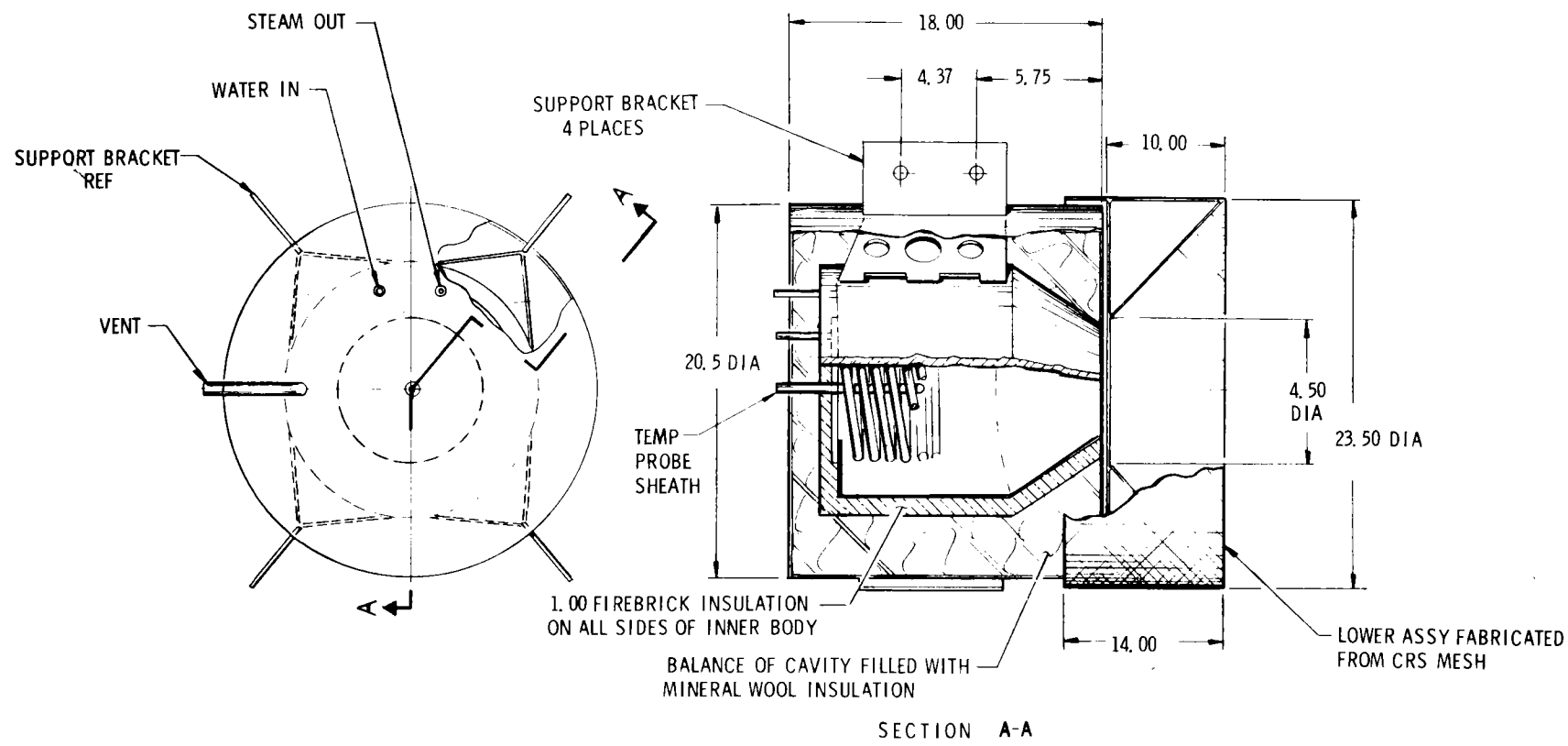


Figure A-2. Converter (Receiver) Assembly, Steam Engine

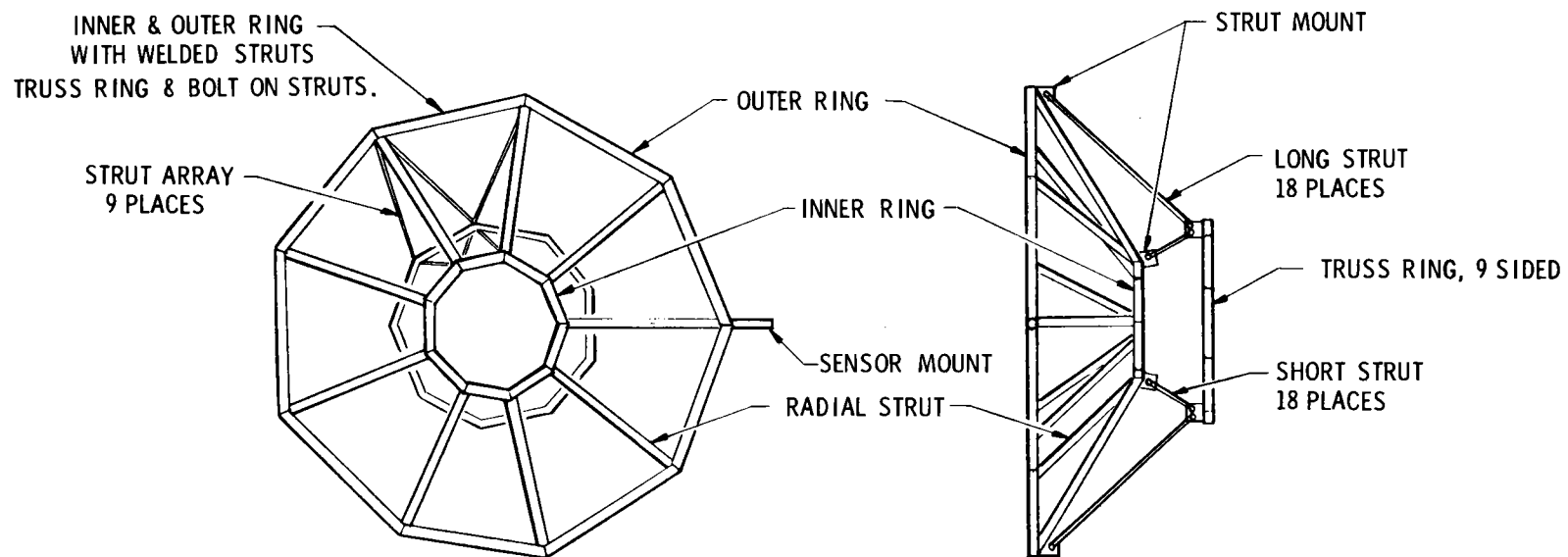
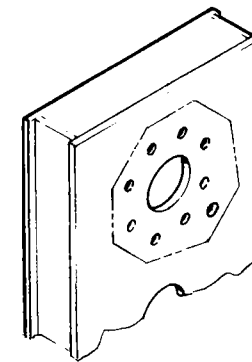
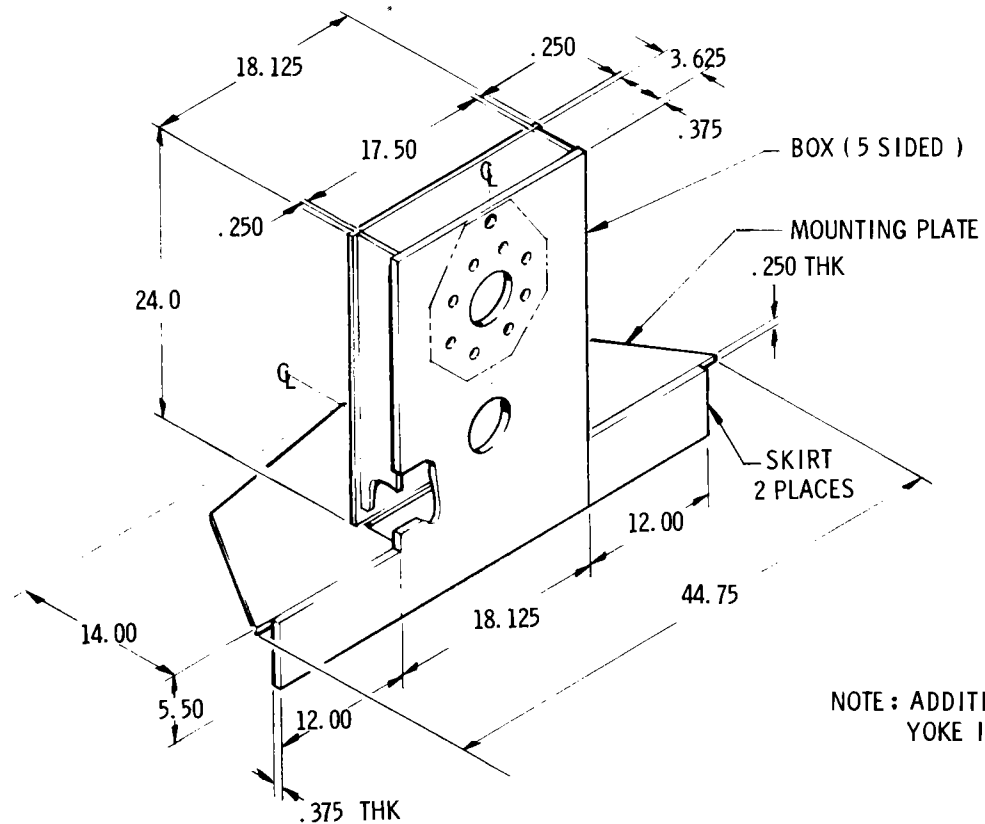


Figure A-3. Backup Structure

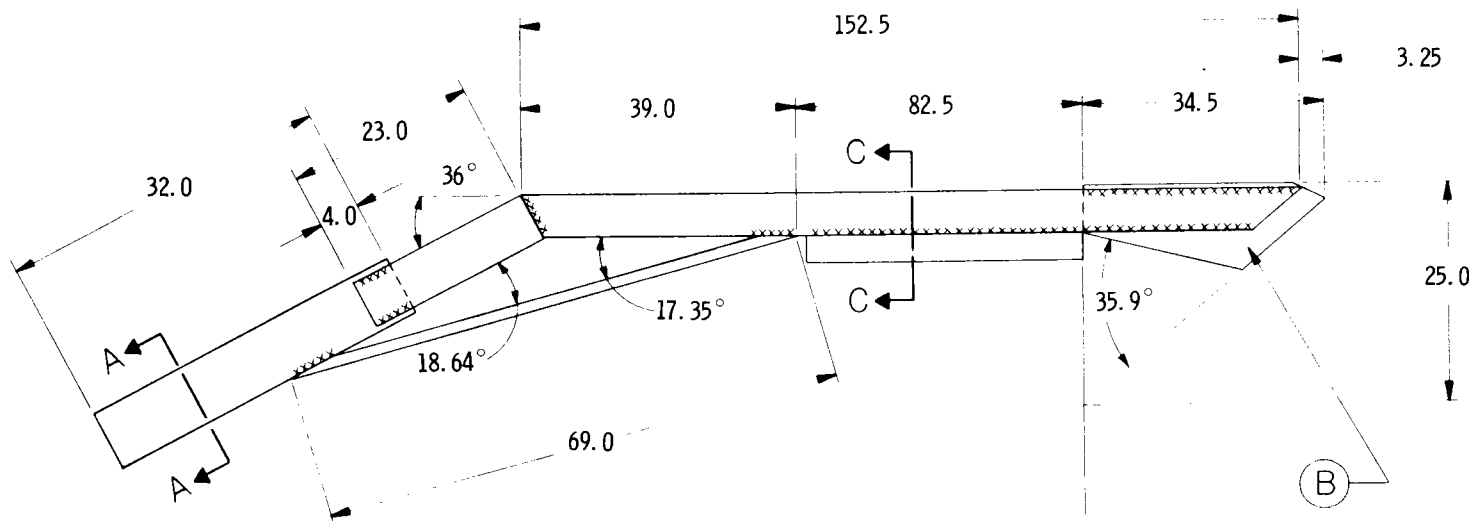


ACTUATOR ARM MOUNT -
ALTERNATE POSITION

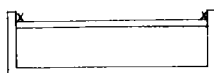
NOTE : ADDITIONAL PLATES ARE ADDED AFTER
YOKE IS WELDED IN PLACE.

Figure A-4. Yoke Assembly

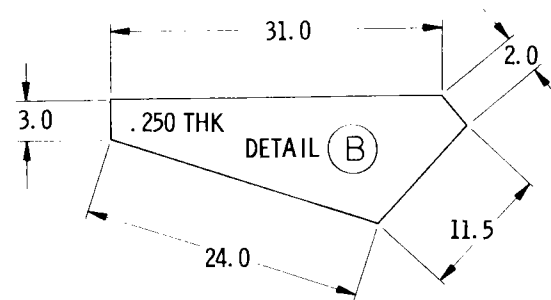
A-6



BOX MADE FROM 4 x 1.58 CHANNEL WITH FLAT STOCK WELDED INSIDE OF FLANGES. FINAL DIMENSIONS OF BOX MUST BE 4 x 1.50

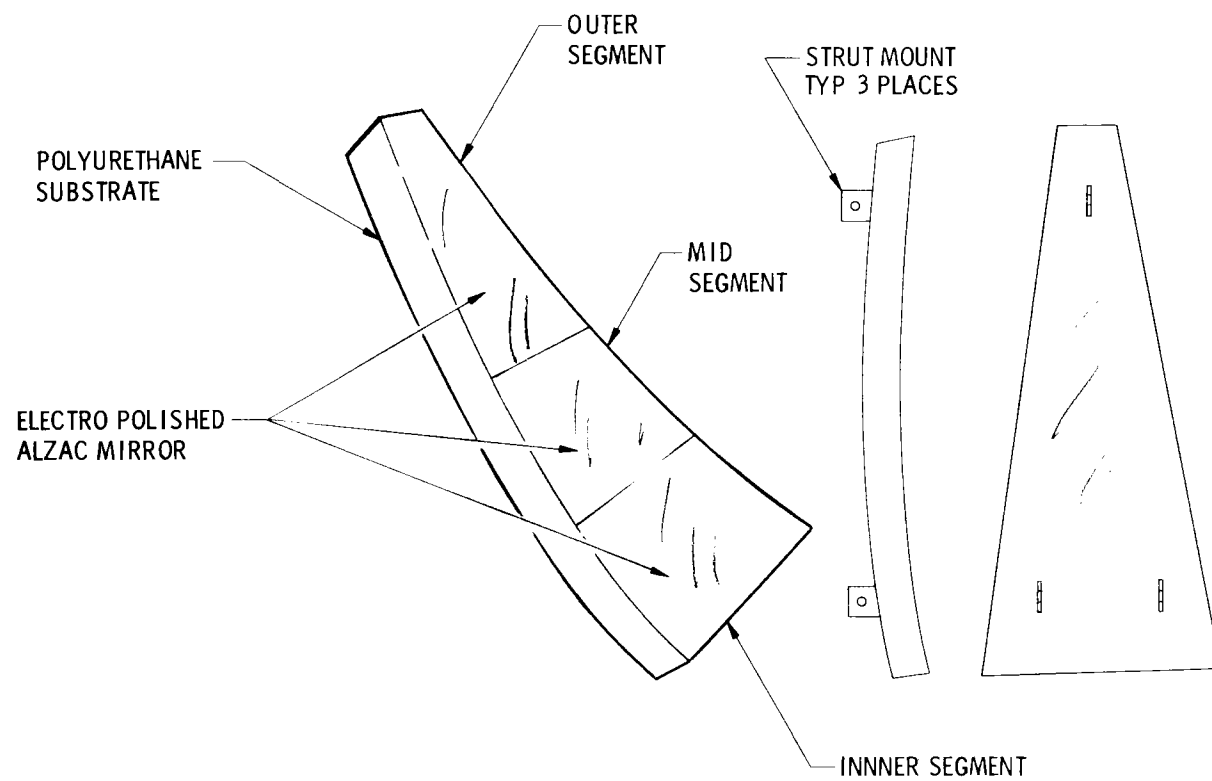


TORSIONAL STIFFENING RIB, .065 MTL BROKEN TO APPROX 2.50 AT BASE 96.0 LONG. (APPROX 4.00 ON SIDES)



4 REQUIRED

Figure A-5. Converter Support



18 REQUIRED

Figure A-6. Concentrator Segment Petal

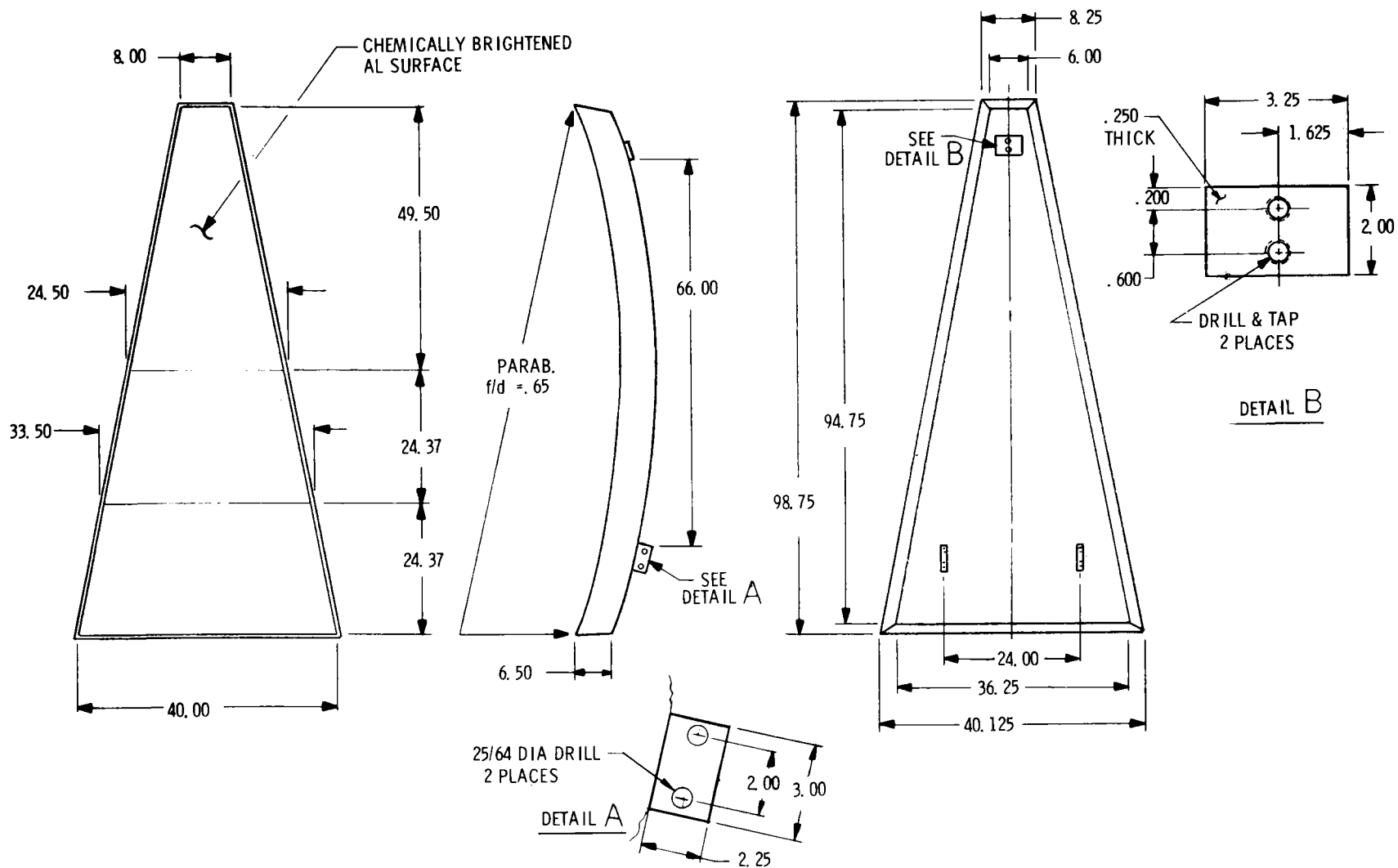
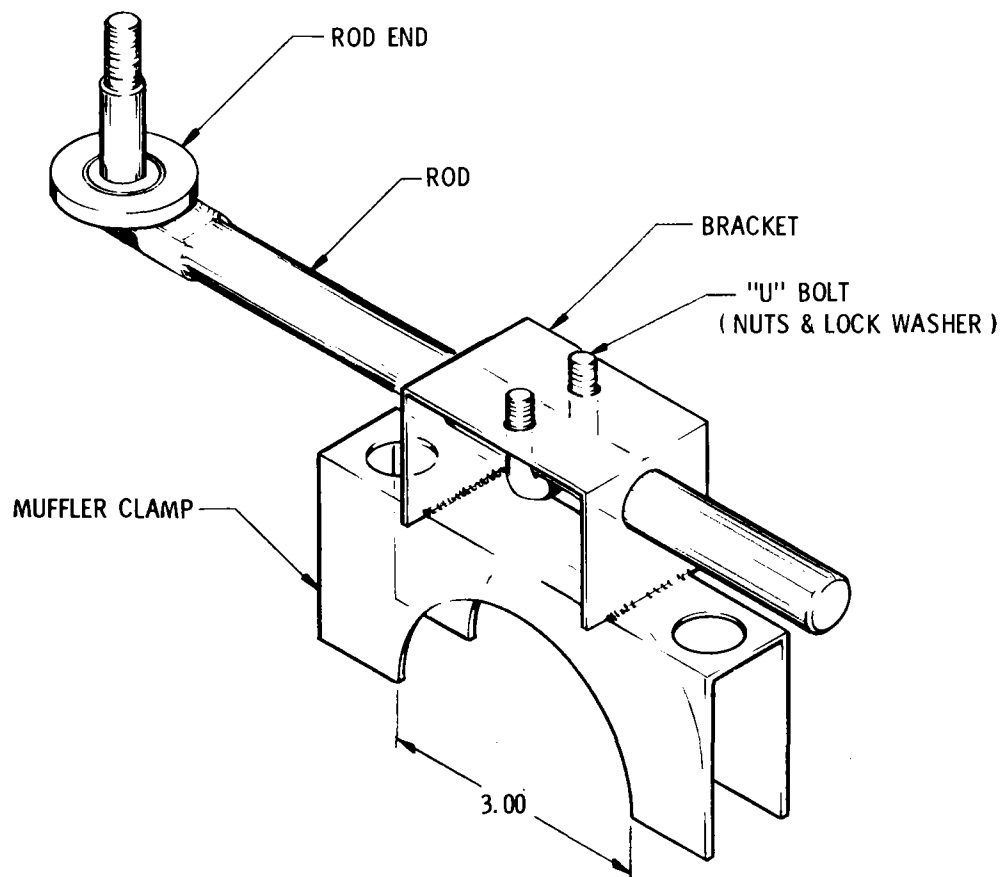


Figure A-7. Mirrored Petal Assembly



NOTE: ALL SEAMS WELDED

Figure A-8. Strut Assembly

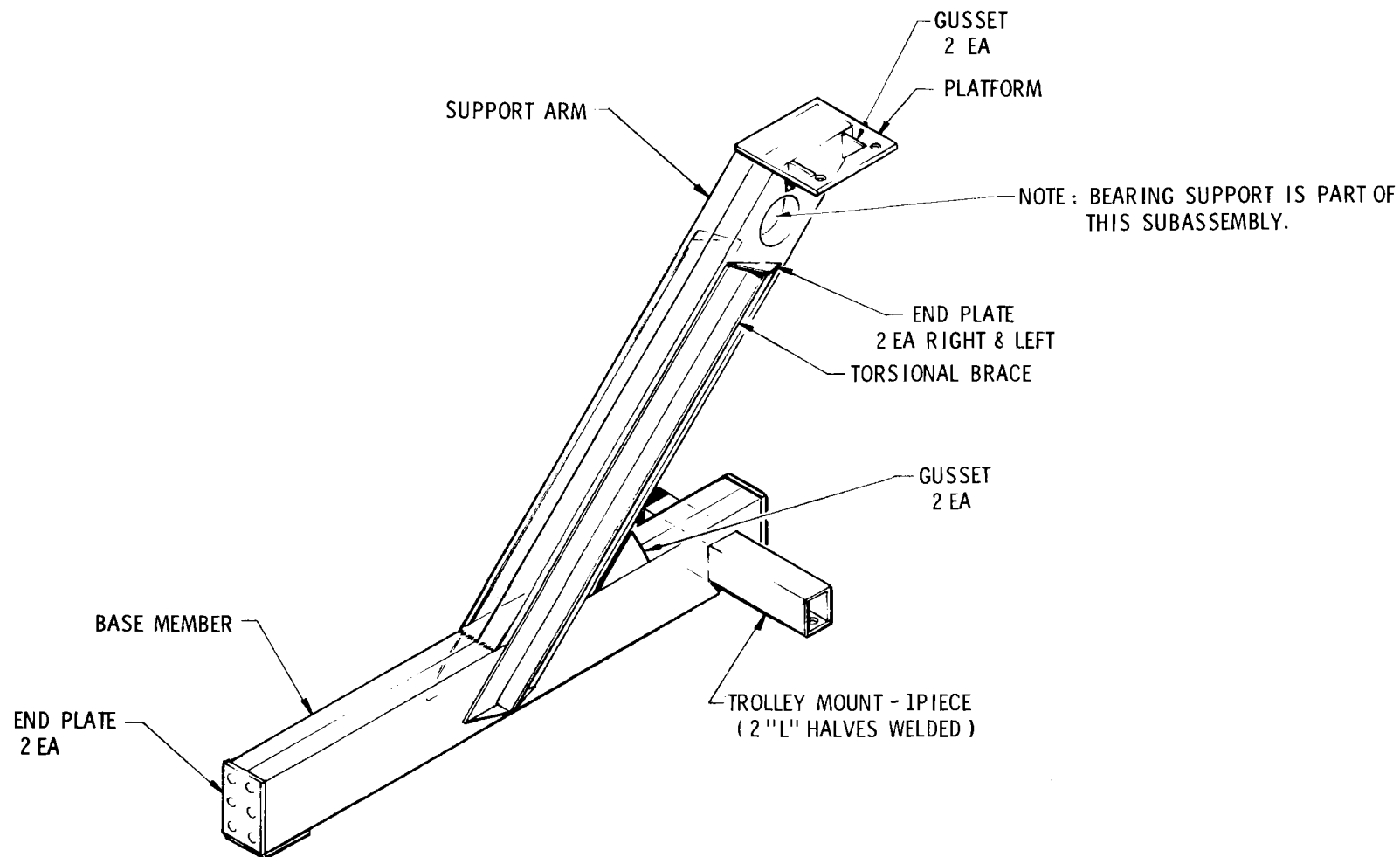
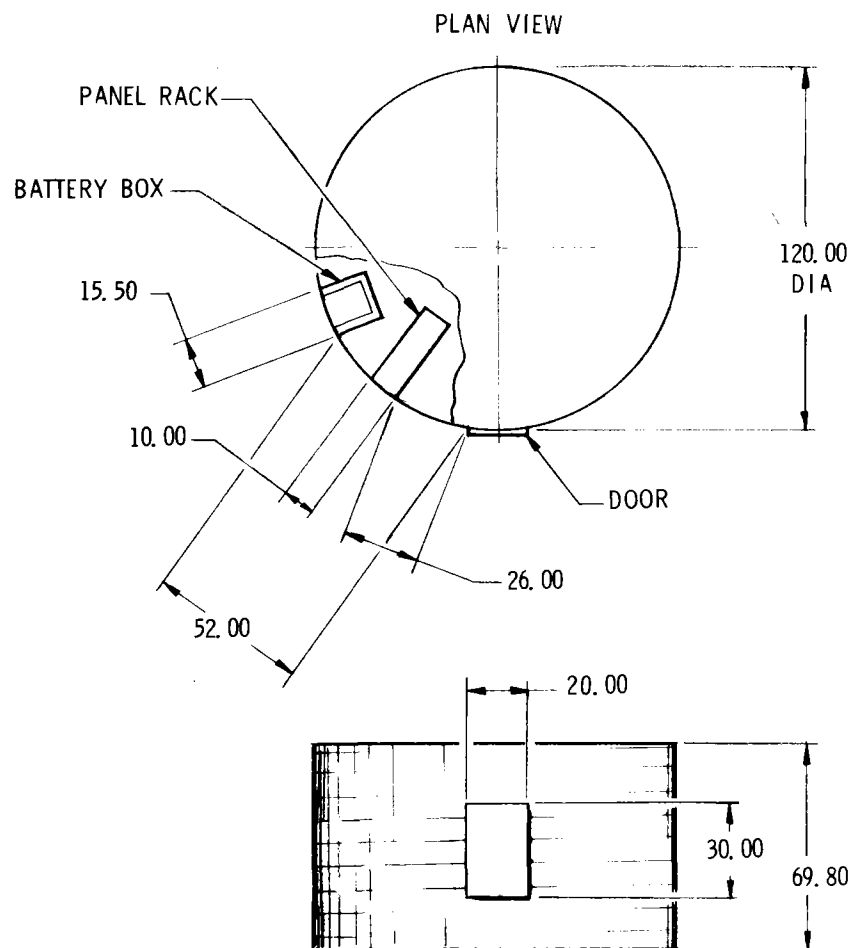


Figure A-9. Cantilever Support Structure



COPPER-STEEL CULVERT STOCK
12 GA, 1x3 CORRUGATION
2 OZ GALVANIZED COATED

Figure A-10. Base Enclosure

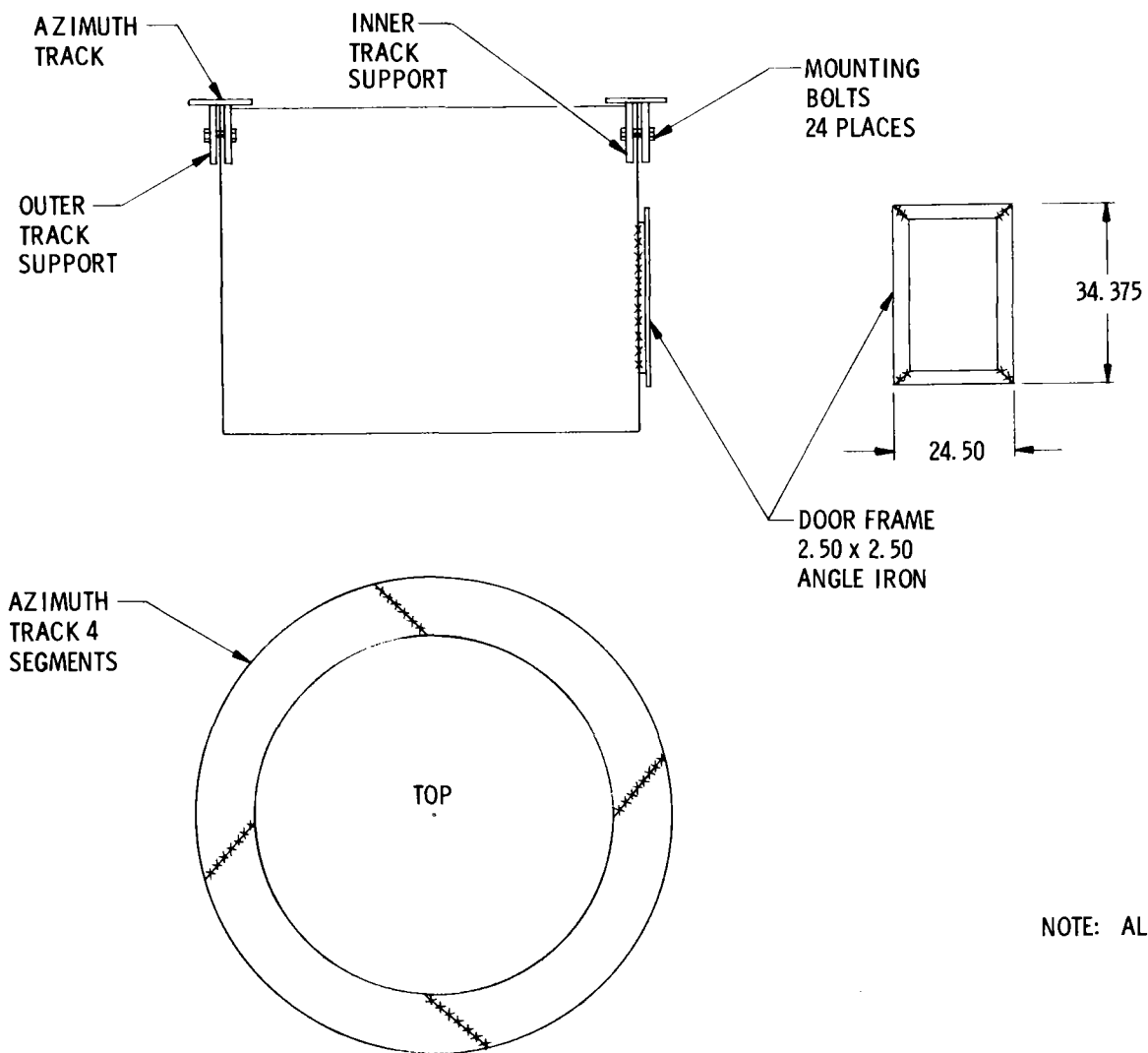


Figure A-11. Azimuth Ring, Door Frame

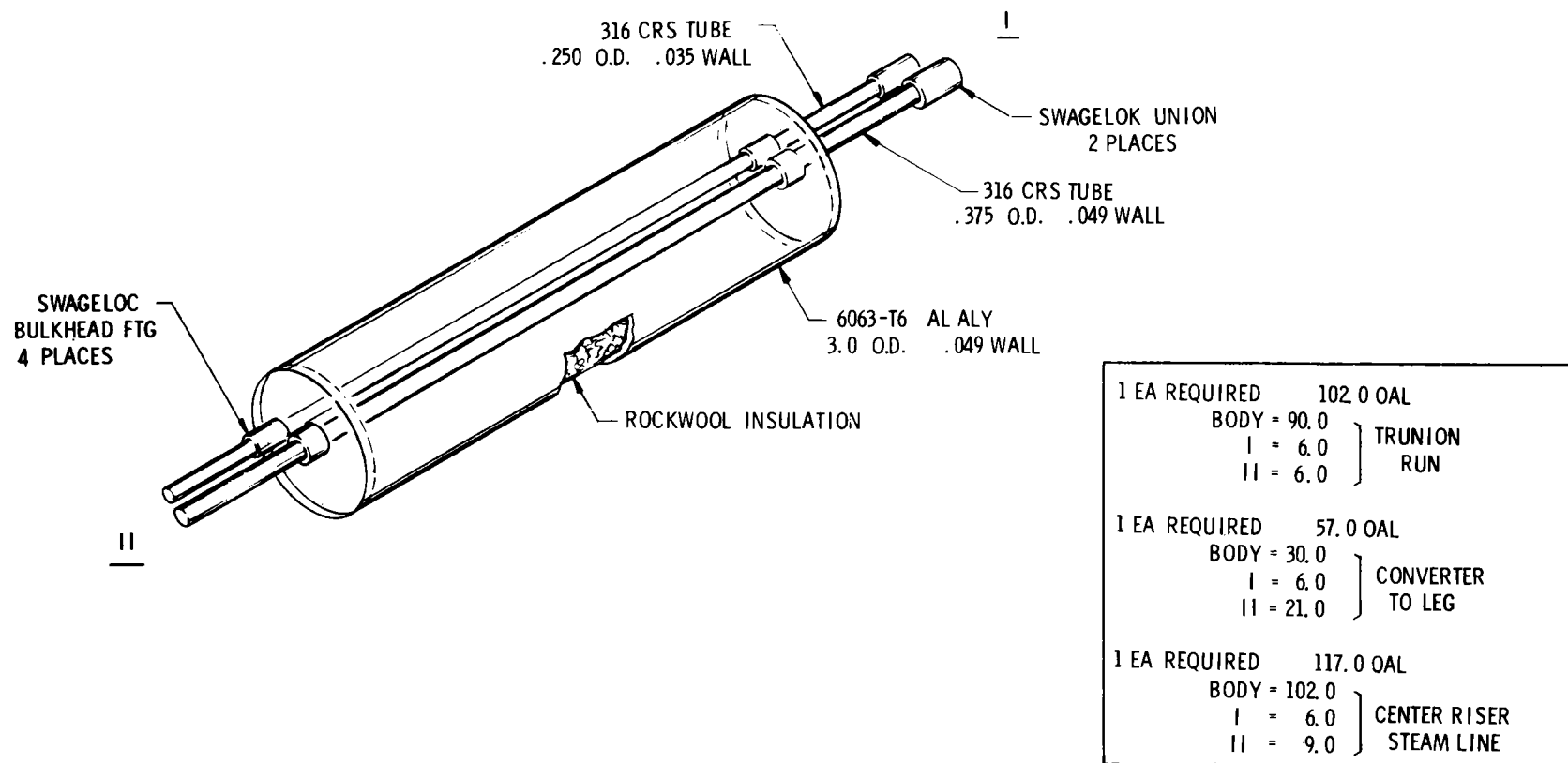


Figure A-12. Transport Line Assemblies

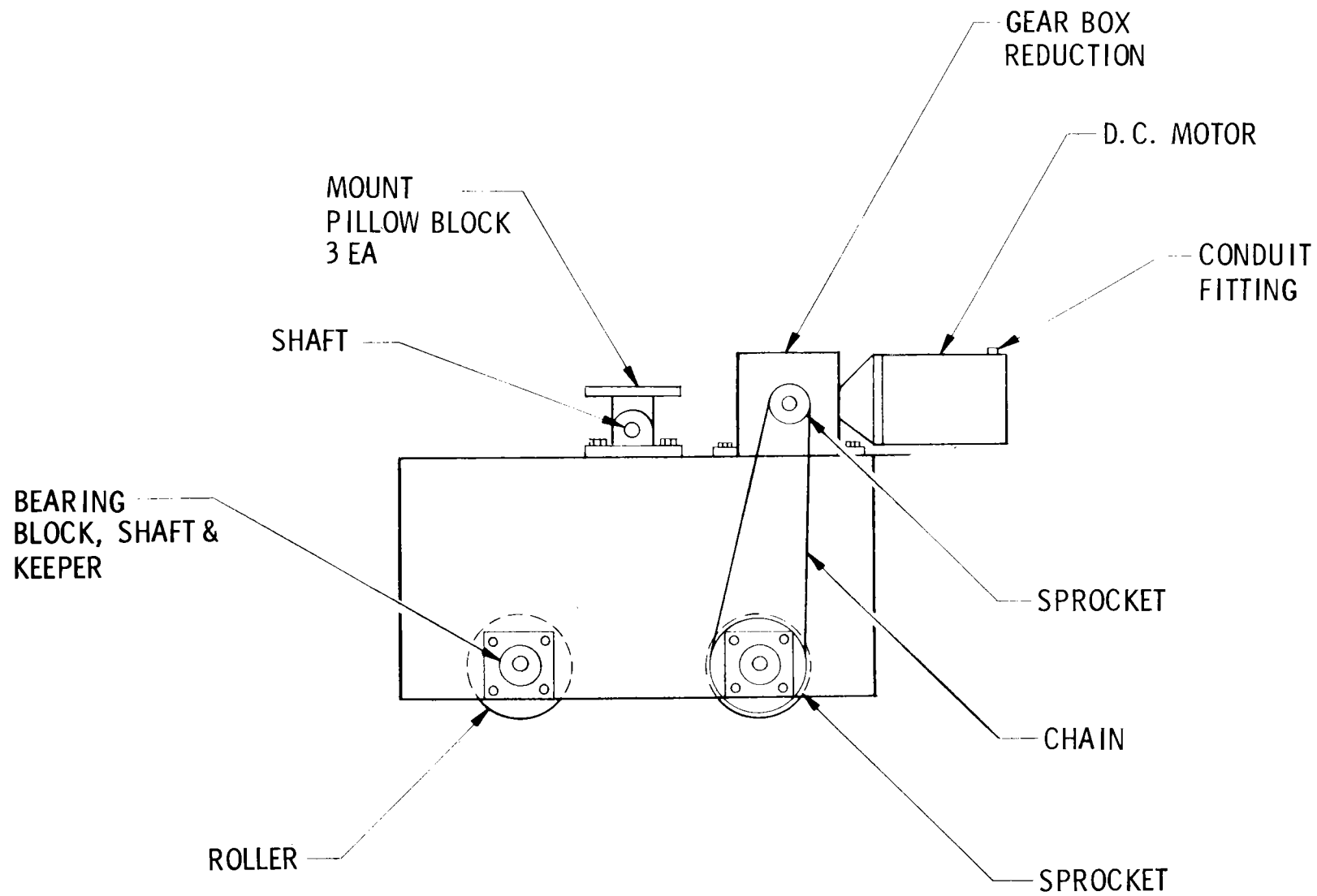


Figure A-13. Trolley Assembly

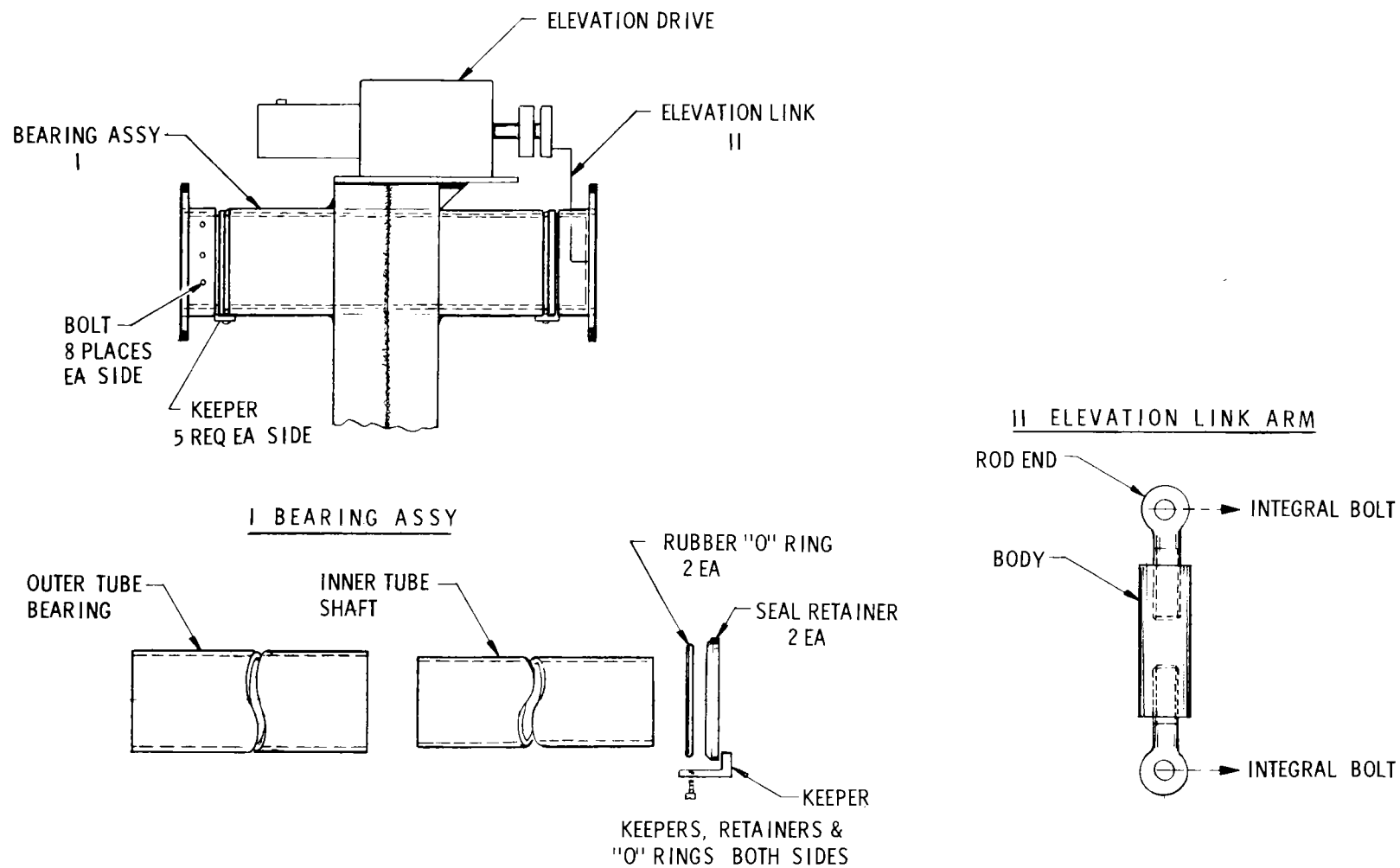


Figure A-14. Bearing Assembly and Elevation Drive

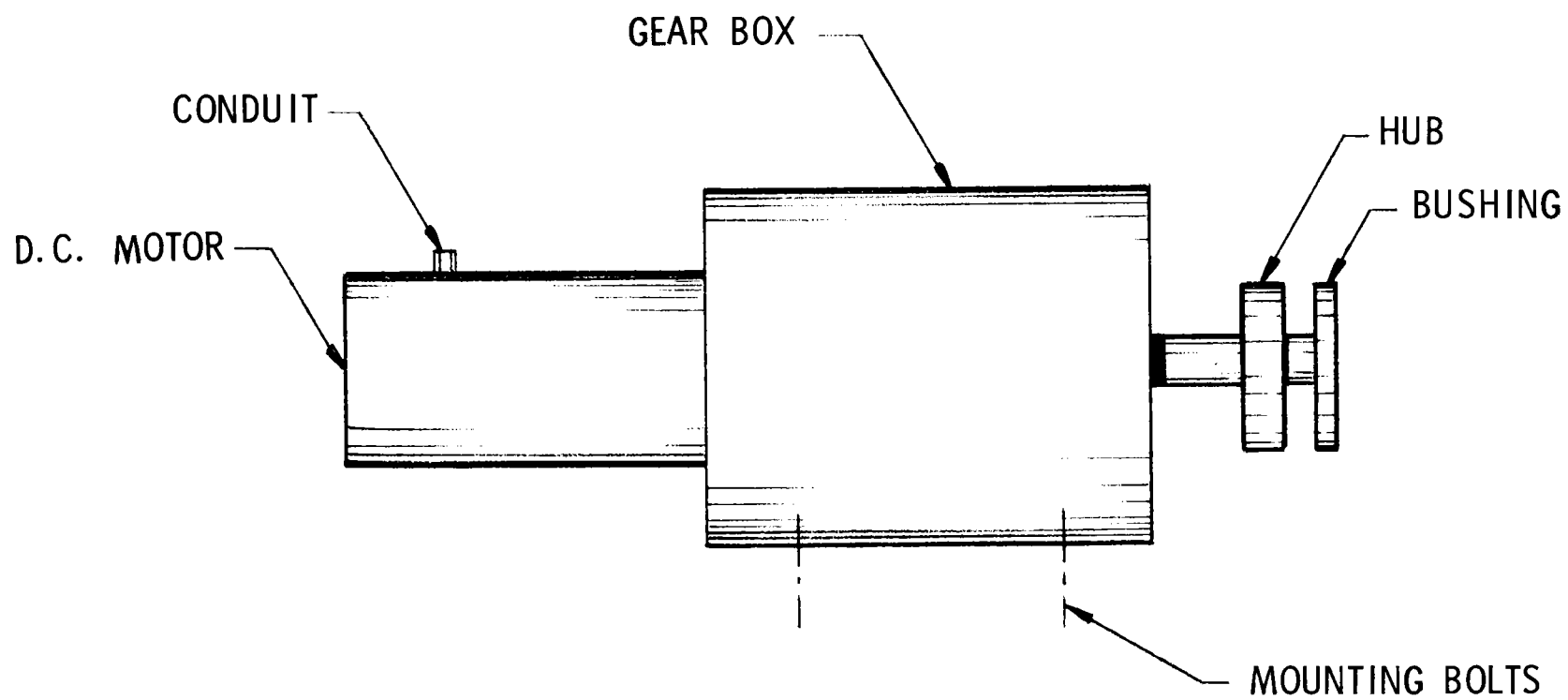


Figure A-15. Elevation Drive

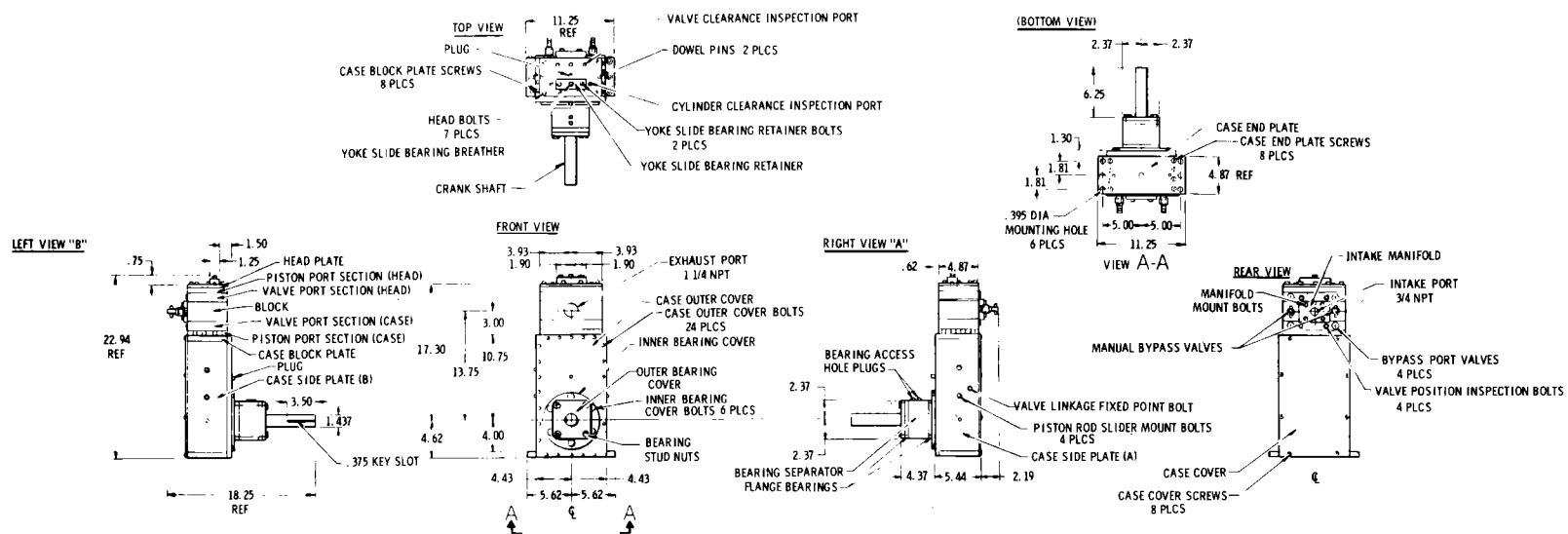


Figure A-16. Exterior Outline, Steam Engine

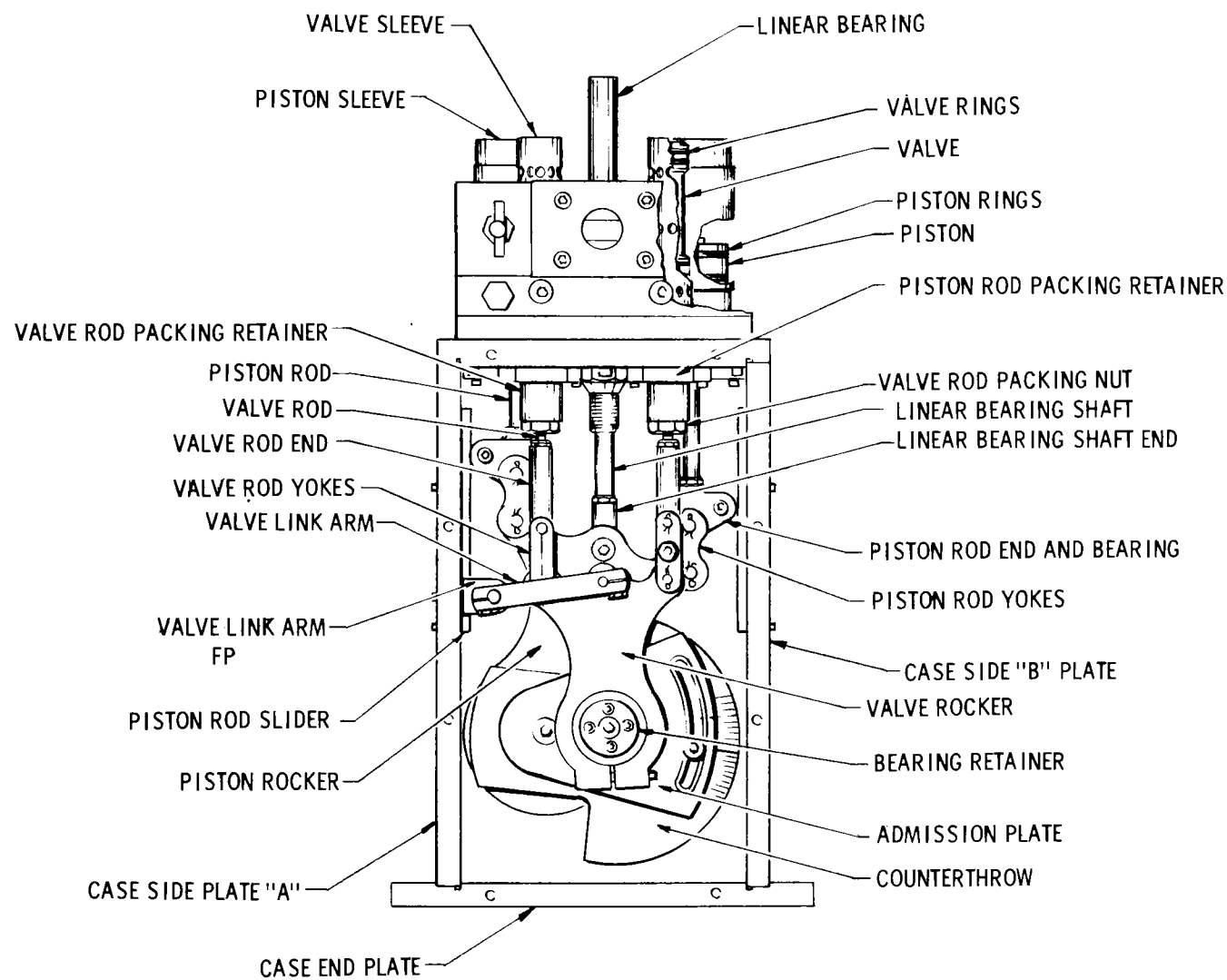


Figure A-17. Interior Outline, Steam Engine

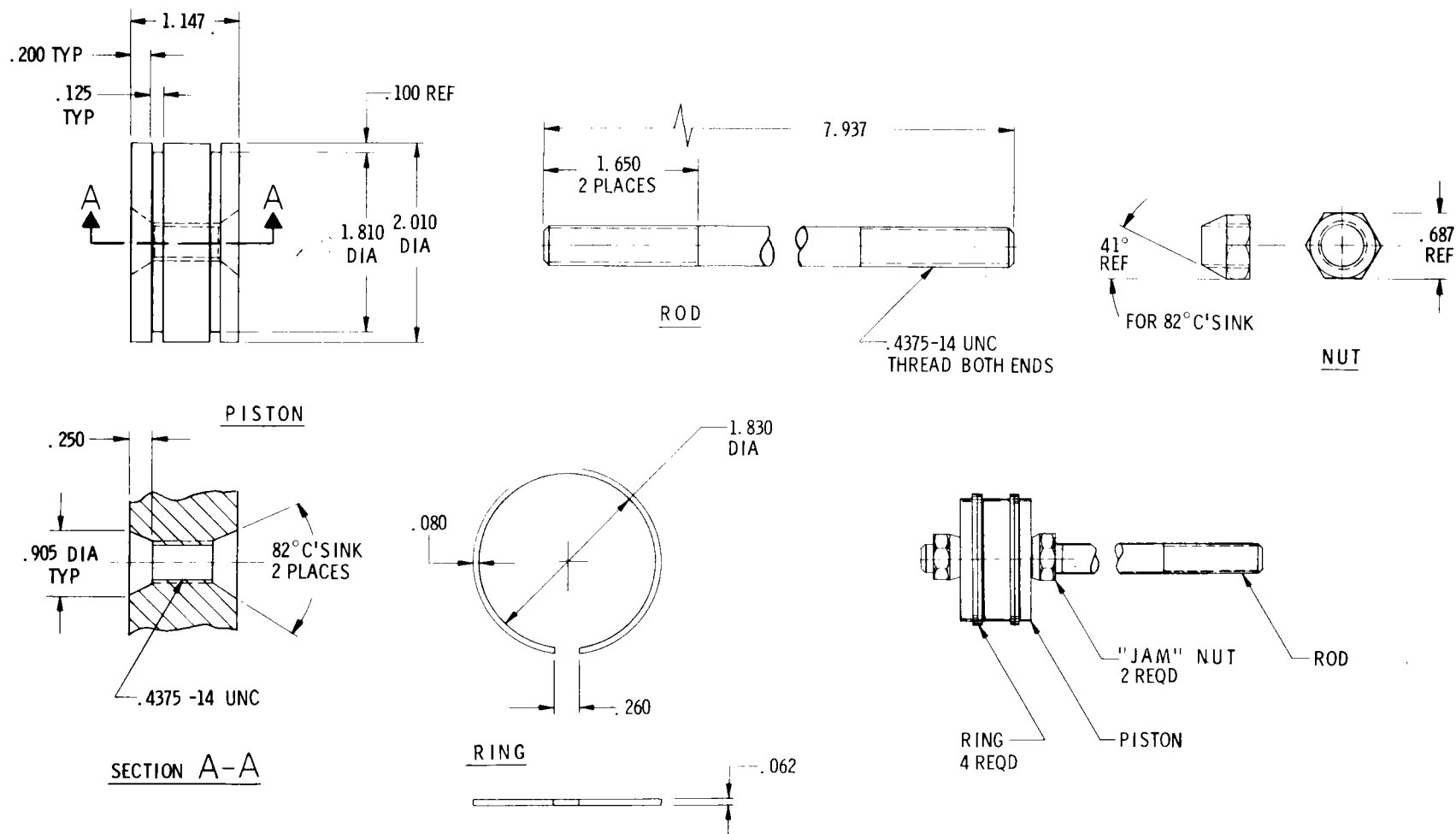


Figure A-18. Rod and Piston Assembly, Steam Engine

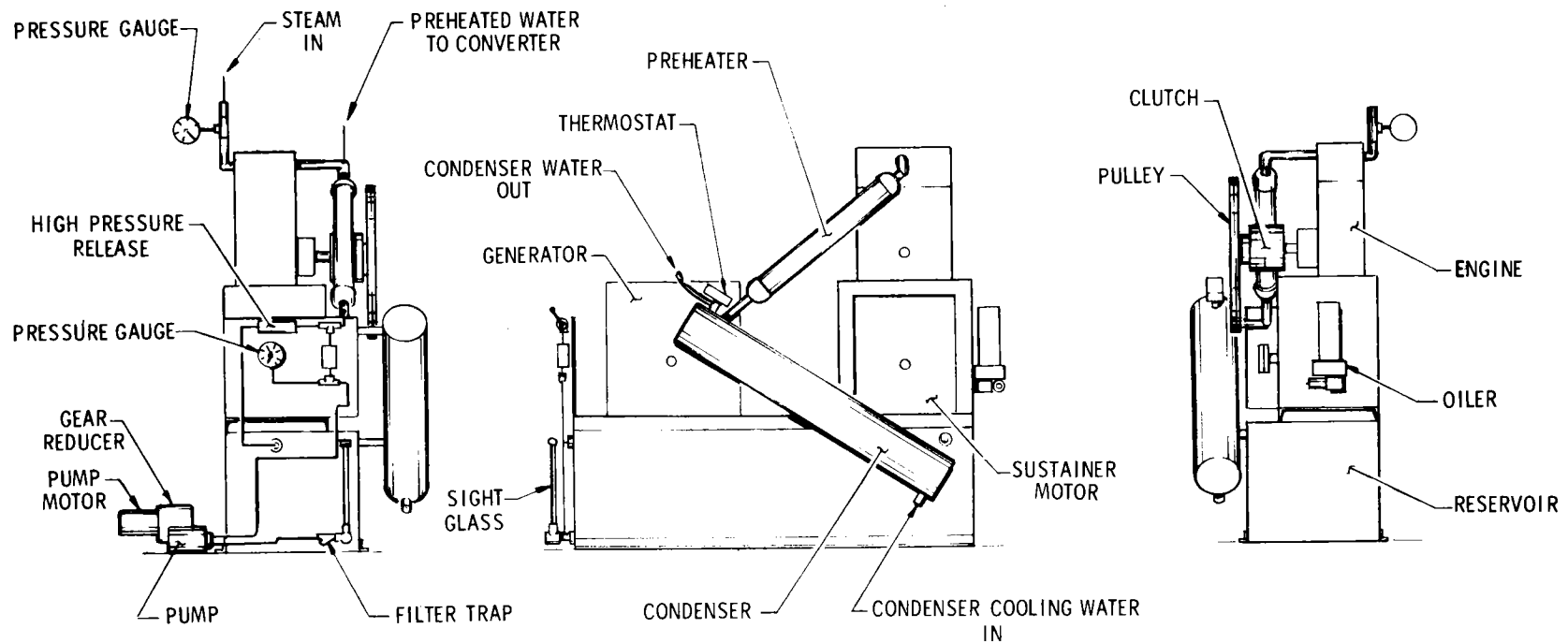


Figure A-19. Power Cart Assembly

SUMMARY SHEET

SUB-ASSEMBLY	MATERIAL COST	LABOR MANHOURS	LABOR DOLLARS	COST PER SUB-ASSY
Receiver Assembly	391.27	12.05	96.42	487.69
Backup Structure	476.57	17.11	136.84	613.41
Petal Assembly	3,066.84	7.80	63.16	3,130.00
Receiver Strut	169.24	1.79	14.32	183.56
Cantilever Support	842.78	15.16	121.26	964.04
Elevation Mechanism	601.37	4.47	35.79	637.16
Azimuth & Trolley Assembly	746.18	9.32	74.53	820.71
Yoke Assembly	175.34	7.37	58.95	234.29
Base Assembly	336.61	8.26	66.10	402.71
Electrical	288.50	8.58	68.63	357.13
Foundation	550.05	76.62	612.93	1,162.98
Steam Engine	123.13	33.55	268.38	391.51
Condenser	41.85	2.30	18.36	60.21
Preheater	20.40	1.16	9.26	29.66
Hotwell	797.96	3.05	24.42	822.38
Power Cart	2,396.89	7.37	58.95	2,455.84
Transport	438.77	3.93	31.43	470.20
TOTALS	\$11,463.75	219.97	\$1,759.73	\$13,223.48

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Receiver (Converter) Assy.	1 ea.	391.27	O.G. Part #7531-100-A
2 Outer Body	1 ea.	138.55	
3 Outer Cover	1 ea.		Body, 316 CRS, 13.0 x 63.6 x .063
4 Outer Cover	1 ea.	87.30	Top, 316 CRS, 20.25 dia. x .063
5 Outer Cover	1 ea.		Bottom, 316 CRS, 20.25 dia. x .063
6 Protective Shroud	1 ea.	51.25	316 CRS, 12.50 x 63.60, wire cloth
7 Fire Brick	7 lbs.	15.55	1 in. layer (2400 ^o F max. wk. temp.) Apx. 603 in ³
8 Mineral Wool	2.32 ft ³	9.75	Mineral Wool Insulation
9 Inner Container	1 ea.	132.48	
10 Body	1 ea.		316 CRS, 7.25 x 35.72 x .125
10A Support Bkt.	4 ea.	83.73	304 CRS, 5.5 x 6.0 x .250 (8 pcs.)
11 Top	1 ea.		316 CRS, 12.00 dia. x .125
12 Face Plate	1 ea.	48.75	Inconel, 12.25 dia x .157 x dished 1.50
13 Port Entry Cone	1 ea.		Inconel, 6.25 x 35.72 x .125 (Truncated cone)
14 Inlet Pipe	1 ea.	2.79	316 CRS, .25 tube x 12.0 long x .035 wall
15 Outlet Pipe	1 ea.	2.90	304 CRS, .375 tube x 15.0 long x .049 wall
16 Heat Exchang Mth.	75 lbs.	39.75	Aluminum
17 Helix	1 ea.	28.00	319 CRS, .250 tube x 8 ft. x .065 wall
18 Fitting	2 ea.	3.00	Swedgelock

ITEM	QTY	MAT'L COST	DESCRIPTION
Receiver (Converter) Assy. (cont'd)			
19	Temp Probe	1 ea.	15.50
20	Tube	1 ea.	8.00 316 CRS, .25 tube x 6.00 x .035 wall
21	Thermo Couple	1 ea.	Chromel-alumel x 10.0 long
22	Sending Unit	1 ea.	7.50
23	Transport Line*	1 ea.	173.40** 26 ft. @ \$6.67/ft.

B-4

*4 segments, see transport line P/L's

**Cost not included in total #1 above

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Backup Structure	1 ea.	476.57	
2 Outer Ring	1 ea.	62.46	
3 Tube Segment	9 ea.	6.72	6063 T6 al.al. 3.00 OD x 70.75 x .049 wall (tube)
4 Strut Mount	9 ea.	.22	6061 T6 al.al. 2.0 x 3.0 x .250
5 Inner Ring	1 ea.	30.33	
6 Tube Segment	9 ea.	3.15	6063 T6 al.al. 3.00 OD x 33.125 x .049 wall (tube)
7 Strut Mount	9 ea.	.22	6061 T6 al.al. 2.0 x 3.0 x .250
8 Truss Ring	1 ea.	296.11	
9 Tube Segment	9 ea.	1.97	6063 T6 al.al. 3.0 x 20.75 x .049 wall (tube)
10 Strut Mount	9 ea.	.22	6061 T6 al.al. 2.0 x 3.0 x .250
11 Strut Radial	9 ea.	6.98	6063 T6 al.al. 3.0 x 73.50 x .049 wall (tube)(welded)
12 Strut Truss (long)	18 ea.	3.23	6063 T6 al.al. 1.50 x 57.0 x .049 wall (tube)
13 Strut End	36 ea.	1.61	1.375 x 12.0 x .125
14 Bolt	36 ea.	.14	1/2 - 10 x 1 1/2
15 Nut	36 ea.	.08	1/2 - 10
16 Washer	64 ea.	.04	1/2
17 Strut. Truss (short)	18 ea.	.96	6063 T6 al.al. 1.50 x 16.75 x .049 wall (tube)(bolted)
18 Strut End	36 ea.	1.61	1.375 x 10.0 x .125
19 Bolt	36 ea.	.14	1/2 - 10 x 1 1/2
20 Nut	36 ea.	.08	1/2 - 10
21 Washer	64 ea.	.04	1/2
22 Sensor Mount	1 ea.	1.28	6063 T6 al.al. 3.00 x 13.50 x .049 wall (tube)

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Yoke (2 required)	1 ea.	87.67	
2 Mounting Plate	2 ea.	17.68	
3 Box	1 ea.	44.61	
4 Top	1 ea.	1.34	6061 T6 al.al. 17.375 x 3.125 x .250
5 Side	2 ea.	1.89	6061 T6 al.al. 24.00 x 3.125 x .250
6 Outside	1 ea.	10.89	6061 T6 al.al. 24.00 x 18.00 x .250
7 Inside	1 ea.	28.60	6061 T6 al.al. 29.50 x 18.00 x .375
8 Skirt	2 ea.	3.85	6061 T6 al.al. 12.50 x 6.00 x .375

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Receiver Strut	1 ea.	42.31	
2 Tube arm	1 ea.	14.94	6063 T6 al.al. .049 wall x 3.00 dia. x 152.5 (tube)
3 Receiver mount	1 ea.	11.36	Stl. 31.0 x 15.0 x .250
4 Stiffening Rib	1 ea.	4.72	6063 T6 al.al. .065 x 8.0 x 96.0
5 Short arm	1 ea.	2.28	6063 T6 al.al. .049 wall x 3.00 dia. x 23.0
6 Base	1 ea.	9.01	
7 Channel	1 ea.	3.26	6063 T6 al.al. channel 4.0 x 1.58 thick x 32.0 long
8 Box plate	1 ea.	1.80	6063 T6 al.al. .250 x 3.50 x 32.0
9 Strut	1 ea.	3.95	6061 T6 al.al. tube .049 wall x 1.50 dia. x 69.0

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Concentrator Mirror Assy.	1 ea.	3066.84	
2 Petal	18 ea.	170.38	
3 (Petal Unit)	1 ea.	170.38	
4 Inner Reflector	1 ea.		Electro Polished Alzac 24.0 x 60.0 x .032
5 Mid. Reflector	1 ea.	77.62	Electro Polished Alzac 30.0 x 24.0 x .032
6 Outer Reflector	1 ea.		Electro Polished Alzac 40.0 x 24.0 x .032
7 Substrate	45 lbs.	73.59	Polyurethane foam (2 densities)*
8 Moisture Coat	A/R	5.00	Latex Base Paint, apx. 2 qts (moisture & U.V. Barrier)
9 Strut Mount	3 ea.	.37	Al.al. 3.0 x 6.0 x .250
10 Strut Assy.	1 ea.	3.26	2 ea. Required
11 Rod	1 ea.	.13	
12 Rod End	1 ea.	1.88	Morse TF-GY
13 Nut	1 ea.	.04	Hex 3/8 - 24
14 Lock Washer	1 ea.	.04	Split Lock 3/8
15 Bracket	1 ea.	.05	Stl. 1.375 x 5.50 x 14 GA.
16 "U" Bolt	1 ea.	.26	9/16 x 1 1/4
17 Nut	2 ea.	.01	Hex 1/4 - 20
18 Washer	2 ea.	.03	Split Lock 1/4
19 Muffler Clamp	1 ea.	.79	

*Proprietary Information

ITEM	QTY	MAT'L COST	DESCRIPTION
Concentrator Mirror Assy. (cont'd)			
20	Strut Assy.	1 ea.	3.26
21	Rod Threaded	1 ea.	.05 Al.al. 2.50 x .50 dia.
22	Rod Domed	1 ea.	.08 Al.al. 5.25 x .50 dia.
23	Rod End	1 ea.	1.88 Morse TF-GY
24	Nut	1 ea.	.04 Hex 3/4 - 24
25	Washer	1 ea.	.04 Split Lock 3/8
26	Bracket	1 ea.	.05 Stl. 1.345 x 5.50 x 14 GA.
27	"U" Bolt	1 ea.	.26 9/16 x 1 1/4
28	Nut	2 ea.	.01 Hex 1/4 - 20
29	Washer	2 ea.	.03 Split Lock 1/4
30	Muffler Clamp	1 ea.	.79 5/16 x 3

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Cantilever Support	1 ea.	842.78	
2 Support arm	2 ea.*	32.47	Stl. 97.625 x 10.00 x 2.50 channel
3 Platform	1 ea.	5.97	Stl. 14.687 x 11.937 x .250
3A Bolt	4 ea.	.21	1/2 - 23 x 2 1/2
4 Gusset	2 ea.	.40	Stl. 6.0 x 6.0 x .250 (diag. cut to make two)
5 Torsional Brace	2 ea.	33.05	Stl. 6.0 x 6.0 x 5/16 x 98.25, angle iron**
6 End plate	2 ea.	.52	Stl. 8.0 x 8.0 x .250 (diag. cut to make two)
7 Conduit fitting	1 ea.	3.00	Pipe el., 45°, 3 1/2 in. (right side)
8 Cable clamp	2 ea.	.15	
8A Screw	2 ea.	.05	Phms 8-32 x 1
8B Nut	2 ea.	.05	Hex #8
8C Lock washer	2 ea.	.03	#8
9 Base member	2 ea.*	44.15	Stl. 130.0 x 10.0 x 2.50 channel
10 End plate	2 ea.	1.09	Stl. 10.0 x 5.25 x .375
10A Castor	1 ea.	20.49	Rapistan U-265R-FR
11 Trolley mount	1 ea.*	12.60	Stl. 4.0 x 4.0 x .250 x 36.0, angle iron
11A Castor mount	1 ea.	1.38	
12 Gusset	2 ea.	3.75	Stl. 17.0 x 13.0 x .25

*(2 pc. box section)

** (left & right)

ITEM	QTY	MAT'L COST	DESCRIPTION
Cantilever Support (cont'd)			
13	"Y" Member	2 ea.	41.92
14	Brace	4 ea.	5.84 Stl. 3.125 x 10.250 x 38.0, 10 Ga channel
15	Body	2 ea.*	5.84 Stl. 3.125 x 10.250 x 40.75, 10 Ga channel
15A	Castor mount	2 ea.	1.38 Stl.
16	Support channel	4 ea.	1.03 Stl. 1.25 x 2.0 x 84.0, 10 Ga channel
17	Deck	-----	136.50
18	Outer	4 ea.	28.35 Stl. 90.0 x 24.0, 10 Ga
19	Pop Rivet	128 ea.	.02 3/16 dia. x 3/8 long
20	Inner	1 ea.	14.78 Stl. 42.50 x 42.50, 10 Ga
20A	Pop Rivet	156 ea.	.24
21	Skirt	4 ea.	37.87 Stl. 95.75 x 24.0, 10 Ga
22	Pop Rivet	156 ea.	.02 3/16 dia. z 3/8 long
23	Castor support	3 ea.	40.77
24	Top plate	3 ea.	.12 Stl. 4.06 x 4.16 x .375
25	I-beam	3 ea.	11.86 Stl. 25.25 x 4.16 deep x 4.06 flange
26	Foot	3 ea.	1.23 Stl. 8.625 x 6.50 x .250
27	Slider	3 ea.**	.20 Stl. 2 x 2 x .186 x 2, angle iron
27A	Bolt	6 ea.	.05 3/8 - 16 x 1 GR5 cad.
27B	Lock washer	6 ea.	.04 3/8

*(2 pc. box section)

**fab from 2 pcs; 6 req

ITEM	QTY	MAT'L COST	DESCRIPTION
Cantilever Support (cont'd)			
28	Retainer leg	1 ea.	117.07
29	Top plate	1 ea.	.12 Stl. 4.06 x 4.16 x .395
30	I-beam	1 ea.	11.86 Stl. 26.0 x 4.16 deep x 4.06 flange
31	Castor	3 ea.	34.15 Rapistan #U-265R-FR
32	Bolt	12 ea.	.08 3/8 - 16 x 1 1/2
33	Nut	12 ea.	.05 3/8 Hex
34	Washer	12 ea.	.03 3/8
35	Lock washer	12 ea.	.06 3/8

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Base Assembly (Enclosure)	1 ea.	336.61	
2 Base (stock)	1 ea.	92.00	(Kaiser Steel, Culver & Stock) 10.0 ft. dia. x 69.0 in., 203 Coating, Cu. stl, 109 Ga
3 Door frame	1 ea.	7.94	
4 Side	2 ea.	2.12	34.375 Long
5 Top	1 ea.	1.85	2.50 x 2.50 x .187 - 24.50 Long
6 Bottom	1 ea.	1.85	Angle iron 24.50 Long
7 Azimuth Ring Assy.	1 ea.	183.87	
8 Track	1 ea.	126.47	Stl. 6.00 x 92.00 x .375, 4 ea. Required
9 Outer support	1 ea.	22.10	Stl. 6.00 x 377.0 x .125, Fab. from 3 or 4 pieces
10 Inner support	1 ea.	22.10	Stl. 6.00 x 377.0 x .125, Fab. from 3 or 4 pieces
11 Mounting Bolt	24 ea.	.36	5/8 - 11 x 3
12 Nut	24 ea.	.19	Hex 5/8 - 11
13 Panel rack	1 ea.	8.64	
14 End	2 ea.	1.40	Stl. 12.50 x 24.0 x 16 Ga
15 Side	2 ea.	2.66	Stl. 15.0 x 36.0 x 16 Ga
16 Bolt	4 ea.	.07	1/4 - 20 x 2 1/2
17 Nut	4 ea.	.03	Hex 1/4 - 20
18 Washer	4 ea.	.03	Split lock, 1/4

ITEM	QTY	MAT'L COST	DESCRIPTION
1	Base Assembly (Enclosure) (cont'd)		
19	Battery Box	1 ea.	5.52
20	Frame	1 ea.	3.80 2 ea. 15.25 & 14.75*
21	Mounting leg	2 ea.	.62 2 ea. 10.0
22	Bolt	4 ea.	.08 3/8 - 16 x 2 1/2
23	Nut	4 ea.	.04 Hex 3/8 - 16
24	Foundation Anchor	1 ea.	38.64
25	Clete	8 ea.	.74 Stl. 10.0 Long x 3 x 3 x .187 Angle Iron
26	Pad	8 ea.	.49 Stl. 4.5 x 4.0 x .250
27	Bolt	8 ea.	.46 3/4 - 10 x 1 1/2
28	Bolt	8 ea.	.62 3/4 - 10 x 2 1/2
29	Nut	16 ea.	.26 Hex 3/4 - 10
30	Washer	16 ea.	.10 Split lock 3/4
31	Anchor	8 ea.	1.80 Phillips Red Head 3/4

*(Fab. from 2.50 x 2.50 x .187 Angle Iron)

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Leg Transport Line Assy.	1 ea.	72.04	
2 Transport Tube	1 ea.	21.19	304 CRS 38.00 x 1.50 dia x 16 Ga Wall
3 Cross Tube	1 ea.	4.00	304 CRS 14.00x3.00 dia.x16 Ga Wall*
4 End Plate	2 ea.	.25	304 CRS 1.50 dia. x 16 Ga
5 Spacer	1 ea.	.25	304 CRS 1.50 dia. x 16 Ga
6 Steam Tube	1 ea.	9.67	304 CRS .375 Tubex .049 wall x 50.00 long
7 Bulkhead Ftg	2 ea.	3.50	3/8 Swedgelock bulkhead ftg. #SS-600-1-4
8 Union Ftg	1 ea.	6.70	3/8 Swedgelock bulkhead ftg. #SS-600-6
9 Return Water Tube	1 ea.	11.63	1/4 wall .035 x 50.00 316 CRS
10 Bulkhead Ftg	2 ea.	2.80	1/4 Swedgelock Bulkhead ftg. #SS-400-1-2
11 Union Ftg	1 ea.	4.60	1/4 Swedgelock Bulkhead ftg. #SS-400-6
12 Mineral Wool	.2 ft ³	.90	

*(Rolled from flat stock)

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Converter Transport Line	1 ea.	51.20	
2 Transport tube	1 ea.	2.23	Al.al. 6063 T6, 3.0 x 30.0 x .049 wall
3 End cap	2 ea.	.05	Al.al. 6063 T6, 2.875 dia. x .250
4 Spacer	1 ea.	.05	304 CRS, 2.75 dia. x 18 Ga
5 Feed water blkhd ftg	2 ea.	2.80	Swedgelock, 1/4 in. Bulkhead ftg. #SS-400-1-2
6 Steam line blkhd ftg	2 ea.	3.50	Swedgelock, 3/8 in. Bulkhead ftg. #SS-600-1-4
7 Steam line	1 ea.	9.67	304 CRS, .375 tube x .049 wall x 57.0 long
8 Union ftg	1 ea.	6.70	Swedgelock, 3/8 union, #SS-600-6
9 Feed water line	1 ea.	13.25	316 CRS, .250 tube x .035 wall x 57.0 long
10 Union ftg	1 ea.	4.60	Swedgelock, 1/4 union, #SS-400-6
11 Mineral wool	.5 ft ³	2.00	Mineral wool insulation
12 Center Riser	1 ea.	84.55	
13 Transport tube	1 ea.	7.58	Al.al. 6063 T6, 3.0 x 102.0 x .049 wall
14 End cap	2 ea.	.05	Al.al. 6063 T6, 2.875 dia. x .250
15 Spacer	3 ea.	.05	304 CRS, 2.75 dia. x 18 Ga
16 Feed water blkhd ftg	2 ea.	2.80	Swedgelock, 1/4 in. Bulkhead ftg. #SS-400-1-2
17 Steam line blkhd ftg	2 ea.	3.50	Swedgelock, 3/8 in. Bulkhead ftg. #SS-600-1-4
18 Steam line	1 ea.	22.62	304 CRS, .375 dia. x .049 wall x 117.0 long
19 Union ftg	1 ea.	6.70	Swedgelock, 3/8 union, #SS-600-6
20 Feed water line	1 ea.	27.20	316 CRS, .250 tube x .035 wall x 117.0 long
21 Union ftg	1 ea.	4.60	Swedgelock, 1/4 union, #SS-400-6
22 Mineral wool	.75 ft ³	3.00	Mineral wool insulation

ITEM	QTY	MAT'L COST	DESCRIPTION
Converter Transport Line (cont'd)			
23	Trunion Line	1 ea.	76.78
24	Transport tube	1 ea.	6.69 Al.al. 6063 T6, 3.0 x 90.0 x .049 wall
25	End cap	2 ea.	.05 Al.al. 6063 T6, 2.875 dia. x .250
26	Spacer	3 ea.	.05 304 CRS, 2.875 dia. x 18 Ga
27	Feed water blkhd ftg	2 ea.	2.80 Swedgelock, 1/4 in. Bulkhead ftg. #SS-400-1-2
28	Steam line blkhd ftg	2 ea.	3.50 Swedgelock, 3/8 in. Bulkhead ftg. #SS-600-1-4
29	Steam line	1 ea.	19.72 304 CRS, .375 dia. x .049 wall x 102.00 long
30	Union ftg	1 ea.	6.70 Swedgelock, 3/8 union, #SS-600-6
31	Feed water line	1 ea.	23.72 316 CRS, .250 tube x .035 wall x 102.00 long
32	Union ftg	1 ea.	4.60 Swedgelock, 1/4 union, #SS-400-6
33	Mineral wool	.6 ft ³	2.50 Mineral wool insulation
34	Elevation Flex Line	1 ea.	70.60 Swedgelock #SS-6HO-L6, 3/8 union type 34 long
35	Azimuth Flex Line	1 ea.	70.60 Swedgelock #SS-6HO-L6, 3/8 union type 34 long
36	Elevation Flex Line	1 ea.	6.50 United Industrial #SAE-100-R2, Type A, 1/4, 30 long
37	Azimuth Flex Line	1 ea.	6.50 United Industrial #SAE-100-R2, Type A, 1/4, 30 long

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Trolley Assembly	1 ea.	373.09	2 ea. req/system, left & right, mirror images
2 Box	1 ea.	21.21	
3 Side	2 ea.	3.67	Stl. 19.625 x 6.625 x .375
4 Partition	3 ea.	2.15	Stl. 9.50 x 6.75 x .250
5 Lid	1 ea.	7.42	Stl. 22.125 x 12.125 x .375
6 Pillow Block	3 ea.	7.97	Seal master MP16 (1 in.)
7 Shaft	1 ea.	2.42	Stl. 1018 9.0 x 1.0 dia.
8 Bolt	4 ea.	.15	7/16 - 14 x 2
9 Lock washer	4 ea.	.04	Split 7/16
10 Flat washer	4 ea.	.04	7/16
11 Gear box	1 ea.	77.25	Dayton mod. 4Z008
11A Mounting feet	1 pr.	5.52	Dayton 6 x 500
12 Sprocket	1 ea.	13.32	Morse TLB 319-2H
13 Bushing	1 ea.	3.82	Morse TL 1008
14 Bolt	4 ea.	.15	7/16 - 14 x 2
14A Lock washer	6 ea.	.04	7/16
15 Nut	2 ea.	.06	7/16

ITEM	QTY	MAT'L COST	DESCRIPTION
Trolley Assembly (cont'd)			
16	D.C. Motor	1 ea.	91.59 Dayton mod 2M168 (1/2 HP)
17	Conduit fitting	1 ea.	1.45 T&B 2520 Streign relief
17A	Reducer	1 ea.	.30 T&B 610 (3/4 to 1/2)
18	Bolt	4 ea.	.05 3/8 - 16 x 1
19	Drive chain	1 ea.	5.75 Cullman #35-2, 3/8 pitch (5 ft. long)
20	Sprocket	1 ea.	20.00 Morse TLB 360-2 PT 117950
21	Bushing	1 ea.	4.63 Morse TL 1610
22	Bearing Block	4 ea.	7.98 Seal master SF-16C (1 in.)
23	Roller	2 ea.	61.20
24	Shaft	2 ea.	2.85 Stl. 1018 1.0 dia. x 17.0
25	End	4 ea.	2.44 Stl. 7.75 dia. x .250
26	Body	2 ea.	9.25 Stl. tube 6.75 dia. x 7.75 x .50 wall

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Altitude Mechanism	1 ea.	601.37	
2 Bearing Assembly	1 ea.	111.93	
3 Outer tube	1 ea.	52.22	Stl. Const. tube 82.50 x 7.50 \pm .023 I.D. x .375 wall
4 Grease fitting	2 ea.	.20	Zerks (straight)
5 Inner tube	1 ea.	48.33	Stl. Const. tube 26.50 x 7.48 \pm .022 O.D. x .250 wall
6 "O" ring	2 ea.	1.07	.125 x 7.50 I.D. (Buna-n)
7 Retainer	2 ea.	.58	.250 x 7.50 I.D. x 8.25 O.D. (from .375 wall tube)
8 Screw	16 ea.	.26	6 - 32 x 1/2 Socket head
9 Bolt	16 ea.	.06	3/8 - 16 x 1
10 Bolt	16 ea.	.08	3/8 - 16 x 1 3/2
11 Lockwasher	16 ea.	.04	3/8
12 Nut	16 ea.	.04	3/8 - 16
13 Elevation Link	1 ea.	11.14	
14 Rod end	2 ea.	4.82	Morse TM-10Y, 5/8 - 18
15 Body	1 ea.	1.50	Stl. rod, 1.25 dia.
16 Elevation Drive	1 ea.	412.60	
17 D.C. motor	1 ea.	91.59	Dayton, D.C. Motor, 1/2 HP
18 Conduit fitting	1 ea.	1.70	

ITEM	QTY	MAT'L COST	DESCRIPTION
Altitude Mechanism (cont'd)			
Elevation Drive (cont'd)			
19	Gear box	1 ea. 278.13	Browning Reducer 300 DCR-LE1800
20	Hub	1 ea. 23.07	Browning HR-1
21	Bushing	1 ea. 14.05	Browning R-1 1 1/4 in. Bore, type 1
22	Mounting bolt	4 ea. .21	1/2 - 13 x 2
23	Nut	4 ea. .11	1/2 - 13
24	Lock washer	4 ea. .10	1/2
25	Washer	4 ea. .10	1/2
26	Drive plate	1 ea. 1.98	Stl. 5.50 x 10.875 x .625

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Bearing Collar Assembly (El.)	1 ea.	36.05	
2 Collar	1 ea.	5.80	Stl., 8.0 O.D. x 2.00 x .375 wall, Welded Drawn Tube
3 Gimbal end plate	1 ea.	29.29	H.R.C. Stl. 13.375 x 10.50 x 50
4 Bolt	8 ea.	.08	3/8 - 16 x 1 1/2
5 Nut	8 ea.	.04	Hex 3/8 - 16
6 Bearing Collar Assembly	1 ea.	29.65	
7 Collar	1 ea.	5.80	Stl., 8.0 O.D. x 2.00 x .375 wall, Welded Drawn Tube
8 Gimbal end plate	1 ea.	22.89	H.R.C. Stl. 10.50 x 10.50 x 50
9 Bolt	8 ea.	.08	3/8 - 16 x 1 1/2
10 Nut	8 ea.	.04	Hex 3/8 - 16

ITEM	QTY	MAT'L COST	DESCRIPTION
1	Steam Engine OG-3	1 ea.	123.13
2	Sleeve Valve Assy. (set)	1 ea.	3.75
3	Rest Piston Assy. (set)	1 ea.	3.90
4	Head Assy.	1 ea.	35.57
5	Case (Housing) Assy.	1 ea.	57.50
6	Crank Case Assy.	1 ea.	15.31
7	Valve Rod Retainer	2 ea.	2.05
8	Piston Rod Retainer	2 ea.	2.05
9	Misc., Sealer, etc.	A/R	3.00
			Total

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Sleeve Valve Assembly (set)	1 set	3.75	Subtotal
2 Valve sleeve	2 ea.	.25	Stl. seamless tube, 4.935 x 1.25 O.D. x .065 wall
3 Body	2 ea.	.30	Al.al. 7075, .995 dia. x 3.825
4 Ring	16 ea.	.12	Cast iron, .995 I.D. x .050 wall x .062 thick x .125 gap
5 Connecting rod	2 ea.	.25	Stl. .312 dia. x 6.81
6 Set screw	2 ea.	.06	Allen socket 1/4 - 28 x 1/4
7 Rod nut	2 ea.	.05	Hex 3/8 - 24

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Rod and Piston Assy.	2 ea set	3.90	Subtotal
2 Piston	2 ea.	.25	Stl. (1010 etc.) 2.010 dia. x 1.147
3 Connecting rod	2 ea.	.25	Stl. (1010 etc.) .437 dia. x 7.937
4 Piston "jam" nut	2 ea.	.15	Hex nut, 7/16 - 18 (tapered)
5 Ring	8 ea.	.20	Cast iron, 1.830 O.D. x .080 wall x .062 thick x .260 gap
6 Cylinder	2 ea.	.50	Stl. tube, seamless - 2.250 O.D. x 2.125 I.D. x 5.00 long

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Head Assembly	1 ea.	35.57	Subtotal
2 Yoke slide bearing rtr.	1 ea.	.40	Al.al. 7075-T651, 3.838 x 1.275 x .762
3 Breather	1 ea.	.08	Pipe plug, 1.4 pipe sq. head
4 Retainer bolt	2 ea.	.10	Allen socket, cap screw 5/16 - 18 x 1
5 Heat plate	1 ea.	1.95	Al.al. 7075-T651, 7.875 x 4.890 x .500
6 Dowel pin	2 ea.	.02	Drill rod, .250 dia. x .750
7 Plug	1 ea.	.10	Allen socket, 1/4 pipe plug
8 Value clearance inspection plug	2 ea.	.08	Pipe plug, 1/4 sq. head
9 Cylinder clearance inspection plug	2 ea.	.10	Allen socket, 1/4 pipe plug
10 "O" ring	1 ea.	.05	1.00 O.D. x .125, rubber
11 Head bolt	7 ea.	.20	Allen socket, cap screw 5/16 - 18 x 7
12 Piston port sect. head	1 ea.	2.45	Al.al. 7075-T651, 7.875 x 4.890 x .635
13 Dowel pin	2 ea.	.02	Drill rod, .250 dia. x .750
14 "O" ring	2 ea.	.05	1.650 O.D. x .125, rubber
15 "O" ring	1 ea.	.10	3.00 O.D. x .125, rubber
16 "O" ring	1 ea.	.20	12.00 O.D. x .125, rubber

ITEM	QTY	MAT'L COST	DESCRIPTION
Head Assembly (cont'd)			
17	Valve port sect. head	1 ea. 4.43	Al.al. 7075-T651, 7.875 x 4.890 x 1.150
18	Bypass port plug	2 ea. .12	Hex head, 3/8 pipe plug
19	Piston port plug	2 ea. .10	Allen socket, cap screw 5/16 - 18 x 3/4
20	Dowel pin	2 ea. .02	Drill rod, .250 dia. x .750
21	"O" ring	2 ea. .10	2.5 O.D. x .125, rubber
22	"O" ring	2 ea. .06	1.335 O.D. x .125, rubber
23	Block	1 ea. 9.63	Al.al. 7075-T651, 7.785 x 4.890 x 2.50
24	Bypass valve	2 ea. 1.85	Standard 1/4 brass needle valve, 3/8 pipe mounting
25	"O" ring	2 ea. .10	3.00 O.D. x .125, rubber
26	"O" ring	2 ea. .05	.718 O.D. x .125, rubber
27	Intake manifold	1 ea. .62	Al.al. 7075-T651, 3.820 x 2.610 x .620
28	"O" ring	1 ea. .10	3.00 O.D. x .125
29	Mounting bolt	4 ea. .10	Allen socket, cap screw 5/16 - 18 x 1

	ITEM	QTY	MAT'L COST	DESCRIPTION
1	Valveport sect case	1 ea.	4.43	Al.al. 7075-T651, 7.875 x 4.890 x 1.150*
2	Bypass port plug	2 ea.	.12	Hex head, 3/8 pipe plug
3	Piston port plug	2 ea.	.10	Allen socket, cap screw 5/16 - 18 x 3/4
4	Dowel pin	2 ea.	.02	Drill rod, .250 dia. x .750
5	"O" ring	2 ea.	.10	2.5 O.D.
6	"O" ring	2 ea.	.06	1.335 O.D. x .125, rubber
7	Piston port sect case	1 ea.	2.45	Al.al. 7075-T651, 7.875 x 4.890 x .635*
8	Dowel pin	2 ea.	.02	Drill rod, .250 dia. x .750
9	"O" ring	2 ea.	.05	1.650 x .125, rubber
10	"O" ring	1 ea.	.10	3.00 x .125, rubber
11	"O" ring	1 ea.	.20	12.00 x .125, rubber

*(same as head sect)

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Case (Housing) Assy.	1 ea.	57.50	Subtotal
2 Case Outer Cover	1 ea.	14.04	Al.al. 7075-T651, 22.60 x 10.02 x .620
3 Screw	24 ea.	.04	FH.CSK. Slot, 5/16 - 18 x 1 Machine Screw
4 Plug	1 ea.	.08	1/4 Pipe plug Sq. Ho.
5 Inner bearing cover	1 ea.	2.14	Al.al. 7075-T651, 7.5 x 7.5 x .38
6 Cover screw	6 ea.	.04	FH.CSK. Slot M.S. 3/8 - 16 x .75
7 Flange bearing	2 ea.	2.87	Seal Master, #SF-23C (Mod. per Dwg.)
8 Bearing separator	1 ea.	5.62	Al.al. 7075-T651, 4.74 x 4.74 x 2.50
9 Access hole plug	2 ea.	.08	1/4 pipe plug, Sq. No.
10 Outer bearing cover	1 ea.	1.12	Al.al. 7075-T651, 4.74 x 4.74 x .50
11 Bearing stud	4 ea.	.15	Stl., threaded rod, 1/2 - 13 x 5.25
12 Nut	4 ea.	.06	Hex, Stl., 1/2 - 13
13 Crank Shaft	1 ea.	3.68	Stl. Drill Rod (Shafting) 1.437 dia. x 11.62
14 Case Side Plate "A"	1 ea.	7.52	Al.al. 7075-T651, 22.06 x 5.50 x .620
15 Slider mount bolt	2 ea.	.04	Allen socket, 5/16 - 18 x 3/4
16 Fixt point bolt	1 ea.	.04	Allen socket, 5/16 - 18 x 3/4
17 Case Side Plate "B"	1 ea.	7.52	Al.al. 7075-T651, 22.06 x 5.50 x .620
18 Slider mount bolt	2 ea.	.04	Allen socket, 5/16 - 18 x 3/4
19 Case End Plate	1 ea.	3.83	Al.al. 7075-T651, 11.24 x 5.50 x .62
20 Dowel pin	2 ea.	.02	Drill rod, .250 dia. x .750
21 Screw	8 ea.	.04	FH.CSK. Slot M.S., 3/8 - 16 x 1 1/2

	ITEM	QTY	MAT'L COST	DESCRIPTION
	Case (Housing) Assy. (cont'd)			
22	Case Cover	1 ea.	2.53	Al.al. 7075-T651, 15.375 x 8.812 x .187
23	Screw	8 ea.	.04	FH.CSK. Phil. M.S., 5/16 - 18 x .50
24	Piston Rod Slider	2 ea.	.30	Al.al. 7075-T651, 6.00 x 2.00 x .250

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Crankcase Assy. (Internal)	1 ea.	15.31	Subtotal
2 Piston Rod End	2 ea.	.50	Al.al. 7075-TL51, 2.0 x 2.0 x 1.25
3 Screw "	2 ea.	.05	Allen socket cap screw 5/16 - 24 x .250
4 Valve Rod End	2 ea.	.11	Al.al. 7075-T651, .625 x .625 x 2.70
5 Piston Rod Yoke	2 ea.	.60	Std. Heavy Duty Sprocket Chain Master Link (1.25)
6 Valve Rod Yoke	2 ea.	.60	Std. Heavy Duty Sprocket Chain Master Link (1.50)
7 Linear Bearing Shaft	1 ea.	.45	Brass tube, .750 O.D. x .500 I.D. x 9.562
8 Shaft End	1 ea.	.46	Morse Shaft End
9 Valve Link Arm	1 ea.	.16	Al.al. 7075-T651, 4.20 x .62 x .62
10 Valve Lnk Arm Fxer Pnt	1 ea.	.10	Al.al. 7075-T651, .87 x .87 x 1.25
11 Valve Rocker	1 ea.	1.28	Al.al. 7075-T651, 6.00 x 4.25 x .500
12 Bearing retainer	1 ea.	.10	Al.al. 7075-T651, 1.875 dia. x .500
13 Bolt	4 ea.	.06	Mod per Dwg. 4200047
14 Piston Rocker	1 ea.	6.73	Al.al. 7075-T651, 8.125 x 5.75 x 1.44
15 Counterthrow Inner	1 ea.	.55	Stl. (1010 etc.), 3.6 x 3.6 x .62
16 Bolt	4 ea.	.06	Mod. per Dwg. 4200048
17 Counterthrow Outer	1 ea.	.55	Stl. (1010 etc.), 3.6 x 3.6 x .62
18 Throwbushing "B"	1 ea.	.25	Al.al. 7075-T651, 2.68 dia. x 1.25
19 Bolt	8 ea.	.06	Mod. per Dwg. 4200047

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Valve Rod Packing Retainer	2 ea.	2.05	Subtotal
2 Body	2 ea.	.45	Al.al. 7075, 3.00 dia. x 1.690
3 Packing Nut	2 ea.	.25	Stl (1010 etc.), 7.150 dia. x 1.00
4 Packing	A/R	.25	
5 Mounting Bolt	4 ea.	.10	Hex, Cap 5/16 - 24 x 1.00
6 Piston Rod Packing Retainer	2 ea.	2.05	Subtotal
7 Body	2 ea.	.45	Al.al. 7075, 3.00 dia. x 1.690
8 Packing Nut	2 ea.	.25	Stl (1010 etc.), 1.150 dia. x 1.00
9 Packing	A/R	.25	
10 Mounting Bolt	4 ea.	.10	Hex, Cap 5/16 - 24 x 1.00

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Condenser Assembly	1 ea.	41.85	
2 Body	1 ea.	15.00	CRS 36.00 x 28.25 x .060
3 Header plate	2 ea.	1.00	CRS 6.00 dia. x .060
4 Tubes	19 ea.	.80	CRS Tube 31.25 x .500 dia. x .035 wall
5 End plate	2 ea.	1.00	CRS 6.00 dia. x .060
6 Water jacket cplng	2 ea.	.90	CRS 1/2 in. pipe coupling
7 Inlet coupling	1 ea.	1.25	CRS 1 in. pipe coupling
8 Outlet coupling	1 ea.	1.60	CRS 1- 1/4 in. pipe coupling
9 Welding rod, etc.	A/R	3.00	--

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Preheater Assembly	1 ea.	20.40	
2 Body	1 ea.	6.00	Tube Cu. 2.625 O.D. x 15.50 x .060 wall
3 Coil	1 ea.	4.00	CRS tube, .250 dia. 28 turns wound on 1.8 dia. mandrill (approx. 100 in.)
4 Reducer	2 ea.	2.40	Cu. fitting, 2.5 to 1.5, end cap reducer
5 Elbow	2 ea.	1.80	Cu. fitting, 1.625
6 Welding rod, etc.	A/R	2.00	

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Hotwell	1 ea.	797.96	
2 Tank	1 ea.	450.00	Corrugated Stl. (16 Ga) Galvanized includes lid & fittings (850 gal)
3 Insulation	A/R	25.00	4.5 in. coat of polyurethane foam
4 Heat exchanger	1 ea.	12.00	Cu tube 1/2 in.-15 ft long (circulated around inside)
5 Cooler	1 ea.	72.00	"Finn Tube" 16 ft. (4.50/ft)
6 Shield	1 ea.	9.35	Stl. (13.0 dia. x 3.20 high) 41.0 x 32.0 x 16 Ga
7 Output pump	1 ea.	49.66	Teel #1P798
8 Motor	1 ea.	109.34	Dayton #2M168
9 Jaw Coupling	1 ea.	4.56	Gerbing-Elgin #G-100 5/8
10 Mount	1 ea.	2.35	Stl. 24 x 14 x 14 Ga
11 Solenoid valves	2 ea.	13.43	Skinner Electric #LC20B41
12 Thermostat	1 ea.	19.66	Dayton #7738
13 Misc. Plastic Tube	A/R	2.00	
14 Misc. Fittings	A/R	3.50	3/4 pipe
15 Coupling	4 ea.	2.72	3/4 pipe
16 "T" Fitting	1 ea.	.80	3/4 pipe

ITEM	QTY	MAT'L COST	DESCRIPTION
1 Power Cart Assembly	1	2,396.89	
2 Reservoir	1	240.20	
3 Side	2	37.50	CRS (304) 11 Ga, 10.0 x 36.0
4 Top	1	60.00	CRS (304) 11 Ga, 16.0 x 36.0
5 Bottom	1	60.00	CRS (304) 11 Ga, 16.0 x 36.0
6 End	2	20.00	CRS (304) 11 Ga, 12.0 x 16.0
7 Rail	2	1.50	Stl. angle, 2.0 x 2.0 x 25 x 36.0
8 Coupling	3	1.25	CRS, 3/4 pipe
9 Equipment Mount	1	15.64	
10 Base	1	7.83	Stl. channel 3.0 x 10.0 x 36.0
11 Channel frame	2	2.60	Stl. channel 2.0 x 2.0 x .25 x 47.0
12 Enclosure	1	2.61	Stl. 10.0 x 47.0 x 10 Ga
13 Sight Glass	1	2.32	Teel #6X343
14 "T" Fitting	1	.80	3/4 pipe
15 Nipple	1	.27	3/4 pipe
16 Pump	1	68.19	Giant, #PB42K
17 Pump motor	1	122.60	Dayton, #2M168
18 Gear Reducer	1	94.36	Dayton, #47006
19 Generator	1	850.00	Fidelity #F15-36-534
20 Pully	2	13.23	Browning 3X532
21 Sustainer Motor	1	500.00	Morse #15764
22 Pully	1	13.23	Browning 3X532

ITEM	QTY	MAT'L COST	DESCRIPTION
Power Cart Assembly (cont'd)			
23	Oiler	1	56.83 Lincoln Centroiler #1812
24	Engine	1	-- See Engine Section
25	Clutch	1	245.00 Magnetic Clutch, Rockwell #45138 (90 V.D.C.)
26	Pully	1	39.13 Browning 3X571
27	Condenser	1	-- See Condenser Section
28	Thermostat	1	19.66 Dayton #7738
29	Preheater	1	-- See Preheater Section
30	Pressure gauge	1	4.78 0-.3000 PSIG - Teel #4X790
31	Pressure gauge	1	2.76 0.400 PSIG - Teel #5X938
32	High Pressure Release	1	9.86 Para-plate #BR5-3
33	Filter trap	1	12.50 Dayton 2Z925
34	Check Valve	1	8.37 Pneu-trol #CP2055
35	Tube	A/R	8.50 5/16 CRS Tube (Approx. 8 ft)
36	Tube Fittings	A/R	30.00 Stainless
37	"V" Belt	3	7.96 Grates B-43209

SUMMARY SHEET

SUB-ASSEMBLY	MATERIAL COST	LABOR MANHOURS	LABOR DOLLARS	COST PER SUB-ASSY
Receiver Assembly	378.57	11.45	91.60	470.17
Back Structure	379.17	16.25	130.00	509.17
Petal Assembly	2,877.63	7.50	60.00	2,937.63
Receiver Strut	166.00	1.70	13.60	179.60
Cantilever Support	743.98	14.40	115.20	859.18
Elevation Mechanism	586.14	4.25	34.00	620.14
Azimuth & Trolley Assembly	642.96	8.85	70.80	713.76
Yoke Assembly	170.95	7.00	56.00	226.95
Base Assembly	326.29	7.85	62.80	389.09
Electrical	288.50	8.15	65.20	353.70
Foundation	550.05	72.79	582.28	1,132.33
Stem Engine	123.13	31.87	254.96	378.09
Condenser	41.85	2.18	17.44	59.29
Preheater	20.40	1.10	8.80	29.20
Hotwell	797.96	2.90	23.20	821.16
Power Cart	2,396.89	7.00	56.00	2,452.89
Transport	438.77	3.73	29.86	468.63
TOTALS	\$10,929.24	208.97	\$1,671.74	\$12,600.98

APPENDIX D
COST & PARTS LISTS
25,000 UNITS/YEAR

SUMMARY SHEET

SUB-ASSEMBLY	MATERIAL COST	LABOR MANHOURS	LABOR DOLLARS	COST PER SUB-ASSY
Receiver Assembly	291.20	8.02	64.12	355.32
Backup Structure	270.63	11.38	91.04	361.67
Petal Assembly	2,100.60	3.00	24.00	2,124.60
Receiver Strut	126.46	1.20	9.60	136.06
Cantilever Support	565.24	10.08	80.64	645.88
Elevation Mechanism	451.03	2.98	23.80	474.83
Azimuth & Trolley Assembly	494.69	6.20	49.60	544.29
Yoke Assembly	119.67	4.90	39.20	158.87
Base Assembly	252.46	5.50	44.00	296.46
Electrical	216.38	5.71	45.68	262.06
Foundation	385.04	67.33	538.60	920.64
Steam Engine	92.34	21.83	174.64	266.98
Condenser	31.39	1.53	12.21	43.60
Preheater	15.30	.77	6.16	21.46
Hotwell	638.37	2.04	16.32	654.69
Power Cart	1,797.66	4.90	39.20	1,836.86
Transport	329.03	1.36	10.91	339.99
TOTALS	8,177.54	158.73	1,269.72	9,447.26

SUMMARY SHEET

SUB-ASSEMBLY	MATERIAL COST	LABOR MANHOURS	LABOR DOLLARS	COST PER SUB-ASSY
Receiver Assembly	213.55	4.58	36.64	250.19
Backup Structure	155.56	6.50	52.00	207.56
Petal Assembly	1,540.29	1.34	10.72	1,551.01
Receiver Strut	93.08	.68	5.44	98.52
Cantilever Support	420.38	5.76	46.08	466.46
Elevation Mechanism	330.35	1.70	13.60	344.35
Azimuth & Trolley Assembly	362.70	3.54	28.32	391.02
Yoke Assembly	70.14	2.80	22.40	92.54
Base Assembly	198.89	3.14	25.12	224.01
Electrical	158.68	3.26	26.08	184.76
Foundation	220.02	54.59	436.71	656.73
Steam Engine	73.88	12.75	102.00	175.88
Condenser	25.11	.87	6.96	32.07
Preheater	12.24	.44	3.52	15.76
Hotwell	478.77	1.16	9.28	488.05
Power Cart	958.75	2.80	22.40	981.15
Transport	223.77	.60	4.78	228.55
TOTALS	5,536.56	106.51	852.05	6,388.61