

Report No. TE-18-66

FINAL DESIGN DOCUMENTATION
FOR
SIX-CONVERTER THERMIONIC GENERATOR DESIGN

Contract No. 951230

October 1965

by

P. J. Brosens

Prepared For
Jet Propulsion Laboratory
Pasadena, California

Approved by: George N. Hatsopoulos
G. N. Hatsopoulos,
President

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California Institute of Technology, sponsored by the
National Aeronautics and Space Administration under
Contract NAS7-100.**

NOTICE

This document includes information on Thermo Electron's materials vendors, special processes used for the cleaning and firing of vacuum grade materials, and Flow Chart procedures. This information was not developed under Contract 951230 and is considered proprietary to Thermo Electron Engineering Corporation. It is provided for use by the Jet Propulsion Laboratory with the understanding that it will not be disclosed to any third party without prior written authorization from Thermo Electron.

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SUMMARY

This Design Documentation constitutes the final report of work done by Thermo Electron Engineering Corporation on the Design of a Six-Converter Thermionic Generator for the Jet Propulsion Laboratory under Contract No. 951230. The Documentation includes the design analysis for the generator, and all drawings required for the fabrication of a generator prototype which includes an electron bombardment unit for electrical heating. In addition, suggested materials suppliers, treatment of parts, assembly flow charts, and assembly instructions are given.

NOMENCLATURE

A _i	Absorptivity of cavity surface i
B	Effective emissivity of shielded surface
C _{ij}	Conduction heat transfer coefficient between elements i and j, watts/ ^o K
D _m	Mirror diameter, in.
D	Cavity aperture diameter, in.
e	Cylinder height of converter heat loss area, cm.
E _i	Emissivity of cavity surface i
f	Focal length, in.
F _i	Fraction of solar input striking surface i
F _{ij}	View factor from surface i to surface j
H	Distance from bottom of cavity to pseudo flux source, cm.
H _i	Total thermal flux input arriving at surface i
ℓ	Longitudinal thermal expansion, mils
P _i	Radiative power of black body at temperature T _i , watts/sq. cm.
P _{ii}	Thermal flux radiated directly by all cavity surfaces to surface i, watts
Q _i	Net heat input to surface i, watts
QC	Net heat received by emitter piece of each converter, watts
r	Radial thermal expansion, mils
R _i	Radial dimension of cavity surface element i, cm.
S _i	Surface area of cavity element i, sq. cm.
t	Thickness of support sleeve, rear cavity piece and thickness of electron bombardment unit support element, mils
T _i	Temperature of surface i, ^o K
V _i	Total solar flux arriving at surface i, watts

W_i	Input solar flux striking surface i , watts
W	Total solar flux entering generator cavity, watts
Y	Intermediate function for the calculation of view factors
Z_i	Cavity dimension of element i , cm
ϵ	Change in critical clearance, mils
θ_i	View angle from pseudo flux source to element i , degrees
ψ_i	Solid view angle to element i , steradians

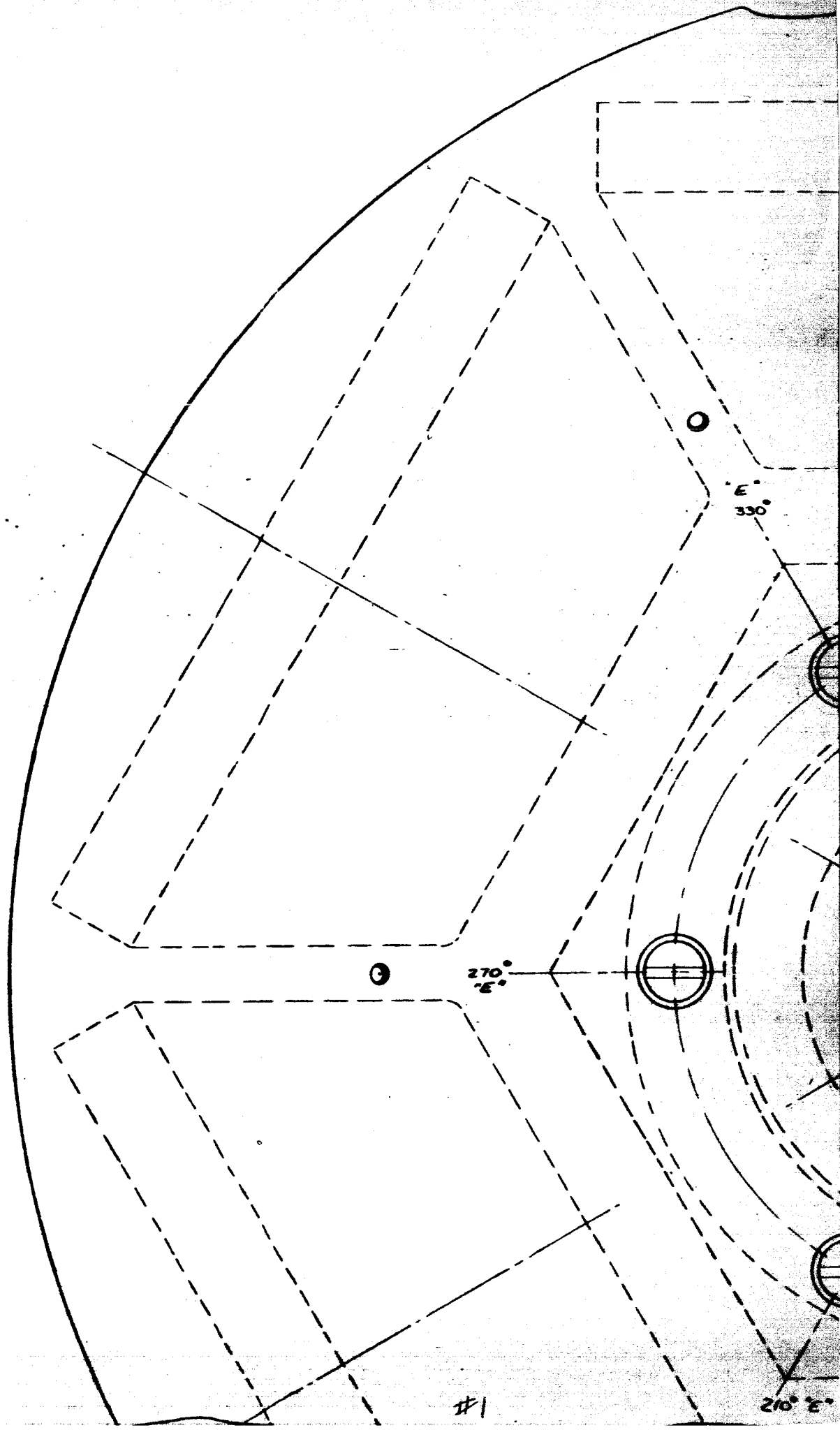
1.1 Preliminary Design of 6-Converter Generator

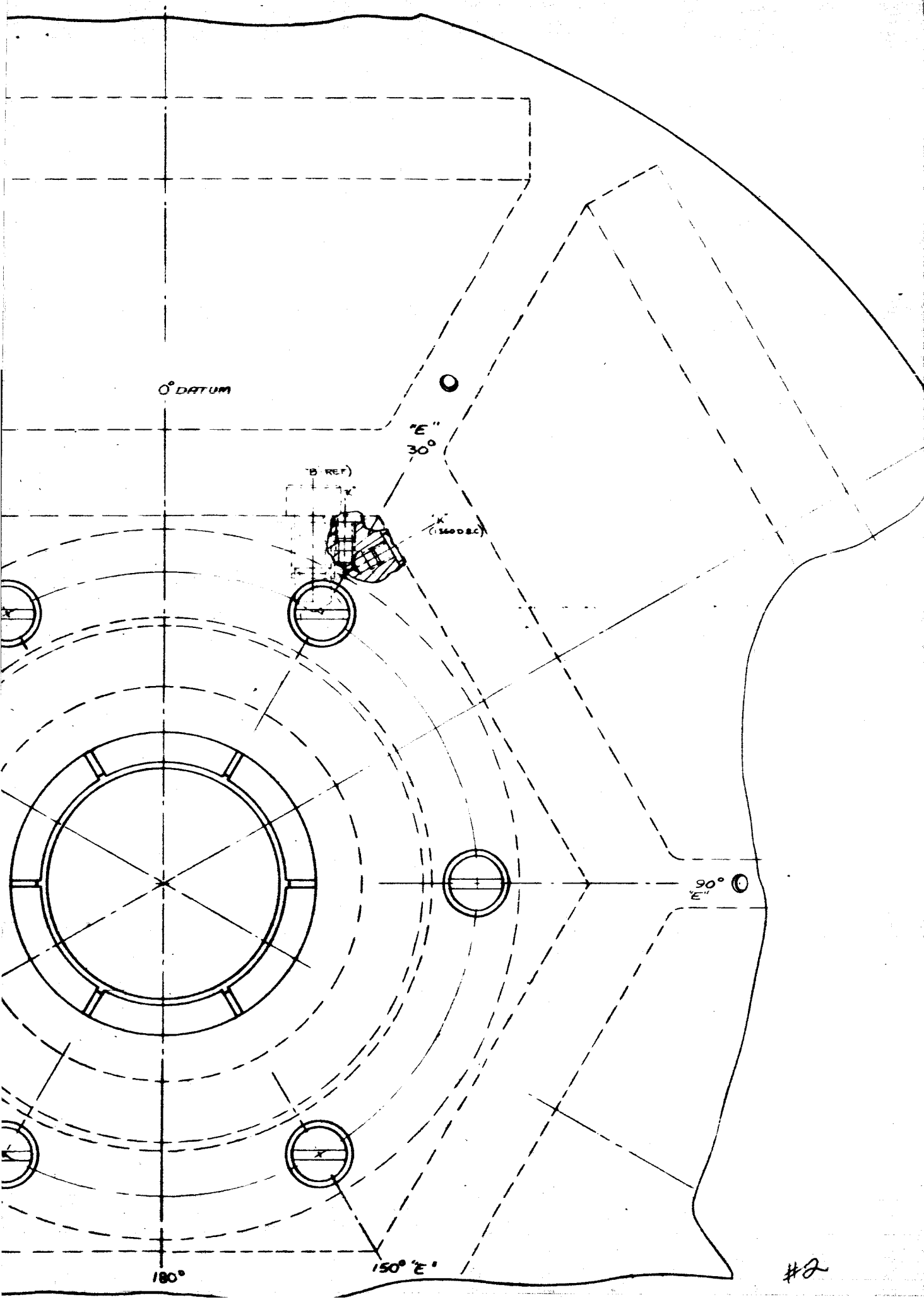
The preliminary layout of the 6-converter generator as submitted to JPL is shown on Figures 1, 2 and 3, TEE Dwg. 550-1000, Sheets 1, 2 and 3. These show correspondingly the geometry of the generator, the shoe-piece modifications required to the Series VIII converter, and the required support structure for mounting the generator in the JPL vacuum chamber.

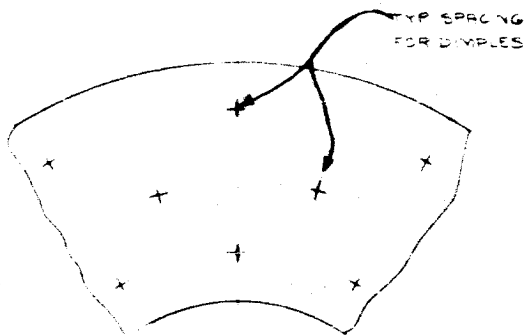
The geometry of the generator selected attempts meeting specified design conditions:

1. All converters must have identical view angles to the heat source to insure uniform heating.
2. All converters must remain compatible for use in Generator JG-3, developed under JPL Contract 950671.
3. The generator must be compatible with a concentrator having a rim angle of 55 degrees.
4. Radiation shield shapes must be such as not to distort as a result of time at temperature or thermal cycling.
5. The generator must be capable of handling its heat transfer in a completely autonomous manner.

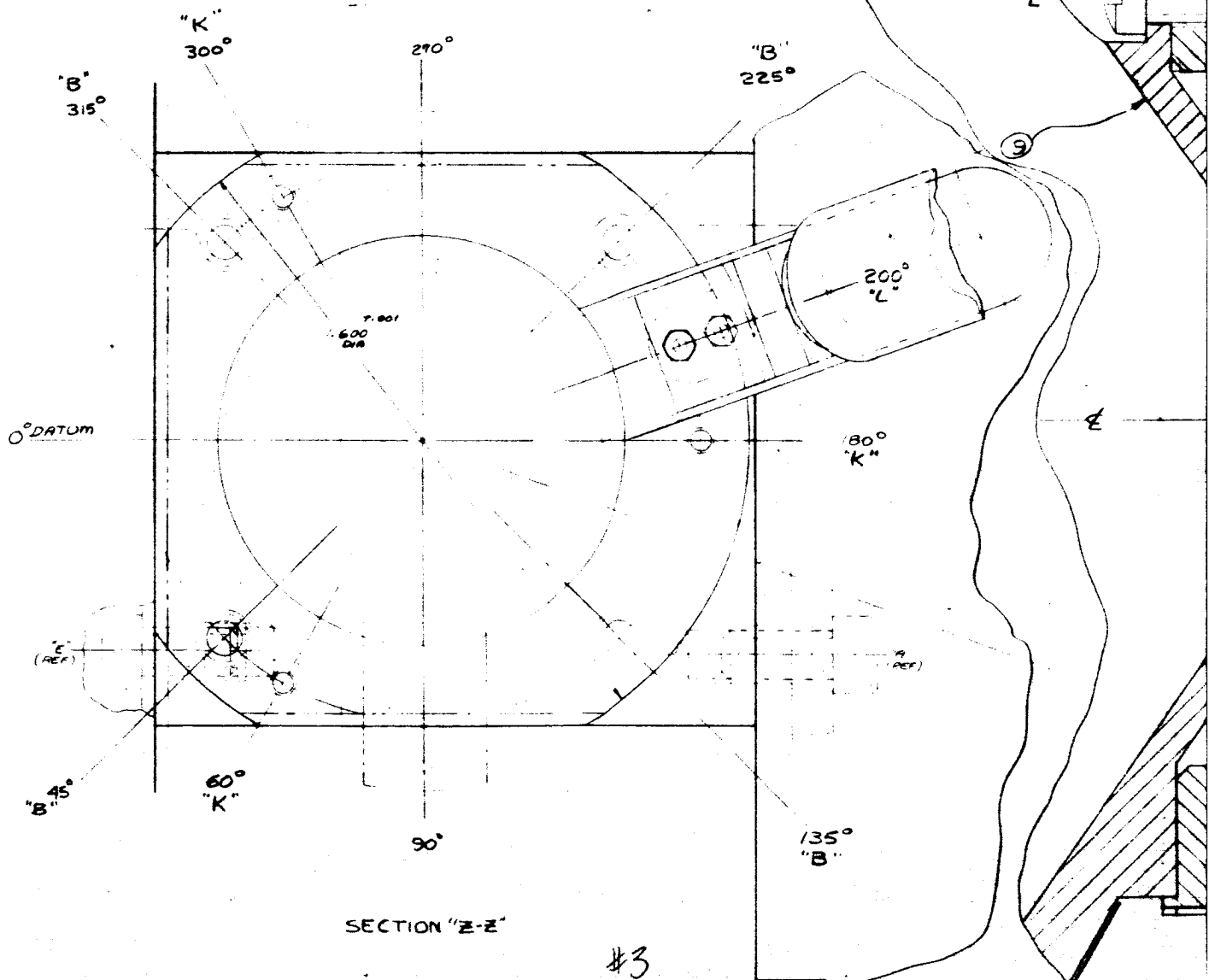
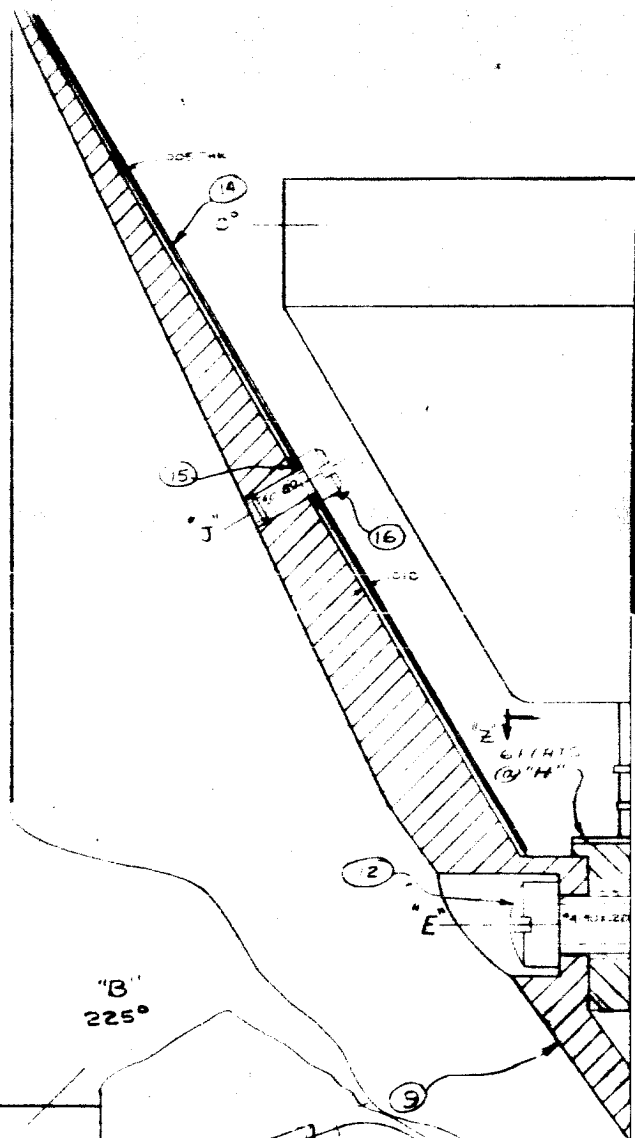
To meet the first condition, it is evident that in order for the 6 converters to have an identical view angle of the heat source, their principal axis of symmetry must be symmetrically located on a conical surface. The apex angle of this cone defines the "angle of tilt" of the converters with respect to the optical axis of the generator. For an apex angle of 180° , the axes of symmetry of the converters lie like the radial spokes of a wheel. A preliminary design evaluation indicated that for any apex angle less than 180° , a mechanical interference between the radiators of the converters is produced, unless the converters are moved away from the optical axis. However, such modification of the converter







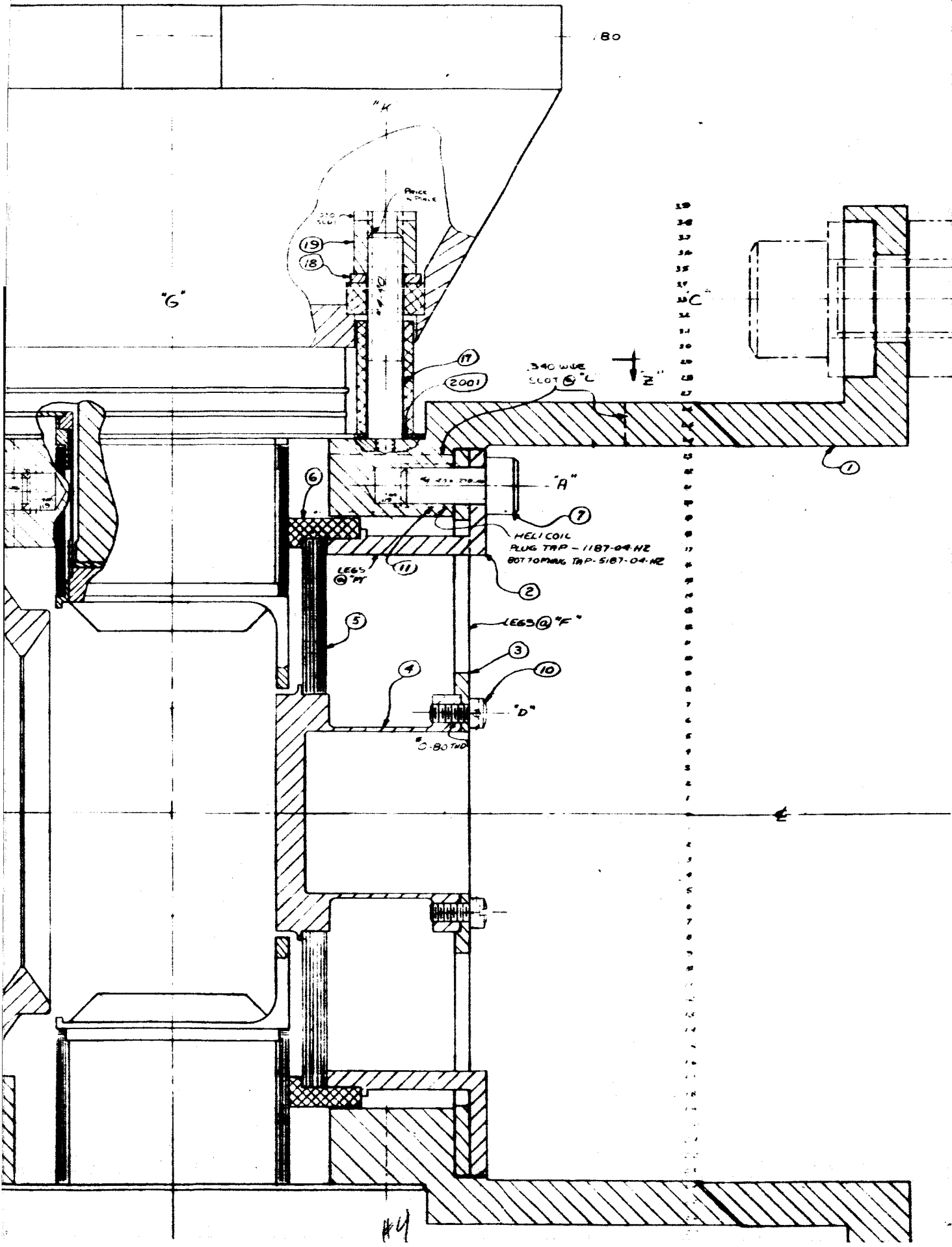
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SHOW DIMPLE PATTERN

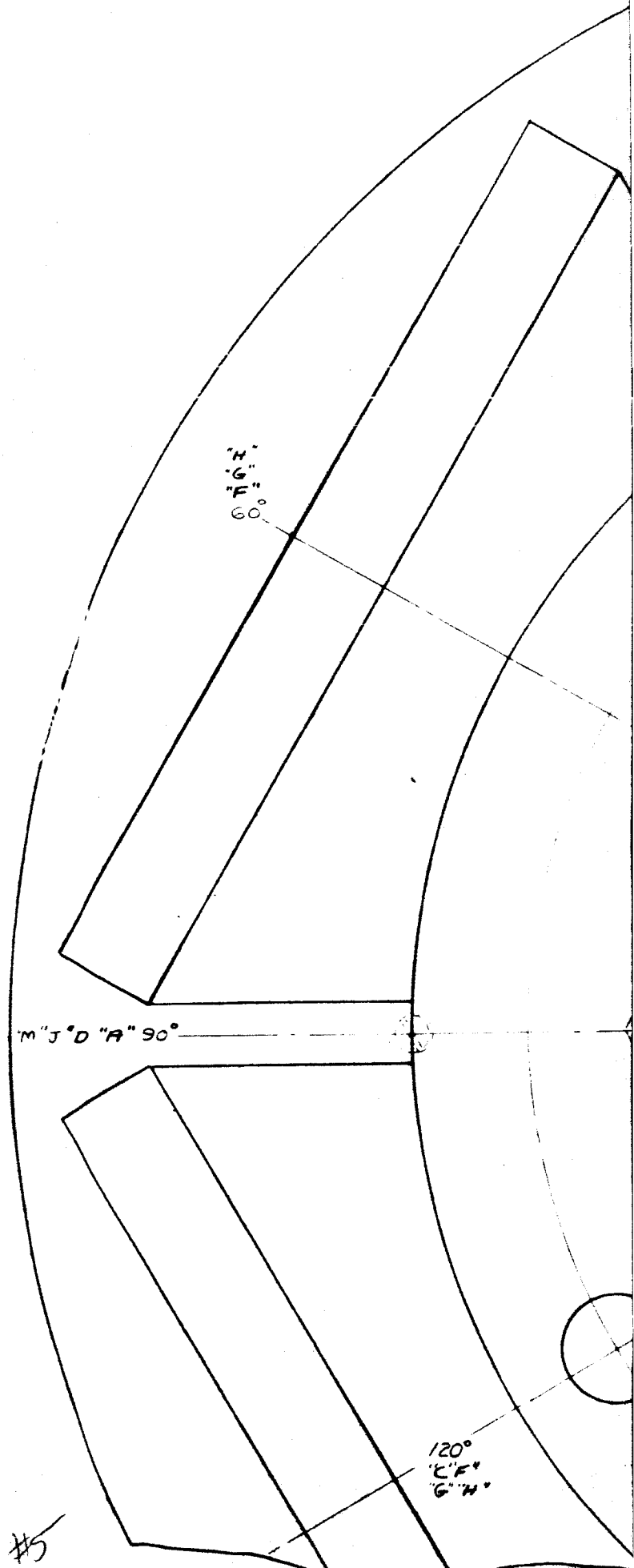
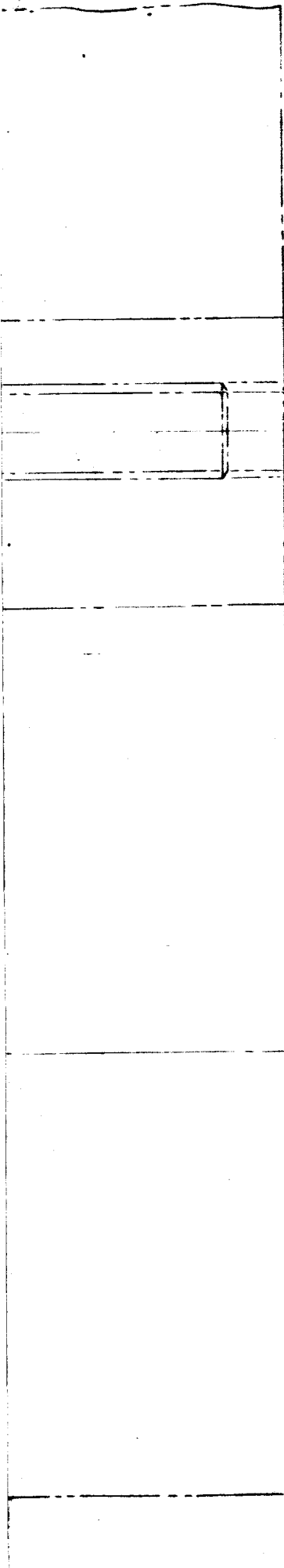


SECTION "Z-Z"

270° FAR SIDE

90° NEAR SIDE





#5

3 DATUM
"C" "D" "F" "G" "H"

"M"
"J"
"A"
30°

330°
"D" "J" "B"

(B)
B
(TAPED & EACH FLAT)
1.360 DIA B.C.
H5 - COIL
PLUS TAP - 1187.042 HZ
BOTTOMING TAP - 5.87 OR HZ

13

150°
"A" "J" "M"

180°
"D" "F" "G" "H"

310°
"A" "J" "M"

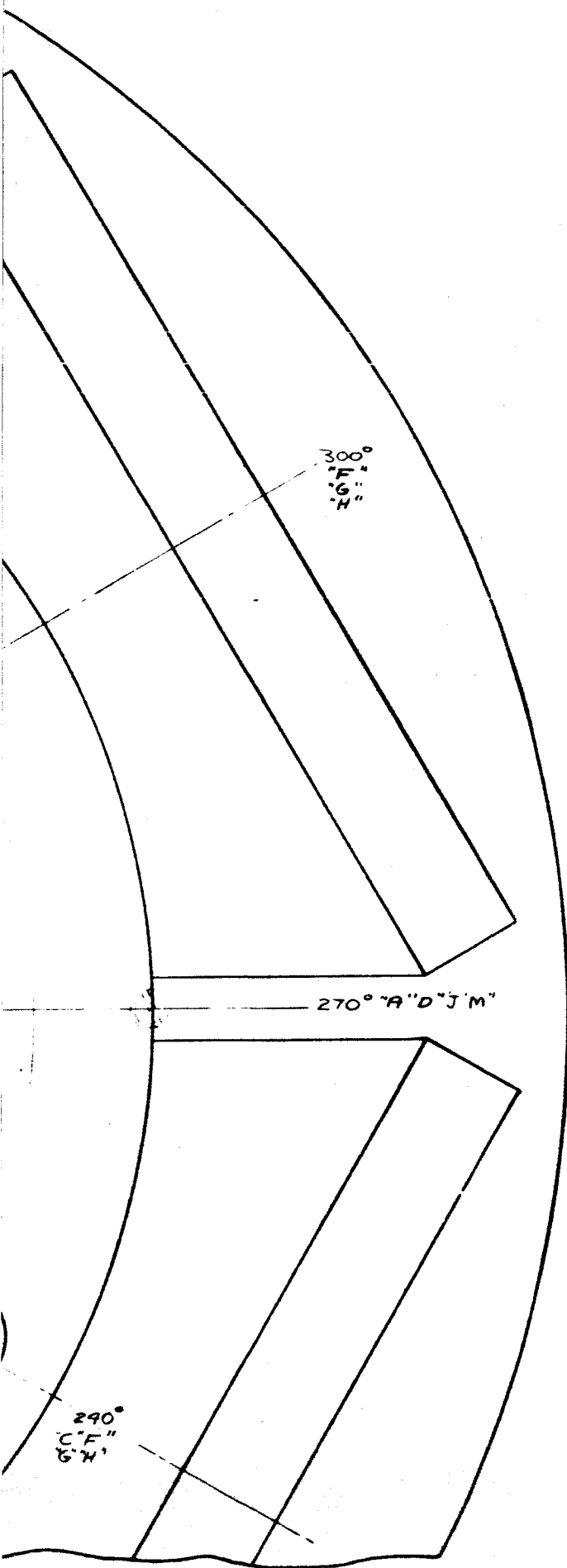


FIGURE 1

- 7 SEE FIXTURE LAYOUTS (3090, 3190 ETC.) FOR FIXTURE INFORMATION.
- 6 UNK = UNKNOWN N.D = NO DRAWING, PROCURE FROM THIS L.O.
- 5 DOTTED LINES INDICATE ROUGH OR PRELIMINARY MACHINING.
- 4 ALL MATING CORNERS & FILLETS ARE .015 X 45° CNFR. AND .010 R. RES.
- 3 MAX. PERMISSABLE TAP DRILL DEPTH AND MIN. PERMISSABLE FULL THREAD DEPTHS ARE SHOWN.
- 2 SECTION LOCATIONS DEFINED BY LETTER LOCATION AT END VIEW.
- 1 NOTES 2 THRU 7 APPLY UNLESS OTHERWISE SPECIFIED.

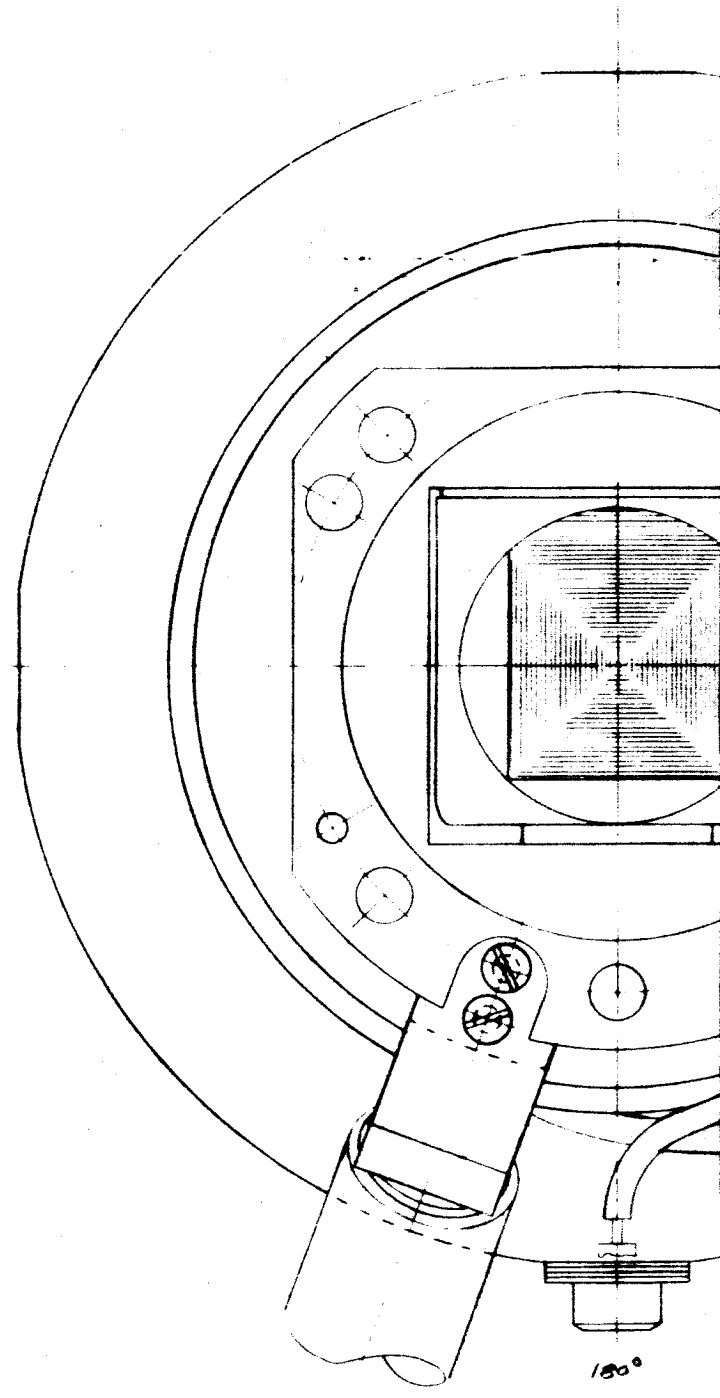
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II																									
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PART				SIZE		REV		REQ		MAT L	
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DECIMAL .X1.03, .XK±.01, .XXX±.000 FILET RADIUS .040 MAXIMUM THREADS: CLASS 2 IF DIA. CONC. WITHIN TIR ALL OTHER DIA. CONC. WITHIN .005 TIR SURFACES TO BE PERF. WITHIN .005 TIR SURFACES TO BE PAR. WITHIN .005 TIR HOLE ANULAR TOL. 0-2.0 RAD.±.05" 2.0-4.0 RAD.±.05" ALL OTHER ANULAR TOL. TO BE ±.0°-30° REMOVE ALL BURRS AND EDGES											
SCALE: 5X1				FINISH							
NEXT ASSY.				SIMILAR TO							
NOTES THERMO ELECTRON 1000 WEST 10TH AVENUE, SUITE 100 MT. PLEASANT, S. DAKOTA 57128											
DRAWN				CHECKED				ENGINEER			
DATE				1/6-14				SIGNATURE			
TITLE:											
S X CONVERTER GENERATOR											
SIZE		DRAWING NUMBER		REV		REV		REV		REV	
11		EFO-1000		1							

0° DATUM

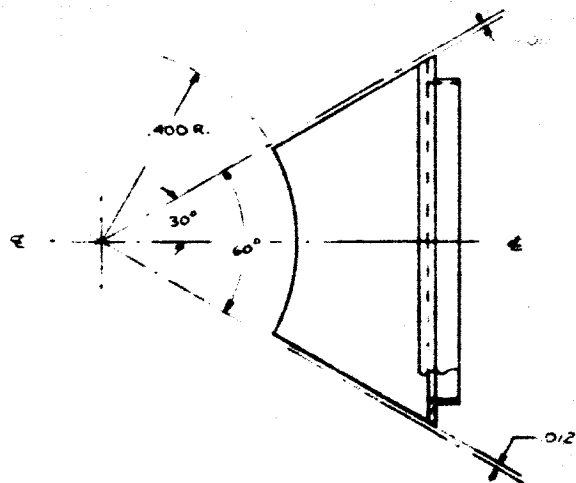
270°



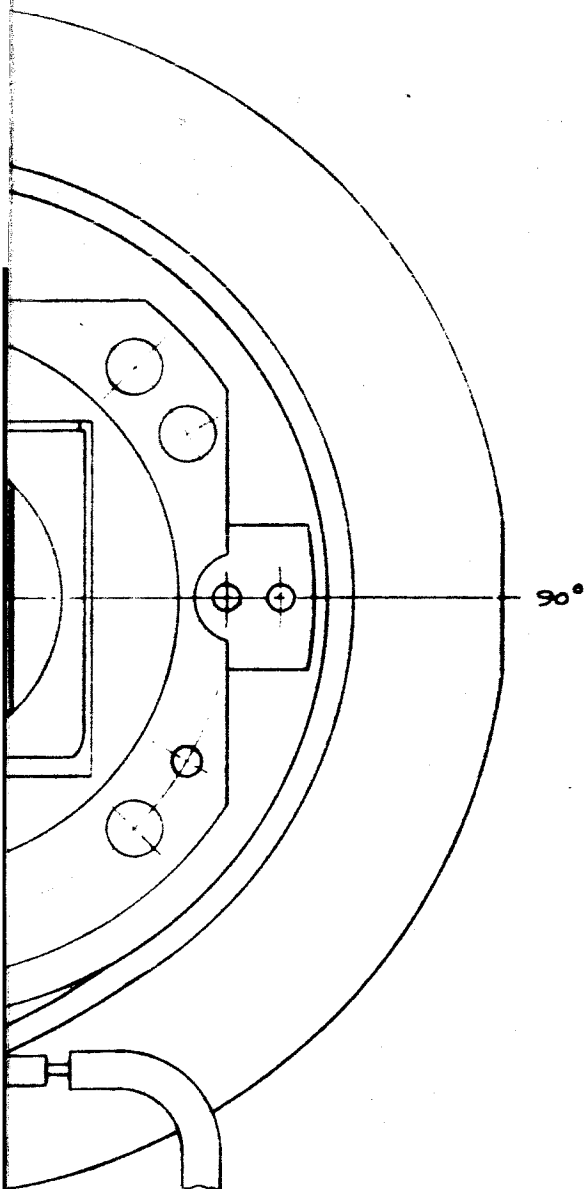
180°

#1

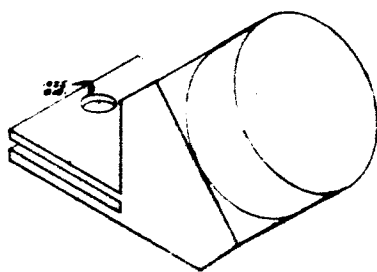
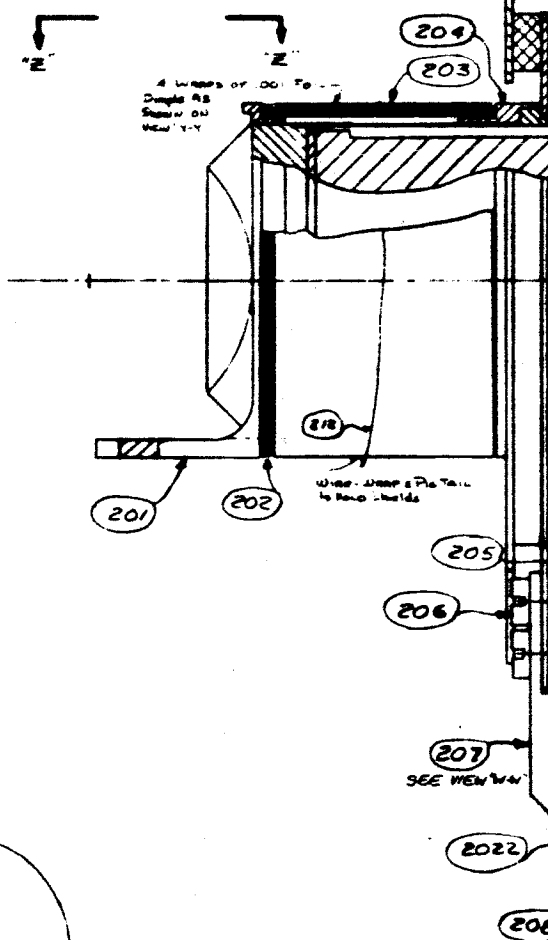
200°
"A"



SECTION "E-E"
PN 201 SHOWN ONLY



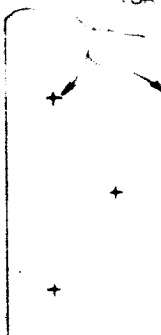
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17



PN 207
(SHOWN FOR CLARIFICATION)
VIEW "W-W"

479-1000

TYP
FOR



(DEV. L.S. 1000)

VIEW "Y-Y"

2021

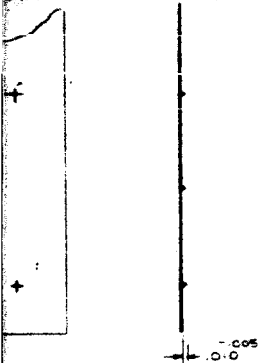
209

210

211

#3

SPACING
DIMPLES



9.0 App. Rev.

FIGURE 2

- 7 SEE FIXTURE LAYOUTS (3090, 3190 ETC.) FOR FIXTURE INFORMATION.
- 6 UNK - UNKNOWN ND - NO DRAWING, PROCURE FROM THIS L.O.
- 5 DOTTED LINES INDICATE ROUGH OR PRELIMINARY MACHINING.
- 4 ALL MATING CORNERS & FILLETS ARE .015 X 45° CHFIL. AND .010 R. RES.
- 3 MAX. PERMISSABLE TAP DRILL DEPTH AND MIN. PERMISSABLE FULL THREAD DEPTHS ARE SHOWN.
- 2 SECTION LOCATIONS DEFINED BY LETTER LOCATION AT END VIEW.
- 1 NOTES 2 THRU 7 APPLY UNLESS OTHERWISE SPECIFIED.

NOTES

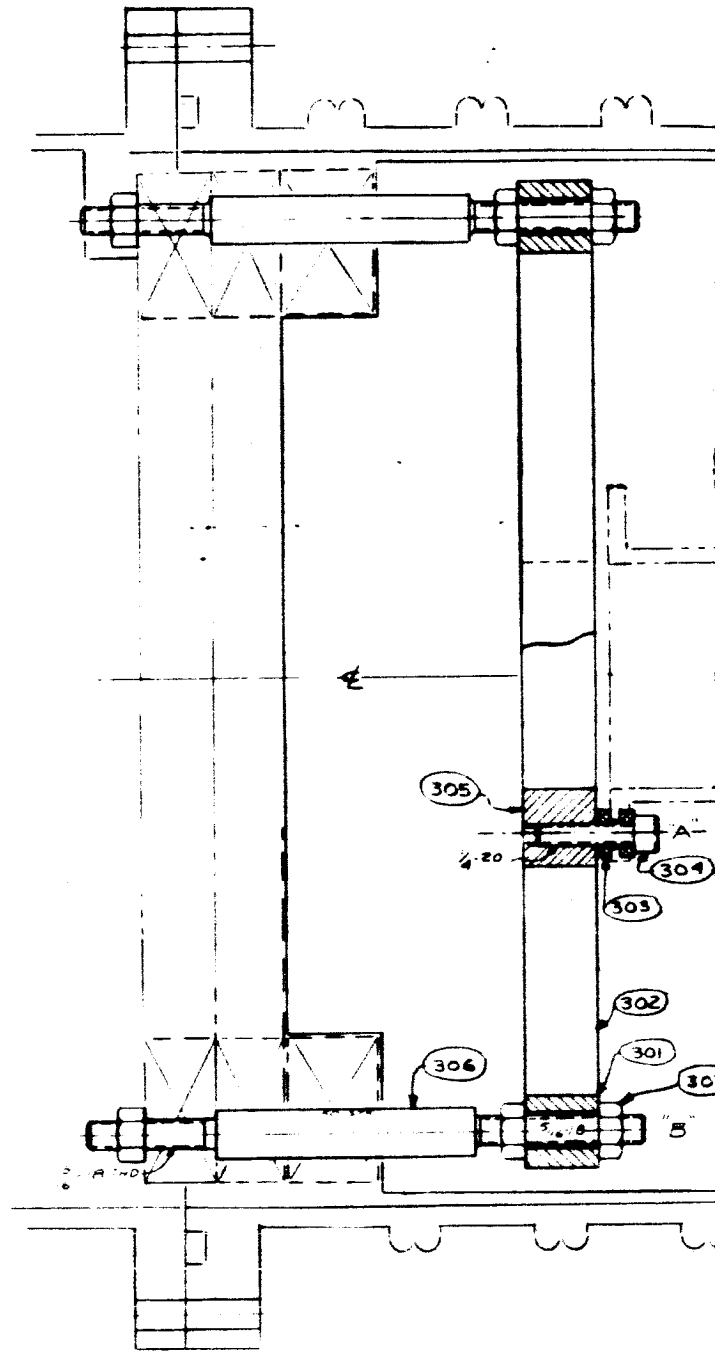
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V												
II												
A												
Q												

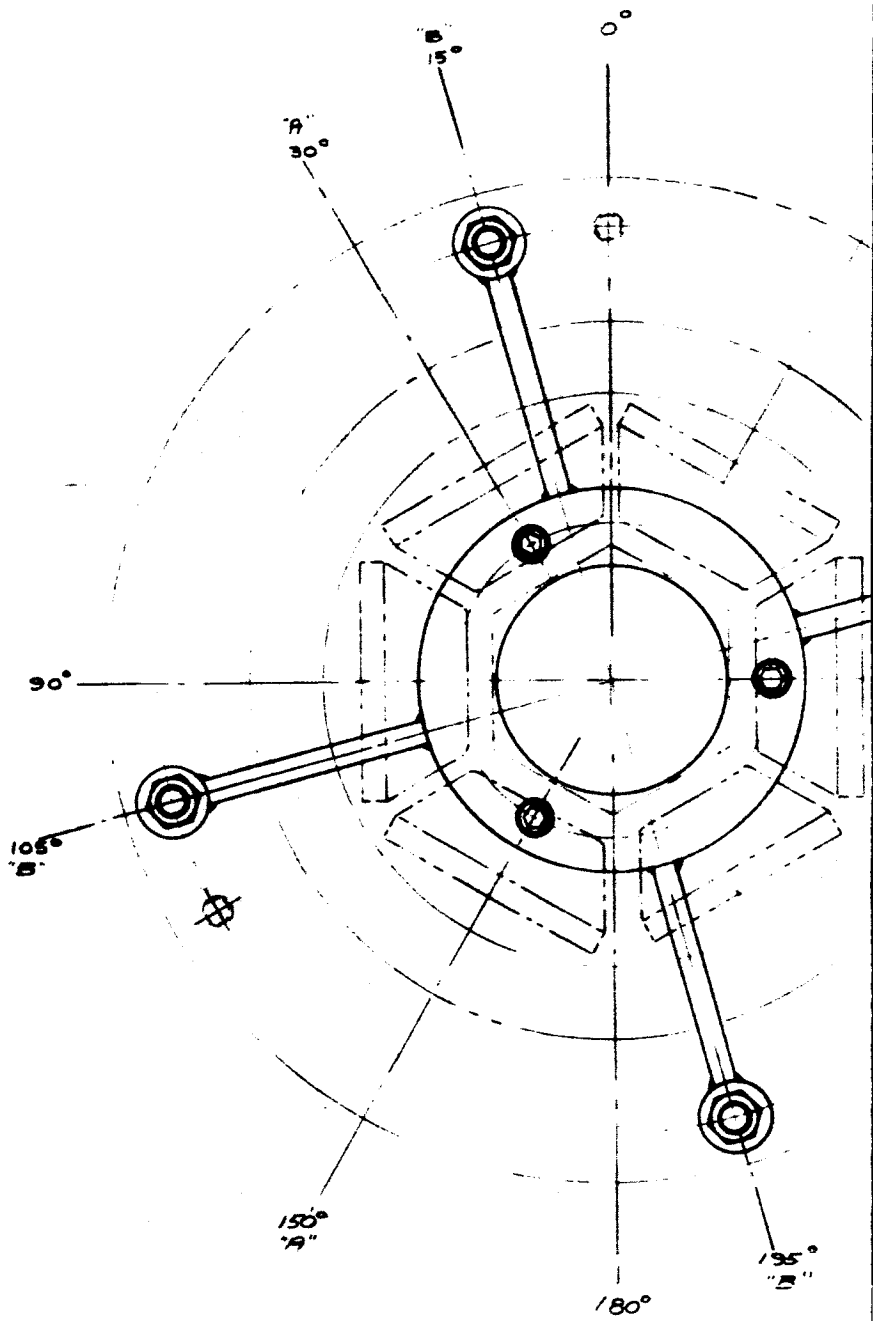
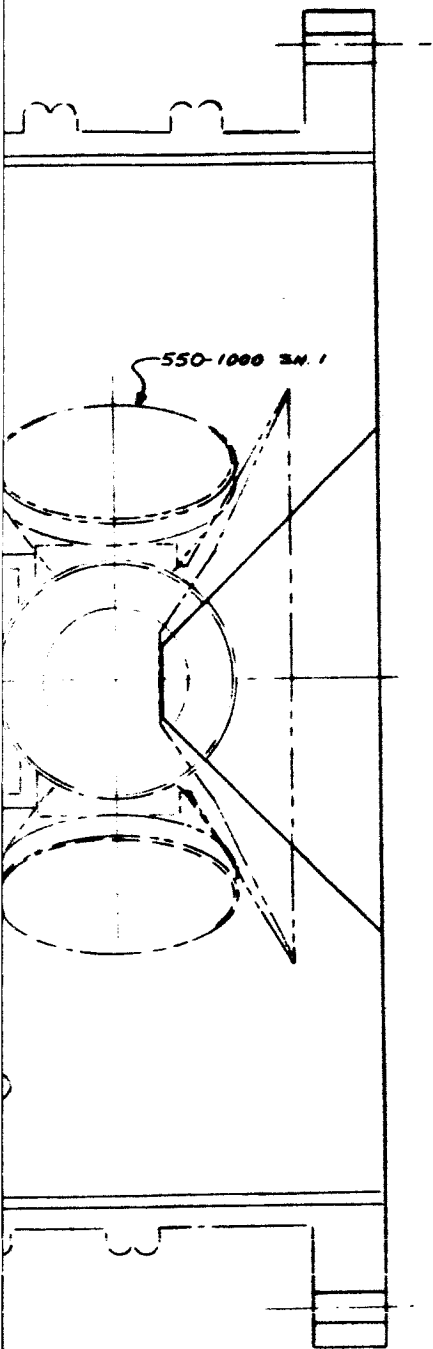
212		1	M.	303 WIRE
211		1	Cu	LEAD TERMINAL
210		1	Cu	LEAD
209		2	Ni	LEAD SLEEVE
208		1	Cu	LEAD SOLDER
207		1	Nb	LEAD CLAMP
206	ND	2	S.S.	100-46 X .25 .75
205	ND	2	S.S.	100-46 X .25 .75
204		1	Ta	SHIELD SUPPORT
203		1	Ta	CONVERTER SHIELD (.001 THK)
202		5	Ta	SHOE PIECE SHIELD (.001 THK)
201		1	Ta	SHOE PIECE

PART	SIZE	REV	REQ	MAT L	NOTES
UNLESS OTHERWISE SPECIFIED					
DECIMAL: X.1.03, XX.1.01, XXX.1.005 FILLET RADIUS: .010 MAXIMUM THREADS: CLASS 2 .010 DIA CONC. WITHIN .100" TIR ALL OTHER DIA CONC WITHIN .005" TIR SURFACES TO BE PERP WITHIN .005" TIR SURFACES TO BE PAR WITHIN .005" TIR HOLE ANGULAR TOL: 0-70 RAD ± 0° 5' 20-40 RAD ± 0° 5' ALL OTHER ANGULAR TOL TO BE 10° 30' REMOVE ALL BURRS AND EDGES					
SCALE: 5 x 1		FINISH:		SIZE: 550-1000	
NEXT ASSY		SIMILAR TO		2	

THERMO ELECTRON		
DRAWN	CHECKED	ENGINEER
REV. 47	VP	VP
TITLE: SIX CONVERTER GENERATOR (CONVERTER)		

#4





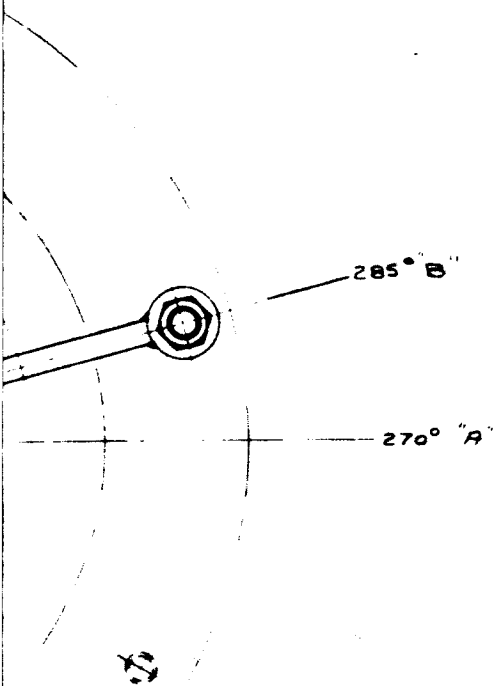


FIGURE 3

7	SEE FIXTURE LAYOUTS (3080, 3190 ETC.) FOR FIXTURE INFORMATION.
6	UNK = UNKNOWN M.D. = NO DRAWING, PROCURE FROM THIS L.O.
5	DOTTED LINES INDICATE BOMON OR PRELIMINARY MACHINING.
4	ALL MATING CORNERS & FILLETS ARE .015 X 45 CHFR. AND .010 R.R.S.
3	MAX. PERMISSABLE TAP DRILL DEPTH AND MIN. PERMISSABLE FULL THREAD DEPTHS ARE SHOWN.
2	SECTION LOCATIONS DEFINED BY LETTER LOCATION AT END VIEW.
1	NOTES 2 THRU 7 APPLY UNLESS OTHERWISE SPECIFIED.

NOTES																									
DESIGN		DATE	INT	DATE	INT	DATE	INT	DATE	INT																
FINALIZED		10/15/78																							
	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z		
1																									
2																									
V																									
II																									
A																									
B																									

positions has the disadvantage that the cavity area is increased considerably while the effective emitter area is maintained constant; thus, the cavity surface utilization factor* is decreased and the fixed losses of the generator are increased. It is evident then that no advantage is gained by tilting the converters, and, for this reason, the planar layout shown in Figure 1 was adopted.

The compatibility of the converter design selected with generator JG-3 has been established by the fabrication of a number of Series VIII converters that conform with the converter layout shown in Figure 2 (except for the emitter shoe piece and associated shielding), and which have been verified to be compatible with the mounting block of generator JG-3.

To avoid distortion of thermal shields and to avoid the possibility of subsequent electrical shorting, the shield shapes have been made as axisymmetric as possible and shields at different electrical potentials are located in such a manner as to be fully effective and yet incapable of distorting in the directions required to effect an electrical short.

Autonomous generator heat transfer is accomplished with the help of a cylindrical generator radiator which also serves as the generator support. To demonstrate this autonomy, the support structure shown in Figure 3 includes insulating ceramic washers at the generator mounting points.

Other features of the preliminary generator design include:

1. Compatibility with the JPL vacuum test chamber.
2. The attachment of the converters is essentially identical to that used in generator JG-3.

*P. J. Brosens, Solar Thermionic Generators for Space Power, ASME Paper, 64-WA/Sol-1 presented at Winter Annual Meeting, Dec. 1964

3. The front cone affords protection to the seals of all converters in case of misorientation, and this protection is assured even at high front cone temperatures by the use of 5 radiation shields behind it.
4. The emitter shoe pieces of the converters are relatively lightweight, and they permit efficient enclosure of the collected thermal flux within the generator cavity. They can be mounted after converter fabrication by electron beam welding their collar extension to the sides of the emitter of the converter.
5. Considerable thermal shielding for the emitter shoe pieces is provided from the rear of the generator.
6. The shape of the emitter shoe pieces can be produced by conventional milling operations.

1.2 Final Design of 6-Converter Generators

Figures 3a, 3b, and 3c, TEE Dwg. 550-1000 Revision A, Sheets 1, 2 and 3, show the layout of the 6-converter generator as finally approved by the JPL technical cognizant personnel. As may be seen, the final design is identical to the preliminary layout with the following exceptions:

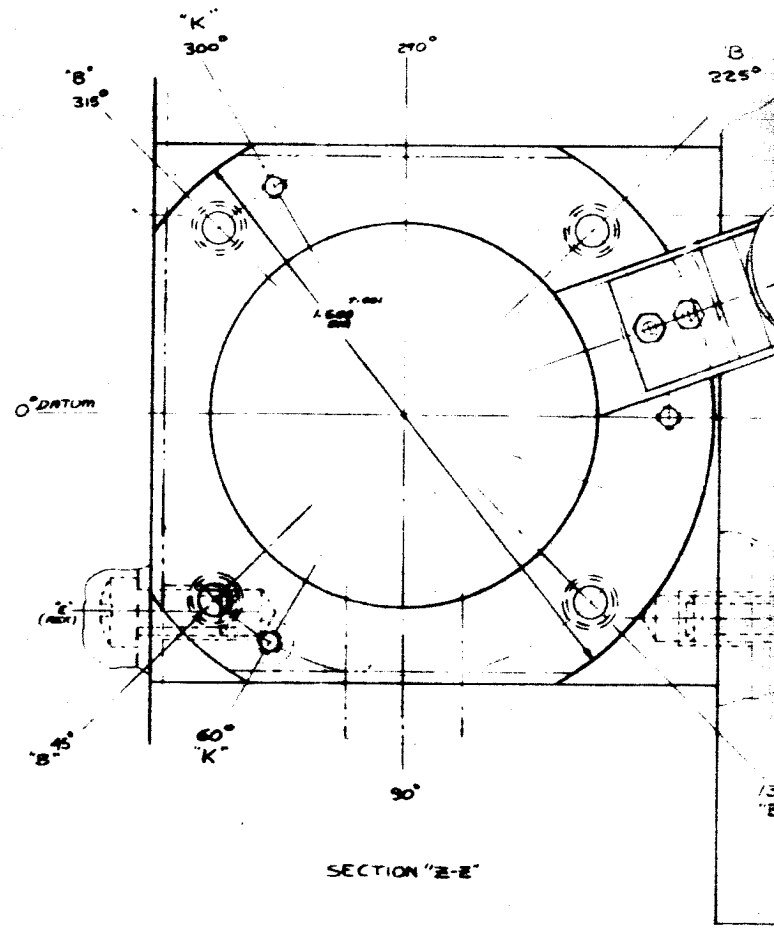
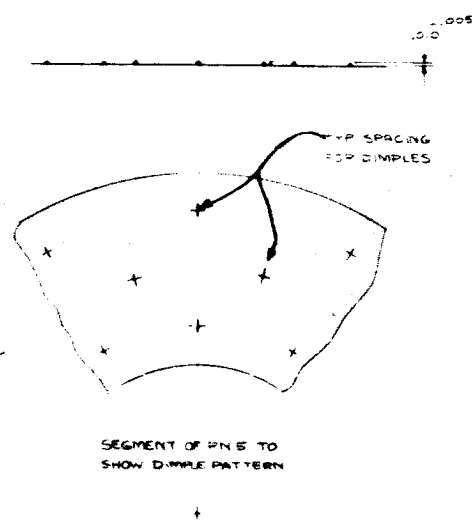
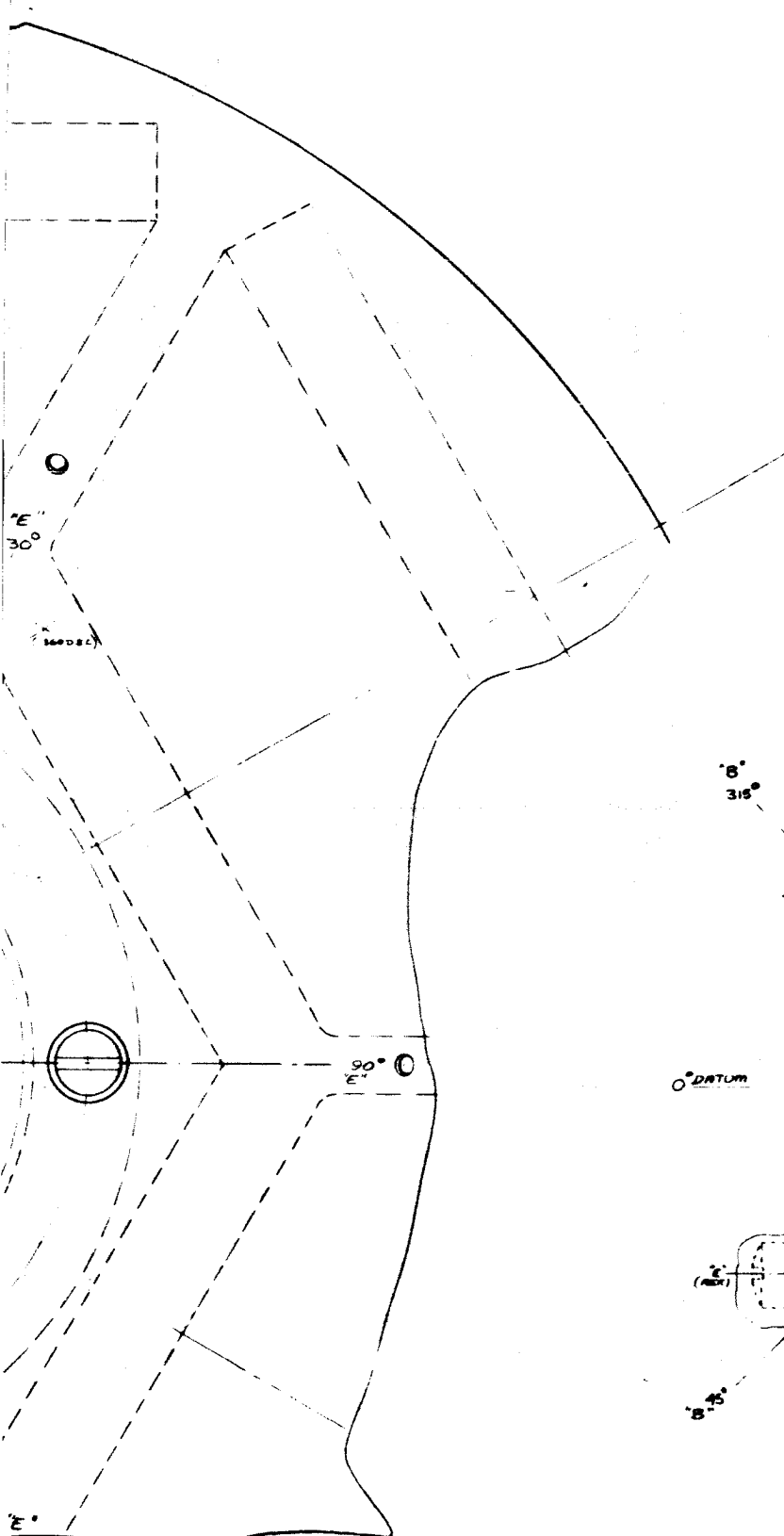
Sheet 1:

Front cone shields: increased in number from 1 to 5 to afford additional protection to the converters from stray radiation. Front cone and rear cavity piece tungsten is the material specified for these parts instead of molybdenum and tantalum, so as to provide greater operating temperature range.

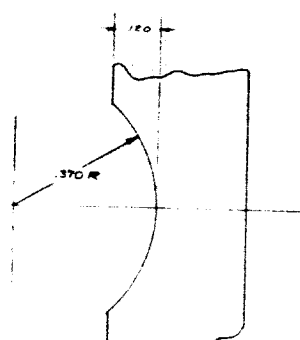
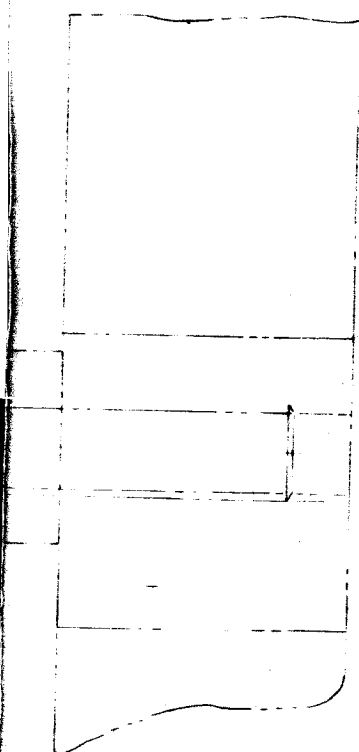
Sheet 2:

Converter shoe piece: electron beam weld is specified as the method of

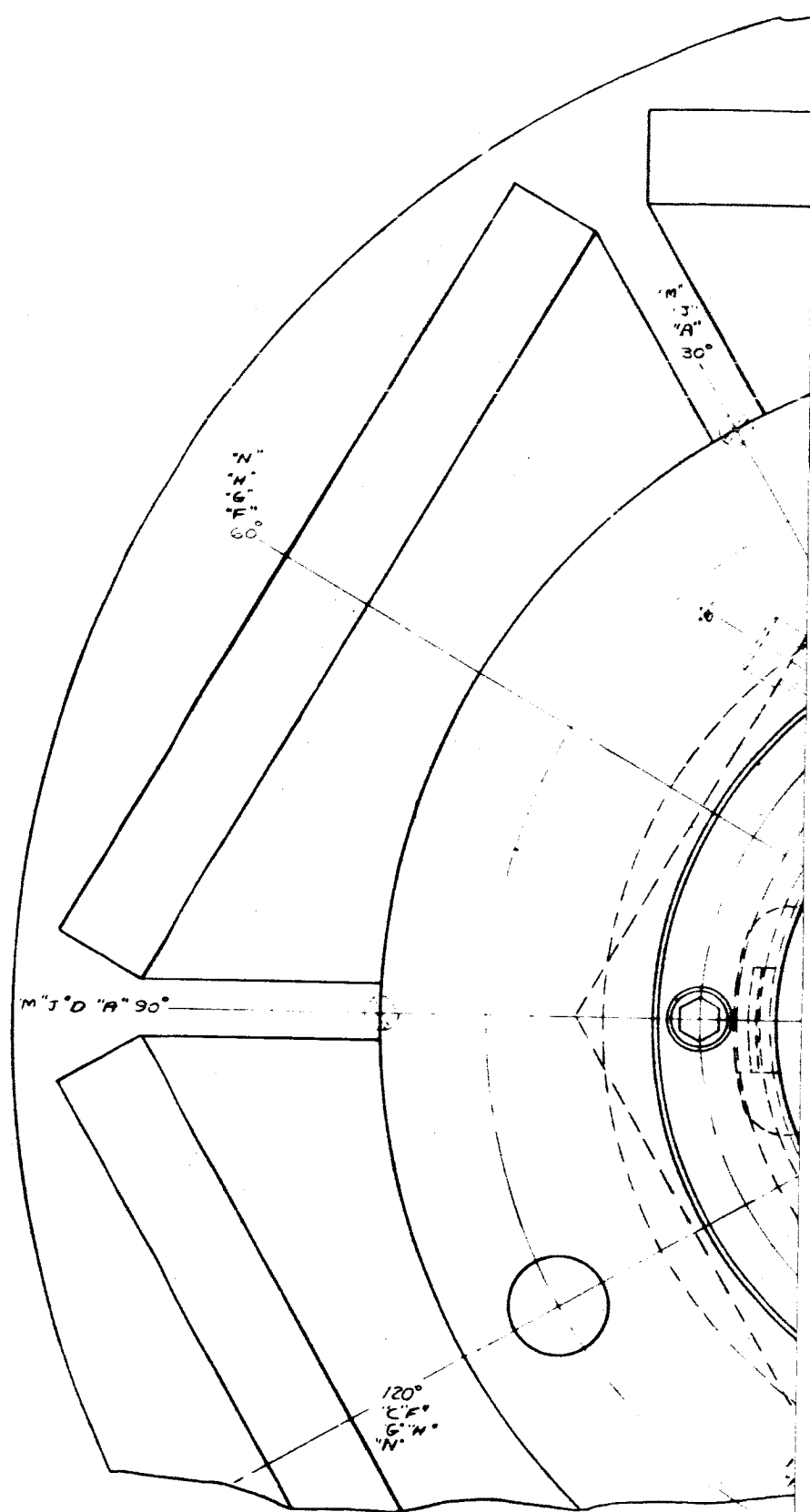
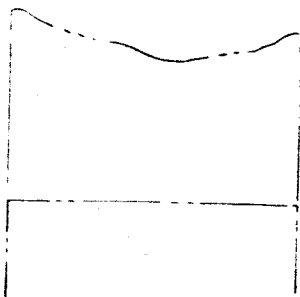




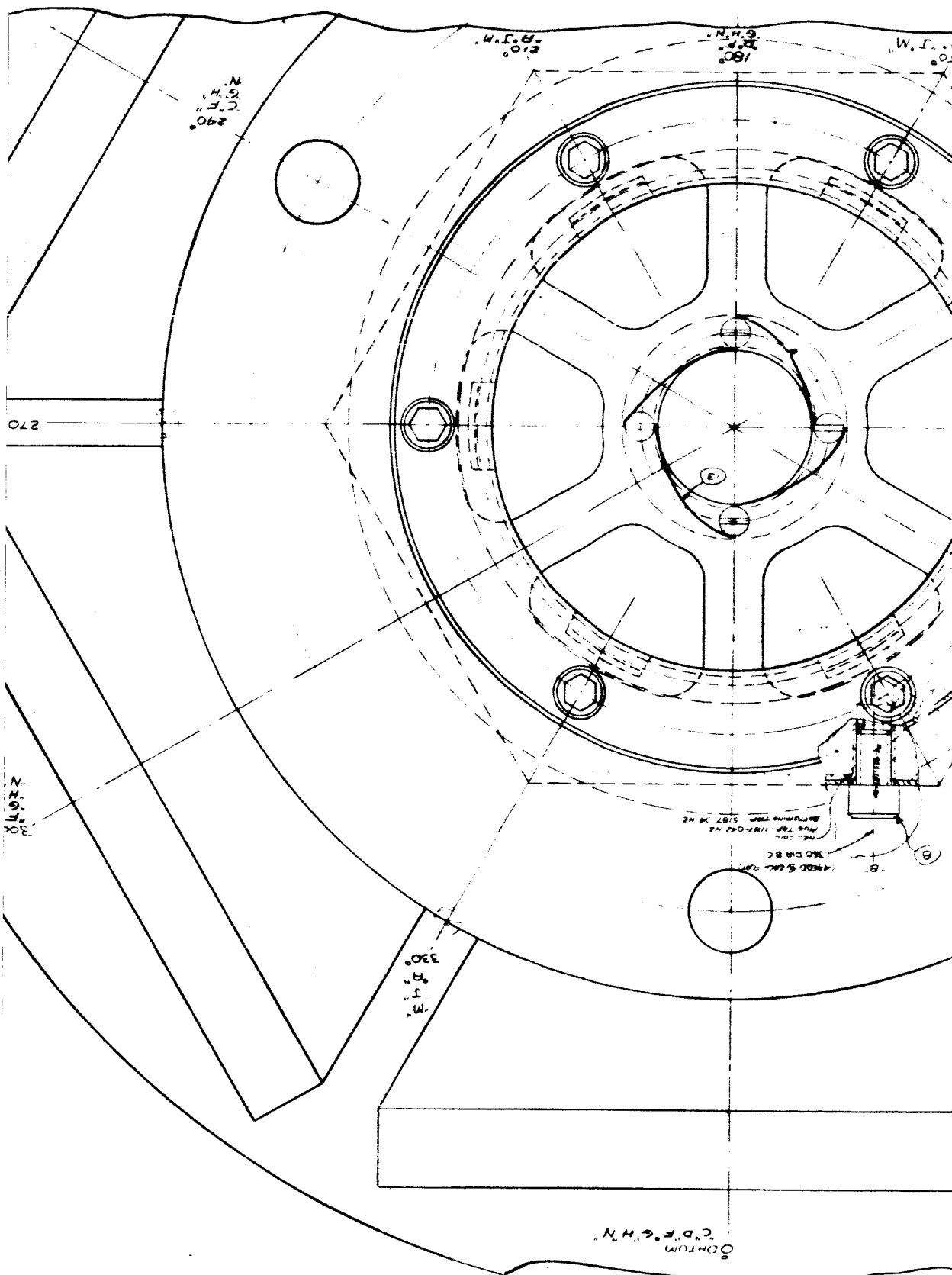
#2

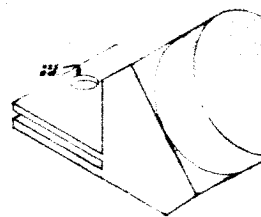
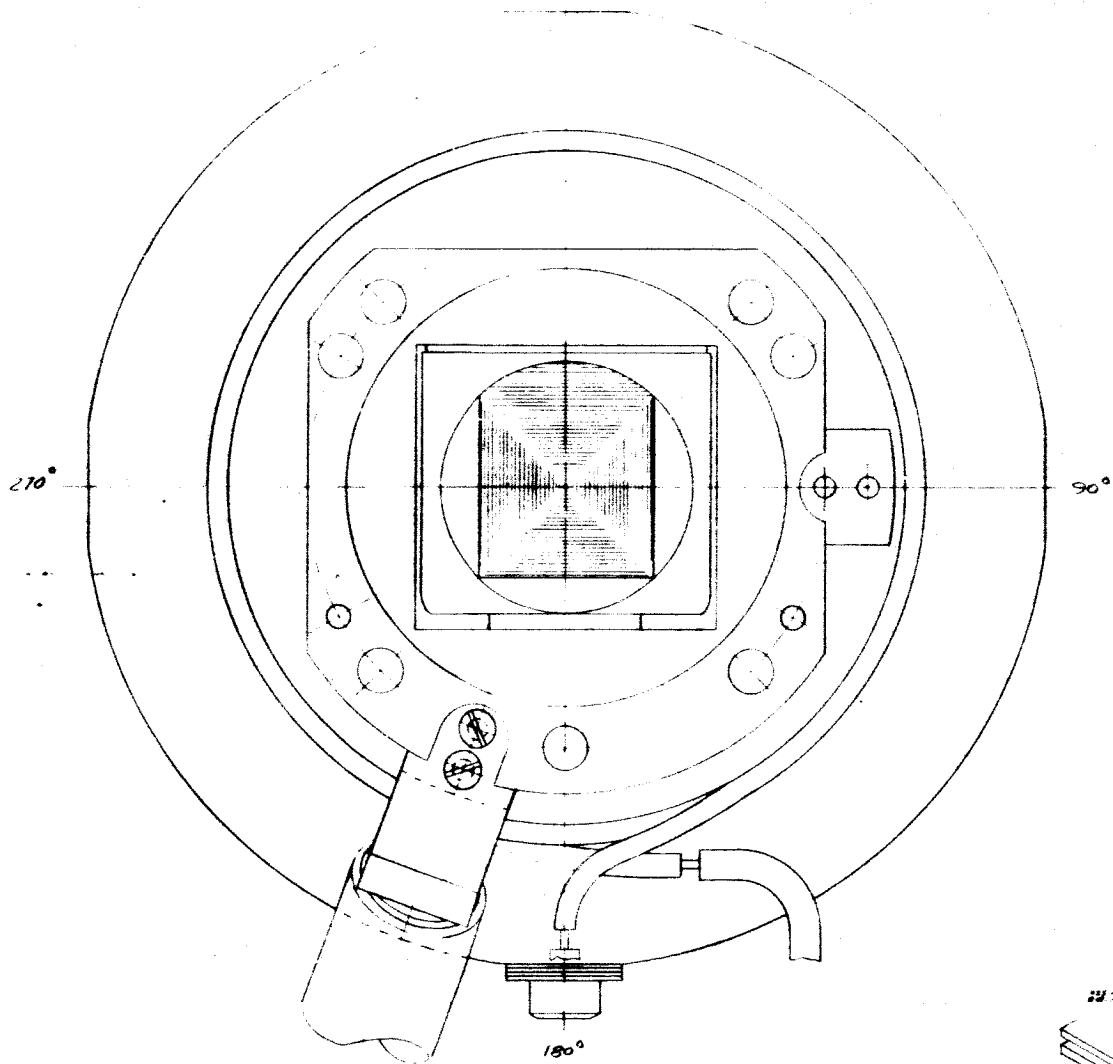


VIEW "Y-Y"
(PN 6 SHOWN ONLY)
TYPICAL CUTOUT @ "N"



S#

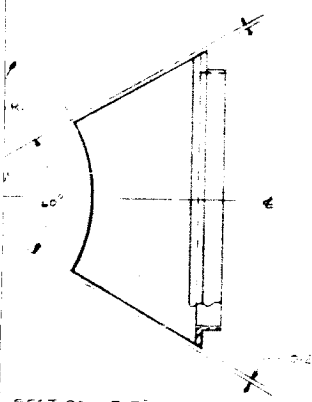




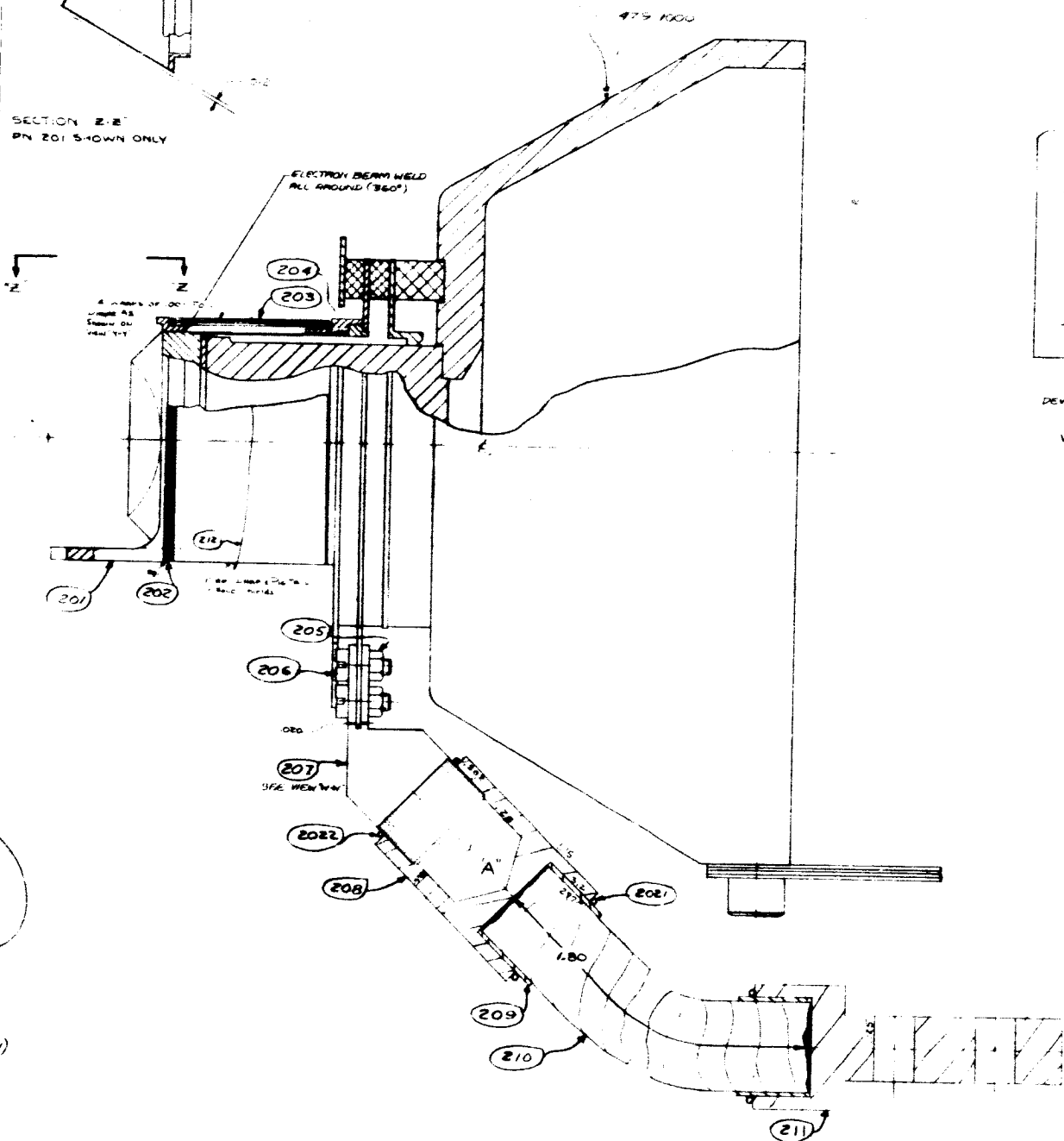
PY 207
SHOWN FOR CLARIFICATION
VIEW "W-W"

200°
"A"

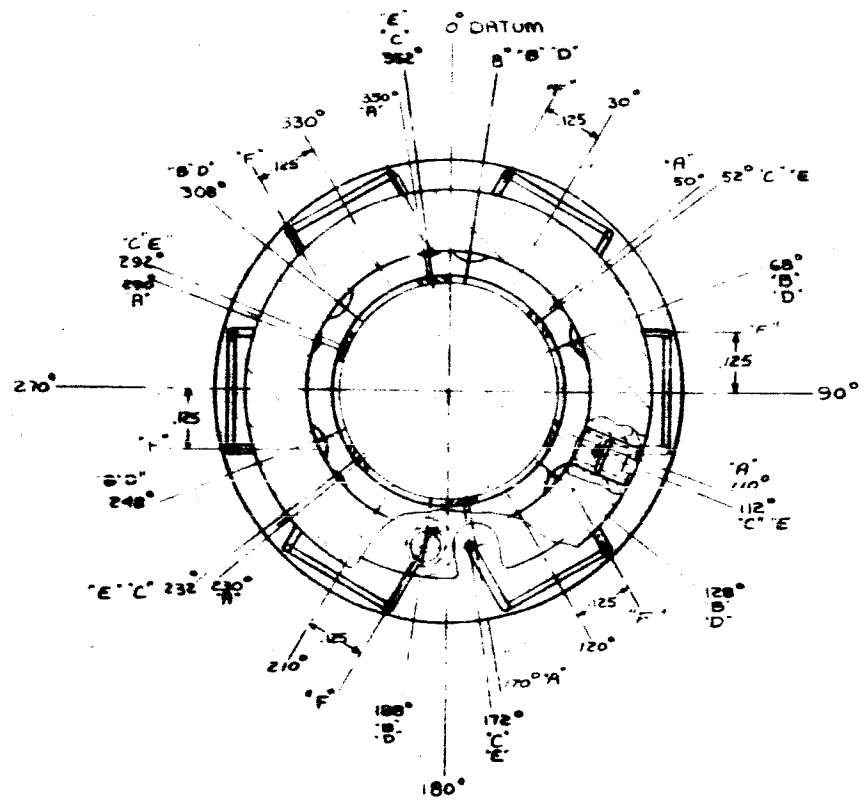
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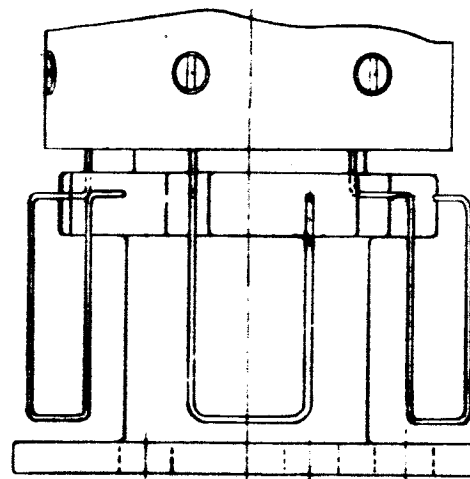
SECTION Z-Z
 PN 201 SHOWN ONLY



DEV. CEN.
 VIEW



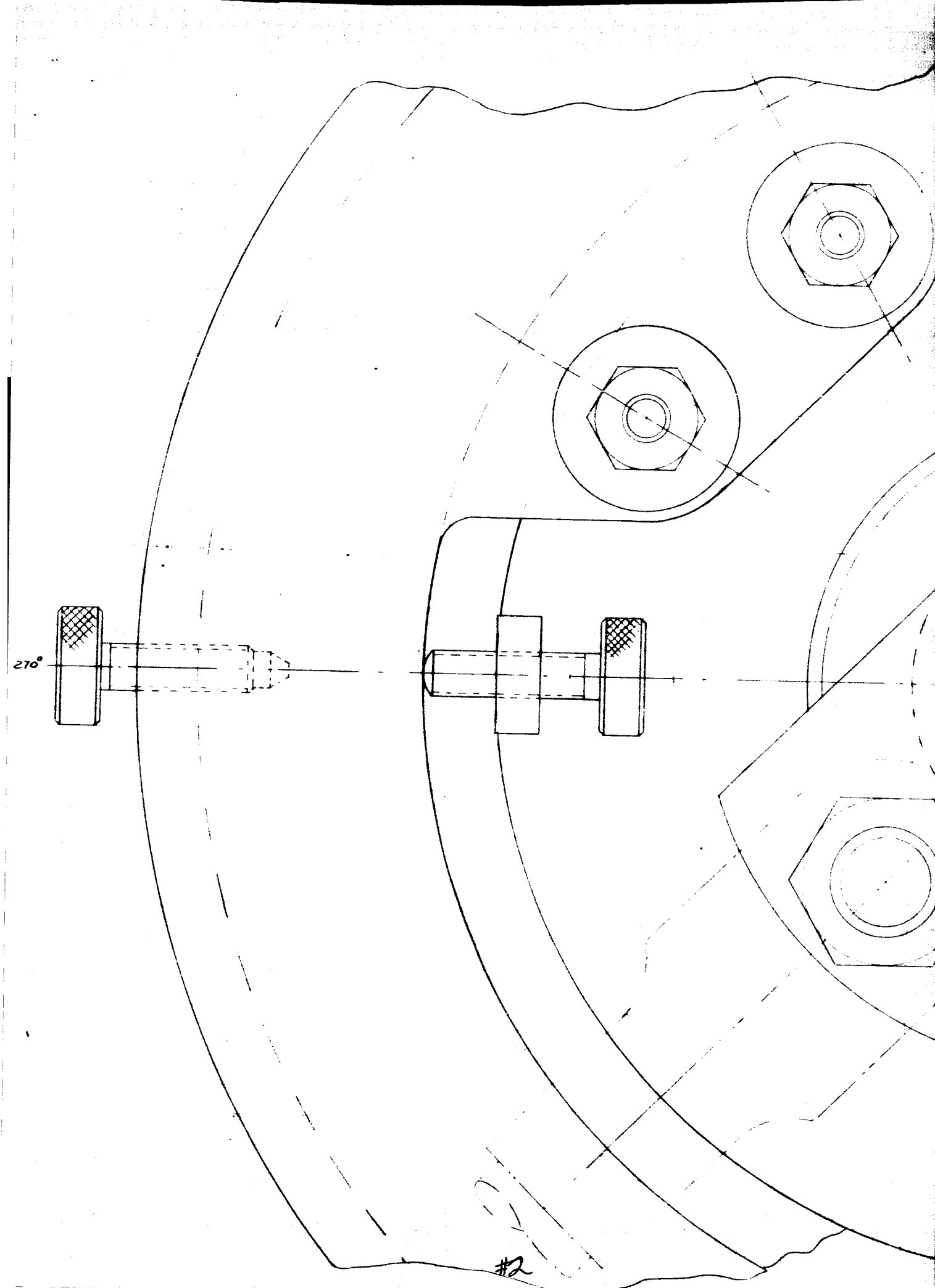
SECTION "Z-Z"



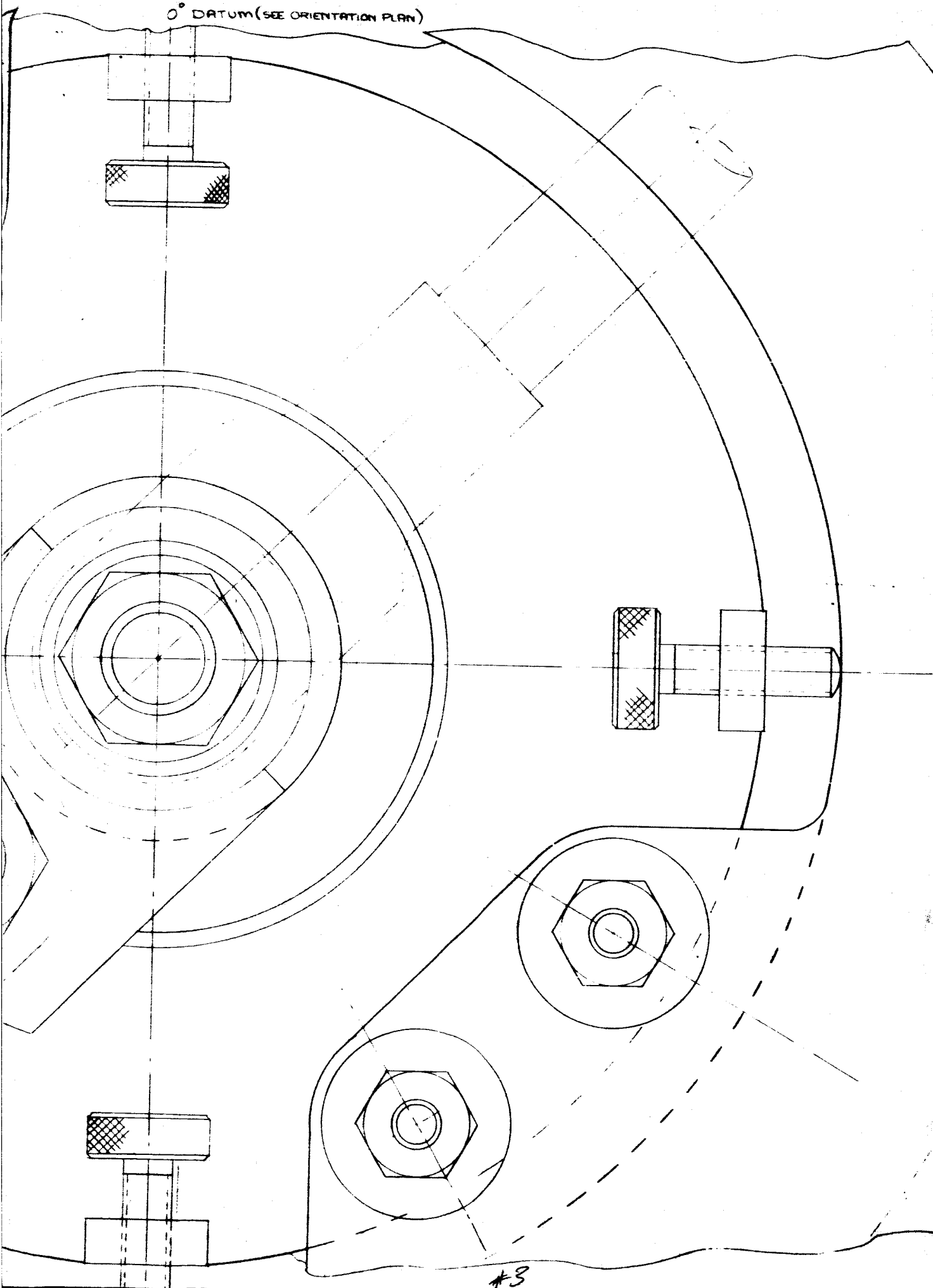
SECTION "Y-Y"

270°

#2



0° DATUM (SEE ORIENTATION PLAN)



attaching the shoe piece to the converter structure.

Sheet 3:

Frame mounting: the "B" holes of the generator extension frame (parts No. 301-302-305) have been enlarged to allow lateral adjustment of the generator position inside the vacuum test chamber.

1.3 Cavity Heat Balance

1.3.1 Assumed Cavity Geometry

For the purpose of conducting a flux distribution analysis, the generator cavity geometry is simplified so that a moderate number of parameters, namely 10, of which 7 are independent, can describe it. The simplified geometry is shown in Figure 4, and, as is immediately apparent, it approaches very closely the actual cavity configuration. The major differences are:

1. Cavity interstitial spaces are lumped with cavity areas and treated analytically as sharing common average absorptivity and emissivity properties. Thus, the values of emissivity and absorptivity which are specifically assumed for the various cavity surfaces must take into account the fact that they include the properties of these interstitial spaces.
2. The shoe pieces of the converters are assumed to form a cylindrical surface of radius R_5 .
3. The faces of the converters are assumed to be flat and circular with radius R_6 .
4. The extensions of the shoe pieces which form the bottom of the cavity are divided into 3 finite elements operating at three corresponding discrete temperature levels.

The emissivity and absorptivity values for each of the defined cavity surface elements can of course be individually assigned arbitrarily.

1.3.2 Input Solar Flux Distribution

One of the required data for the computation of the solar flux in a thermionic generator cavity is the actual amount of solar radiation that reaches the individual cavity elements considered in the analysis.

Since most cavity elements are reasonably removed from the focal plane, they will essentially "see" the arriving solar flux as though it had originated at a pseudo point source P on the optical axis, as shown in Figure 5, and with a specified polar distribution of intensity comprised between the rim angle θ_1 of the concentrator and a shadow angle θ_s produced by the generator and its test chamber on the solar concentrator.

Although the intensity produced by an ideal paraboloid increases slightly with θ , the fact that profile errors also increase with θ in actual concentrators has led to the assumption in this analysis that the solar flux is spread spherically with uniform intensity between the angles θ_s and θ_1 from a pseudo point source P, as shown in Figure 5.

The fraction Fi of solar flux reaching each cavity element is then strictly proportional to the value of the solid angle it intercepts as viewed from the pseudo point source P.

For the given data $\theta_1 = 55^\circ$ and $D_m = 9.5$ ft., the focal length computed from the formula:

$$f = (1 + \cos \theta_1) D_m / 4 \sin \theta_1$$

is 54.8 in.

The shadow angle θ_s has been computed assuming a vacuum chamber effective radius of 12.8 in.:

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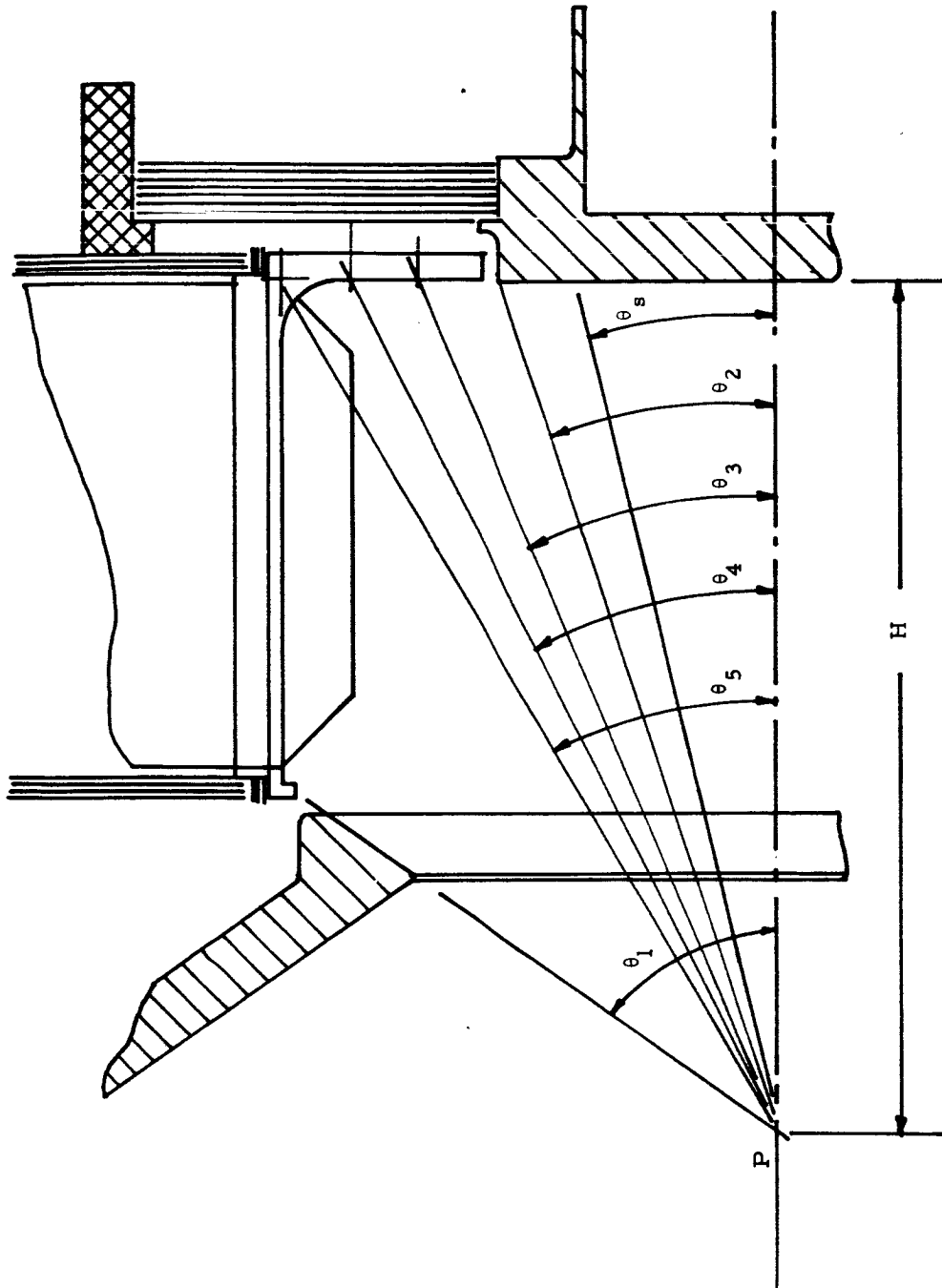


Figure 5. Idealized Input Solar Flux Pattern

$$\tan \theta_s = 12.8/54.8 = .2338$$

$$\theta_s = 13^\circ 10'$$

The value of the other angles appearing in Figure 5 are calculated as follows:

$$\theta_2 = \tan^{-1} (R2/H) = \tan^{-1} (.97/2.95) = 18^\circ 11'$$

$$\theta_3 = \tan^{-1} (R3/H) = \tan^{-1} (1.22/2.95) = 22^\circ 27'$$

$$\theta_4 = \tan^{-1} (R4/H) = \tan^{-1} (1.47/2.95) = 26^\circ 30'$$

$$\theta_5 = \tan^{-1} (R5/H) = \tan^{-1} (1.72/2.95) = 30^\circ 13'$$

The solid angle comprised between θ_s and θ_1 is:

$$\psi = 2\pi (\cos \theta_s - \cos \theta_1)$$

The energy per steradian is therefore:

$$w = \frac{W}{2\pi (\cos \theta_s - \cos \theta_1)}$$

For a surface intercepting a solid angle ψ_i , the corresponding energy is then:

$$W(i) = \frac{W\psi_i}{2\pi (\cos \theta_s - \cos \theta_1)}$$

and the corresponding value of the energy fraction $F(i)$ is:

$$F(i) = \frac{W(i)}{W} = \frac{\psi_i}{2\pi (\cos \theta_s - \cos \theta_1)}$$

For the various cavity surfaces, the values of F are:

$$F1 = .0000$$

$$F2 = (\cos \theta_s - \cos \theta_2) / (\cos \theta_s - \cos \theta_1)$$

$$F3 = (\cos \theta_2 - \cos \theta_3) / (\cos \theta_s - \cos \theta_1)$$

$$F4 = (\cos \theta_3 - \cos \theta_4) / (\cos \theta_s - \cos \theta_1)$$

$$F5 = (\cos \theta_4 - \cos \theta_5) / (\cos \theta_s - \cos \theta_1)$$

$$F6 = (S6)(\cos \theta_5 - \cos \theta_1) / (S6 + S7)(\cos \theta_s - \cos \theta_1)$$

$$F7 = (S7)(\cos \theta_5 - \cos \theta_1) / (S6 + S7)(\cos \theta_s - \cos \theta_1)$$

$$F8 = .0000$$

For the values of θ given:

$$\cos \theta_s = .9737$$

$$\cos \theta_1 = .5735$$

$$\cos \theta_2 = .9500$$

$$\cos \theta_3 = .9242$$

$$\cos \theta_4 = .8949$$

$$\cos \theta_5 = .8641$$

For:

$$R6 = .84 \text{ cm}$$

$$R5 = 1.72 \text{ cm}$$

$$Z7 = 1.73 \text{ cm}$$

$$S6^* = 13.3 \text{ cm}^2$$

$$S6 + S7 = 18.7 \text{ cm}^2$$

$$S7 = 5.4 \text{ cm}^2$$

$$* S6 = 6\pi (R6)^2$$

$$S7 = 2\pi (R5)(Z7) - S6$$

and:

$$S_6/(S_6 + S_7) = .711$$

$$S_7/(S_6 + S_7) = .289$$

The calculated values of energy fractions are then:

$$F_1 = .0000$$

$$F_2 = .0591$$

$$F_3 = .0645$$

$$F_4 = .0732$$

$$F_5 = .0770$$

$$F_6 = .5162$$

$$F_7 = .2100$$

$$F_8 = .0000$$

1.3.3 View Factor Derivation

To derive the view factors between the various area elements defined for the generator cavity in Figure 4, three basic relationships were used:

1. The sum of the view factors from any one surface to all other surfaces including itself is unity.
2. For any pair of elements, the products of area times the view factor to the other area are equal.
3. For two discs having a common axis of symmetry, the view factor from one to the other is given by the expression: *

$$F_{12} = (Y_{12}/2) \left(1 - \sqrt{1 - (2 R_2/R_1 Y)^2} \right)$$

where R_1 and R_2 are the respective radii and Y is an intermediate function defined in terms of the distance Z between the discs by:

$$Y_{12} = 1 + (Z/R_1)^2 + (R_2/R_1)^2$$

*Ref. NACA TN 2836, December 1952, Radiant-Interchange Configuration Factors, D. C. Hamilton and W. R. Morgan

The resulting equations for the evaluation of all view factors are given below in FORTRAN notation where:

- . denotes a floating point constant
- / denotes a division
- * denotes a multiplication
- ** denotes exponentiation to the constant following the symbol

and where the cavity areas S1, S2 ... S9 are given by:

$$\begin{aligned}
 S1 &= \pi * R1 **2 \\
 S2 &= \pi * R2 **2 \\
 S3 &= \pi * R3 **2 - S2 \\
 S4 &= \pi * R4 **2 - S3 - S2 \\
 S5 &= \pi * R5 **2 - S4 - S3 - S2 \\
 S6 &= 6. * \pi * R6 **2 \\
 S7 &= 2. * \pi * R5 * Z7 - S6 \\
 S8 &= \pi (R1 + R5) * Z8 \\
 S9 &= \pi * R5 **2
 \end{aligned}$$

View Factor Equations:

$$\begin{aligned}
 F11 &= 0. \\
 Y12 &= 1. + (Z1/R1)**2 + (R2/R1) **2 \\
 F12 &= 0.5 * Y12 * (1. - (1. - (2. + (R2/R1)/Y12)**2)**0.5) \\
 Y13 &= 1. + (Z1/R1) ** 2 + (R3/R1) **2 \\
 F13 &= 0.5 * Y13 * (1. - (1. - (2. * (R3/R1)/Y13) **2) **0.5) - F12 \\
 Y14 &= 1. + (Z1/R1)**2 + (R4/R1)**2 \\
 F14 &= 0.5 * Y14 * (1. - (1. - (2. * (R4/R1)/Y14)**2)**0.5) - F12 - F13 \\
 Y15 &= 1. + (Z1/R1)**2 + (R5/R1) \\
 F15 &= 0.5 * Y15 * (1. - (1. - (2. * (R5/R1)/Y15)**2)**0.5) - F12 - F13 - F14
 \end{aligned}$$

$$Y19 = 1. + (Z9/R1)**2 + (R5/R1)**2$$

$$F19 = 0.5 * Y19 * (1. - (1. - (2. * (R5/R1)/Y19)**2)**0.5)$$

$$F18 = 1. - F19$$

$$F17 = (S7/(S7+S6)) * (1. - F12 - F13 - F14 - F15 - F18)$$

$$F16 = (S6/S7) * F17$$

$$F21 = *S1/S2 * F12$$

$$F22 = 0.$$

$$F23 = 0.$$

$$F24 = 0.$$

$$F25 = 0.$$

$$Y29 = 1. + (Z7/R2)**2 + (R5/R2)**2$$

$$F29 = 0.5 * Y29 * (1. - (1. - (2. * (R5/R2)/Y29)**2)**0.5)$$

$$F26 = (S6/(S6+S7)) * (1. - F29)$$

$$F27 = (S7/S6) * F26$$

$$F28 = 1. - F21 - F26 - F27$$

$$F31 = (S1/S3) * F13$$

$$F32 = 0.$$

$$F33 = 0.$$

$$F34 = 0.$$

$$F35 = 0.$$

$$F92 = (S2/S9) * F29$$

$$Y93 = 1. + (Z7/R5)**2 + (R3/R5)**2$$

$$F93 = 0.5 * Y93 * (1. - (1. - (2. * (R3/R5)/Y93)**2)**0.5) - F92$$

$$F39 = (S9/S3) * F93$$

$$F36 = (S6/(S6+S7)) * (1. - F39)$$

$$F37 = (S7/S6) * F36$$

$$F38 = 1. - F31 - F36 - F37$$

$F_{41} = (S_1/S_4) * F_{14}$
 $F_{42} = 0.$
 $F_{43} = 0.$
 $F_{44} = 0.$
 $F_{45} = 0.$
 $Y_{94} = 1. + (Z_7/R_5)^{**2} + (R_4/R_5)^{**2}$
 $F_{94} = 0.5 * Y_{94} * (1. - (1. - (2. * (R_4/R_5) / Y_{94})^{**2})^{**0.5}) - F_{92} - F_{93}$
 $F_{49} = (S_9/S_4) * F_{94}$
 $F_{46} = (S_6/S_6 + S_7) * (1. - F_{49})$
 $F_{47} = (S_7/S_6) * F_{46}$
 $F_{48} = 1. - F_{41} - F_{46} - F_{47}$
 $F_{51} = (S_1/S_5) * F_{15}$
 $F_{52} = 0.$
 $F_{53} = 0.$
 $F_{54} = 0.$
 $F_{55} = 0.$
 $Y_{95} = 2. + (Z_7/R_5)^{**2}$
 $F_{95} = 0.5 * Y_{95} * (1. - (1. - (2. / Y_{95})^{**2})^{**0.5}) - F_{92} - F_{93} - F_{94}$
 $F_{59} = (S_9/S_5) * F_{95}$
 $F_{56} = (S_6/(S_6 + S_7)) * (1. - F_{59})$
 $F_{57} = (S_7/S_6) * F_{56}$
 $F_{58} = 1. - F_{51} - F_{56} - F_{57}$
 $F_{61} = (S_1/S_6) * F_{16}$
 $F_{62} = (S_2/S_6) * F_{26}$
 $F_{63} = (S_3/S_6) * F_{36}$
 $F_{64} = (S_4/S_6) * F_{46}$
 $F_{65} = (S_5/S_6) * F_{56}$

$$\begin{aligned}
F_{96} &= (S_6/(S_6 + S_7)) * (1. - F_{92} - F_{93} - F_{94} - F_{95}) \\
F_{69} &= (S_9/S_6) * F_{96} \\
F_{66} &= (S_6/(S_6 + S_7)) * (1. - F_{62} - F_{63} - F_{64} - F_{65} - F_{69}) \\
F_{67} &= (S_7/S_6) * F_{66} \\
F_{68} &= 1. - F_{61} - F_{62} - F_{63} - F_{64} - F_{65} - F_{66} - F_{67} \\
F_{71} &= F_{61} \\
F_{72} &= F_{62} \\
F_{73} &= F_{63} \\
F_{74} &= F_{64} \\
F_{75} &= F_{65} \\
F_{76} &= F_{66} \\
F_{77} &= F_{67} \\
F_{78} &= F_{68} \\
F_{81} &= (S_1/S_8) * F_{18} \\
F_{82} &= (S_2/S_8) * F_{28} \\
F_{83} &= (S_3/S_8) * F_{38} \\
F_{84} &= (S_4/S_8) * F_{48} \\
F_{85} &= (S_5/S_8) * F_{58} \\
F_{86} &= (S_6/S_8) * F_{68} \\
F_{87} &= (S_7/S_8) * F_{78} \\
F_{88} &= 1. - F_{81} - F_{82} - F_{83} - F_{84} - F_{85} - F_{86} - F_{87}
\end{aligned}$$

1.3.4 Heat Balance Equations

Each cavity surface i receives directly a solar input W_i , the fraction F_i of the total solar input W :

$$W_i = F_i * W \quad (1)$$

and it thermally radiates a flux per unit area:

$$E_i * P_i \quad (2)$$

$$\text{where: } P_i = \text{SIGMA} * T_i^{**4} \quad (3)$$

$$\text{and: } \text{SIGMA} = 5.679 \text{ E} - 12 \text{ (E = exponentiation)}$$

If we denote by V_i and H_i the total thermal and solar fluxes arriving at each area i , the following matrix equations describe the cavity heat balance:

$$[E_{ij}] * [H_i] = [P_{ii}] \quad (4)$$

$$\text{and } [A_{ij}] * [V_i] = [W_i] \quad (5)$$

$$\text{where } [P_{ii}] = [F_{ij}] * [E_i * P_i * S_i] \quad (6)$$

$$E_{ij} = -F_{ij} * (1 - E_i) \text{ for } i \neq j \quad (7)$$

$$E_{ij} = 1 - (1 - E_i) * F_{ii} \text{ for } i = j \quad (8)$$

and A_{ij} is obtained using the expressions for E_{ij} and substituting A_i for E_i

The net heat input at each surface is then:

$$Q_i = E_i * (H_i - S_i * P_i) + A_i * V_i \quad (9)$$

1.3.5 Finite Difference Equations for Shoe Pieces

In the previous section, it is assumed that all cavity temperatures are known (viz. Eq. 3). This is actually not the case, for the temperature distribution in the shoe piece elements S3, S4, S5 and S7 shown in Figure 6 will actually depend on the amount of heat received by these elements which in turn depends on their temperature. The governing equations are as follows:

$$Q_3 = C_{34} * (T_3 - T_4) + S_3 * P_3 * B \quad (10)$$

$$Q_4 = C_{45} * (T_4 - T_5) + S_4 * P_4 * B - C_{34} * (T_3 - T_4) \quad (11)$$

$$Q_5 = C_{57} * (T_5 - T_7) + S_5 * P_5 * B - C_{45} * (T_4 - T_5) \quad (12)$$

$$Q_7 = C_{76} * (T_7 - T_6) + S_7 * P_7 * B - C_{57} * (T_5 - T_7) \quad (13)$$

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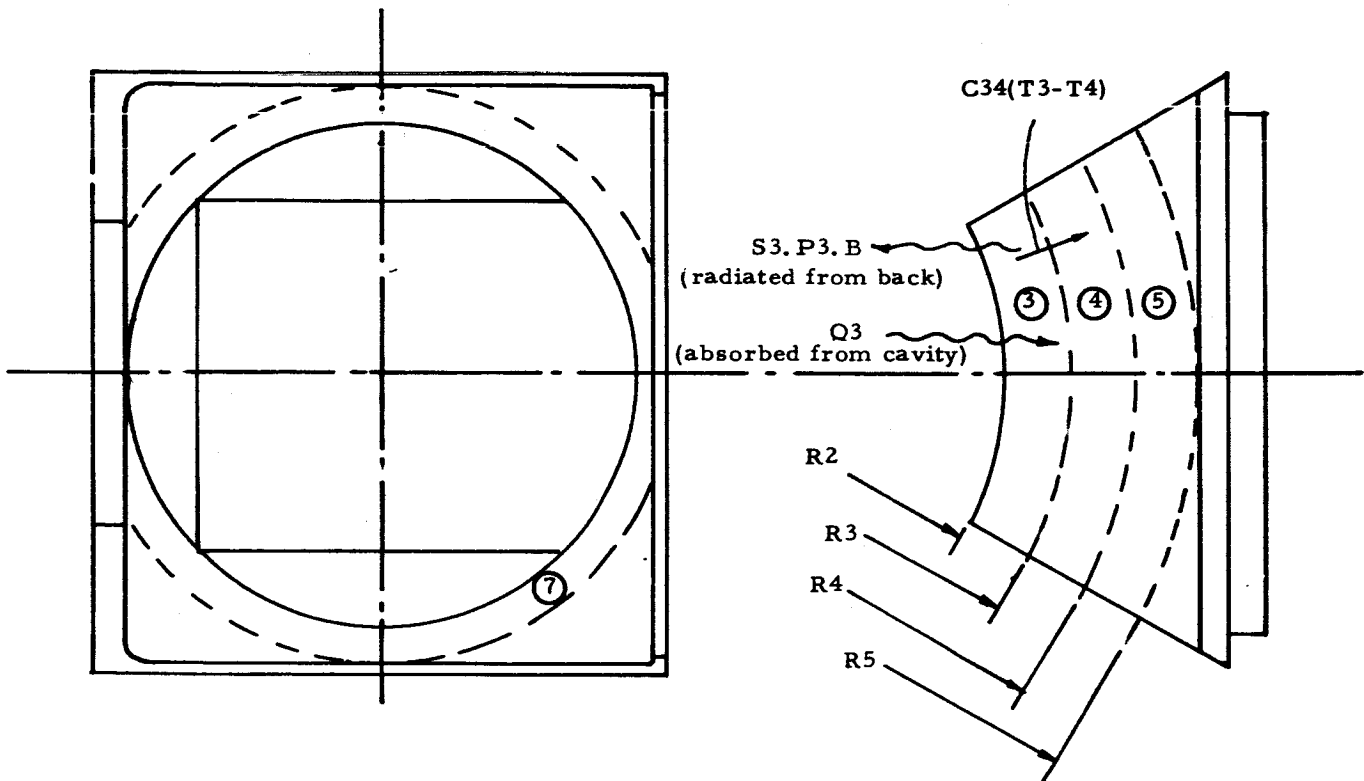


Figure 6. Shoe Piece Heat Transfer Elements and Typical Heat Transfer Terms

where b and C_{ij} are radiation and conduction heat transfer constants which determine the magnitude of individual heat transfer terms for the shoe piece elements. Assuming that the effectiveness of the shielding of the shoe piece elements is equivalent to reducing the radiation losses to 10% of black body, $B = 0.10$.

The calculation of C_{34} , C_{45} , C_{57} and C_{76} is performed as follows:

$$C_{ij} = ks/x \quad (14)$$

where k is the thermal conductivity of tantalum, assumed to be 0.80 watts/cm-deg C, s is the average cross-sectional area of each element interface:

$$s_{34} = \pi * R_3 * \text{thickness} = .765 \text{ sq. cm.}$$

$$s_{45} = \pi * R_4 * \text{thickness} = .925 \text{ sq. cm.}$$

$$s_{57} = \pi * R_5 * \text{thickness} = 1.080 \text{ sq. cm.}$$

assuming that the shoe piece extension measures .040 in. in thickness, and similarly:

$$x_{76} = .264 \text{ sq. cm.}$$

assuming that the thickness of the main shoe piece element is .020 in., and x is the average element heat transfer distance:

$$x_{34} = .25 \text{ cm.}$$

$$x_{45} = .25 \text{ cm.}$$

$$x_{57} = .50 \text{ cm. (assumed)}$$

$$x_{76} = .50 \text{ cm.}$$

The value of x_{76} is assumed as large as 0.50 cm. to account for the relatively poor thermal contact expected between elements S_6 and S_7 .

Using the above values in Equation 14, the calculation of the conduction constants yields:

$$C_{34} = 2.45 \text{ watt/deg. C}$$

$$C_{45} = 2.96 \text{ watt/deg. C}$$

$$C_{57} = 1.73 \text{ watt/deg. C}$$

$$C_{76} = 0.42 \text{ watt/deg. C}$$

1.3.6 Computer Program

To solve Equations 2 to 13, it is still needed to establish the temperature of the rear cavity piece T2. Since previous studies have confirmed that it is desirable that this temperature be as high as possible to reduce generator thermal losses, Figure 7 indicates what is the maximum achievable temperature from the standpoint of evaporation rate for tantalum. If a limit of 1.2 mils per year is adopted, the corresponding maximum rear cavity temperature is 2360 deg. K. Although the final design specifies that this piece is made of W, this assumption regarding its upper temperature limit has been maintained.

The computer program required to solve the heat balance problem is presented in flow diagram form in Figure 8, and in actual form in Figure 8a, and it includes an iteration loop to solve the non-linear simultaneous Equations (10) to (13).

1.3.7 Numerical Solutions

The computer program was used to calculate the cavity heat transfer at 3 values of aperture, assuming the performance of JPL concentrator S/N1 as illustrated in Figure 9. The cavity aperture diameters were 0.9, 1.0, and 1.2 inches respectively. As in previous thermionic generator designs, surface emissivities and absorptivities were assumed equal to 0.25 and 0.50 respectively,

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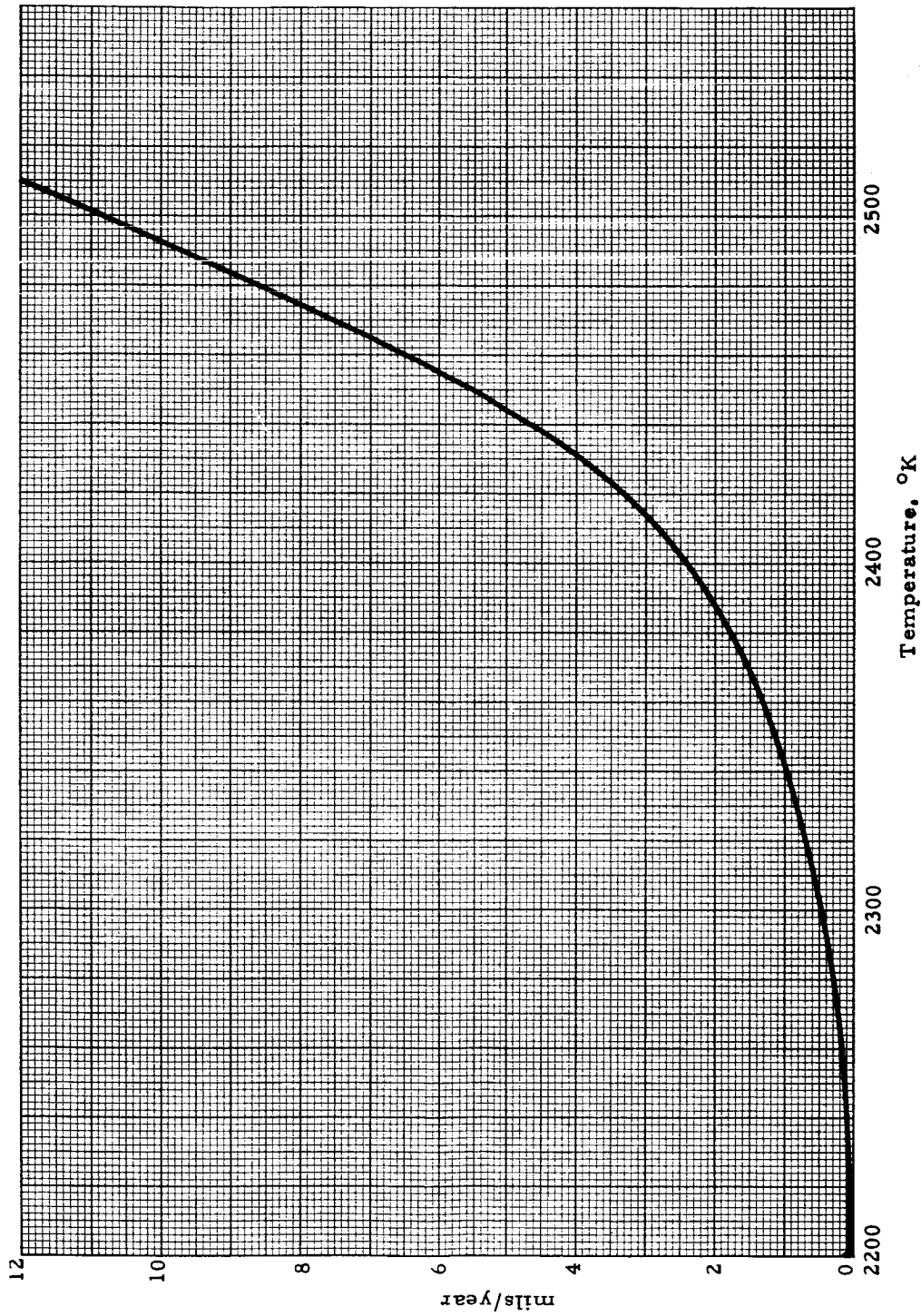


Figure 7. Evaporation Rate of Tantalum

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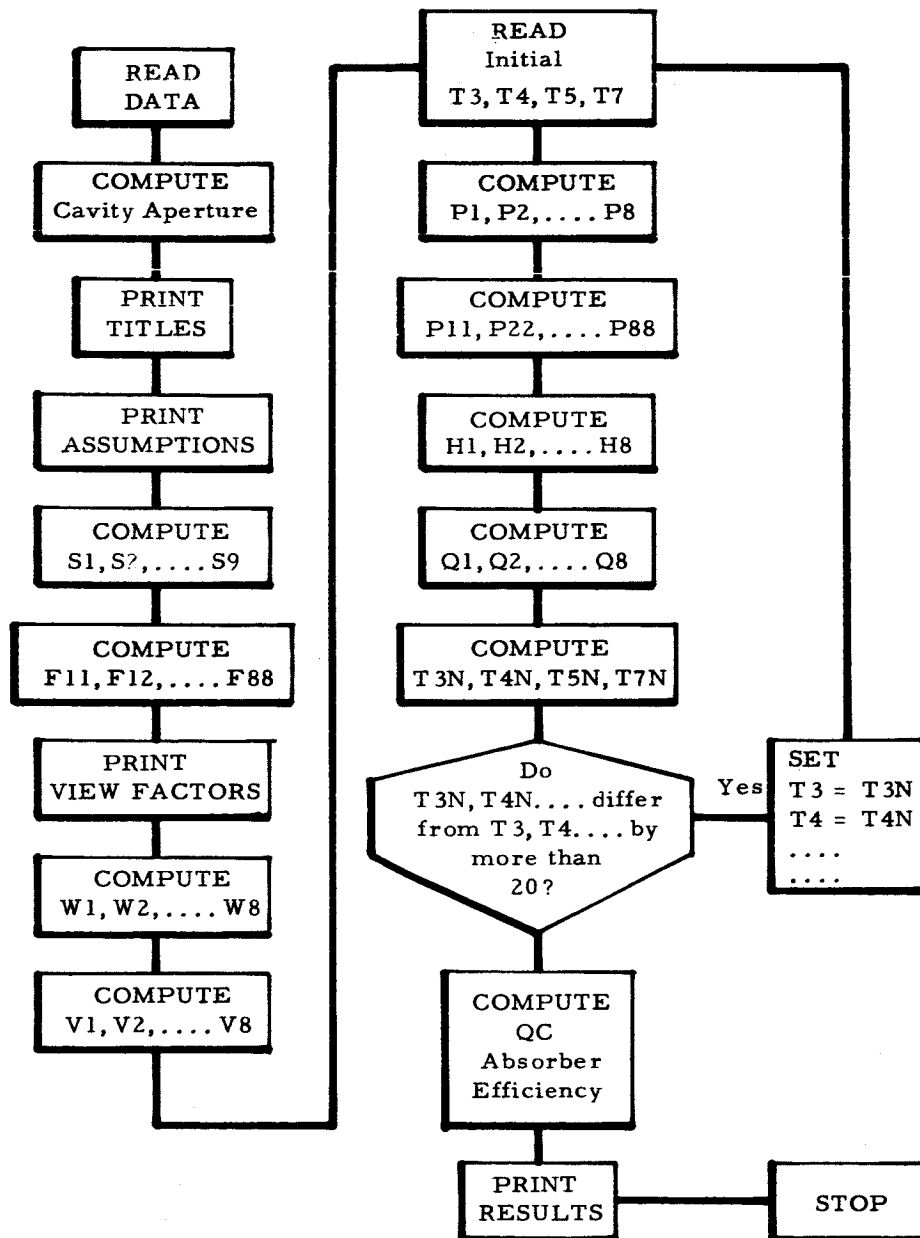


Figure 8. Computer Program Flow Chart

[illegible]

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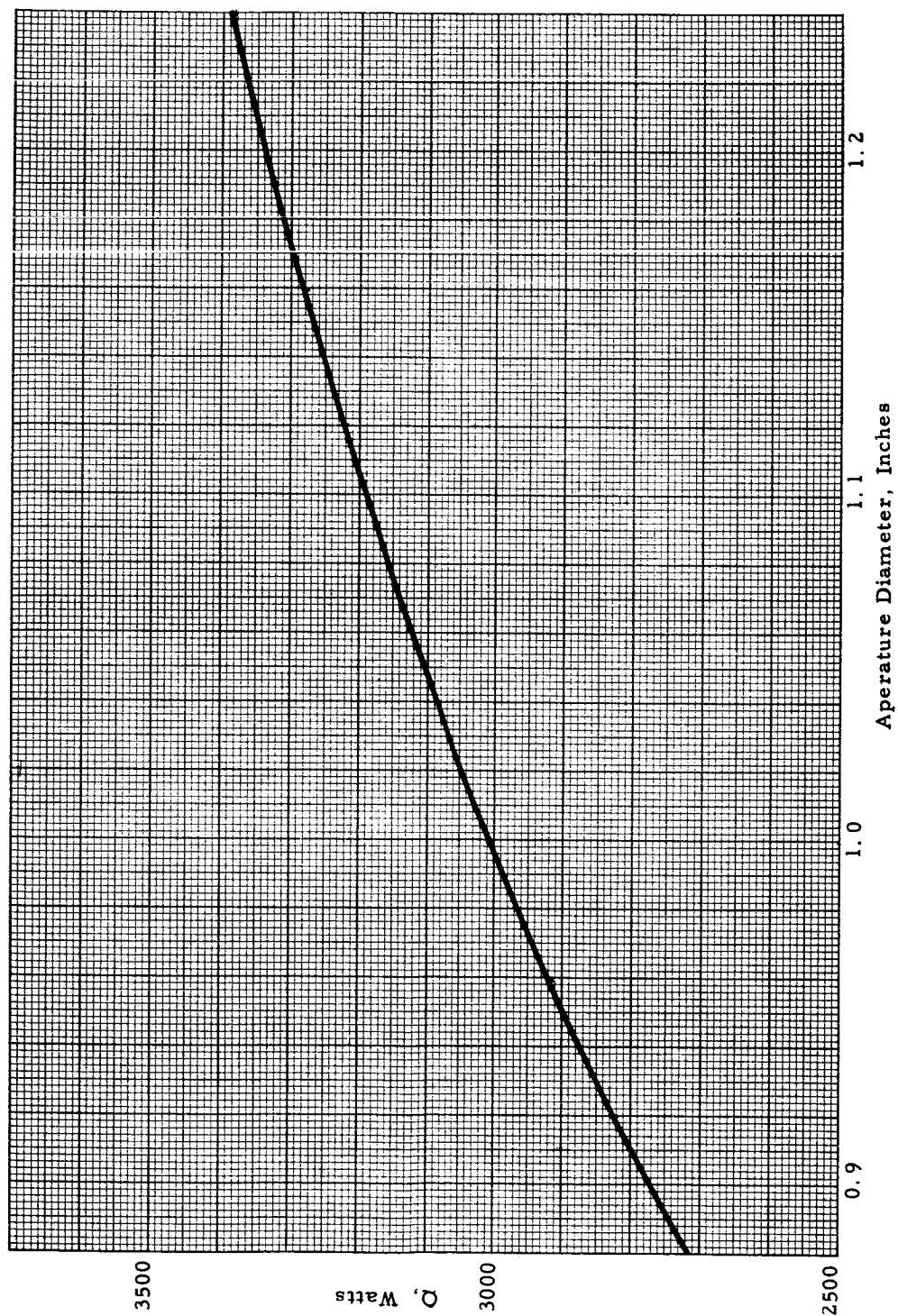


Figure 9. Thermal Power Delivered to the Generator
Cavity by JPL Mirror S/N 1

except for the emitter faces where the corresponding values were 0.35 and 0.80. The computer print-outs for these three runs are given in Tables 1, 2 and 3. The corresponding values of heat input QC to the thermionic converters are given in Figure 10. The absorber efficiency QC/w is nearly constant, and it is maximum at an aperture diameter of 0.9 inch. As a result of these calculations, the aperture diameter selected for the generator design is 1.0 inch.

For this value of aperture diameter, the computer was further used to evaluate the generator heat transfer at four different values of heat input, and the corresponding print-outs are given in Tables 4 through 7. The results have been plotted on Figure 11. The four values of heat input would correspond, for JPL concentrator S/N1, to solar fluxes of 50, 70, 90, and 130 watts/ft² respectively.

1.4 Generator Thermal Analysis

1.4.1 Converter Heat Losses

The converter heat losses consist of the heat losses which occur in conveying to the emitter the heat QC delivered by the cavity and those which occur after the emitter has received this heat. The first losses occur by radiation from an area illustrated in Figure 12. For a value of e of 0.14 cm. and assuming that the radiation loss to the shielding* is 10 watts per sq. cm. at 2000°K, this loss is:

$$q = \pi \times 1.68 \times 0.14 \times 10 = 7.4 \text{ watts per converter.}$$

The converter losses are calculated assuming the thermal model for the Series VIII converter**:

$$q \text{ (electron cooling)} = 2.66 \text{ watts/amp.}$$

$$q \text{ (interelectrode radiation)} = 28.2 \text{ watts}$$

* The Appendix recapitulates the calculation of the ideal radiation heat transfer through a series of N shields.

** Second Monthly Progress Report for Thermal Energy Storage/Converter Prototype Design, Fabrication and Testing, JPL Contract 950976/NAS7-100, April 1965, by S. Merri and L. van Someren, TEE Report TE 77-65.

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TABLE 1

COMPUTED GENERATOR THERMAL BALANCE											
CAVITY APERTURE (INCH) = 0.900											
TOTAL SOLAR INPUT (WATTS) =2720.000											
CAVITY DIMENSIONS (CM)											
R1 =1.143	R2 =0.970	R3 =1.220	R4 =1.470	R5 =1.720							
R6 =0.840	Z1 =2.134	Z7 =1.730	Z8 =0.705	Z9 =0.404							
CAVITY ABSORPTIVITIES											
A1 =1.00	A2 =0.50	A3 =0.50	A4 =0.50								
A5 =0.50	A6 =0.80	A7 =0.50	A8 =0.50								
CAVITY EMISSIVITIES											
E1 =1.00	E2 =0.25	E3 =0.25	E4 =0.25								
E5 =0.25	E6 =0.35	E7 =0.25	E8 =0.25								
SOLAR FLUX DISTRIBUTION RATIOS											
F1 =0.0000	F2 =0.0591	F3 =0.0645	F4 =0.0732								
F5 =0.0770	F6 =0.5162	F7 =0.2100	F8 =0.0000								
SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)											
C34 =2.45	C45 =2.95	C57 =1.73	C76 =0.42	B =0.20							
TEMPERATURES (DEG K)											
T2 = 2360.00	T6 = 2000.00	T8 = 1000.00									
VIEW FACTORS											
0.000000+000	0.142227+000	0.681801+001	0.719759+001	0.716507+001	0.399243+000	0.161975+000	0.847485+001				
0.197483+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.385673+000	0.156470+000	0.280374+000				
0.162692+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.428690+000	0.173922+000	0.234696+000				
0.139826+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.461616+000	0.187281+000	0.211278+000				
0.117377+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.497600+000	0.201880+000	0.183144+000				
0.123203+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.185013+000				
0.123203+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.185013+000				
0.598847+001	0.121375+000	0.636619+001	0.703940+001	0.723623+001	0.388061+000	0.157439+000	0.718512+001				
HEAT RADIATED BY THE CAVITY 516.54714											
HEAT ABSORBED BY HEAR CAVITY PIECE 34.87											
HEAT ABSORBED BY FRONT CONE PIECE 246.00638											
NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 256.22748											
ABSORBER EFFICIENCY (PER CENT) 56.52077											



TABLE 2

COMPUTED GENERATOR THERMAL BALANCE											
CAVITY APERTURE (INCH) = 1.000											
TOTAL SOLAR INPUT (WATTS) =3000.000											
CAVITY DIMENSIONS (CM)											
R1 =1.270	R2 =0.970	R3 =1.220	R4 =1.470	R5 =1.720							
R6 =0.840	Z1 =2.045	Z7 =1.730	Z8 =0.550	Z9 =0.315							
CAVITY ABSORPTIVITIES											
A1 =1.00	A2 =0.50	A3 =0.50	A4 =0.50								
A5 =0.50	A6 =0.80	A7 =0.50	A8 =0.50								
CAVITY EMISSIVITIES											
E1 =1.00	E2 =0.25	E3 =0.25	E4 =0.25								
E5 =0.25	E6 =0.35	E7 =0.25	EA =0.25								
SOLAR FLUX DISTRIBUTION RATIOS											
F1 =0.0000	F2 =0.0591	F3 =0.0645	F4 =0.0732								
F5 =0.0770	F6 =0.5162	F7 =0.2100	F8 =0.0000								
SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)											
C34 =2.45	C45 =2.95	C57 =1.73	C76 =0.42	B =0.20							
TEMPERATURES (DEG K)											
T2 = 2360.00	T6 = 2000.00	T8 = 1000.00									
VIEW FACTORS											
0.000000+000	0.144700+000	0.698512+001	0.739335+001	0.736551+001	0.408169+000	0.165597+000	0.640982+001				
0.248045+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.385673+000	0.156470+000	0.209811+000				
0.205777+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.428690+000	0.173922+000	0.191611+000				
0.177320+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.461616+000	0.187281+000	0.173784+000				
0.148983+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.497600+000	0.201880+000	0.151557+000				
0.155502+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.152713+000				
0.155502+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.152713+000				
0.628636+001	0.120045+000	0.637927+001	0.710671+001	0.734976+001	0.393143+000	0.159501+000	0.560913+001				
HEAT RADIATED BY THE CAVITY 657.64063											
HEAT ABSORBED BY REAR CAVITY PIECE 42.39											
HEAT ABSORBED BY FRONT CONE PIECE 208.71534											
NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 280.36993											
ABSORBER EFFICIENCY (PER CENT) 56.07397											

6165

TABLE 3

COMPUTED GENERATOR THERMAL BALANCE									
CAVITY APERTURE (INCH) = 1.200									
TOTAL SOLAR INPUT (WATTS) =3328.000									
CAVITY DIMENSIONS (CM)									
R1 =1.524	R2 =0.970	R3 =1.220	R4 =1.470	R5 =1.720					
R6 =0.840	Z1 =1.730	Z7 =1.730	Z8 =0.239	Z9 =0.134					
CAVITY ABSORPTIVITIES									
A1 =1.00	A2 =0.50	A3 =0.50	A4 =0.50						
A5 =0.50	A6 =0.80	A7 =0.50	A8 =0.50						
CAVITY EMISSIVITIES									
E1 =1.00	E2 =0.25	E3 =0.25	E4 =0.25						
E5 =0.25	E6 =0.35	E7 =0.25	E8 =0.25						
SOLAR FLUX DISTRIBUTION RATIOS									
F1 =0.0000	F2 =0.0591	F3 =0.0645	F4 =0.0732						
F5 =0.0770	F6 =0.5162	F7 =0.2100	F8 =0.0000						
SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)									
CSA =2.45	CA5 =2.95	CS7 =1.73	CT6 =0.42	B =0.20					
TEMPERATURES (DEG K)									
T2 = 2360.00	T6 = 2000.00	T8 = 1000.00							
VIEW FACTORS									
0.000000+000	0.159880+000	0.782320+001	0.829389+001	0.821420+001	0.406629+000	0.164972+000	0.252065+001		
0.394557+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.385673+000	0.156470+000	0.631997+001		
0.331872+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.428690+000	0.173922+000	0.655166+001		
0.286441+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.461616+000	0.167281+000	0.646622+001		
0.239224+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.497600+000	0.201880+000	0.612967+001		
0.223079+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.651363+001		
0.223079+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.651363+001		
0.755098+001	0.766973+001	0.462654+001	0.560872+001	0.630506+001	0.464885+000	0.188607+000	0.288974+001		
HEAT RADIATED BY THE CAVITY 954.39355									
HEAT ABSORBED BY REAR CAVITY PIECE 41.96									
HEAT ABSORBED BY FRONT CONE PIECE 9A.15934									
NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 301.17029									
ABSORBER EFFICIENCY (PER CENT) 54.29752									

6141

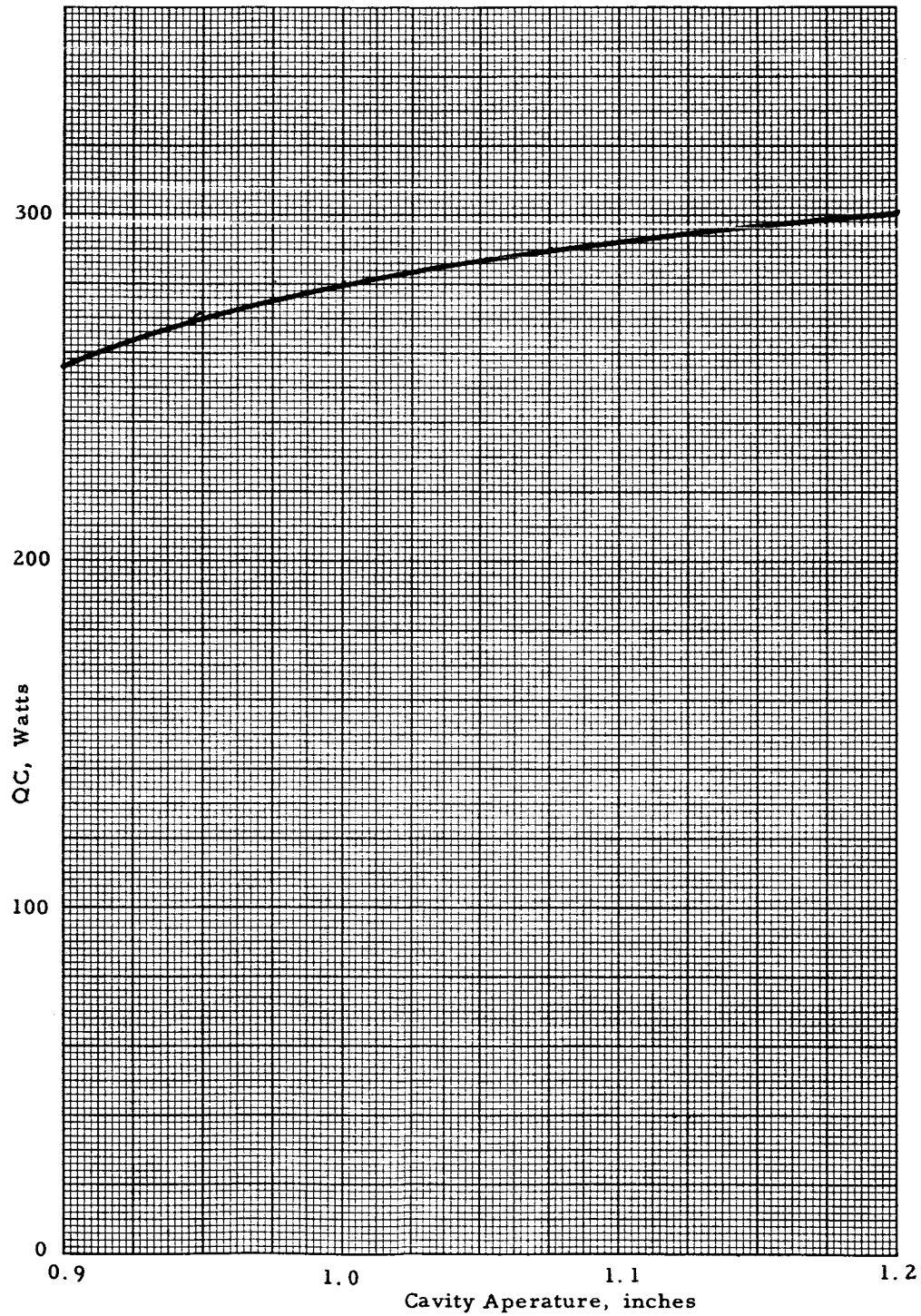


Figure 10. Calculated Converter Thermal Input vs. Cavity Aperture Size

6162

TABLE 4

COMPUTED GENERATOR THERMAL BALANCE									
CAVITY APERTURE (INCH) = 1.000									
TOTAL SOLAR INPUT (WATTS) =1666.667									
CAVITY DIMENSIONS (CM)									
R1 =1.270	R2 =0.970	R3 =1.220	R4 =1.470	R5 =1.720					
R6 =0.840	Z1 =2.045	Z7 =1.730	Z8 =0.550	Z9 =0.315					
CAVITY ABSORPTIVITIES									
A1 =1.00	A2 =0.50	A3 =0.50	A4 =0.50						
A5 =0.50	A6 =0.80	A7 =0.50	A8 =0.50						
CAVITY EMISSIVITIES									
E1 =1.00	E2 =0.25	E3 =0.25	E4 =0.25						
E5 =0.25	E6 =0.35	E7 =0.25	E8 =0.25						
SOLAR FLUX DISTRIBUTION RATIOS									
F1 =0.0000	F2 =0.0591	F3 =0.0645	F4 =0.0732						
F5 =0.0770	F6 =0.5162	F7 =0.2100	F8 =0.0000						
SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)									
C34 =2.45	C45 =2.95	C57 =1.73	C76 =0.42	S =0.20					
TEMPERATURES (DEG K)									
T2 = 2360.00	T6 = 2000.00	T8 = 1000.00							
VIEW FACTORS									
0.00000+000	0.14470+000	0.698512+001	0.739335+001	0.736551+001	0.408169+000	0.165597+000	0.156470+000	0.640952+001	
0.248046+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.385673+000	0.428690+000	0.173922+000	0.191611+000	
0.205777+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.461616+000	0.201880+000	0.167281+000	0.173784+000	
0.177320+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.497600+000	0.110704+000	0.201880+000	0.151597+000	
0.148963+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.272866+000	0.110704+000	0.110704+000	0.152713+000	
0.155502+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.110704+000	0.152713+000	
0.155502+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.110704+000	0.152713+000	
0.628636+001	0.120044+000	0.637927+001	0.710071+001	0.734976+001	0.393143+000	0.159501+000	0.159501+000	0.159501+000	
HEAT RADIATED BY THE CAVITY 493.09972									
HEAT ABSORBED BY REAR CAVITY PIECE -21.37									
HEAT ABSORBED BY FRONT CONE PIECE 143.06495									
NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 134.04160									
ABSORBER EFFICIENCY (PER CENT) 48.25496									

6161

TABLE 5

COMPUTED GENERATOR THERMAL BALANCE											
CAVITY APERTURE (INCH) = 1.000											
TOTAL SOLAR INPUT (WATTS) =2333.333											
CAVITY DIMENSIONS (CM)											
R1 =1.270	R2 =0.970	R3 =1.220	R4 =1.470	R5 =1.720							
R6 =0.840	Z1 =2.045	Z7 =1.730	Z8 =0.550	Z9 =0.315							
CAVITY ABSORPTIVITIES											
A1 =1.00	A2 =0.50	A3 =0.50	A4 =0.50								
A5 =0.50	A6 =0.80	A7 =0.50	A8 =0.50								
CAVITY EMISSIVITIES											
E1 =1.00	E2 =0.25	E3 =0.25	E4 =0.25								
E5 =0.25	E6 =0.35	E7 =0.25	E8 =0.25								
SOLAR FLUX DISTRIBUTION RATIOS											
F1 =0.0000	F2 =0.0591	F3 =0.0655	F4 =0.0732								
F5 =0.0770	F6 =0.5162	F7 =0.2100	F8 =0.0000								
SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)											
C34 =2.45	C45 =2.95	C57 =1.73	C76 =0.42	B =0.20							
TEMPERATURES (DEG K)											
T2 = 2360.00	T6 = 2000.00	T8 = 1000.00									
VIEW FACTORS											
0.00000+000	0.14470+000	0.698512+001	0.739335+001	0.736551+001	0.408169+000	0.165597+000	0.640952+001				
0.248076+000	0.00000+000	0.00000+000	0.00000+000	0.00000+000	0.385673+000	0.156470+000	0.209811+000				
0.205777+000	0.00000+000	0.00000+000	0.00000+000	0.00000+000	0.428690+000	0.173922+000	0.191611+000				
0.177320+000	0.00000+000	0.00000+000	0.00000+000	0.00000+000	0.461616+000	0.167281+000	0.173784+000				
0.148963+000	0.00000+000	0.00000+000	0.00000+000	0.00000+000	0.497600+000	0.201880+000	0.151557+000				
0.153502+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.152713+000				
0.155502+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.152713+000				
0.628636+001	0.120084+000	0.637927+001	0.710671+001	0.734976+001	0.393143+000	0.159501+000	0.566913+001				
HEAT RADIATED BY THE CAVITY 570.72771											
HEAT ABSORBED BY REAR CAVITY PIECE 10.17											
HEAT ABSORBED BY FRONT CONE PIECE 174.77482											
NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 207.25403											
ABSORBER EFFICIENCY (PER CENT) 53.29391											



6160

TABLE 6

COMPUTED GENERATOR THERMAL BALANCE									
CAVITY APERTURE (INCH) = 1.000									
TOTAL SOLAR INPUT (WATTS) = 3000.000									
CAVITY DIMENSIONS (CM)									
R1 = 1.270	R2 = 0.970	R3 = 1.220	R4 = 1.470	R5 = 1.720					
R6 = 0.840	Z1 = 2.045	Z7 = 1.730	Z8 = 0.550	Z9 = 0.315					
CAVITY ABSORPTIVITIES									
A1 = 1.00	A2 = 0.50	A3 = 0.50	A4 = 0.50						
A5 = 0.50	A6 = 0.80	A7 = 0.50	A8 = 0.50						
CAVITY EMISSIVITIES									
E1 = 1.00	E2 = 0.25	E3 = 0.25	E4 = 0.25						
E5 = 0.25	E6 = 0.35	E7 = 0.25	E8 = 0.25						
SOLAR FLUX DISTRIBUTION RATIOS									
F1 = 0.0000	F2 = 0.0591	F3 = 0.0845	F4 = 0.0732						
F5 = 0.0770	F6 = 0.5162	F7 = 0.2100	F8 = 0.0000						
SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)									
C34 = 2.45	C45 = 2.95	C57 = 1.73	C76 = 0.42	B = 0.20					
TEMPERATURES (DEG K)									
T2 = 2360.00	T6 = 2000.00	T8 = 1000.00							
VIEW FACTORS									
0.00000+000	0.144700+000	0.698512+001	0.739335+001	0.736551+001	0.408169+000	0.165597+000	0.640992+001		
0.288046+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.385673+000	0.156470+000	0.209811+000		
0.205777+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.428690+000	0.173922+000	0.191611+000		
0.177320+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.461616+000	0.187281+000	0.173784+000		
0.148963+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.497600+000	0.201880+000	0.151557+000		
0.195502+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.152713+000		
0.195502+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.152713+000		
0.628636+001	0.120044+000	0.637927+001	0.710671+001	0.734976+001	0.393143+000	0.159501+000	0.560913+001		
HEAT RADIATED BY THE CAVITY 657.64063									
HEAT ABSORBED BY REAR CAVITY PIECE 42.39									
HEAT ABSORBED BY FRONT CONE PIECE 208.71534									
NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 280.36993									
ABSORBER EFFICIENCY (PER CENT) 56.07397									

6166

TABLE 7

COMPUTED GENERATOR THERMAL BALANCE											
CAVITY APERTURE (INCH) = 1.000											
TOTAL SOLAR INPUT (WATTS) =4333.333											
CAVITY DIMENSIONS (CM)											
R1 =1.270	R2 =0.970	R3 =1.220	R4 =1.470	R5 =1.720							
R6 =0.840	Z1 =2.045	Z7 =1.730	Z8 =0.550	Z9 =0.315							
CAVITY ABSORPTIVITIES											
A1 =1.00	A2 =0.50	A3 =0.50	A4 =0.50								
A5 =0.50	A6 =0.80	A7 =0.50	A8 =0.50								
CAVITY EMISSIVITIES											
E1 =1.00	E2 =0.25	E3 =0.25	E4 =0.25								
E5 =0.25	E6 =0.35	E7 =0.25	E8 =0.25								
SOLAR FLUX DISTRIBUTION RATIOS											
F1 =0.0000	F2 =0.0591	F3 =0.0645	F4 =0.0732								
F5 =0.0770	F6 =0.5162	F7 =0.2100	F8 =0.0000								
SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)											
C3A =2.45	C45 =2.95	C57 =1.73	C76 =0.42	B =0.20							
TEMPERATURES (DEG K)											
T2 = 2360.00	T6 = 2000.00	T8 = 1000.00									
VIEW FACTORS											
0.000000+000	0.144700+000	0.698512+001	0.739335+001	0.736551+001	0.408169+000	0.165597+000	0.640952+001				
0.248044+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.385673+000	0.156470+000	0.209811+000				
0.205777+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.428690+000	0.173922+000	0.191611+000				
0.177320+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.461616+000	0.187281+000	0.173764+000				
0.148963+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.497600+000	0.201880+000	0.151557+000				
0.155502+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.152713+000				
0.155502+000	0.857142+001	0.554392+001	0.733268+001	0.937349+001	0.272866+000	0.110704+000	0.152713+000				
0.628638+001	0.120044+000	0.637927+001	0.710671+001	0.734976+001	0.393143+000	0.159501+000	0.560913+001				
HEAT RADIATED BY THE CAVITY 833.64928											
HEAT ABSORBED BY REAR CAVITY PIFCE 107.04											
HEAT ABSORBED BY FRONT CONE PIFCE 277.12372											
NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 424.91321											
ABSORBER EFFICIENCY (PER CENT) 58.83415											

6151

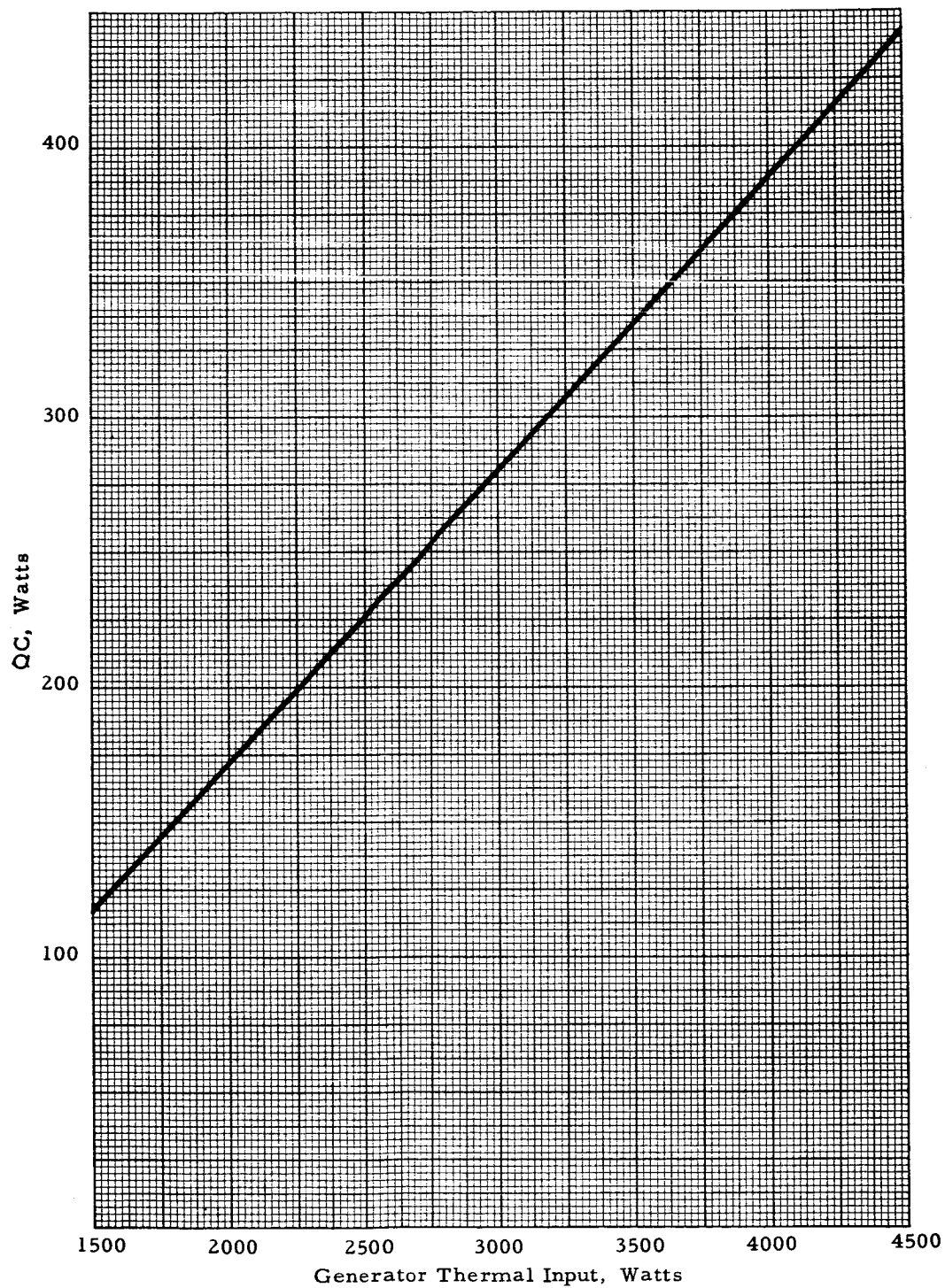


Figure 11. Calculated Thermal Input at Converter
vs. Generator Thermal Input

6156

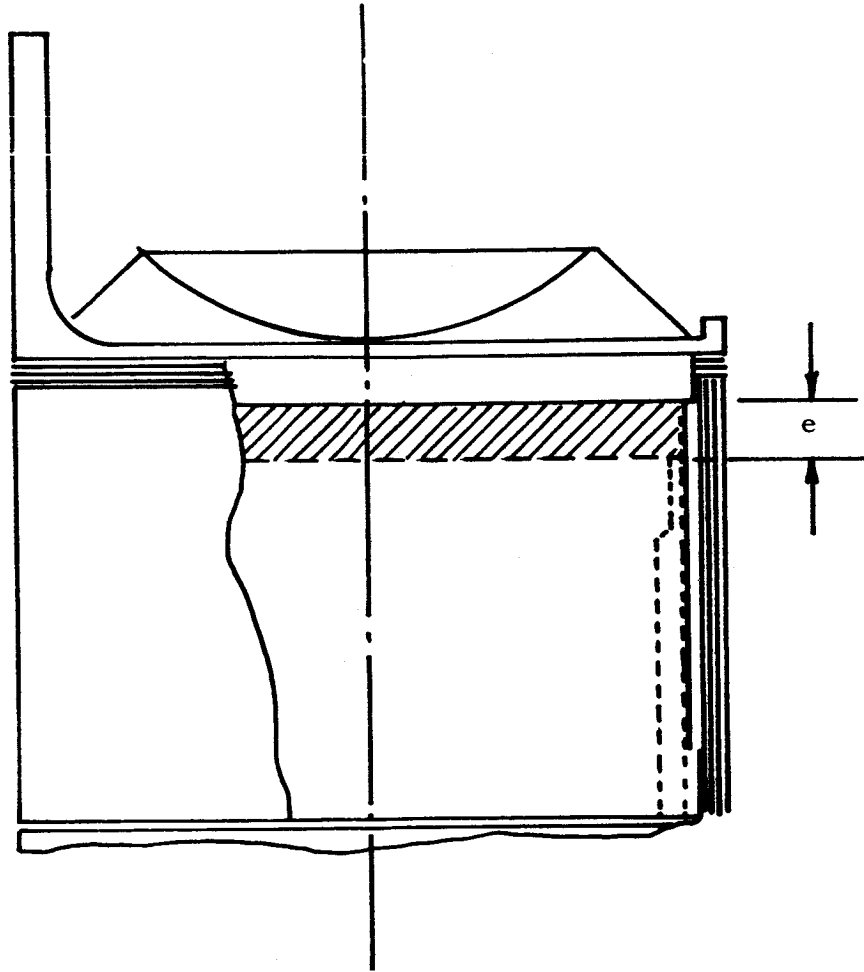


Figure 12. Converter Heat Loss Area

$$q(\text{cesium conduction}) = 10.0 \text{ watts}$$

$$q(\text{emitter support}) = 39.0 \text{ watts}$$

The total converter losses at 2000°K are then given in terms of the output current by:

$$QC = 77.2 + 7.4 + 2.66 I_o \text{ watts}$$

and this relationship is plotted in Figure 13.

For the four calculated values of QC of 134, 207, 280, and 425 watts, the corresponding values of converter output current are 18.5, 46.2, 73.5, and 128 amperes respectively.

1.4.2 Rear Cavity Heat Losses

The rear cavity piece rejects the heat received from the cavity by radiation and by conduction. The radiator occurs from the back side and from the lateral area and it is computed as follows:

Average diameter of support sleeve:	1.4 cm
Length of support sleeve:	0.8 cm
Tantalum conductivity:	0.7 watts/cm-deg C
Heat loss at back side:	$q_B = \epsilon A \sigma T^4 \quad T = 2360 \text{ deg K}$ $= 0.25 \times 1.54 \times 176.2$ $= 68 \text{ watts for unshielded case}$ $= 0.25 \times 68 = 17 \text{ watts for shielded case}$
Lateral radiation:	$q_L = \epsilon \pi D L' \sigma T^4 \quad L' = 0.4 \text{ cm assumed}$ $= 0.440 \times 176.2 = 78 \text{ watts}$
Conduction heat transfer:	$q_C = kA(T_1 - T_2)/L \quad T_2 = 1200 \text{ deg K assumed}$

6152

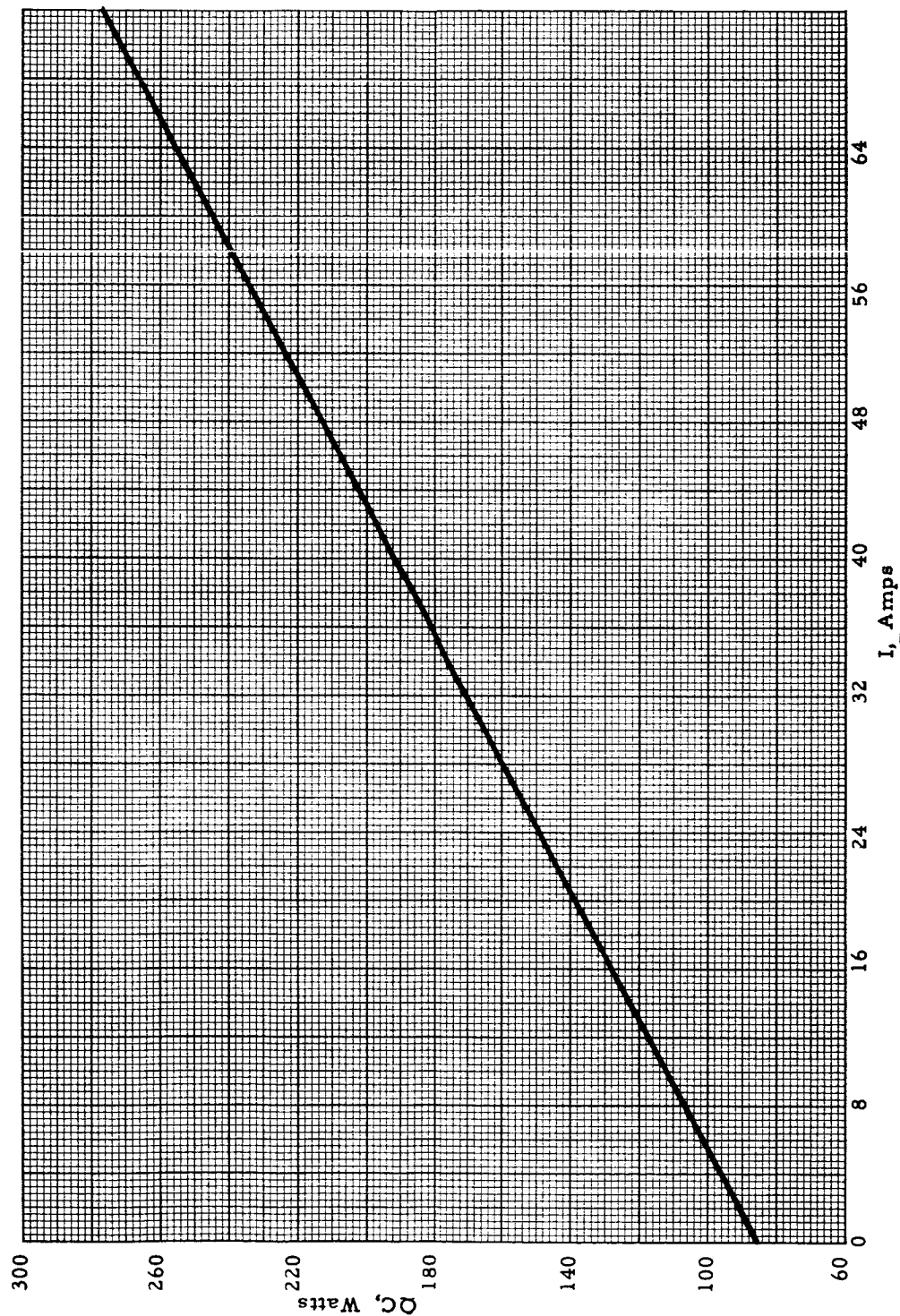


Figure 13. Converter Output Current vs. Thermal Input at 2000°K

$$\begin{aligned}
 q_C &= 0.7 \times \pi \times 1.4 \times t \times 1160 / .8 \\
 &= 4460 \text{ t watts for } t \text{ expressed} \\
 &\quad \text{in cm} \\
 &= 11.15 \text{ t watts for } t \text{ expressed} \\
 &\quad \text{in mils}
 \end{aligned}$$

$$\text{Total loss: } q_{\text{shielded}} = 95 + 11.15 \text{ t watts}$$

$$q_{\text{unshielded}} = 146 + 11.15 \text{ t watts}$$

These relationships are plotted in Figure 14. It is seen that for the maximum input predicted of 107 watts, the cavity piece should have a support sleeve thickness of 1 mil and that shielding is required. Since a thickness of 1 mil is not realistic for an element of this size, the selection of the thickness of the supporting sleeve must be governed by structural considerations. A thickness of 5 mils would be practical.

1.4.3 Generator Radiator Heat Transfer

The lateral area of the generator radiator can be calculated by assimilating the geometry to a cylinder with a height of 4.5 cm and a diameter of 6.7 cm. Its value is 95.7 cm^2 . The area at the bottom of this radiator corresponds to that of a circle with a diameter of 9.77 cm or 74.7 cm^2 . The total area of the generator radiator is thus 170.4 cm^2 . At an effective emissivity of 0.85, the heat radiated as a function of temperature is given by Figure 15. If it is conservatively assumed that the heat received by the radiator is equal to 80% of the heat absorbed by the rear cavity piece, Q2, and the emitter shoe pieces, (Q3 + Q4 + Q5 + Q7), the maximum heat rejection at 90 w/sq. ft. for the generator radiator is 435 watts, and the corresponding average radiator temperature will be 852 deg K, which is an acceptable value in terms of conventional generator design practice.

* The case at 130 w/sq. ft. is not considered because it results in an obvious overheated condition for the generator, viz., 128 amperes per converter when the maximum design current of Series VIII converters is of the order of 75 amps.

6150

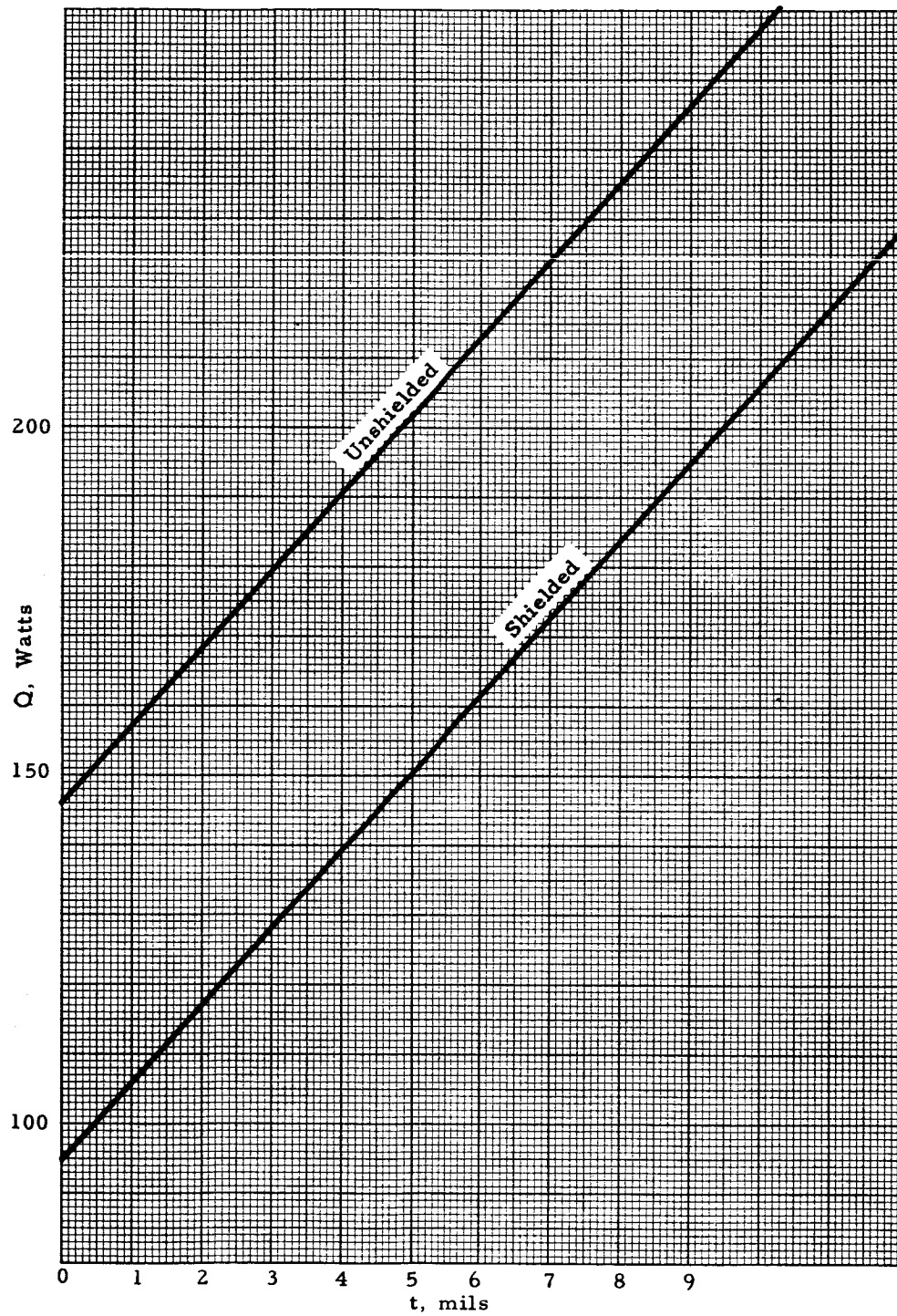


Figure 14. Heat Transfer Characteristics of Rear Cavity Piece

6147

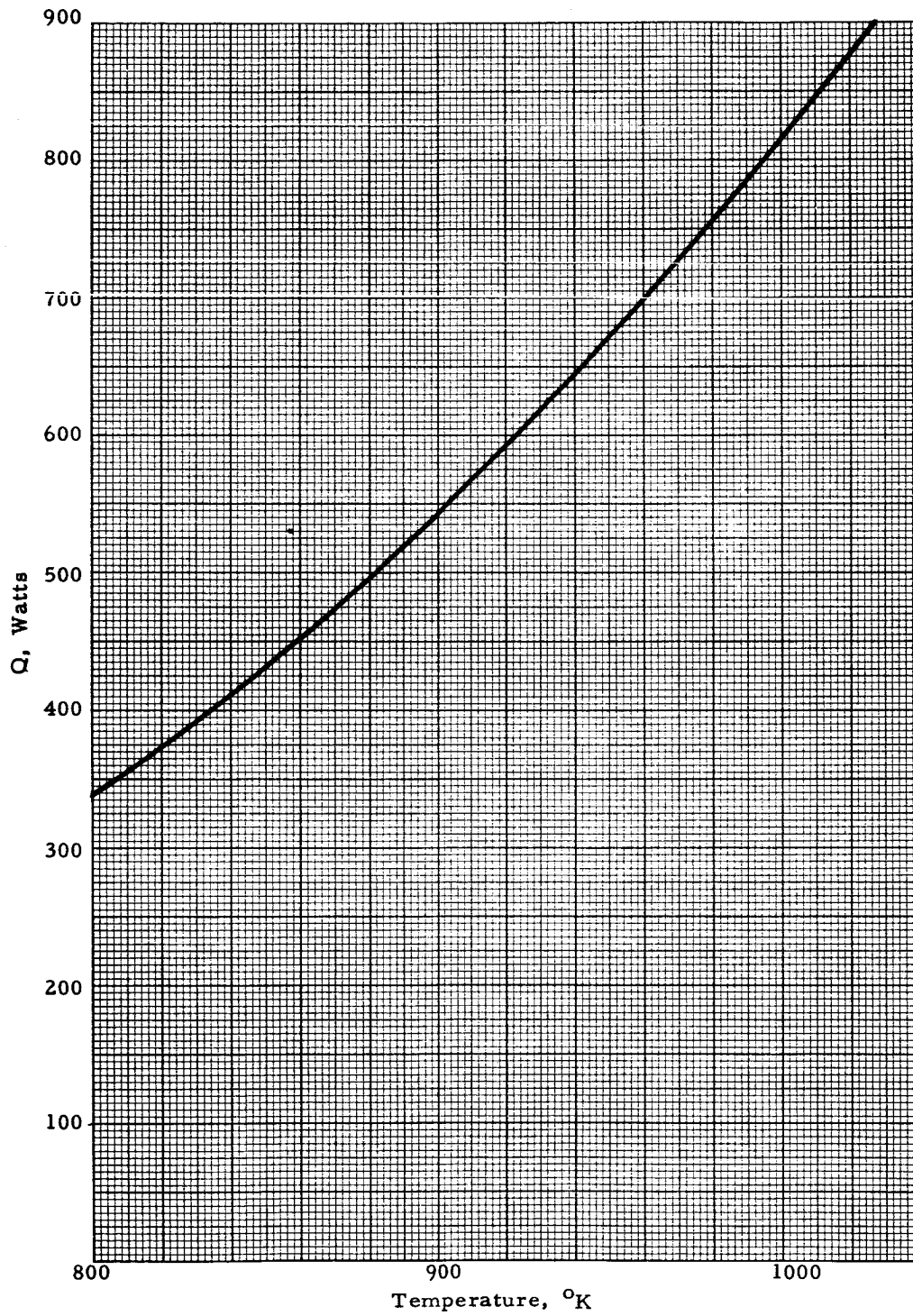


Figure 15. Heat Transfer Characterisitic for Generator Radiator

1.5 Generator Electrical Output Characteristics

1.5.1 Generator I-V Characteristic

The generator I-V characteristic is simply obtained by multiplying by 6 the output voltage of an individual converter and subtracting from it the expected voltage drop in the interconnecting leads. Figure 16 shows a representative I-V characteristic for a Series VIII converter obtained on converter VIII-S-9 (May 14, 1965). The voltage drop in interconnecting leads was measured on converter VIII-P-3 (August 12, 1964 Data Sheet 27), and it amounted to 1.45 millivolt/ampere for a single converter, or 8.70 millivolts/ampere in a series of 6 converters. This loss is plotted in Figure 17. Figure 18 then gives the expected generator I-V characteristic.

1.5.2 Generator Output

For the four selected values of heat input, the corresponding output currents were found in Section 1.4.1 to be 18.5, 46.2, 73.5, and 128 amperes respectively. Figure 18 shows that at the three lower output currents, the output voltages will be 5.2, 4.0 and (by extrapolation) 2.35 volts. Figure 19 gives the resulting curves of generator power output, generator-absorber efficiency, P_G/W , and generator efficiency, $P_G/(W - Q_{BB})$, where Q_{BB} is the radiation loss from a black body cavity at 2000°K and having an aperture of 1.0 inch (460 watts). As may be seen, the design goal of an efficiency of 10% for a maximum power input of 2500 watts is not achieved. This is because of insufficient electrical output from the converters at any value of heat input. The maximum power output of a Series VIII converter at 2000°K is found from Figure 16 to be at 0.55 volts, and is equal to 37.4 watts. It is thus seen that for 6 converters, without considering the voltage drop in the interconnecting leads, the maximum possible power output is only 225 watts.

6153

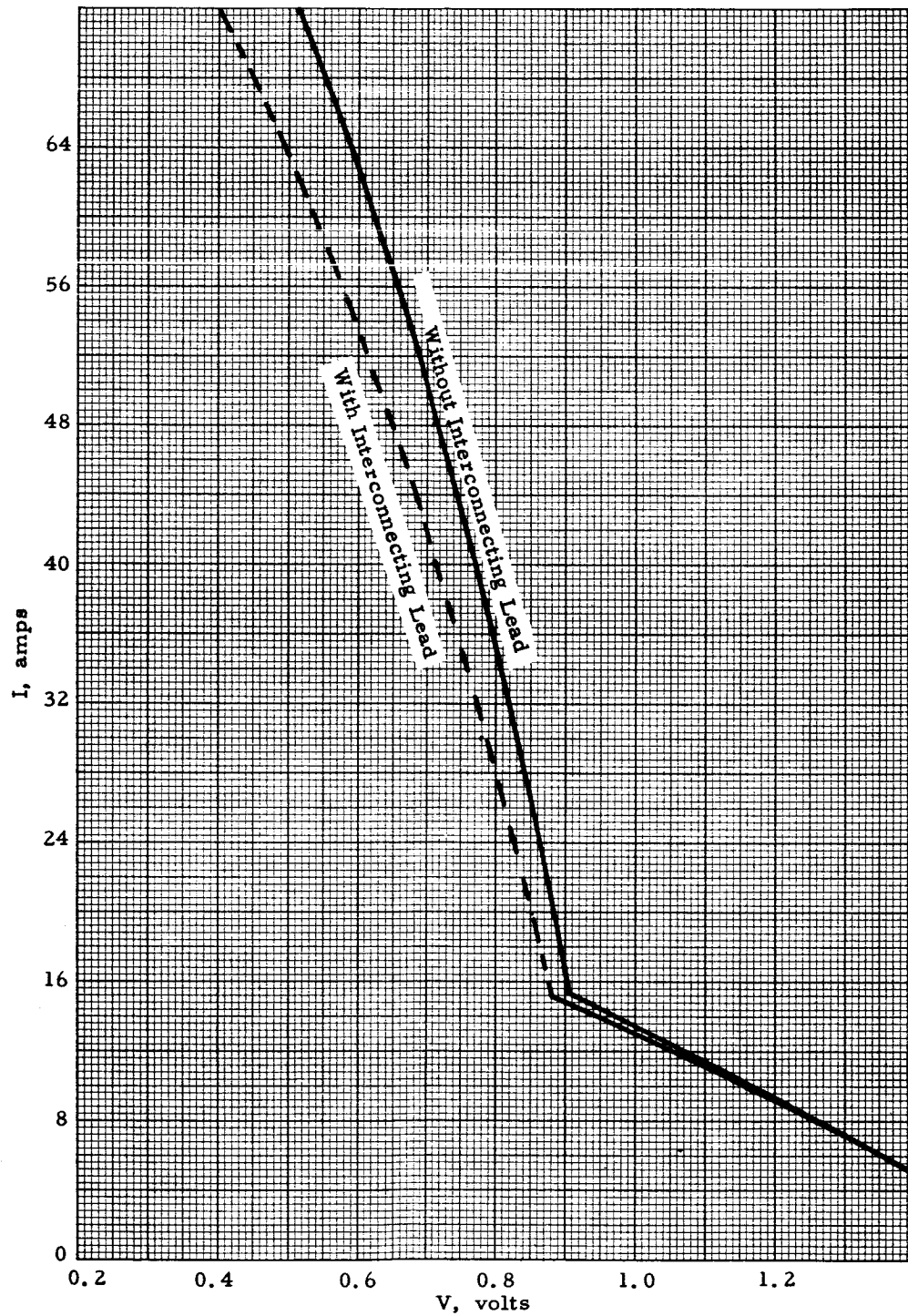


Figure 16. Converter I-V Characteristic

6149

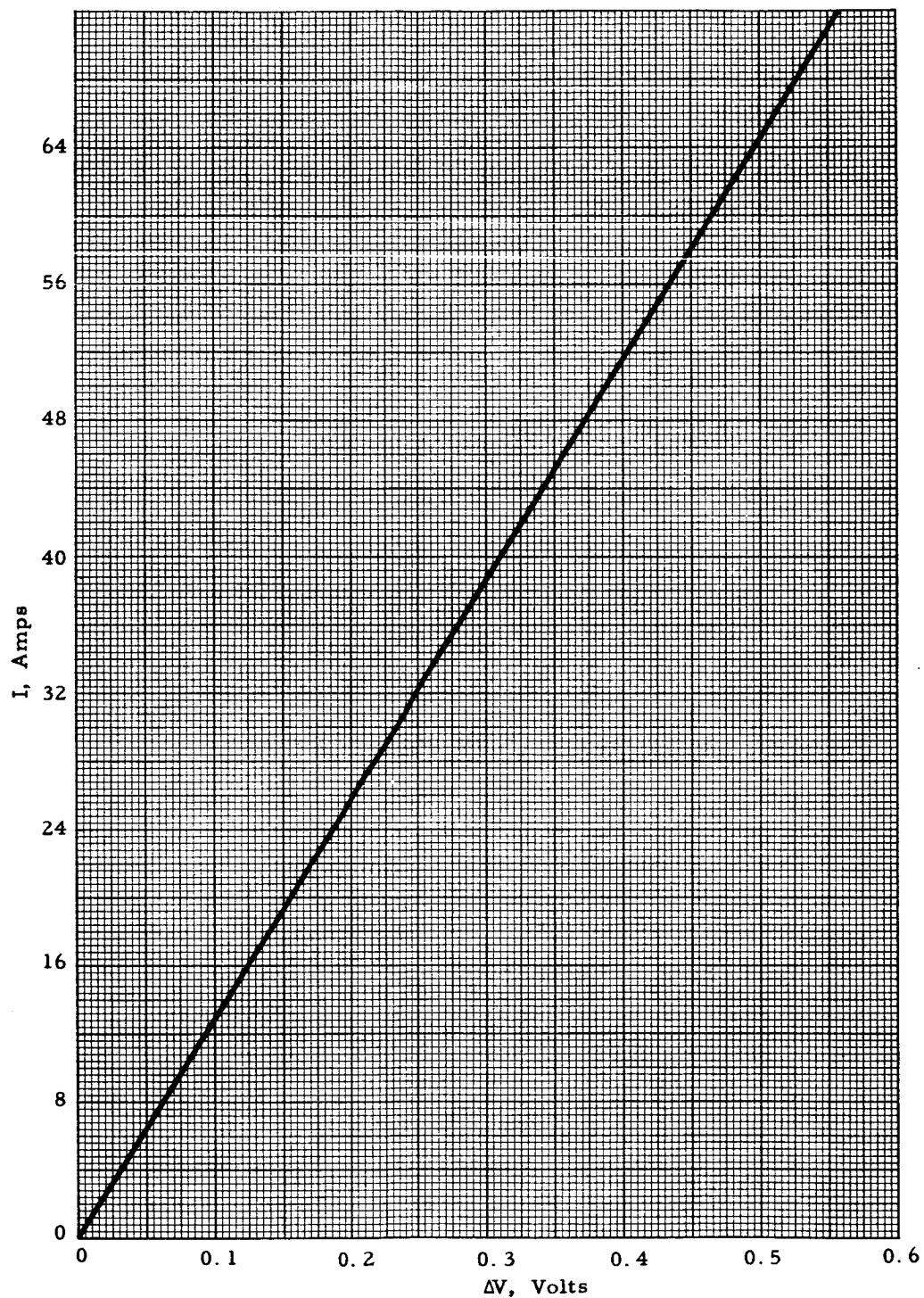


Figure 17. Voltage Drop in Interconnecting Leads

6145

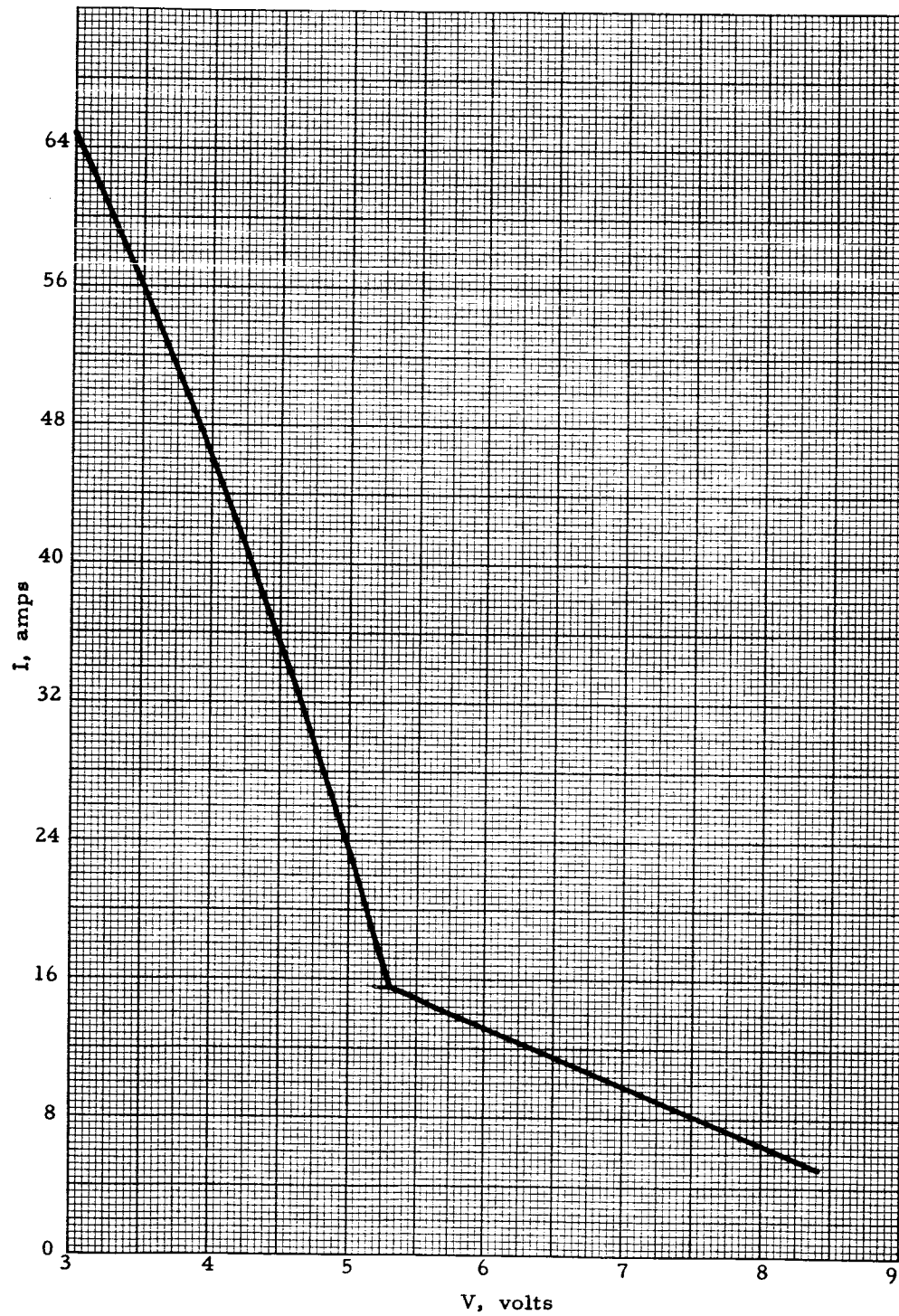


Figure 18. Generator I-V Characteristic

6154

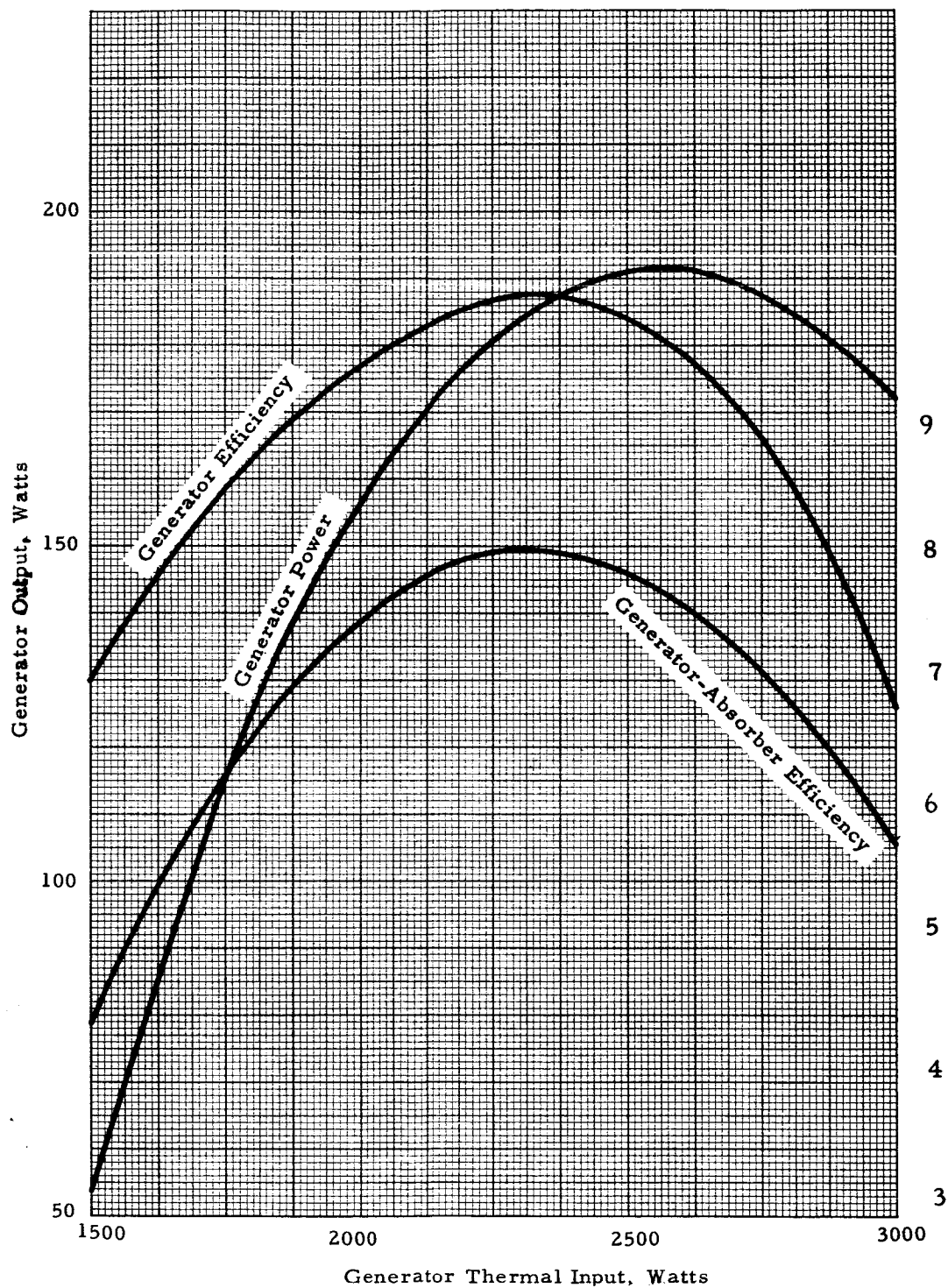


Figure 19. Generator Output Efficiency vs. Thermal Input

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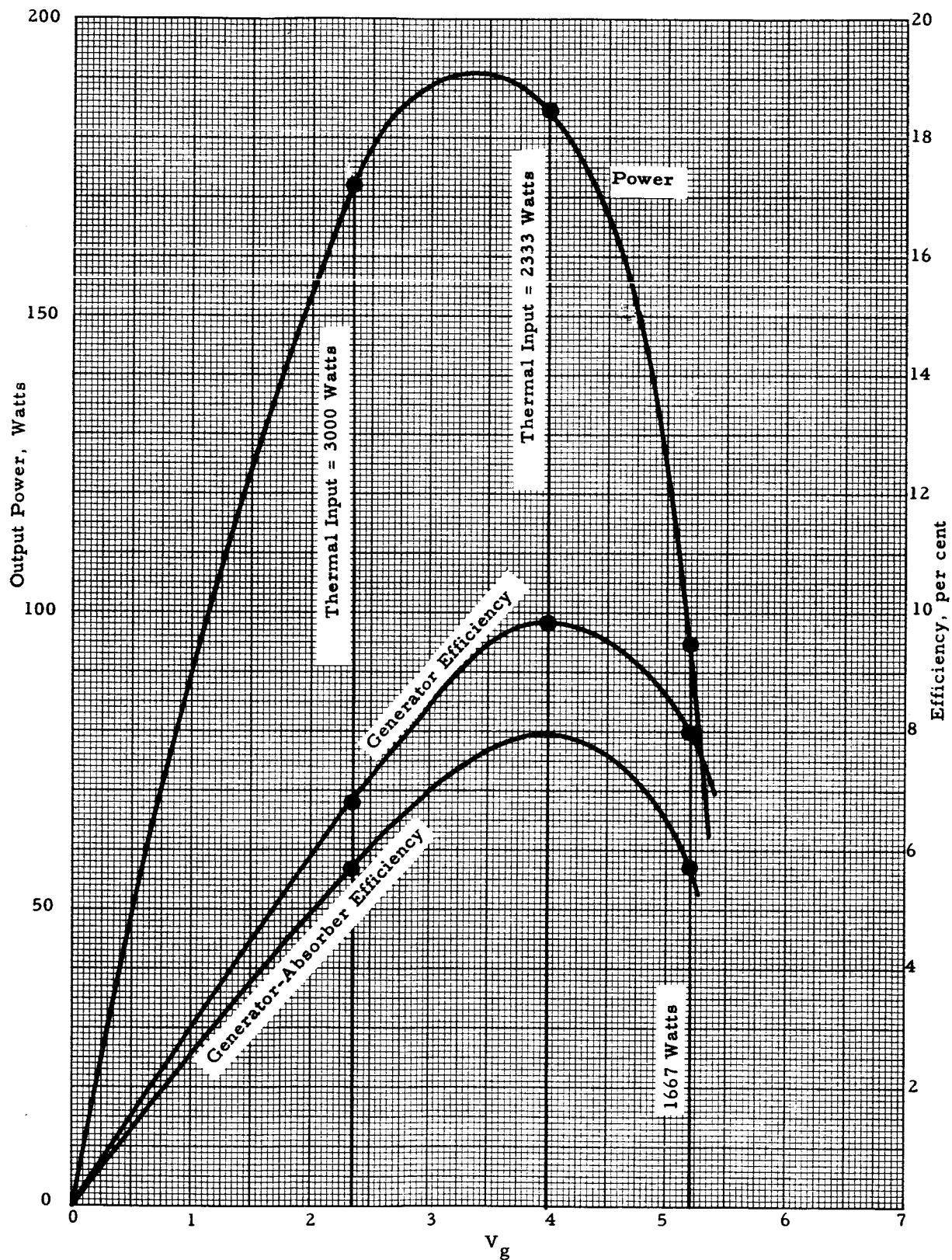


Figure 19a. Generator Output and Efficiency vs. Output Voltage

1.6 Calculation of Changes of Critical Clearances

1.6.1 Adjacent Emitter Shoe Pieces

Figure 20 shows the geometry of the clearance between adjacent emitter shoe pieces. For longitudinal and transverse displacements ℓ and r respectively, due to thermal expansion, the clearance between adjacent emitter shoe pieces changes by:

$$\epsilon = 1.732 r + \ell$$

The magnitude of r is given by:

$$r = (\alpha \Delta T)L_r$$

For tantalum, $(\alpha \Delta T) = 12.9$ mils/inch* at 1700°C , the length L_r , is maximum at the plane of the emitter and is equal to 0.38 inch. Therefore, $r = 4.90$ mils.

The magnitude of ℓ is given by the net difference in expansion between the generator block and the converter emitter structure. The generator block expands by $\ell_b = (\alpha \Delta T)L_b$.

For molybdenum at 700°C , $(\alpha \Delta T) = 3.8$ mils/inch. The length L_b is equal to the distance from the generator axis to the converter support plane and is 1.21 inch.

The emitter structure expands by $\ell_e = (\alpha \Delta T)L_e$ where $L_e = 0.47$ inch and $(\alpha \Delta T)$ is the thermal expansion of tantalum at the average temperature $(1700 + 700)/2 = 1200^\circ\text{C}$ which is 8.6 mils/inch.

We then find:

$$\ell = 0.47 \times 8.6 - 1.21 \times 3.8 = -.56 \text{ mils}$$

and,

$$\epsilon = 1.732 \times 4.90 - .56 = \underline{7.9 \text{ mils}}$$

is the decrease in the clearance between adjacent emitter shoe pieces. If the spacing between these elements at room temperature is 20 mils, at operating

* Handbook of Thermophysical Properties of Materials.

6143

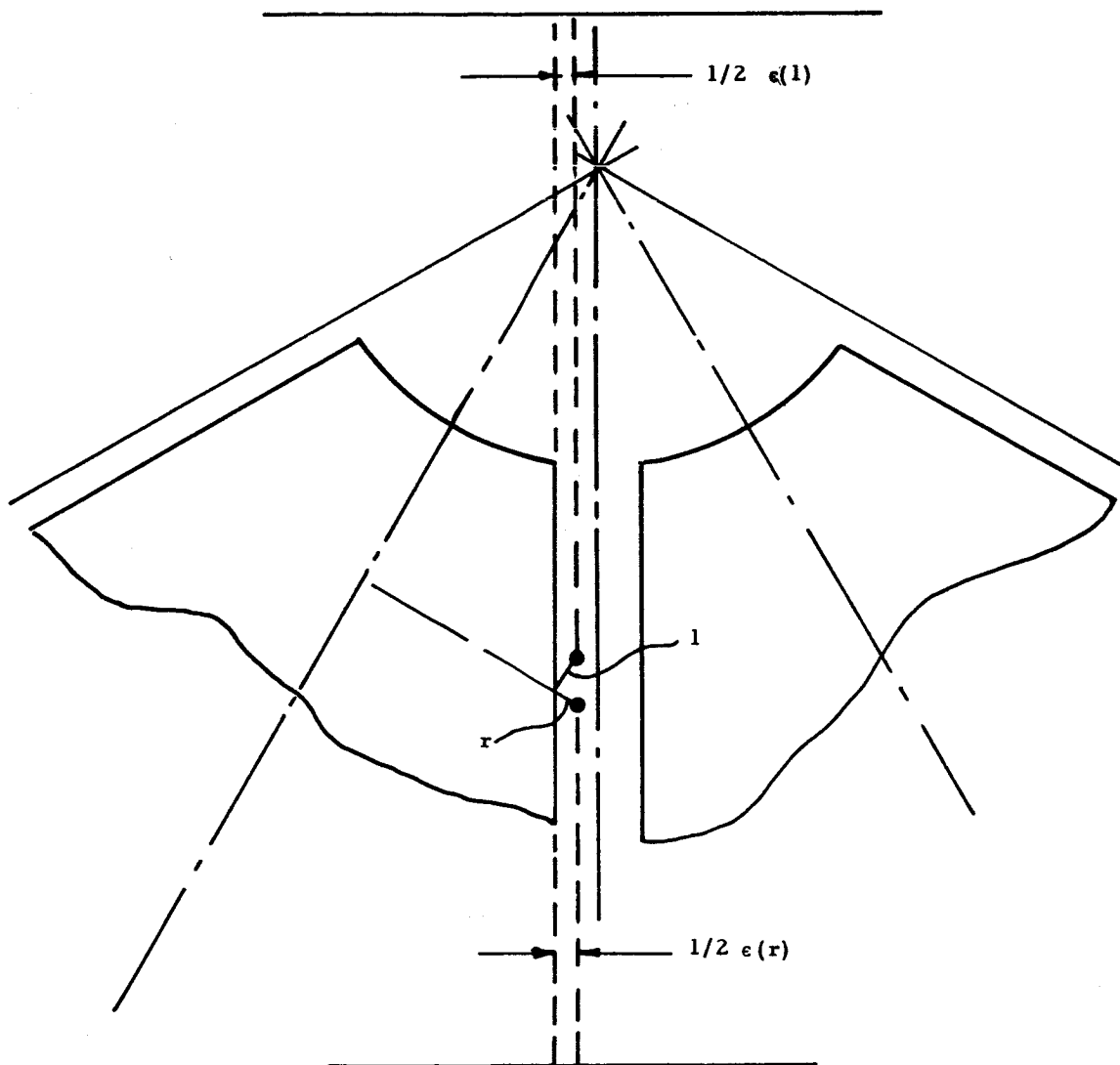


Figure 20. Critical Clearance Dimensions

temperature it will be 12 mils, a value which is consistent with thermionic generator design practice, particularly for one with a somewhat more complicated geometry.

1.6.2 Shoe Piece - Rear Cavity Piece

The change in this clearance is given by the sum of the radial expansion of the rear cavity piece and the value of ℓ corresponding to the tip of a shoe piece.

The radial expansion of the rear cavity piece is given by:

$$r_r = R (\alpha \Delta T)$$

For the temperature achieved by the rear cavity piece of 2360°K or 2087°C, $(\alpha \Delta T)$ equals 10.8 mils/inch. Since the rear cavity piece has a radius of 0.38 inch, $r_r = 4.1$ mils.

The value of ℓ corresponding to the tip of a shoe piece is obtained by adding a term $L(\alpha \Delta T)$ to the previous calculated value of ℓ :

$$L = 0.3 \text{ inch}$$

$$(\alpha \Delta T), \text{ tantalum at } 1700^\circ\text{C} = 12.9 \text{ mils/inch}$$

$$\ell_{\text{tip}} = -.56 + 3.87 = 3.31 \text{ mils}$$

The decrease in clearance between the rear cavity piece and the tip of the surrounding shoe pieces is then $4.1 + 3.3 = \underline{7.4 \text{ mils}}$. For an initial value of 20 mils, the spacing will thus decrease to 12.6 mils.

1.6.3 Shoe Piece - Front Cone

The change in the clearance between the emitter shoe pieces and the front cone is given by the difference between the radial emitter expansion, which has already been calculated as being 4.90 mils, and the displacement of the front cone. This last term is again a term $L(\alpha \Delta T)$ where L is the distance from the center line of a converter to the plane of the front cone or 0.39 inch,

and $(\alpha \Delta T)$ is the thermal expansion of molybdenum at 700°C: 3.8 mils/inch. The displacement of the front cone is then: $2.8 \times 0.39 = 1.48$ mils.

The decrease in clearance between the front cone and the emitter shoe pieces is accordingly: $4.90 - 1.48 = \underline{3.4 \text{ mils}}$. For an initial value of 20 mils, the spacing will decrease to 16.6 mils.

1.7 Preliminary Design of Electron Bombardment Unit

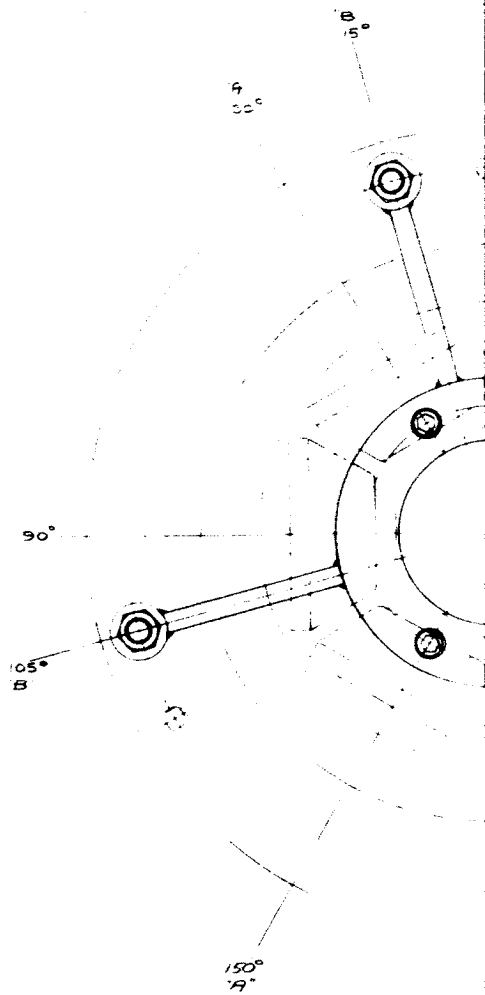
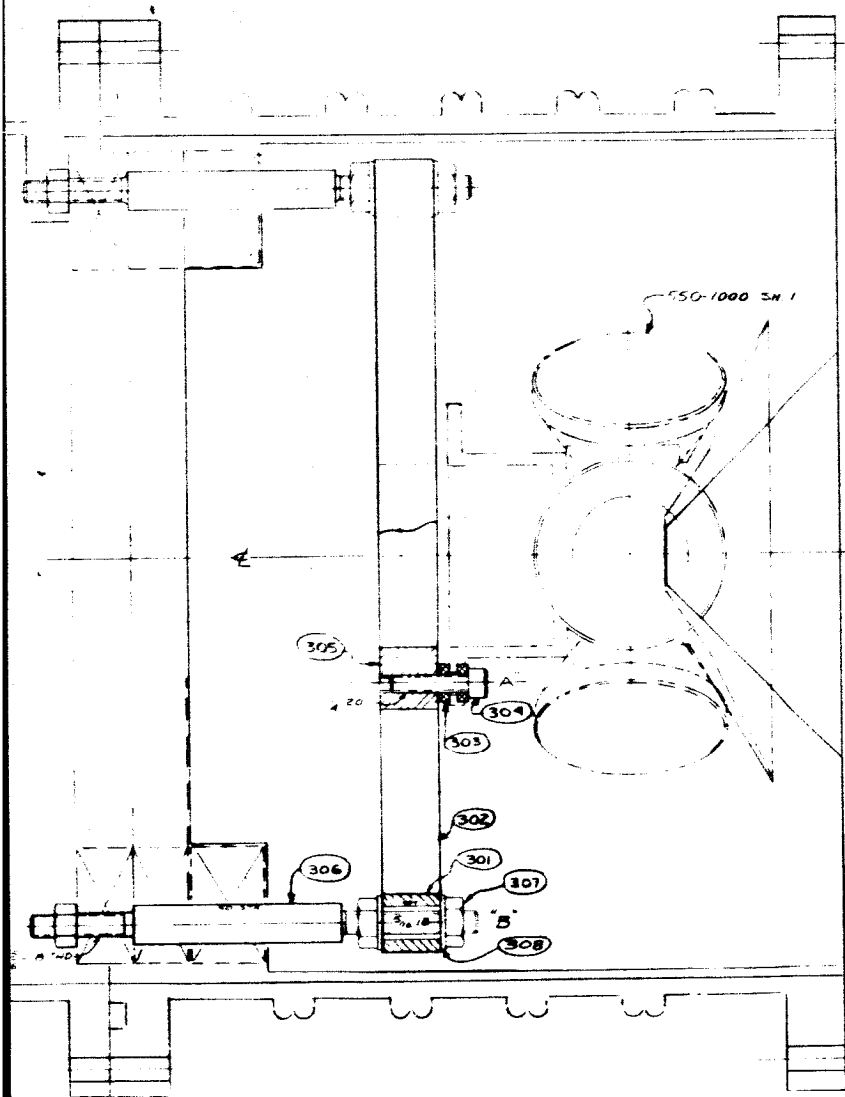
1.7.1 Preliminary Layout

Figure 21, Dwg. 549-1000, shows the initially proposed design for the electron bombardment unit. The unit consists essentially of a concentric filament support structure which holds 6 individual U-shaped filaments. The central support penetrates the cavity to act as an electrostatic shield for the rear cavity piece. Because of its exposure to the cavity thermal radiation, it is important to provide it with a heat barrier section which can reduce the cavity heat losses, without causing overheating of the filament support to such an extent that it becomes an important source of bombardment current. The choice of filament size and the design of the heat barrier section of the control filament support are discussed in the next two sections. The other design features presented by the electron bombardment unit of Figure 21 are:

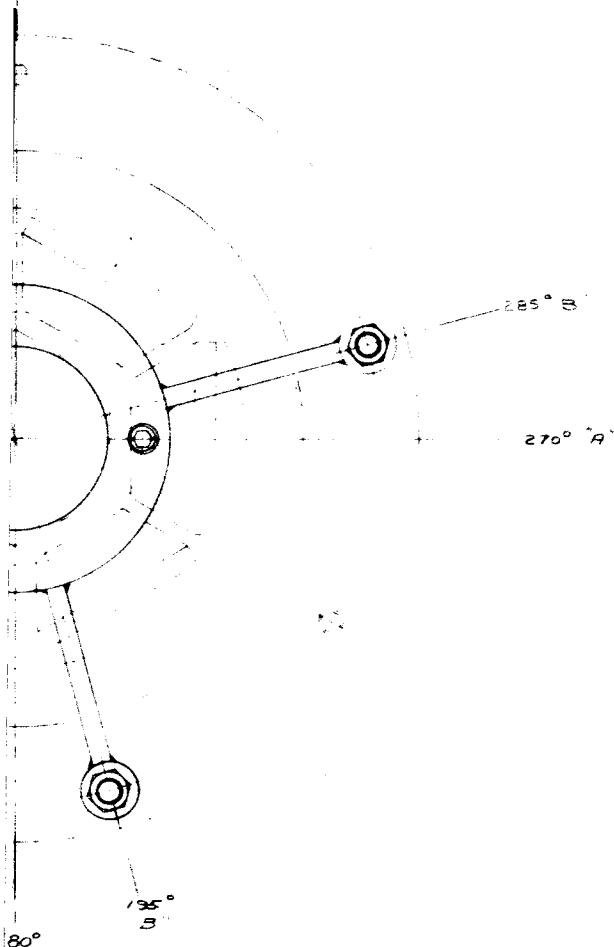
1. Shielding of the high voltage insulator to prevent metallic deposits and consequent leakage currents.
2. Easy adjustments in traverse and height are provided by two independent sets of 4 screw adjustments.
3. The unit is easily demountable from the generator by releasing 4 thumb screws.

1.7.2 Selection of Bombardment Filament Size

The filaments of the electron bombardment unit should be capable of delivering the full power output of the JPL electron bombardment power supply



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FIGURE

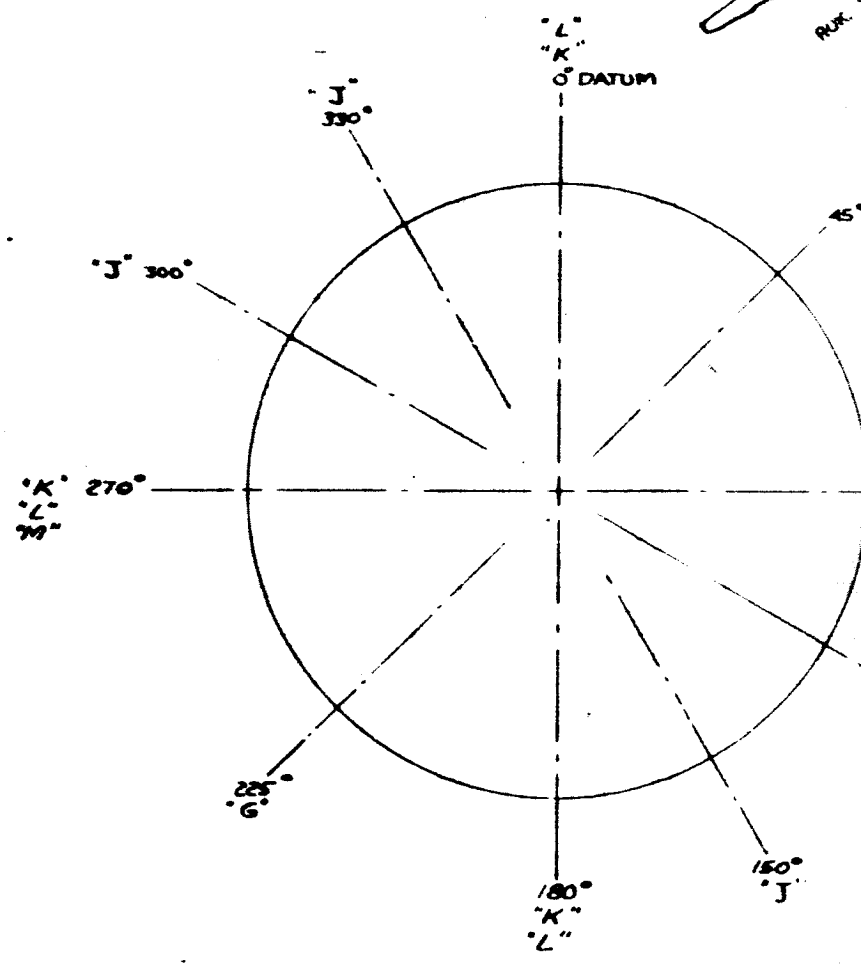
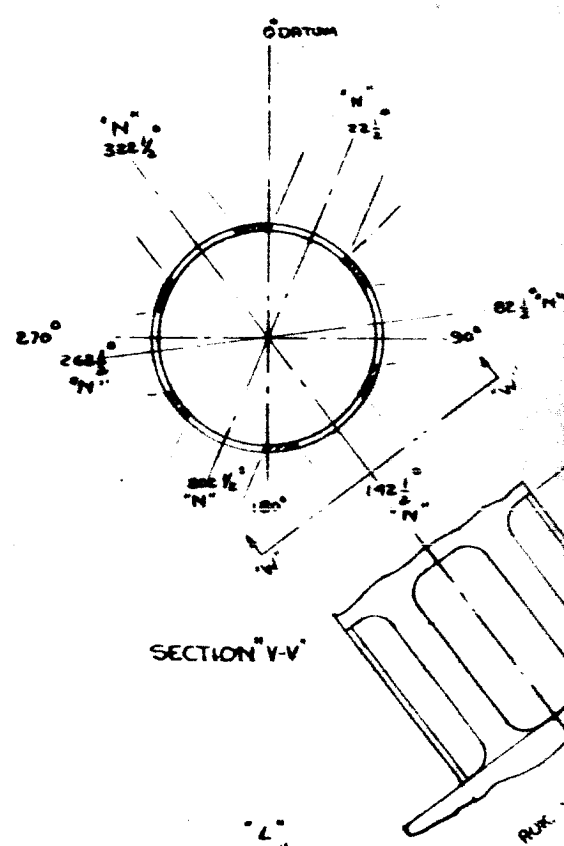
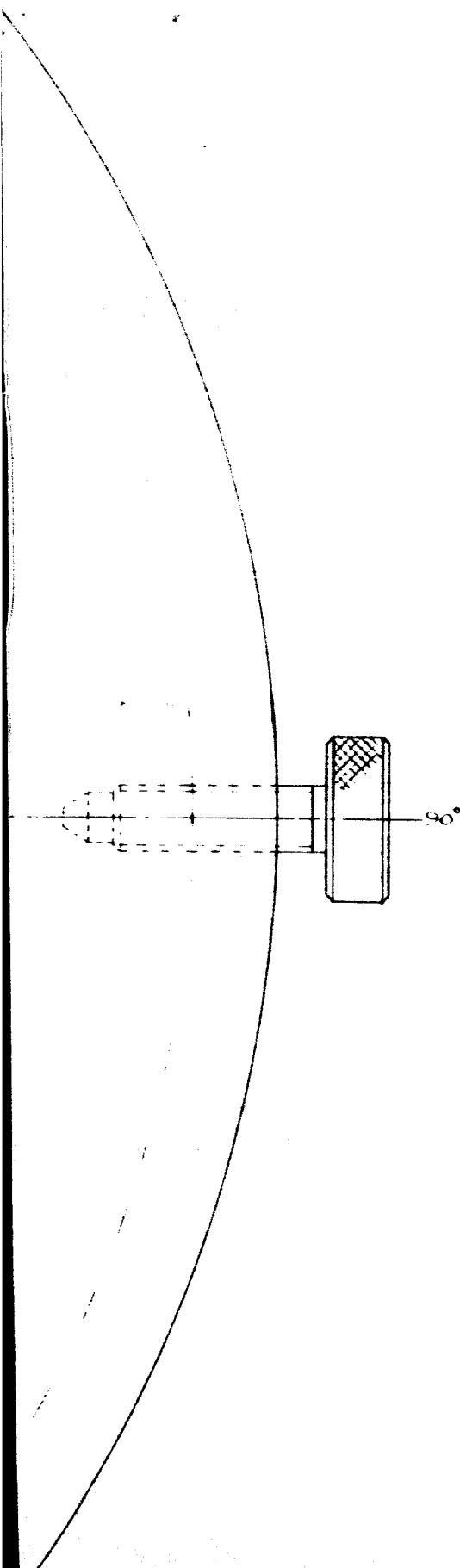
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6. UNK = UNKNOWN, N.D. = NO DRAWING
5. DOTTED LINES INDICATE ROUGH OR
4. ALL MATING CORNERS & FILLETS ARE
3. MAX. PERMISSIBLE TAP DRILL DEPTH
2. THREAD DEPTHS ARE SHOWN
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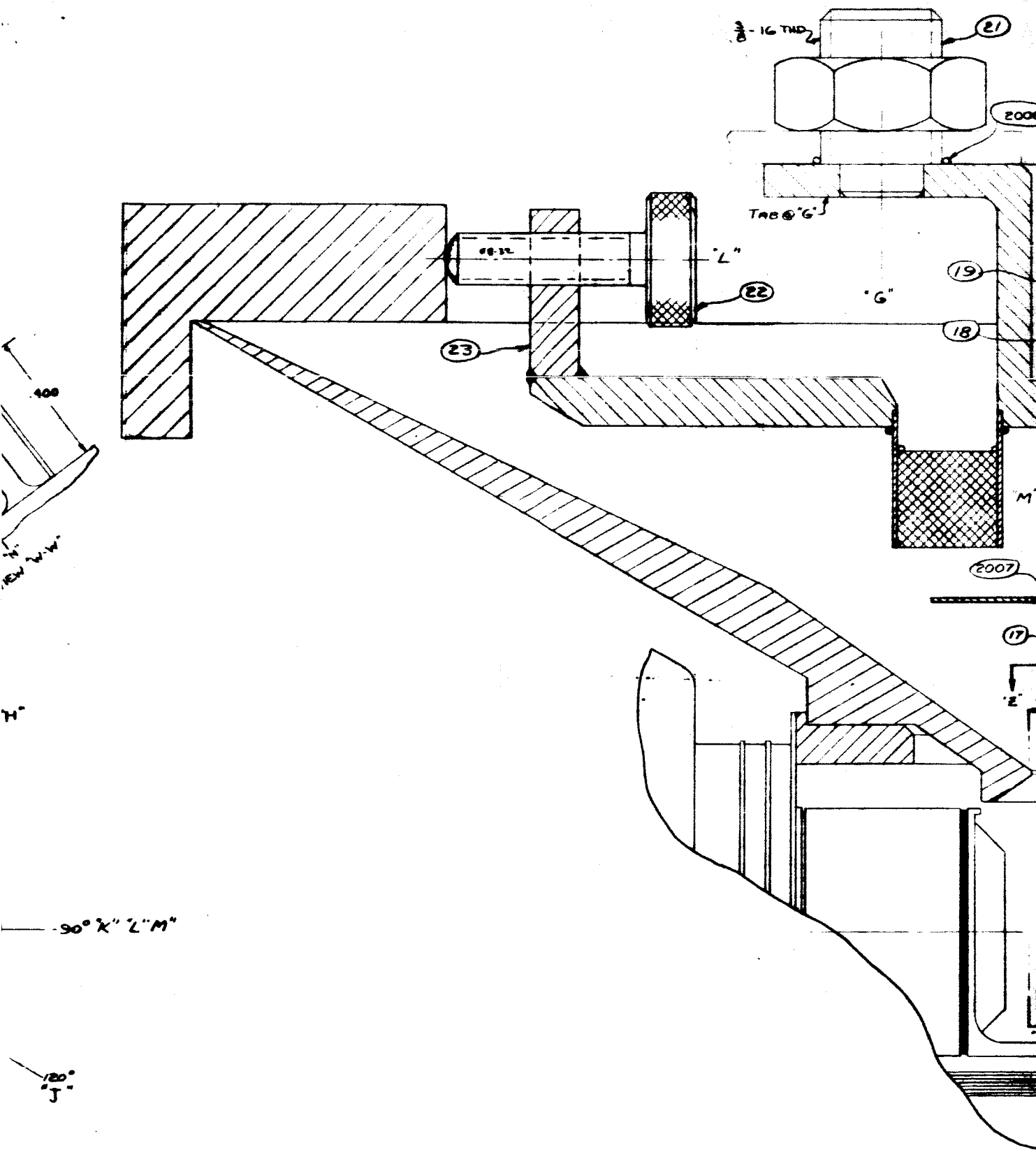
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of 3A at 1000 volts. This is an emission of 500 mA per filament. Since the length of each filament is 5.2 cm., and the corresponding emission length is estimated at 2.5 cm., the emission current per unit of filament length should be 200 mA/cm.

Also, the filament supply current should not exceed one-sixth of the available 100 ampere filament current of the JPL filament power supply.

Figure 22 shows that for filament currents of less than 16 amperes, an emission current density of 200 mA/cm. is achieved with filaments having a diameter of about 0.4 mm or less, i.e., approximately 0.015 inch in diameter. The corresponding filament life at this maximum input condition is of the order of 300 hours. This is clearly a rather marginal value, particularly if any extended operation is required during outgassing of the generator prior to the actual runs. The condition was reviewed with the technical cognizant personnel at JPL, and it was agreed to relax the requirement that the maximum total filament current be less than 100 amperes to the extent required to achieve a design life of 2000 hours. Figure 22 then shows that the filament diameter should be 30 mils, with a filament current of 30 amperes for the emission of 200 mA per centimeter, and a filament voltage of 0.6 volts/cm which, for a filament length of 5.2 cm. is adequately within the 5 volt limit of the JPL power supply. The design condition is then:

Maximum Filament Current	180 amperes
Maximum Filament Voltage	3.2 volts
Maximum Bombardment Current	3 amperes
Bombardment Voltage	1000 volts
Minimum Filament Life	2000 hours
Filament Diameter	0.030 inch

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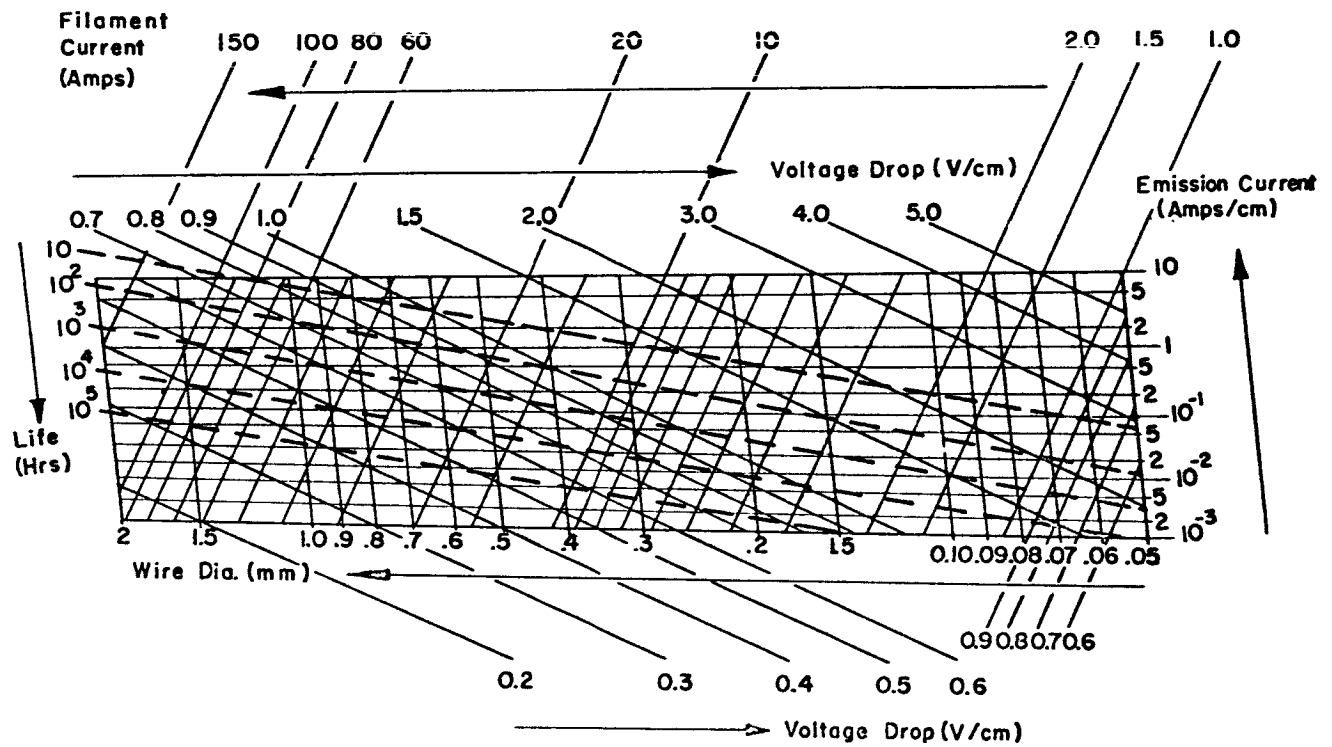


Figure 22. Tungsten Filament Characteristics
 (Kohl, "Materials and Techniques
 for Electron Tubes", p. 278)

1.7.3 Control of Heat Losses in Electron Bombardment Structure

As discussed in Section 1.7.1, the heat losses of the electron bombardment support structure can be minimized by providing the central filament support structure with an adequate heat resistance. The heat loss through this resistance can be adequately estimated with the basic conduction equation:

$$Q = k_s \Delta T/L$$

To avoid overheating the portion of the filament support that is within the cavity, an upper temperature limit of 1800°K can be specified for it. Assuming a maximum temperature of 800°K on the remainder of the support structure, $\Delta T = 1000^{\circ}\text{K}$. The length of the heat resistance element as selected in the design is 1.0 cm. Assuming a thermal conductivity for tantalum of 0.70 watts/cm-deg K, and for the diameter of 1.2 cm. of the heat resistance element, the heat loss becomes:

$$Q = 0.7 \times \pi \times 1.2 \times 1000 \times t = 2640 t \text{ watts}$$

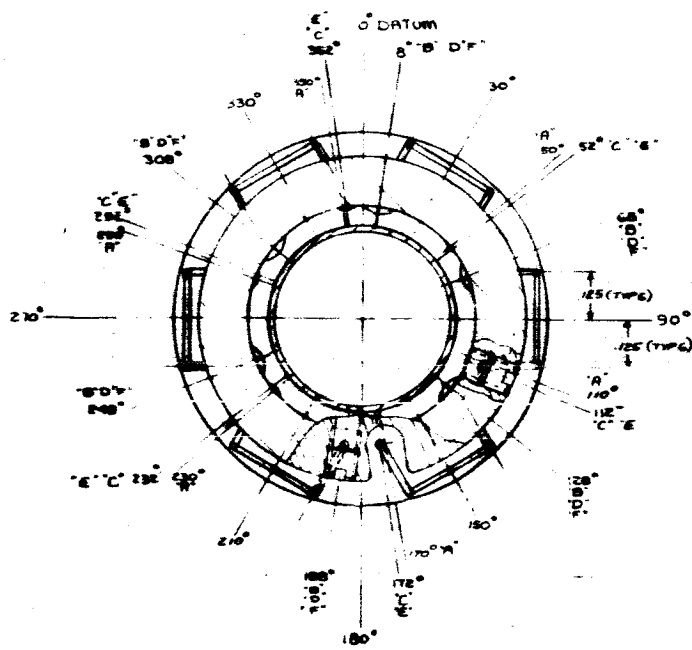
where t is the wall thickness in centimeters. If t is expressed in mils,

$$Q = 6.60 t \text{ watts.} \quad (15)$$

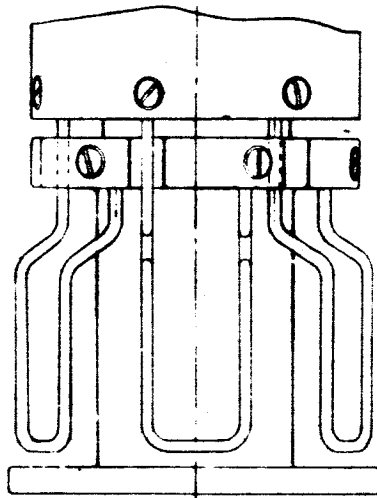
The heat actually received by the portion of the filament structure exposed to the interior of the cavity is essentially equal to the radiant heat transfer corresponding to the surface area of the filament support which is approximately 18 watts per sq. cm. for 10 sq. cm., or 180 watts. From Equation (18) it is then seen that the thickness of the resistance heat transfer element must then be approximately 27 mils.

1.8 Final Design of Electron Bombardment Unit

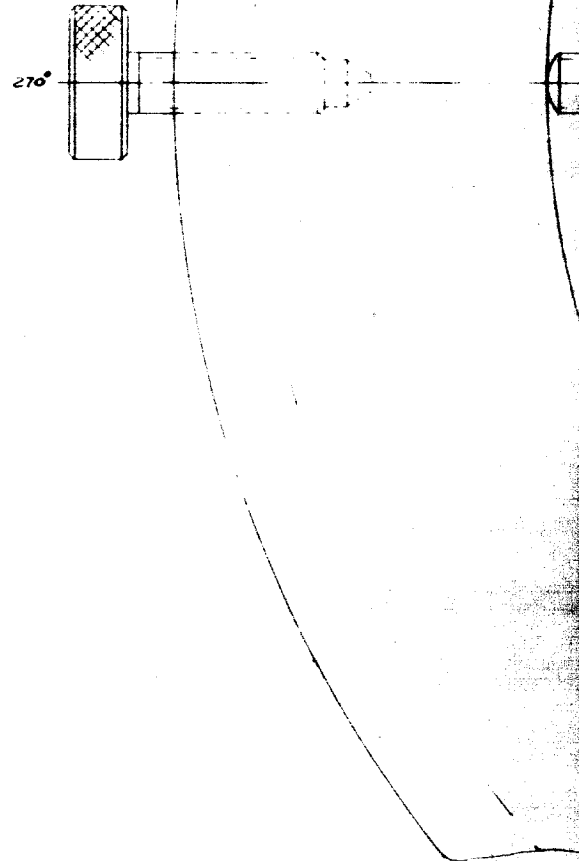
Figure 23, Dwg. 549-1000, Revision A, shows the layout of the electron bombardment unit as finally approved by JPL. The layout is identical to that of Figure 21, except that the filament size has been increased to 0.030 inch

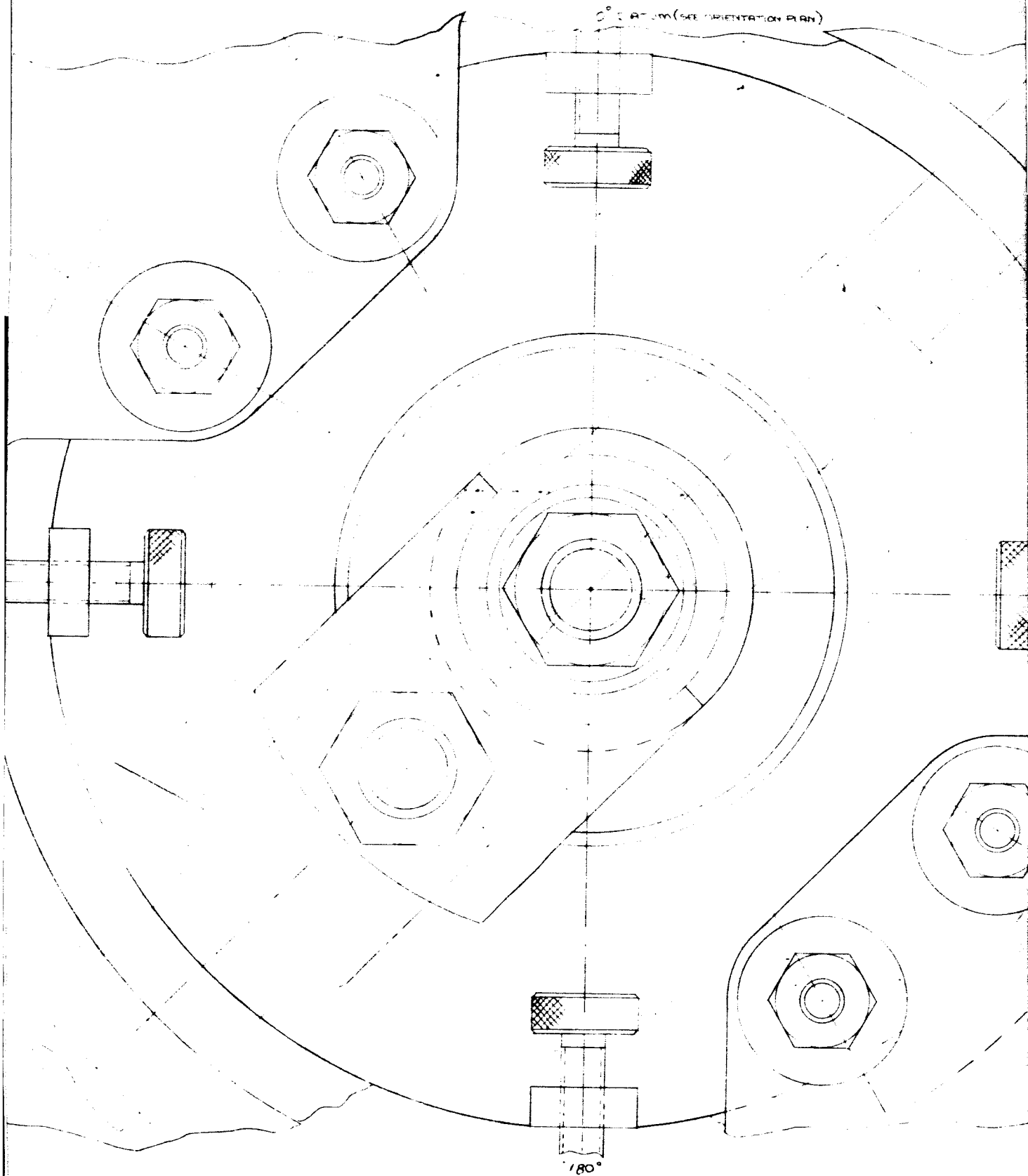


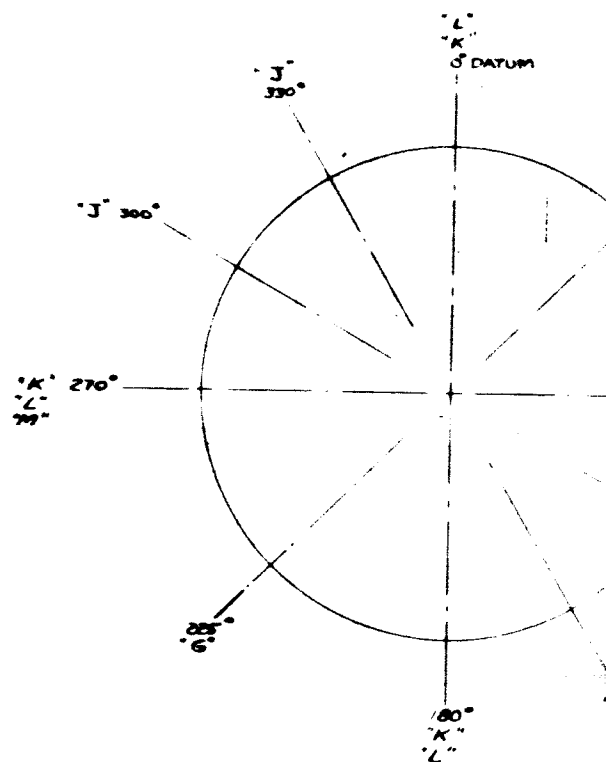
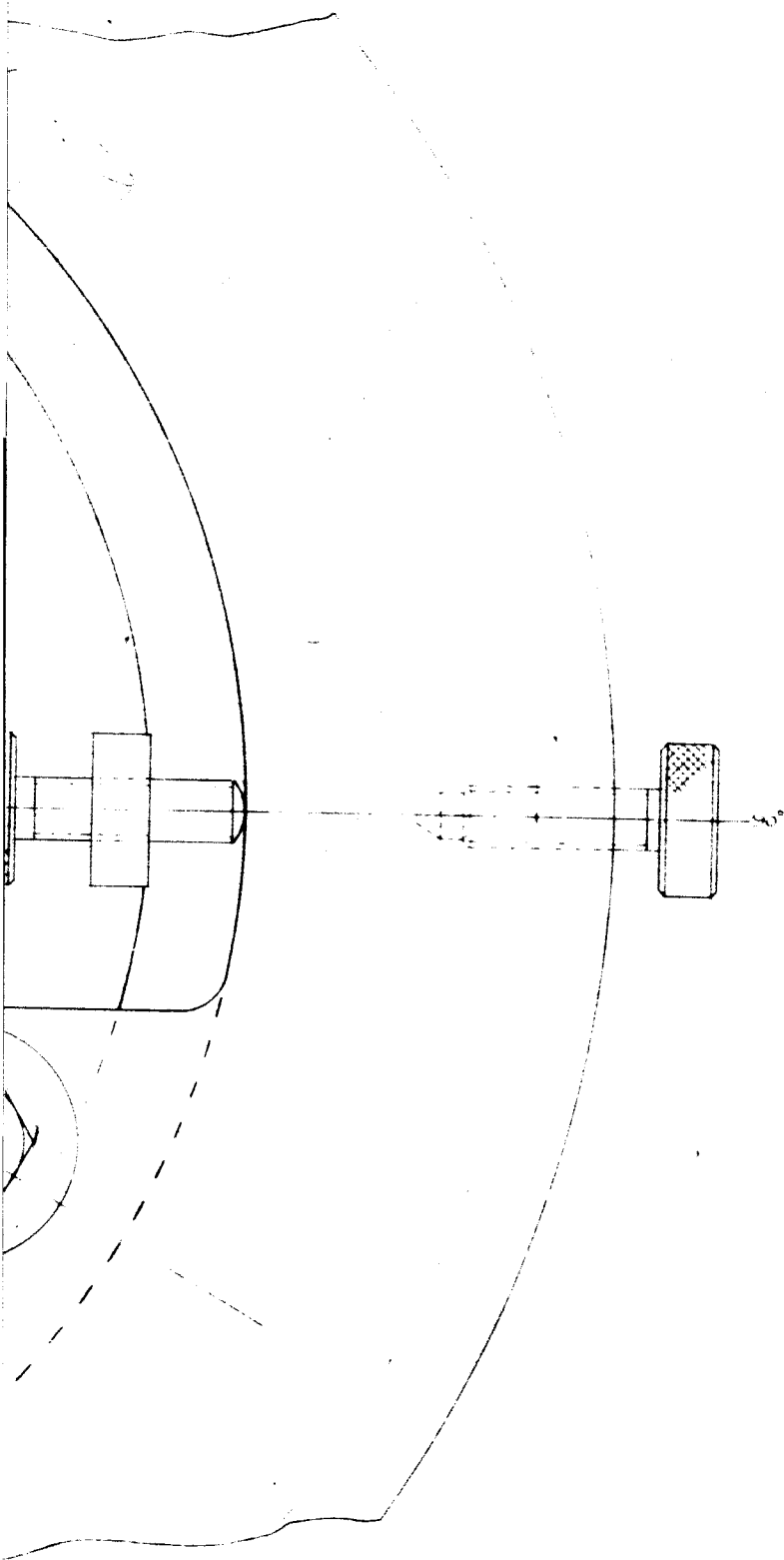
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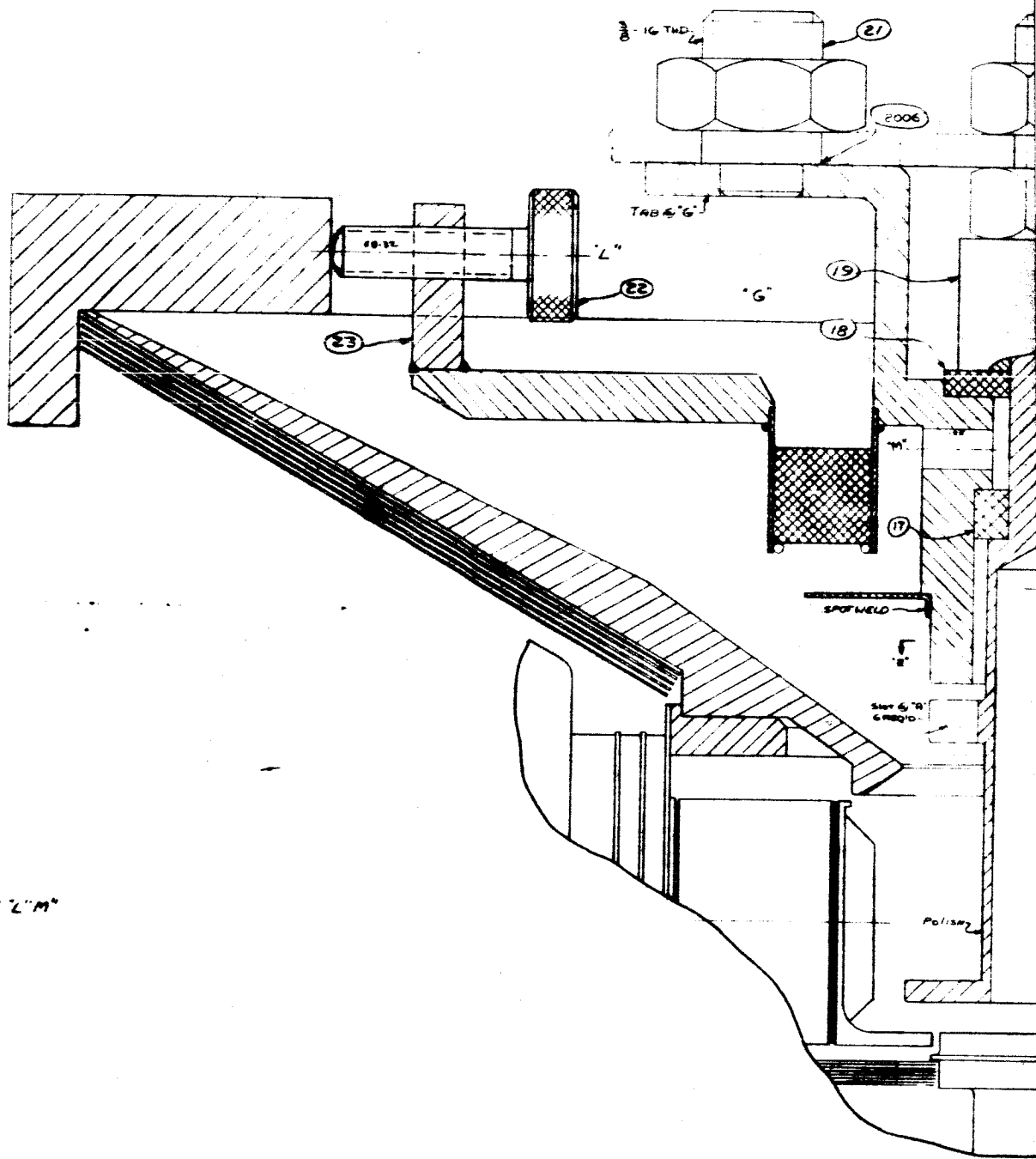
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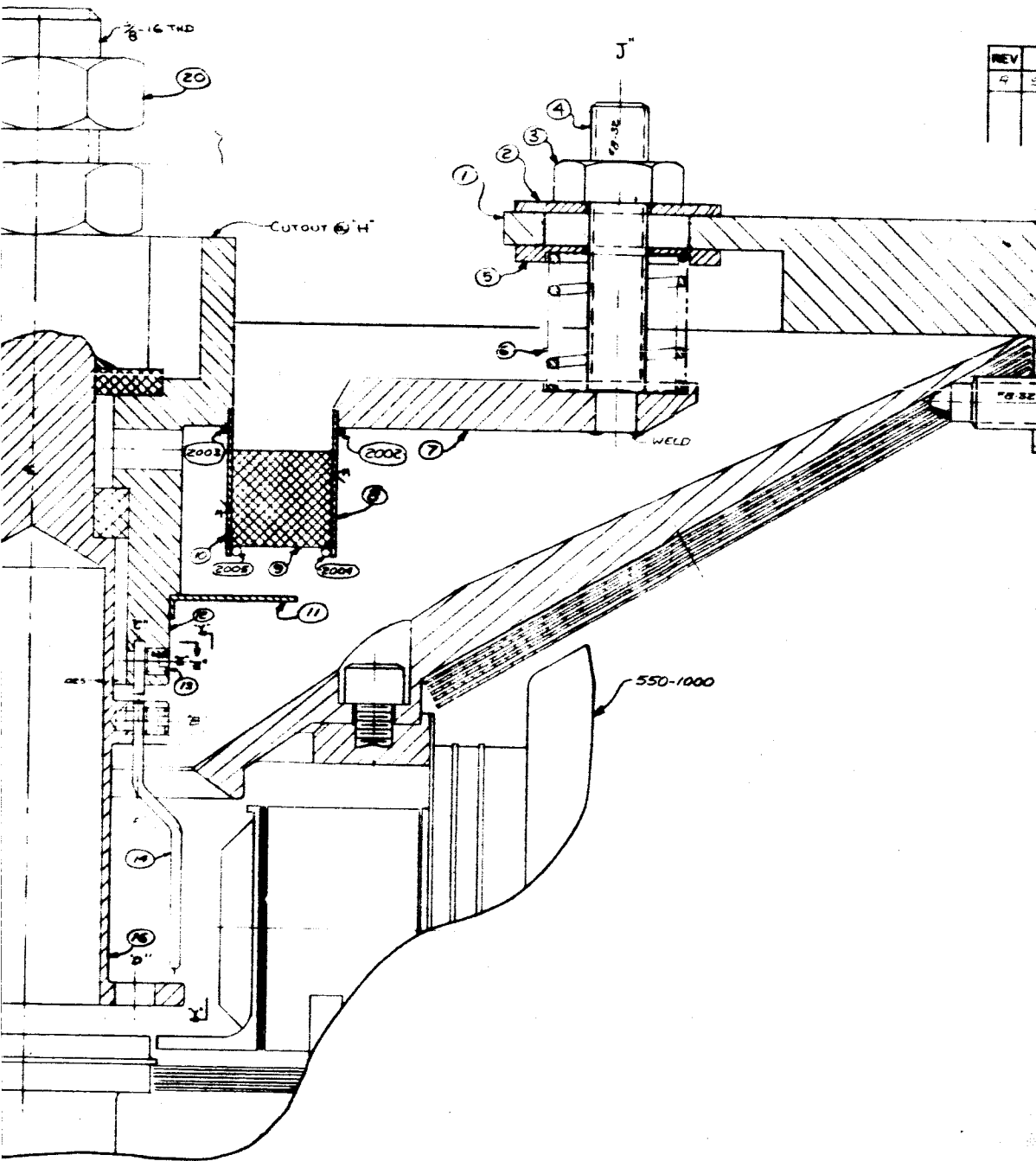






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FIGURE 23

24	B	4	SS	CLAMP THUMB SCREW.
23	B	4	SS	SUPPORT (ADJ. SCREW)
22	B	4	SS	TURNING ADJUST SCREW
21	B	1	Ta	TERMINAL STUD
20	ND	3	SS	5/16 HEX ND JAM NUT
19	A	1	SS	WASHER (LOCATING)
18	B	1	A10 ₂	INSULATING WASHER
17	B	1	A10 ₂	LOW VOLTAGE INSULATOR
16	C	1	Ta	FILAMENT SUPPORT CENTRAL
15				
14	B	6	W	FILAMENT
13	A	12	Ta-W	FILAMENT SET SCREW (SHORT)
12	B	1	Ta	FILAMENT SUPPORT OUTER
11	B	1	Ta	METAL VIBRO SHIELD
10	B	1	DA142	INSULATOR FLANGE INNER
9	C	1	A10 ₂	HIGH VOLTAGE INSULATOR
8	B	1	DA142	INSULATOR FLANGE OUTER
7	C	1	SS	MOVABLE SUPPORT
6	ND	4	SS	LEE # LC 935F-1 (SPRING)
5	A	4	SS	SPRING RETAINING WASHER
4	B	4	SS	THREADED POST.
3	ND	4	SS	8-32 HEX ND NUT (RIGHT HAND)
2	A	4	SS	WASHER
1	D	1	SS	MAIN SUPPORT RING

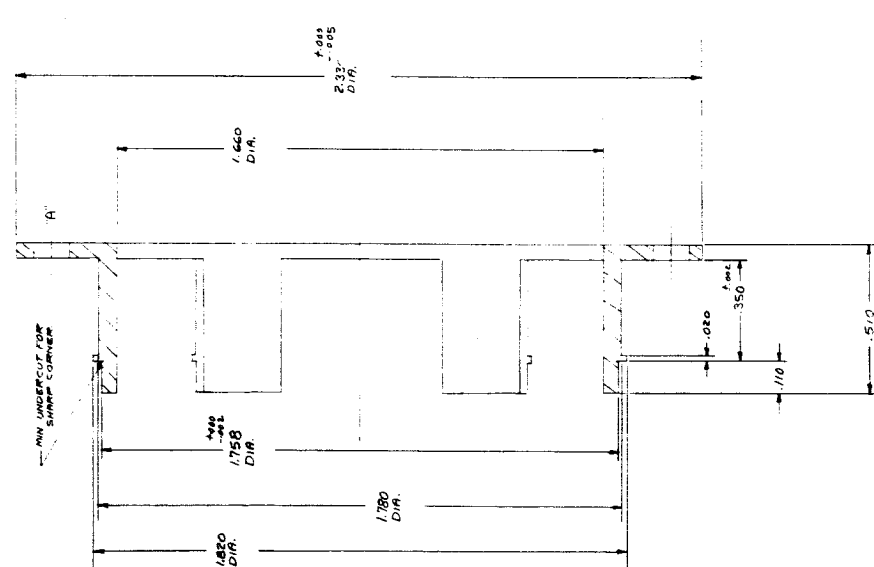
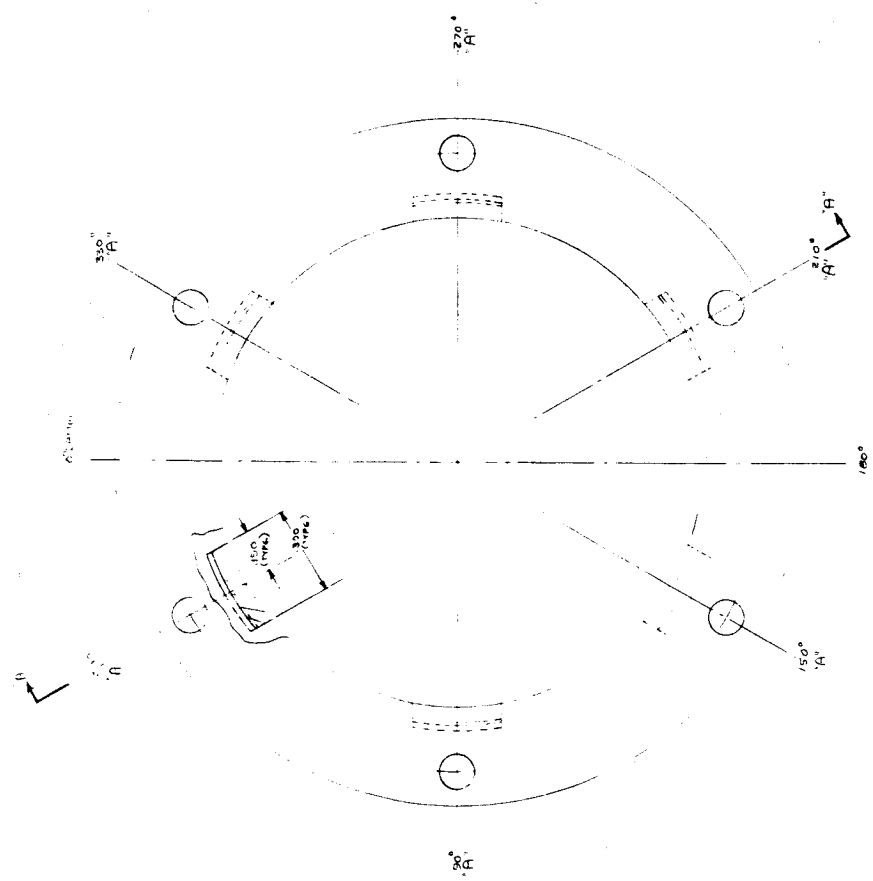
PARTS LIST				NOTES			
PARTS LISTED ARE SHOWN IN THE FOLLOWING ORDER: 1. PARTS LISTED IN THE PARTS LIST 2. PARTS LISTED IN THE PARTS LIST 3. PARTS LISTED IN THE PARTS LIST 4. PARTS LISTED IN THE PARTS LIST 5. PARTS LISTED IN THE PARTS LIST 6. PARTS LISTED IN THE PARTS LIST 7. PARTS LISTED IN THE PARTS LIST 8. PARTS LISTED IN THE PARTS LIST 9. PARTS LISTED IN THE PARTS LIST 10. PARTS LISTED IN THE PARTS LIST 11. PARTS LISTED IN THE PARTS LIST 12. PARTS LISTED IN THE PARTS LIST 13. PARTS LISTED IN THE PARTS LIST 14. PARTS LISTED IN THE PARTS LIST 15. PARTS LISTED IN THE PARTS LIST 16. PARTS LISTED IN THE PARTS LIST 17. PARTS LISTED IN THE PARTS LIST 18. PARTS LISTED IN THE PARTS LIST 19. PARTS LISTED IN THE PARTS LIST 20. PARTS LISTED IN THE PARTS LIST 21. PARTS LISTED IN THE PARTS LIST 22. PARTS LISTED IN THE PARTS LIST 23. PARTS LISTED IN THE PARTS LIST 24. PARTS LISTED IN THE PARTS LIST 25. PARTS LISTED IN THE PARTS LIST 26. PARTS LISTED IN THE PARTS LIST 27. PARTS LISTED IN THE PARTS LIST 28. 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PARTS LISTED IN THE PARTS LIST 167. PART							

from a previous value of 0.015 inch, as explained in Section 1.7.2, and the point of attachment of the lower filament ends has been displaced so as to lay outside the generator cavity to avoid overheating. The inner filament support, part No. 16, which was originally shown with six cut-outs in a view "V-V", no longer includes these cut-outs because the thermal calculation of Section 1.7.3 indicates that these are unnecessary.

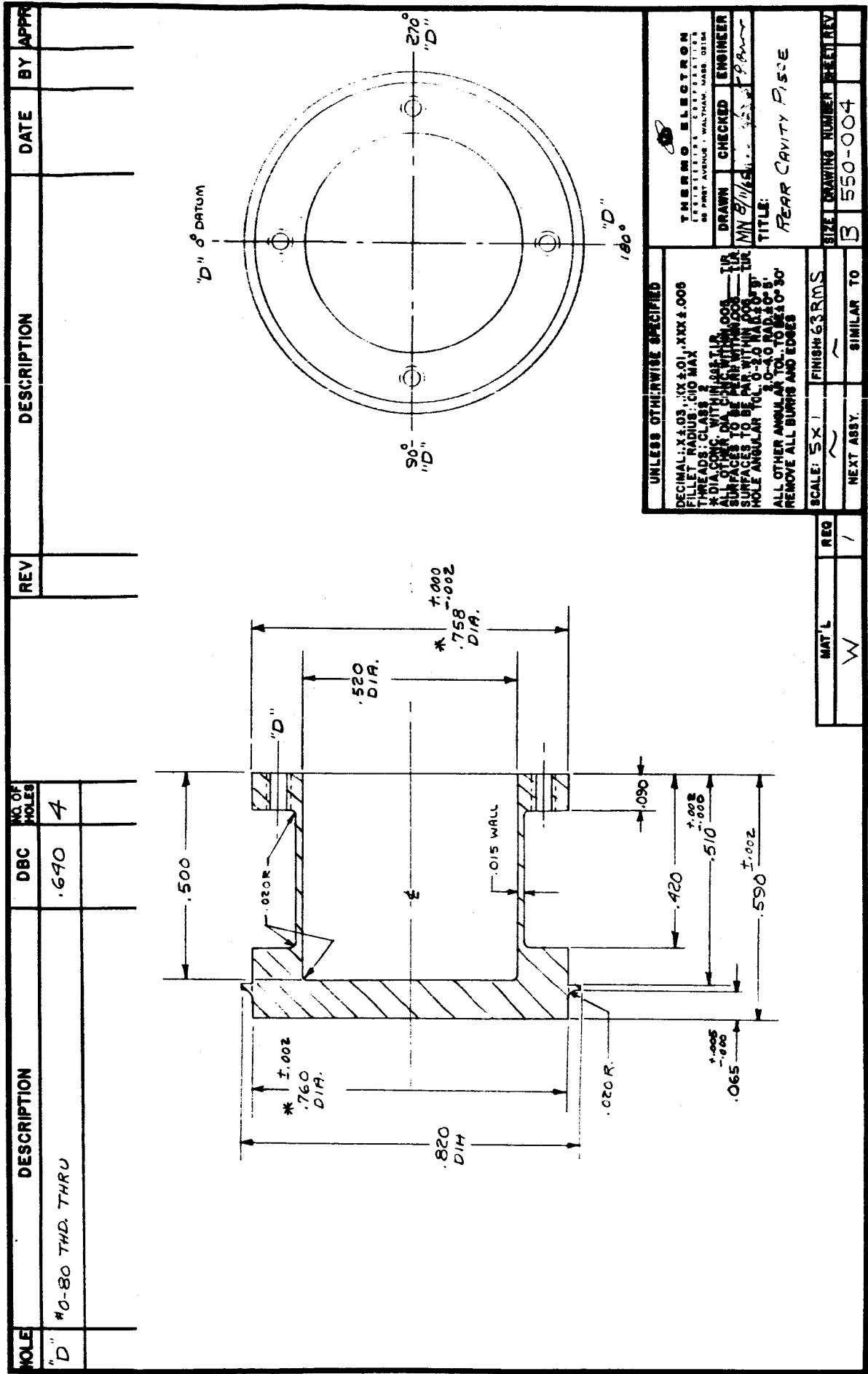
2.1 Detailed Mechanical Drawings
for the Generator

550-001 to
550-2001

REV	DESCRIPTION	DATE	BY
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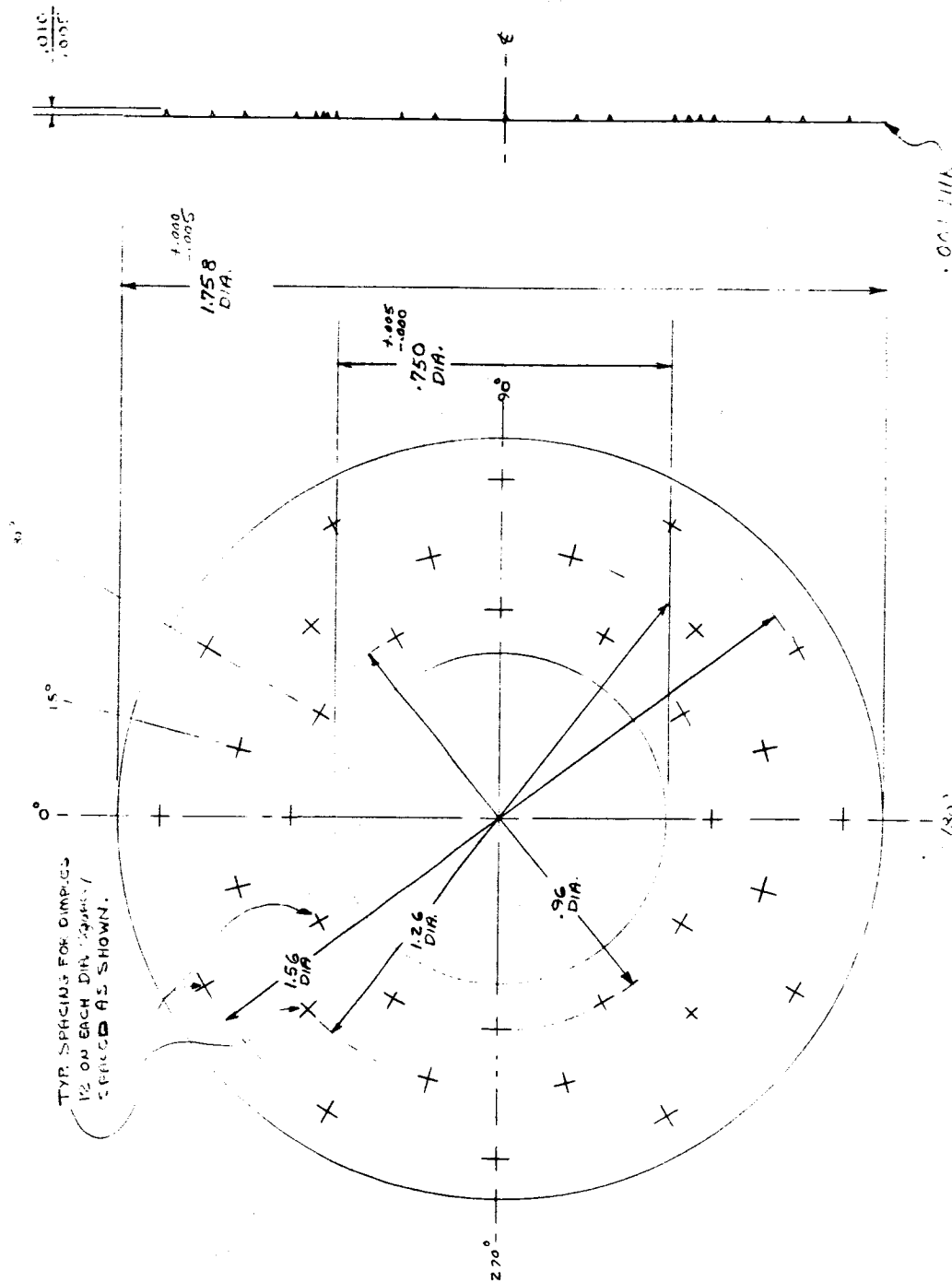
UNLESS OTHERWISE SPECIFIED		THERMO ELECTRON	
DESIGNED BY	DATE	DRAWN BY	CHECKED BY
10/1/60	10/1/60	10/1/60	10/1/60
TITLE		PART NAME	
HEAT SHIELD		HEAT SHIELD	
SCALE		SHEET NO.	
1/1		1	
NEXT SET		SIMILAR TO	
1		D	
1		1	



UNLESS OTHERWISE SPECIFIED DECIMAL: X.03, XX.01, XXX.008 FILLET RADIUS: CHO MAX THREADS: CLASS 2 # DIA. CORN. WITHIN .005 DIA. ALL OTHER CORN. WITHIN .005 DIA. SURFACES TO BE FINISHED TO .005 DIA. HOLE ANGULAR TO .005 DIA. ALL OTHER ANGULAR TO .005 DIA. REMOVE ALL BURRS AND EDGES	
SCALE: 5X FINISH: 63 RMS NEXT ASSY. TO SIMILAR TO	

THERMO ELECTRON ELECTRONIC CORPORATION 80 FIRST AVENUE, WALTHAM, MASS. 02154	
DRAWN: MN 8/11/68 CHECKED: [Signature] ENGINEER: [Signature]	TITLE: REAR CAVITY PLATE
SIZE: DRAWING NUMBER: 550-004	

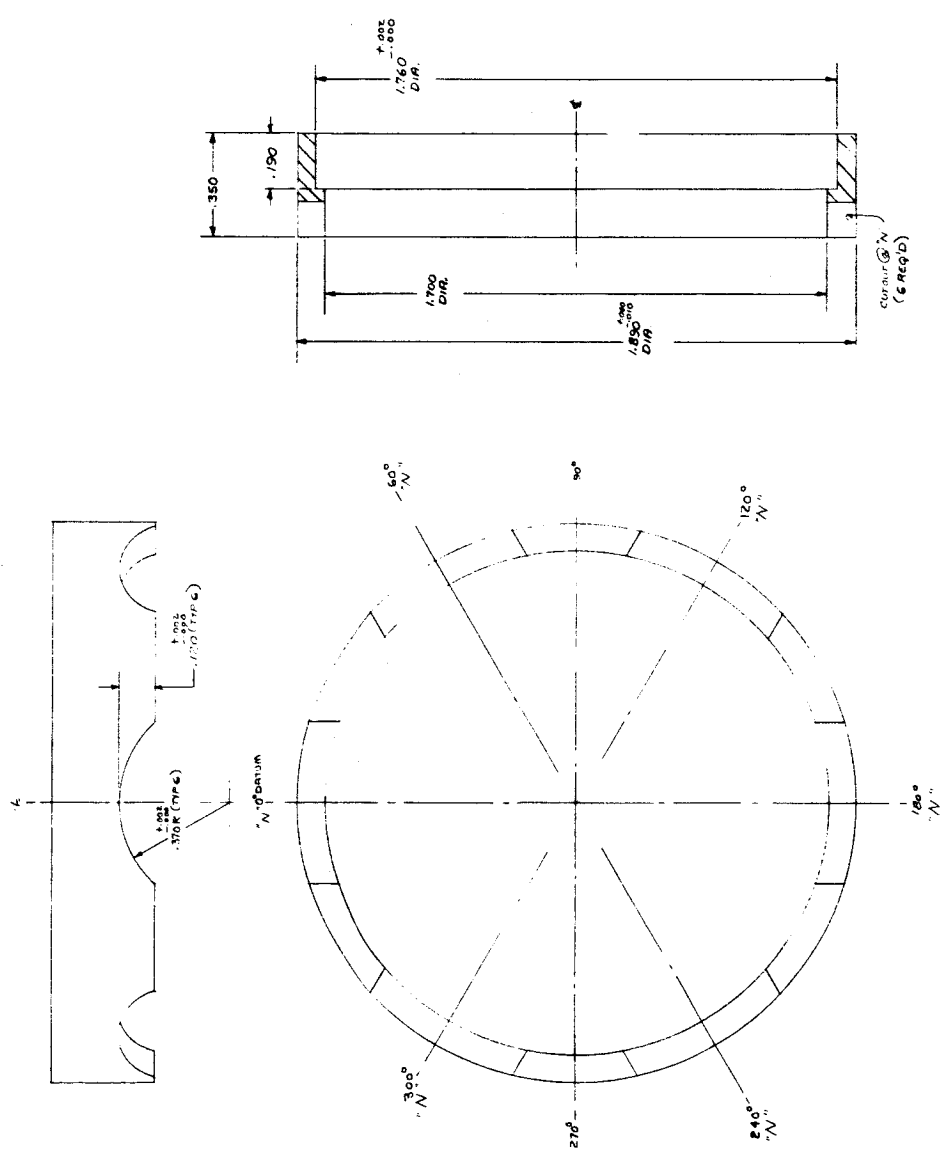
NO.	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED DECIMAL: X.03 XX.01 XXX.003 FILLET RADIUS: 0.0 MAX THREADS: CLASS 2 ALL DIMENSIONS ARE TO CENTER UNLESS OTHERWISE SPECIFIED SURFACES TO BE FLAT WITHIN .003" TIR SURFACES TO BE PAR WITHIN .003" TIR HOLE ANGULAR TOL. 0-2.0 RAD. 10° ALL OTHER ANGULAR TOL. TO BE ±0° 30' REMOVE ALL BURRS AND EDGES		THORNDYKE ELECTRON 120 WEST AVENUE - WALTHAM, MASS 01981 DRAWN: [] CHECKED: [] ENGINEER: [] TITLE: REPAIR SHIELD
SCALE: 5 X 1 FINISH: [] NEXT ASSY: [] SIMILAR TO: []	SIZE: [] DRAWING NUMBER: [] REV: []	510 005

MAT'L	REQ
Mo	E

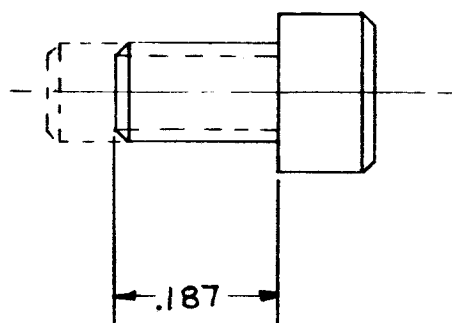
REV	DESCRIPTION	DATE	BY



VACUUM ELECTRON		DATE	
SHIELD INSULATOR		DATE	
PART NO. 550-006		REV. 1	
DRAWN BY		CHECKED BY	
DATE		DATE	

UNLESS OTHERWISE SPECIFIED		 THERMO ELECTRON ENGINEERING CORPORATION 85 FIRST AVENUE • WALTHAM, MASS. 02154	
DECIMAL : .X ± .03 , .XX ± .01 , .XXX ± .005 FILLET RADIUS : .010 MAX THREADS : CLASS 2 * DIA. CONC. WITHIN ____ T.I.R. ALL OTHER DIA. CONC. WITHIN .005 ____ T.I.R. SURFACES TO BE PERP. WITHIN .005 ____ T.I.R. SURFACES TO BE PAR. WITHIN .005 ____ T.I.R. HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9' 2.0-4.0 RAD. ± 0° 5' ALL OTHER ANGULAR TOL. TO BE ± 0° 30' REMOVE ALL BURRS AND EDGES			
SCALE: 5 X 1 FINISH: --- ----- -----			
NEXT ASSY.	SIMILAR TO	SIZE	DRAWING NUMBER
		A	550-007
		SHEET	REV

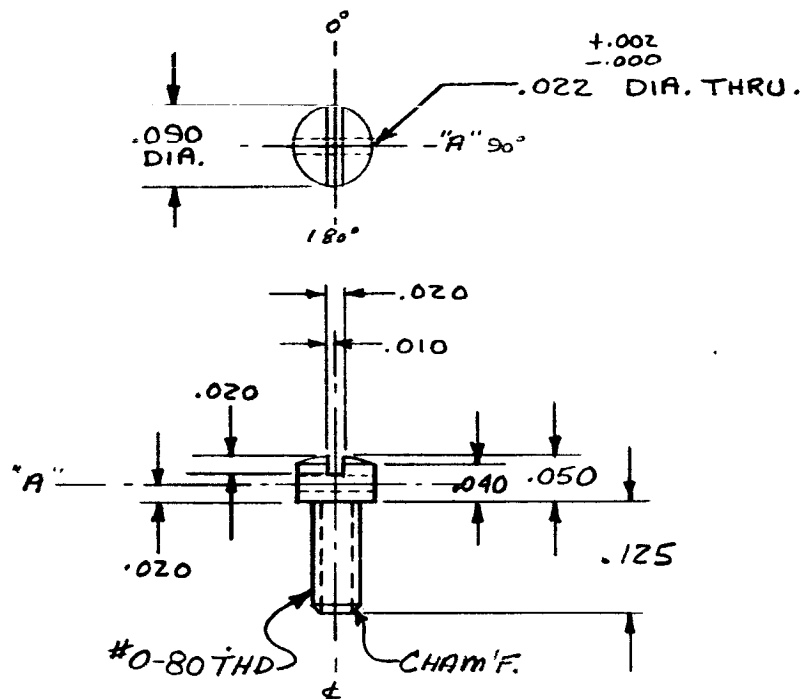
REV	DESCRIPTION	DATE	BY	APPR



MADE FROM #4-40 SOC. HD. CAP SCREW X
.250 LNG.

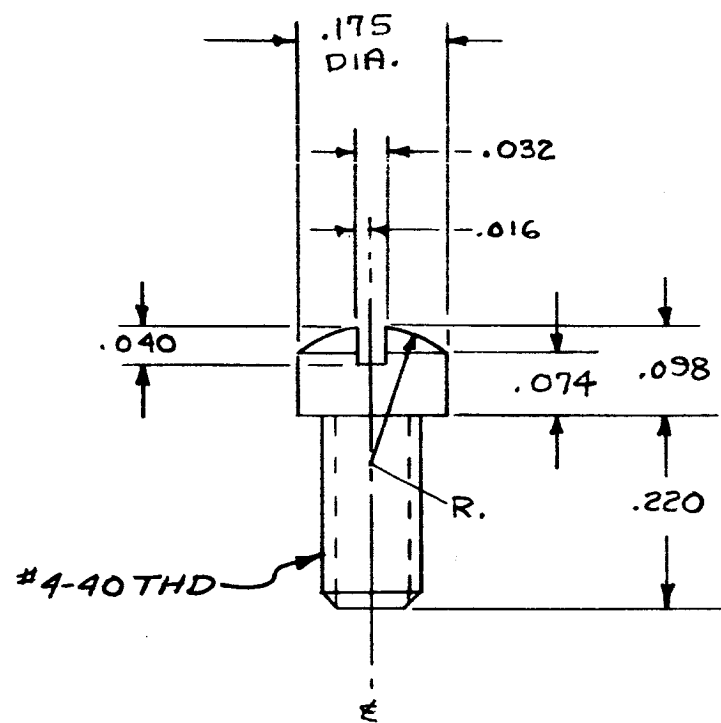
UNLESS OTHERWISE SPECIFIED DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005 FILLET RADIUS: .010 MAX THREADS: CLASS 2 * DIA. CONC. WITHIN ____ T.I.R. ALL OTHER DIA. CONC. WITHIN .005 ____ T.I.R. SURFACES TO BE PERP. WITHIN .005 ____ T.I.R. SURFACES TO BE PAR. WITHIN .005 ____ T.I.R. HOLE ANGULAR TOL. 0-2.0 RAD ± 0° 9' 2.0-4.0 RAD ± 0° 5' ALL OTHER ANGULAR TOL. TO BE ± 0° 30' REMOVE ALL BURRS AND EDGES		 THERMO ELECTRON ENGINEERING CORPORATION 85 FIRST AVENUE • WALTHAM, MASS. 02154		
				DRAWN MN 8/17/65
TITLE: SCREW (RE-OP)		SCALE: 5x1		FINISH:
MAT'L S.S.	REQ 24	SIZE A	DRAWING NUMBER 550-008	SHEET REV NEXT ASSY. SIMILAR TO

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005 FILLET RADIUS: .010 MAX THREADS: CLASS 2 * DIA. CONC. WITHIN .005 T.I.R. ALL OTHER DIA. CONC. WITHIN .005 T.I.R. SURFACES TO BE PERP. WITHIN .005 T.I.R. SURFACES TO BE PAR. WITHIN .005 T.I.R. HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9' 2.0-4.0 RAD. ± 0° 5' ALL OTHER ANGULAR TOL. TO BE ± 0° 30' REMOVE ALL BURRS AND EDGES		THERMO ELECTRON ENGINEERING CORPORATION 85 FIRST AVENUE • WALTHAM, MASS. 02154					
					DRAWN MN 8/17/65	CHECKED RB 8/19/65	ENGINEER P.B. 8/19/65
		TITLE: HIGH TEMP. SCREW					
		MAT'L Ta-W	REQ 4	SCALE: 5x1	FINISH: —	SIZE A	DRAWING NUMBER 550-010
NEXT ASSY.		SIMILAR TO					

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
 FILLET RADIUS: .010 MAX
 THREADS: CLASS 2
 * DIA. CONC. WITHIN T.I.R.
 ALL OTHER DIA. CONC. WITHIN .005 T.I.R.
 SURFACES TO BE PERP. WITHIN .005 T.I.R.
 SURFACES TO BE PAR. WITHIN .005 T.I.R.
 HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9'
 2.0-4.0 RAD. ± 0° 5'
 ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
 REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
 ENGINEERING CORPORATION
 85 FIRST AVENUE • WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 8/17/65	J. 012 8/19/65	P. 012 8/19/65

TITLE:
 HIGH Temp SCREW

MAT'L	REQ	SCALE: 5 x 1	FINISH: -	SIZE	DRAWING NUMBER	SHEET	REV
Ta-W	6	NEXT ASSY.	SIMILAR TO	A	550-012		

A diagram of a horizontal beam. On the left end, there is a distributed load represented by a rectangle with diagonal hatching. A vertical dashed line passes through the center of this rectangle. To the right of the distributed load, there is a point load represented by a downward-pointing arrow. The distance between the center of the distributed load and the point load is labeled as 1.010.

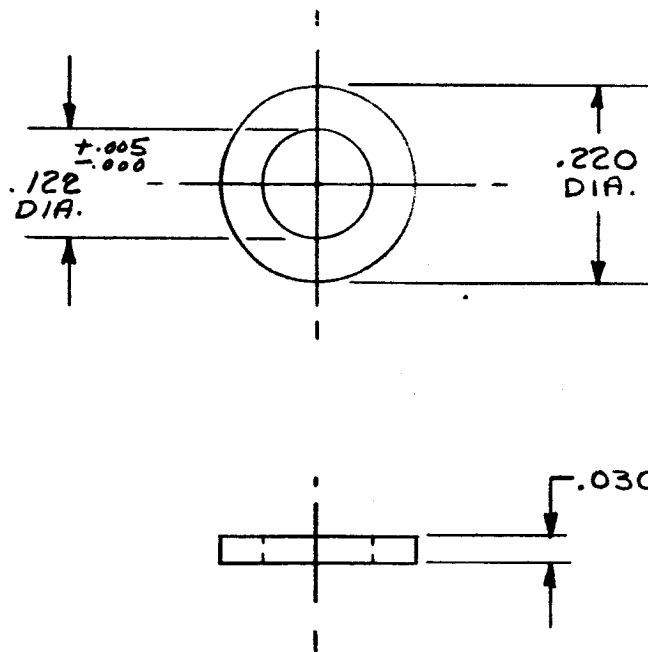
UNLESS OTHERWISE SPECIFIED		 THERMO ELECTRON ENGINEERING CORPORATION 85 FIRST AVENUE • WALTHAM, MASS. 02154							
DECIMAL: .X±.03, .XX±.01, .XXX±.005 FILLET RADIUS: .010 MAX THREADS: CLASS 2 * DIA.CONC. WITHIN ____ T.I.R. ALL OTHER DIA. CONC.WITHIN.005____ T.I.R. SURFACES TO BE PERP.WITHIN.005____ T.I.R. SURFACES TO BE PAR.WITHIN.005____ T.I.R. HOLE ANGULAR TOL. 0-2.0 RAD.±0° 9' 2.0-4.0 RAD.±0° 5' ALL OTHER ANGULAR TOL. TO BE ±0° 30' REMOVE ALL BURRS AND EDGES		<table border="1" style="width: 100%;"> <tr> <th>DRAWN</th> <th>CHECKED</th> <th>ENGINEER</th> </tr> <tr> <td>MN 8/17/65</td> <td>RCS 8/17/65</td> <td>P. Brown</td> </tr> </table>		DRAWN	CHECKED	ENGINEER	MN 8/17/65	RCS 8/17/65	P. Brown
DRAWN	CHECKED	ENGINEER							
MN 8/17/65	RCS 8/17/65	P. Brown							
		TITLE:							
		WASHER							
SCALE: 5 x 1	FINISH: G3 PMS	SIZE	DRAWING NUMBER						
NEXT ASSY.	SIMILAR TO	A	550-015						

NO. OF HOLES	DESCRIPTION	DBC	REV	DESCRIPTION	DATE	BY APPR

#0-80 THD.
 UNDERCUT LAST THD. T8
 .112 DIA.
 .060
 .410
 .740
 #4-40 THD.
 THD. RELIEF PERMISSIBLE.

UNLESS OTHERWISE SPECIFIED		THERMO ELECTRON	
DECIMALS: $\pm .03$, $\pm .01$, $\pm .005$	XX $\pm .01$, $\pm .005$	1000 ELECTRON	ENGINEER
FILLET RADIUS: .010 MAX	THREADS: CLASS 2	1000 ELECTRON	CHECKED
ALL OTHER DIA. COMPLY WITH .005	ALL OTHER DIA. COMPLY WITH .005	1000 ELECTRON	DRAWN
SURFACES TO BE FINISHED WITHIN .005	SURFACES TO BE FINISHED WITHIN .005	1000 ELECTRON	DATE
HOLE ANGULAR TOL. $0-1.0$ RAD. $0-90^\circ$	HOLE ANGULAR TOL. $0-1.0$ RAD. $0-90^\circ$	1000 ELECTRON	TITLE
ALL OTHER ANGULAR TOL. TO BE $0-30^\circ$	REMOVE ALL BURRS AND EDGES	1000 ELECTRON	SIZE
SCALE: 5" X 1"	FINISH: 63 RMS	1000 ELECTRON	DRAWING NUMBER
NEXT ASSY.	SIMILAR TO	1000 ELECTRON	REV
MAT'L	REQ	1000 ELECTRON	
S.S.	18	1000 ELECTRON	

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
 FILLET RADIUS: .010 MAX
 THREADS: CLASS 2
 * DIA. CONC. WITHIN ____ T.I.R.
 ALL OTHER DIA. CONC. WITHIN .005 ____ T.I.R.
 SURFACES TO BE PERP. WITHIN .005 ____ T.I.R.
 SURFACES TO BE PAR. WITHIN .005 ____ T.I.R.
 HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9'
 2.0-4.0 RAD. ± 0° 5'
 ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
 REMOVE ALL BURRS AND EDGES



THERMO ELECTRON
 ENGINEERING CORPORATION
 85 FIRST AVENUE • WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
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MN 8/17/65	JS 8/19/65	A. Brown
------------	------------	----------

TITLE:

WASHER

MAT'L

REQ

SS

18

SCALE: 5x1

FINISH: 63 RMS

NEXT ASSY.

SIMILAR TO

SIZE

DRAWING NUMBER

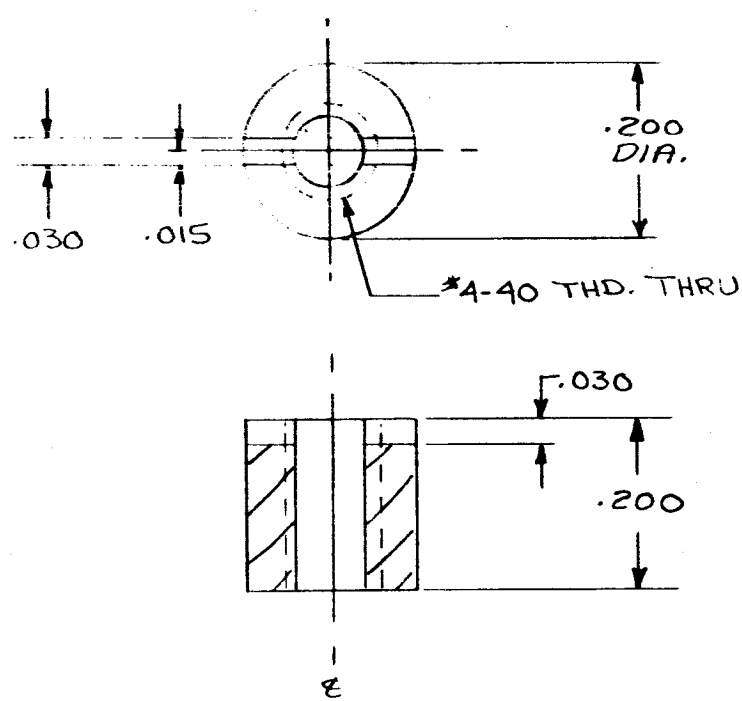
SHEET

REV

A

550-018

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
 FILLET RADIUS: .010 MAX
 THREADS: CLASS 2
 * DIA. CONC. WITHIN ____ T.I.R.
 ALL OTHER DIA. CONC. WITHIN .005 ____ T.I.R.
 SURFACES TO BE PERP. WITHIN .005 ____ T.I.R.
 SURFACES TO BE PAR. WITHIN .005 ____ T.I.R.
 HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9'
 2.0-4.0 RAD. ± 0° 5'
 ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
 REMOVE ALL BURRS AND EDGES

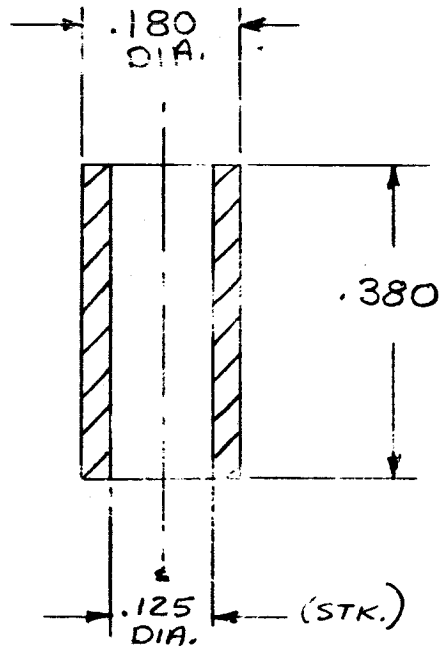
THERMO ELECTRON
 ENGINEERING CORPORATION
 85 FIRST AVENUE • WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 8/17/65	ROS 8/19/65	PRM

TITLE:
 NUT

MAT'L	REQ	SCALE: 5x1	FINISH: 63RMS	SIZE	DRAWING NUMBER	SHEET	REV
S.S.	18	NEXT ASSY.	SIMILAR TO	A	550-019		

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005

FILLET RADIUS: .010 MAX

THREADS: CLASS 2

* DIA. CONC. WITHIN T.I.R.

ALL OTHER DIA. CONC. WITHIN .005 T.I.R.

SURFACES TO BE PERP. WITHIN .005 T.I.R.

SURFACES TO BE PAR. WITHIN .005 T.I.R.

HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9'

2.0-4.0 RAD. ± 0° 5'

ALL OTHER ANGULAR TOL. TO BE ± 0° 30'

REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE • WALTHAM, MASS. 02154

DRAWN **CHECKED** **ENGINEER**

MN 8/17/69 J. S. 23/5 P. Brown

TITLE:

STUD INSULATOR

MAT'L

REQ

Al₂O₃

18

SCALE: 5 x 1

FINISH: —

— 479-58

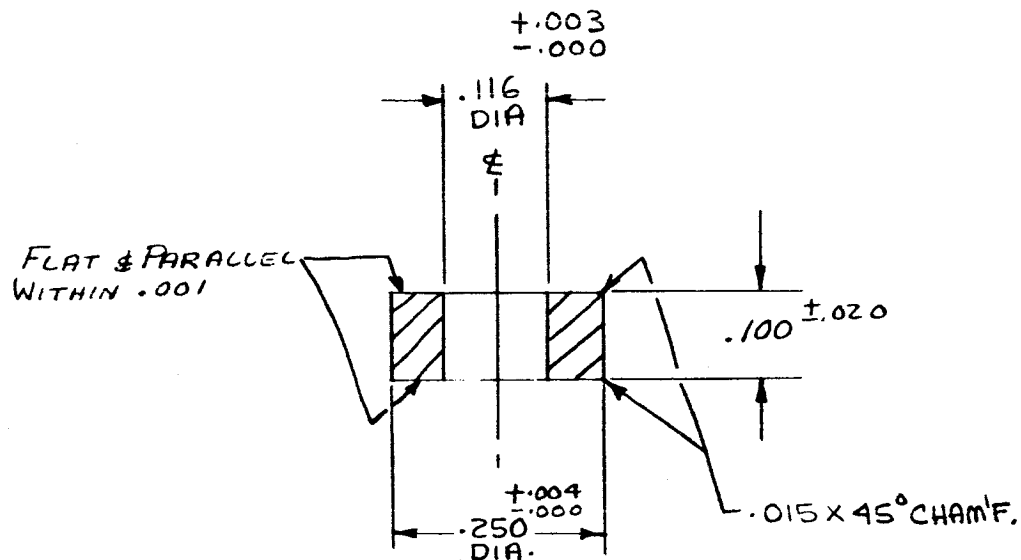
NEXT ASSY.

SIMILAR TO

SIZE **DRAWING NUMBER** **SHEET** **REV**

A 550-020

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005

FILLET RADIUS: .010 MAX

THREADS: CLASS 2

* DIA. CONC. WITHIN T.I.R.

ALL OTHER DIA. CONC. WITHIN .005 T.I.R.

SURFACES TO BE PERP. WITHIN .005 T.I.R.

SURFACES TO BE PAR. WITHIN .005 T.I.R.

HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9'

2.0-4.0 RAD. ± 0° 5'

ALL OTHER ANGULAR TOL. TO BE ± 0° 30'

REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE • WALTHAM, MASS. 02154

DRAWN **CHECKED** **ENGINEER**

MN 8/10/65 *[Signature]* *[Signature]* *[Signature]*

TITLE:

WASHER

MAT'L

REQ

SCALE: 5x1

FINISH: —

Al₂O₃

18

479-36

NEXT ASSY.

SIMILAR TO

SIZE **DRAWING NUMBER** **SHEET** **REV**

A

550-021

[illegible]

[illegible]

REV	DESCRIPTION	DATE	BY	APPR

Technical drawing of a circular part with the following dimensions and tolerances:

- Overall width: .780
- Overall height: .740
- Inner square width: .390
- Inner square height: .370
- Circle diameter: .687 DIA.
- Circle tolerance: $\begin{matrix} +.005 \\ -.000 \end{matrix}$
- Surface finish: .001 THK

UNLESS OTHERWISE SPECIFIED	
DECIMAL: X $\pm$.03, XX $\pm$.01, XXX $\pm$.005	
FILLET RADIUS: .010 MAX	
THREADS: CLASS 2	
*DIA. CONC. WITHIN T.I.R.	
ALL OTHER DIA. CONC. WITHIN .005 T.I.R.	
SURFACES TO BE PERP. WITHIN .005 T.I.R.	
SURFACES TO BE PAR. WITHIN .005 T.I.R.	
HOLE ANGULAR TOL. 0-2.0 RAD. $\pm$ 0° 9'	
2.0-4.0 RAD. $\pm$ 0° 5'	
ALL OTHER ANGULAR TOL. TO BE $\pm$ 0° 30'	
REMOVE ALL BURRS AND EDGES	

THERMO ELECTRON	
ENGINEERING CORPORATION	
85 FIRST AVENUE • WALTHAM, MASS. 02154	
DRAWN	CHECKED
MN 8/4/65	RBS 8/2/65
ENGINEER	
P. Brown	
TITLE:	
SHOE PIECE SHIELD	

MAT'L	REQ	SCALE: 5 x 1	FINISH: ~	SIZE	DRAWING NUMBER	SHEET	REV
Ta	5	~	~	A	550-202		
		NEXT ASSY.	SIMILAR TO				

NO.	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR
1								

0.001 THK.

TYP SPACING FOR DIMPLES

DEVELOPED LENGTH = 9.0 APPROX.

UNLESS OTHERWISE SPECIFIED

DECIMAL: X.03, XX.01, XXX.005
FRACTION: 1/32, 1/16, 1/8, 1/4, 1/2, 3/4, 1, 1 1/2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100

UNLESS OTHERWISE SPECIFIED

DECIMAL: X.03, XX.01, XXX.005
FRACTION: 1/32, 1/16, 1/8, 1/4, 1/2, 3/4, 1, 1 1/2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100

THERMO ELECTRON
 TESTERIES - LABORATORIES
 80 FIRST AVENUE - WALTHAM, MASS 01901
 DRAWN: 9/1/68 CHECKED: 9/1/68 ENGINEER: 9/1/68
 TITLE: CONVERTER SHIELD
 SIZE: B DRAWING NUMBER: 550-203

MAT'L: Ta REQ: 1
 SCALE: 5 X 1 FINISH: —
 NEXT ASSY: — SIMILAR TO: —

NO. OF HOLES	DESCRIPTION	DBC	REV	DESCRIPTION	DATE	BY	APPR

.010 X 45° CHAM F.
 .727 DIA.
 .750 DIA.
 .685 DIA.
 .040
 .080
 .170
 ±.002
 ±.005
 ±.002
 ±.005

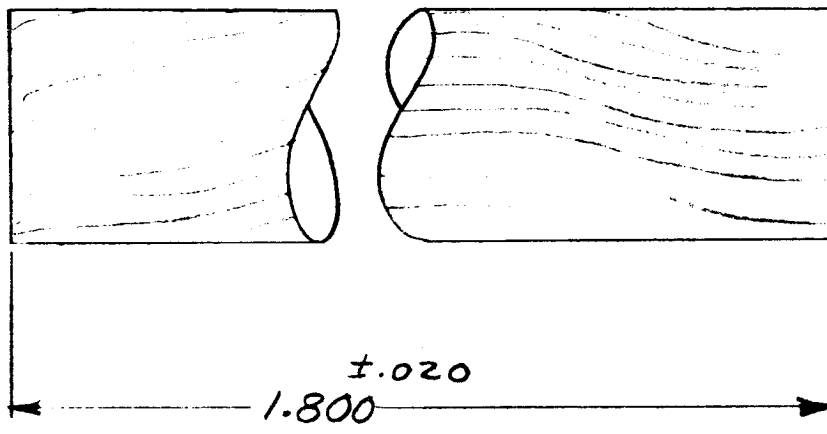
UNLESS OTHERWISE SPECIFIED
 DECIMALS .X .03 .XX ±.01 .XXX ±.005
 FILLET RADIUS .010 MAX
 THREADS: CLASS 2
 ALL DIMENSIONS WITHIN TOLERANCES
 SURFACES TO BE PAR WITHIN .005 TIR
 SURFACES TO BE PAR WITHIN .005 TIR
 HOLE ANGULAR TOL 0-20 RAD 40° 8'
 ALL OTHER ANGULAR TOL TO BE 40° 30'
 REMOVE ALL BURRS AND EDGES

THERMO ELECTRON ELECTRONIC CORPORATION 85 FIRST AVENUE - WALTHAM, MASS 02154	
DRAWN	CHECKED
MM 8/4/65	MM 8/4/65
TITLE: SHIELD SUPPORT	
SIZE	DRAWING NUMBER
3	550-204

MAT'L	REQ
Ta	1
SCALE: 5X1	FINISH: 63RMS
NEXT ASSY.	SIMILAR TO

[illegible]

REV	DESCRIPTION	DATE	BY	APPR



MADE FROM:

#4 WELDING CABLE (PARANITE)

UNLESS OTHERWISE SPECIFIED DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005 FILLET RADIUS: .010 MAX THREADS: CLASS 2 * DIA. CONC. WITHIN ____ T.I.R. ALL OTHER DIA. CONC. WITHIN .005 ____ T.I.R. SURFACES TO BE PERP. WITHIN .005 ____ T.I.R. SURFACES TO BE PAR. WITHIN .005 ____ T.I.R. HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9' 2.0-4.0 RAD. ±0° 5' ALL OTHER ANGULAR TOL. TO BE ±0° 30' REMOVE ALL BURRS AND EDGES		 THERMO ELECTRON ENGINEERING CORPORATION 85 FIRST AVENUE • WALTHAM, MASS. 02154			
				DRAWN MN 8/3/65	CHECKED RLS 8/4/65
TITLE: LEAD		SCALE: 5X1		FINISH:	
MAT'L Co	REQ 1	SIZE A	DRAWING NUMBER 550-210	SHEET 1	REV 1
NEXT ASSY.		SIMILAR TO		1	

NO.	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPROV

.92
 .27
 .17
 .312 (574) DIA.
 +.002
 -.000
 DIA.
 .300
 .20
 .100
 .200
 .010
 .125 DIA THRU
 +.005
 .005

UNLESS OTHERWISE SPECIFIED
 DECIMAL: X.03, X.01, .XXX ± .005
 FILLET RADIUS: .010 MAX
 THREADS: CLASS II
 * DIA. CONC. WITHIN .008 TIR
 ALL OTHER DIA. CONC. WITHIN .008 TIR
 SURFACES TO BE PERP. WITHIN .008 TIR
 HOLE ANGULAR TOL. 0-2.0 RAD ± 0.5°
 ALL OTHER ANGULAR TOL. TO BE ± 0-30°
 REMOVE ALL BURRS AND EDGES

SCALE: 5X
 FINISH: 6 RMS
 NEXT ASSY. SIMILAR TO
 MAT'L: Cu
 REQ: 1

THERMO ELECTRON
 100 FIRST AVENUE - WALTHAM, MASS 02154
 DRAWN: [Signature]
 CHECKED: [Signature]
 ENGINEER: [Signature]
 TITLE: LEAD TERMINAL
 SIZE: B
 DRAWING NUMBER: 550-211
 REV:

NO.	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR

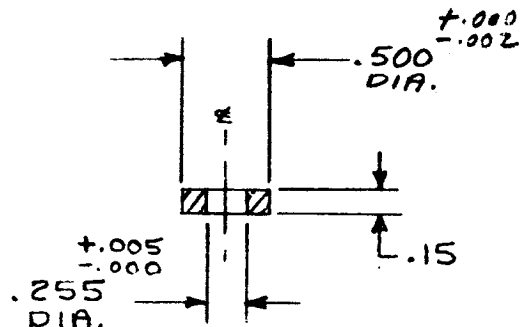
2.375

.75

.25

UNLESS OTHERWISE SPECIFIED		THERMO ELECTRON ELECTRONIC CORPORATION 20 FIRST AVENUE, WALTHAM, MASS 02154	
DECIMAL: X.03, .XX, .01, XXX & .005	FILLET RADIUS: .010 MAX	DRAWN	CHECKED
THREADS: CLASS 2	R. DIA. LONG WITHIN TOLERANCE	MN 8/2/45	RB 8/9/45
ALL DIMENSIONS TO BE GIVEN WITH TOLERANCE	SURFACES TO BE FINISHED TO .005 TIR	TITLE: WEB	
HOLE ANGULAR TO 30-40 RAD. 40° 8'	ALL OTHER ANGULAR TO 30-40 RAD. 40° 8'	REMOVE ALL BURRS AND EDGES	
SCALE: FULL	FINISH: G. 3.00'S	SIZE: DRAWING NUMBER: 550-302	
MAT'L	REQ	B 550-302	
S.S.	4	SIMILAR TO	

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
 FILLET RADIUS: .010 MAX
 THREADS: CLASS 2
 * DIA. CONC. WITHIN ____ T.I.R.
 ALL OTHER DIA. CONC. WITHIN .005 ____ T.I.R.
 SURFACES TO BE PERP. WITHIN .005 ____ T.I.R.
 SURFACES TO BE PAR. WITHIN .005 ____ T.I.R.
 HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9'
 2.0-4.0 RAD. ± 0° 5'
 ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
 REMOVE ALL BURRS AND EDGES



THERMO ELECTRON
 ENGINEERING CORPORATION
 85 FIRST AVENUE • WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
-------	---------	----------

MN 8/3/65	RBS. 8/9/65	RP
-----------	-------------	----

TITLE:

INSULATOR

MAT'L

REQ

SCALE: Full

FINISH: ~

Al₂O₃

6

NEXT ASSY.

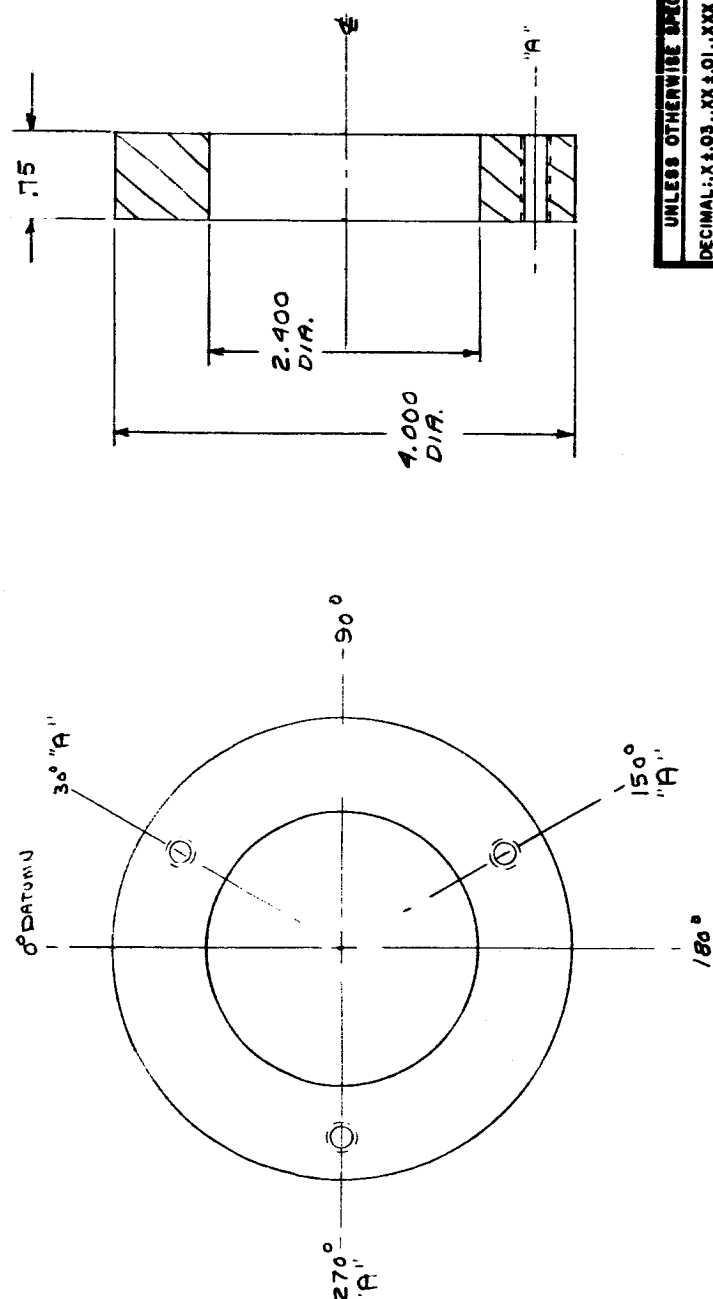
SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
------	----------------	-------	-----

A

550-303

NO.	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR
1	1/4-20 TAP THRU	3.300	3					



UNLESS OTHERWISE SPECIFIED DECIMAL: X.03, XX.01, XXX.005 FRACTIONS: 1/16, 1/8, 1/4, 3/8, 1/2, 5/8, 3/4, 7/8 TOLERANCES: .010 MAX FINISHES: CLASS 2 ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED SURFACES TO BE PAR WITHIN .005" TYP HOLE ANGULAR TO 0-10° MAX 10° BT ALL OTHER ANGULAR TO 0-10° MAX 10° BT REMOVE ALL BURRS AND EDGES		THERMO ELECTRON ELECTRONIC CORPORATION 85 FIRST AVENUE - WALTHAM, MASS 02154 DRAWN: <u> </u> CHECKED: <u> </u> ENGINEER: <u> </u> DATE: <u>8/9/65</u> TITLE: <u>SUPPORT RING</u>
SCALE: FULL SIZE FINISH: 63 RMS NEXT ASSY: <u> </u> SIMILAR TO: <u> </u>		SIZE: <u> </u> DRAWING NUMBER: <u>550-305</u>

MAT'L	REQ
S.S.	1

NO. OF HOLES	DESCRIPTION	DBC	REV	DESCRIPTION	DATE	BY	APPR

5/16-18 THD

.500 DIA. (STK)

5.75

1.312

1.75

5/16-18 THD

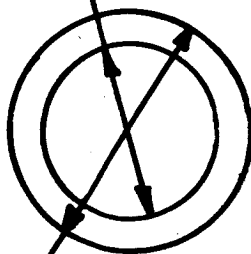
UNLESS OTHERWISE SPECIFIED		THERMO ELECTRON	
DECIMAL: X4.03, XX ±.01, XXX ±.008	FILLET RADIUS: .010 MAX	ENGINEER	DATE
THREADS: CLASS 2	FINISH: WITHIN TOLERANCE	CHECKED	BY
HOLE ANGULAR TO BE PAR WITHIN .008" TIR	HOLE ANGULAR TO BE PAR WITHIN .008" TIR	DRAWN	BY
ALL OTHER ANGULAR TO BE 40° 30'	REMOVE ALL BURRS AND EDGES	TITLE: SUPPORT LENS	
SCALE: 1" = 1"	FINISH: ~	SIZE: DRAWING NUMBER: 554-306	
NEXT ASSY.	SIMILAR TO	REV	

MAT'L	REQ
S.S.	4

REV	DESCRIPTION	DATE	BY	APPR

+0.000
-0.005

O. D.



+0.005
-0.000
.065 I. D.

☒ BRAZE WASHER

USE .002..... THK. SHEET STOCK

☐ BRAZE RING

USE DIA. WIRE

PART		SIZE	LOC	REQ	MAT'L	18	PB130
UNLESS OTHERWISE SPECIFIED							
DEC. ± 1 .XX ± 01 .XXX ± 005							
SCALE:							
ANGLES $\pm 0'30''$		FINISH		$\checkmark$ MAX			
FILLET RAD .010 MAX							
THREADS: CLASS 2							
ALL DIAS. CONCENTRIC WITHIN .005 TIR							
REMOVE ALL BURRS & SHARP EDGES							
NEXT ASSY		SIM TO					
SIZE		NUMBER		REV			
A		550-2001					

NOTES			
THERMO ELECTRON			
ENGINEERING CORP			
WALTHAM 54, MASS.			
DR (M)	8-23-65	ENG (P)	8-23-65
CHK (P)	8/23/65	APP	
TITLE			

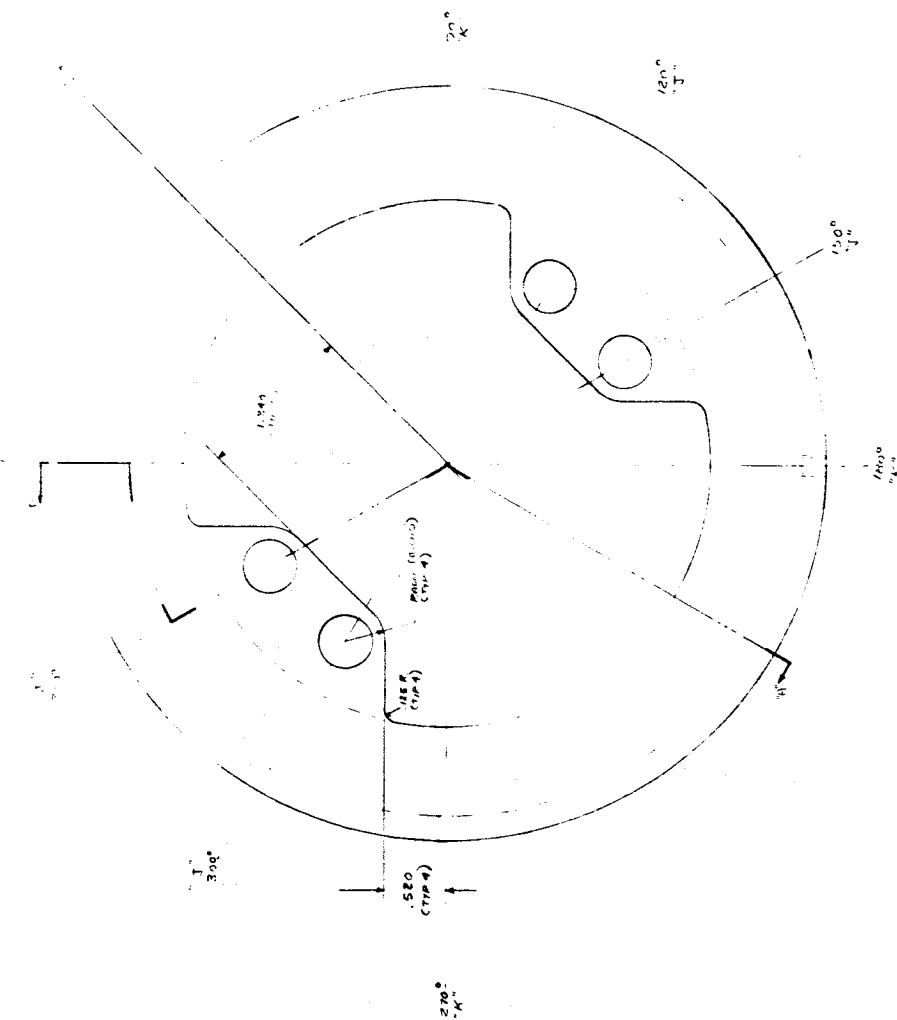
2.2 Detailed Mechanical Drawings
for the
Electron Bombardment Unit

549-001 to

549-2006

REV	DESCRIPTION	DATE	BY
1	437 (1/10/74) (T.M.)		
2	438 (1/10/74) (T.M.)		

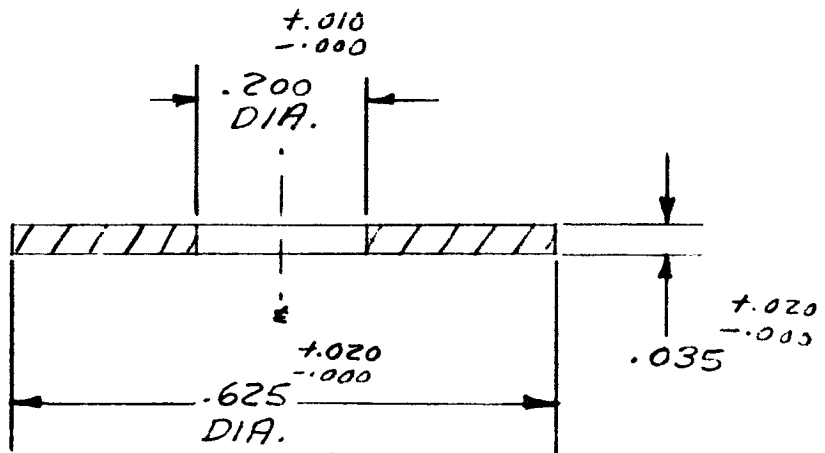
REV	DESCRIPTION	DATE	BY
1	437 (1/10/74) (T.M.)		
2	438 (1/10/74) (T.M.)		



SECTION 20-20"

PROJECT: 437 (1/10/74) (T.M.) DRAWING: 438 (1/10/74) (T.M.) TITLE: Main Support Ring	
DESIGNED: [Signature] CHECKED: [Signature] APPROVED: [Signature]	DATE: 1/10/74 SCALE: 1" = 1'-0" SHEET: 1 OF 1

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
 FILLET RADIUS: .010 MAX
 THREADS: CLASS 2
 * DIA. CONC. WITHIN ____ T.I.R.
 ALL OTHER DIA. CONC. WITHIN .005 ____ T.I.R.
 SURFACES TO BE PERP. WITHIN .005 ____ T.I.R.
 SURFACES TO BE PAR. WITHIN .005 ____ T.I.R.
 HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9'
 2.0-4.0 RAD. ± 0° 5'
 ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
 REMOVE ALL BURRS AND EDGES


THERMO ELECTRON
 ENGINEERING CORPORATION
 85 FIRST AVENUE • WALTHAM, MASS. 02154

DRAWN CHECKED ENGINEER

M/V 8/9/65 A. J. J. S.

TITLE:

WASHER

MAT'L REQ

S.S. 4

SCALE: 5 X 1 FINISH:

NEXT ASSY. SIMILAR TO

SIZE DRAWING NUMBER SHEET REV

A 549-002

NO.	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR

1.00

.120

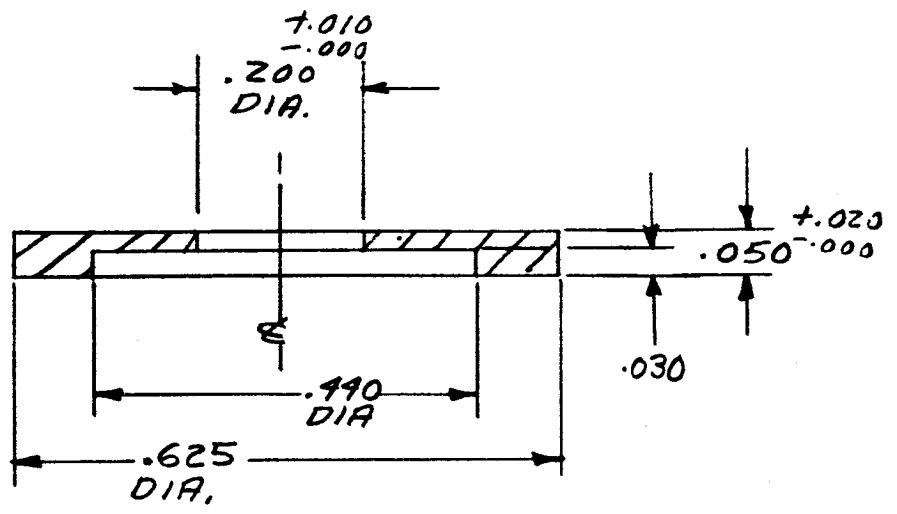
.125 DIA.

#8-32 THD.

CHAM F.

UNLESS OTHERWISE SPECIFIED		THERMO ELECTRON	
DECIMAL: X.03, XX.01, XXX.008	FILLET RADIUS: .010 MAX	DRAWN	CHECKED
THREADS: CLASS 2	* DIA. CONG. WITHIN .008 TIR	MM 8/4/54	85 8/16/54
* DIA. CONG. WITHIN .008 TIR	SURFACES TO BE PAR. WITHIN .008 TIR	TITLE: THREADED POST	
HOLE ANGULAR TOL. 0-2.0 RAD. 0-8°	ALL OTHER ANGULAR TOL. TO BE ±0-30°	SIZE: DRAWING NUMBER: 549.004	
REMOVE ALL BURRS AND EDGES		NEXT ASSY. SIMILAR TO	
SCALE: 5X/	FINISH: 63 RMS		
MAT'L: S.S.	REQ: 4		

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005 FILLET RADIUS: .010 MAX THREADS: CLASS 2 * DIA. CONC. WITHIN ____ T.I.R. ALL OTHER DIA. CONC. WITHIN .005 ____ T.I.R. SURFACES TO BE PERP. WITHIN .005 ____ T.I.R. SURFACES TO BE PAR. WITHIN .005 ____ T.I.R. HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9' 2.0-4.0 RAD. ± 0° 5' ALL OTHER ANGULAR TOL. TO BE ± 0° 30' REMOVE ALL BURRS AND EDGES		 THERMO ELECTRON ENGINEERING CORPORATION 85 FIRST AVENUE • WALTHAM, MASS. 02154					
		DRAWN	CHECKED	ENGINEER			
		MN 8/9/65	R. J. ...	...			
		TITLE: SPRING RETAINER WASHER					
MAT'L	REQ	SCALE: 5 x 1	FINISH:	SIZE	DRAWING NUMBER	SHEET	REV
S.S.	4	—	—	A	549-005		
		NEXT ASSY.	SIMILAR TO				

HOLE	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR

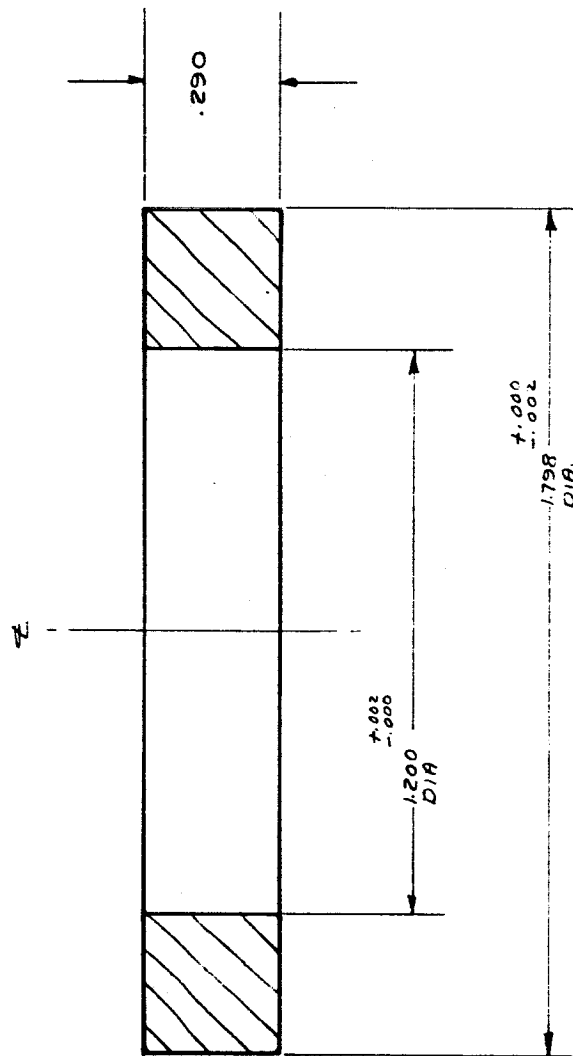
1.828 DIA. $\begin{smallmatrix} +.000 \\ -.002 \end{smallmatrix}$

1.800 DIA. $\begin{smallmatrix} +.002 \\ -.000 \end{smallmatrix}$

.440

UNLESS OTHERWISE SPECIFIED		THERMO ELECTRON ELECTRONIC CORPORATION 80 FIRST AVENUE - WALTHAM, MASS. 02154	
DECIMAL: 1 X .03, XX ± .01, XXX ± .008	FILLET RADIUS: .010 MAX	DRAWN	CHECKED
THREADS: CLASS 2	* DIA. CONG. WITHIN TOLERANCE	MN 8/9/65	ROB 8/9/65
* DIA. CONG. WITHIN TOLERANCE	ALL OTHERS TO BE PERMANENT	TITLE: INSULATOR FLANGE (COVER)	
ALL DIMENSIONS TO BE PERMANENT	SURFACES TO BE FINISHED TO 10-40 RA	SIZE: DRAWING NUMBER: 549-008	
HOLE ANGULAR TO 10-40 RA	ALL OTHER ANGULAR TO 10-40 RA	REV	
REMOVE ALL BURRS AND EDGES	SCALE: 1/2" = 1"	NEXT ASSY. SIMILAR TO	
	FINISH: 63 RMS		
	MAT'L REQ		
	DH 142 1		

NO. OF POLES	DESCRIPTION	DBC	REV	DESCRIPTION	DATE	BY	APPR



THERMO ELECTRON ELECTRONIC EQUIPMENT DIVISION 10000 WILSON AVENUE ANN ARBOR, MICHIGAN 48106		DRAWN M. J. JONES		CHECKED J. J. JONES		ENGINEER J. J. JONES	
TITLE HIGH VOLTAGE INSULATOR							
UNLESS OTHERWISE SPECIFIED		DECIMALS: XX ± .01, XXX ± .005 FRACTIONS: 1/16 MAX HOLE DIA: .0015 MIN ALL OTHER DIA: .0015 MIN SURFACES TO BE FINISHED TO 32 RMS MAX ALL OTHER ANGLES TO 10° TO 30° REMOVE ALL BURRS AND EDGES					
SCALE: 5X1		FINISH		NEXT ASSY.		SIMILAR TO	
MATERIAL Al ₂ O ₃		REQ 1					

Al₂O₃

NO.	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR

1.198 DIA. $\begin{smallmatrix} +.000 \\ -.002 \end{smallmatrix}$

1.170 DIA. $\begin{smallmatrix} +.002 \\ -.000 \end{smallmatrix}$

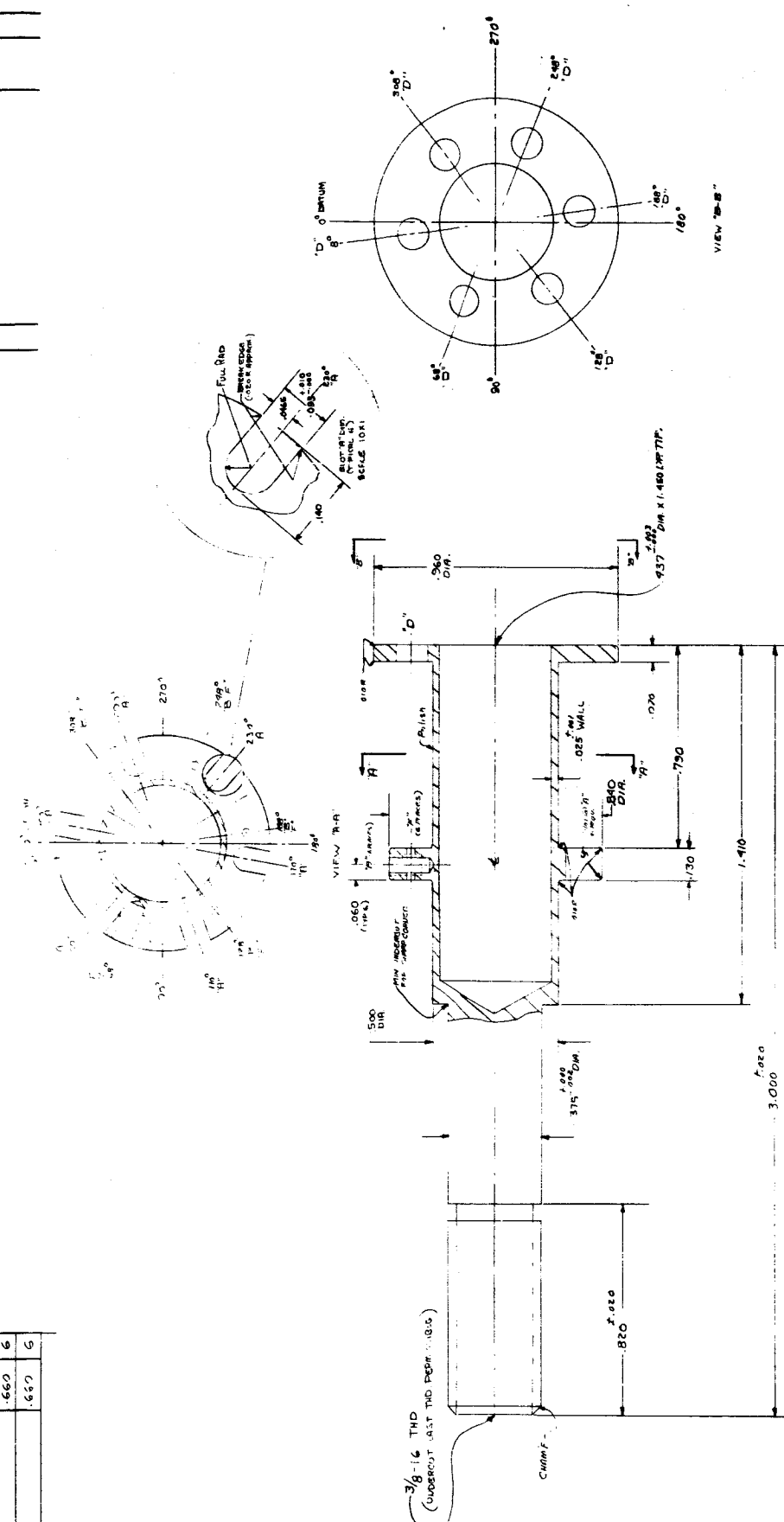
.440

UNLESS OTHERWISE SPECIFIED		THERMO ELECTRON ELECTRONIC CORPORATION 50 FIRST AVENUE - WALTHAM, MASS. 02154	
DECIMAL: X .03, XX .01, XXX .005	FILLET RADIUS: .010 MAX	DRAWN	CHECKED
THREADS: CLASS 2	H DIA. CONE WITHIN .005	WV 8/5/65	8/19/65
ALL OTHER DIA. CONE WITHIN .005	TUR SURFACES TO BE PAR WITHIN .005	TITLE: INSULATOR FLANGE (INNER)	
HOLE ANGULAR TOL. 0-2.0 RAD. 0-90°	2.0-4.0 RAD. 0-90°	SIZE: DRAWING NUMBER: 549-010	
ALL OTHER ANGULAR TOL. TO BE 0-30°		REV	
REMOVE ALL BURRS AND EDGES		B	
SCALE: 5 X 1	FINISH: 6 Z RMS	SIMILAR TO	
MAT'L	REQ	NEXT ASSY.	
DH 142	1		

Technical drawing of a shaft assembly. The drawing shows a cross-section of a shaft with a diameter of .080. A #2-56 screw is shown inserted into the shaft. The screw has a length of .015. The shaft has a .030 wide sawcut x .030 DP.

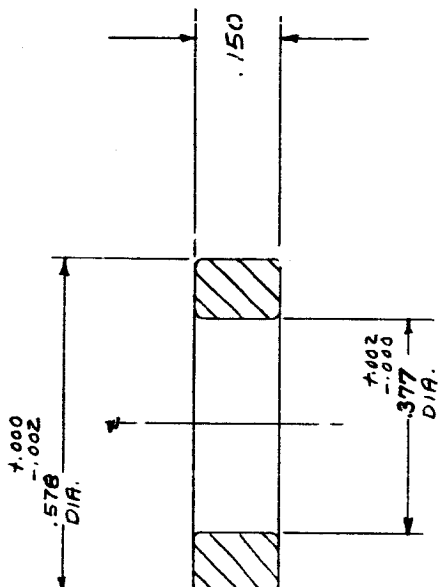
UNLESS OTHERWISE SPECIFIED		 THERMO ELECTRON ENGINEERING CORPORATION 85 FIRST AVENUE • WALTHAM, MASS. 02154							
DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005 FILLET RADIUS: .010 MAX THREADS: CLASS 2 * DIA. CONC. WITHIN ____ T.I.R. ALL OTHER DIA. CONC. WITHIN .005 ____ T.I.R. SURFACES TO BE PERP. WITHIN .005 ____ T.I.R. SURFACES TO BE PAR. WITHIN .005 ____ T.I.R. HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9' 2.0-4.0 RAD. ± 0° 5' ALL OTHER ANGULAR TOL. TO BE ± 0° 30' REMOVE ALL BURRS AND EDGES		<table border="1"> <thead> <tr> <th>DRAWN</th> <th>CHECKED</th> <th>ENGINEER</th> </tr> </thead> <tbody> <tr> <td>MN 8/9/65</td> <td>NBS 8/19/65</td> <td>P. [unclear]</td> </tr> </tbody> </table> TITLE: <i>FILAMENT SET SCREW</i>		DRAWN	CHECKED	ENGINEER	MN 8/9/65	NBS 8/19/65	P. [unclear]
DRAWN	CHECKED	ENGINEER							
MN 8/9/65	NBS 8/19/65	P. [unclear]							
SCALE: 5 X 1	FINISH: ~								
~	~								
NEXT ASSY.	SIMILAR TO	SIZE A	DRAWING NUMBER 549-013						

REV	DESCRIPTION	DATE	BY
1	TRD DWG. 175 DR TIP TRI. 2		
2	42-55 TRD X 130 DR TRI		
3	101 185 TRD X 130 DR TRI		
4	101 185 TRD X 130 DR TRI		
5	101 185 TRD X 130 DR TRI		
6	101 185 TRD X 130 DR TRI		
7	101 185 TRD X 130 DR TRI		
8	101 185 TRD X 130 DR TRI		
9	101 185 TRD X 130 DR TRI		
10	101 185 TRD X 130 DR TRI		
11	101 185 TRD X 130 DR TRI		
12	101 185 TRD X 130 DR TRI		
13	101 185 TRD X 130 DR TRI		
14	101 185 TRD X 130 DR TRI		
15	101 185 TRD X 130 DR TRI		
16	101 185 TRD X 130 DR TRI		
17	101 185 TRD X 130 DR TRI		
18	101 185 TRD X 130 DR TRI		
19	101 185 TRD X 130 DR TRI		
20	101 185 TRD X 130 DR TRI		
21	101 185 TRD X 130 DR TRI		
22	101 185 TRD X 130 DR TRI		
23	101 185 TRD X 130 DR TRI		
24	101 185 TRD X 130 DR TRI		
25	101 185 TRD X 130 DR TRI		
26	101 185 TRD X 130 DR TRI		
27	101 185 TRD X 130 DR TRI		
28	101 185 TRD X 130 DR TRI		
29	101 185 TRD X 130 DR TRI		
30	101 185 TRD X 130 DR TRI		
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33	101 185 TRD X 130 DR TRI		
34	101 185 TRD X 130 DR TRI		
35	101 185 TRD X 130 DR TRI		
36	101 185 TRD X 130 DR TRI		
37	101 185 TRD X 130 DR TRI		
38	101 185 TRD X 130 DR TRI		
39	101 185 TRD X 130 DR TRI		
40	101 185 TRD X 130 DR TRI		
41	101 185 TRD X 130 DR TRI		
42	101 185 TRD X 130 DR TRI		
43	101 185 TRD X 130 DR TRI		
44	101 185 TRD X 130 DR TRI		
45	101 185 TRD X 130 DR TRI		
46	101 185 TRD X 130 DR TRI		
47	101 185 TRD X 130 DR TRI		
48	101 185 TRD X 130 DR TRI		
49	101 185 TRD X 130 DR TRI		
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52	101 185 TRD X 130 DR TRI		
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54	101 185 TRD X 130 DR TRI		
55	101 185 TRD X 130 DR TRI		
56	101 185 TRD X 130 DR TRI		
57	101 185 TRD X 130 DR TRI		
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59	101 185 TRD X 130 DR TRI		
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61	101 185 TRD X 130 DR TRI		
62	101 185 TRD X 130 DR TRI		
63	101 185 TRD X 130 DR TRI		
64	101 185 TRD X 130 DR TRI		
65	101 185 TRD X 130 DR TRI		
66	101 185 TRD X 130 DR TRI		
67	101 185 TRD X 130 DR TRI		
68	101 185 TRD X 130 DR TRI		
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74	101 185 TRD X 130 DR TRI		
75	101 185 TRD X 130 DR TRI		
76	101 185 TRD X 130 DR TRI		
77	101 185 TRD X 130 DR TRI		
78	101 185 TRD X 130 DR TRI		
79	101 185 TRD X 130 DR TRI		
80	101 185 TRD X 130 DR TRI		
81	101 185 TRD X 130 DR TRI		
82	101 185 TRD X 130 DR TRI		
83	101 185 TRD X 130 DR TRI		
84	101 185 TRD X 130 DR TRI		
85	101 185 TRD X 130 DR TRI		
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87	101 185 TRD X 130 DR TRI		
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90	101 185 TRD X 130 DR TRI		
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96	101 185 TRD X 130 DR TRI		
97	101 185 TRD X 130 DR TRI		
98	101 185 TRD X 130 DR TRI		
99	101 185 TRD X 130 DR TRI		
100	101 185 TRD X 130 DR TRI		



TITLE: FILAMENT SUPPORT (CENTRAL) DRAWN BY: [Signature] CHECKED BY: [Signature] DATE: 1/15/60		D 1549-01C
SHEET NO. 7a	TOTAL SHEETS 1	SHEET TO 1

NO.	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR
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UNLESS OTHERWISE SPECIFIED		THERMO ELECTRON ELECTRONIC CORPORATION 20 FIRST AVENUE - WALTHAM, MASS 02154	
DECIMAL: X+.03, XX+.01, XXX+.005	FILLET RADIUS: .010 MAX	DRAWN	CHECKED
THREADS: CLASS 2	# DIA. CONC. WITHIN .005	MM 8/9/65	8/5 8/9/65
ALL OTHER DIA. CONC. WITHIN .005	SURFACES TO BE PAR. WITHIN .005	TITLE: LOW VOLTAGE INSULATOR	
HOLE ANGULAR TOL. 0-3.0 RAD. 10°-9°	ALL OTHER ANGULAR TOL. TO BE 30°-30°	SIZE DRAWING NUMBER	
REMOVE ALL BUMPS AND EDGES	SCALE: 5 X 1	B 549-017	
FINISH: —	NEXT ASSY.	REV	
SIMILAR TO			

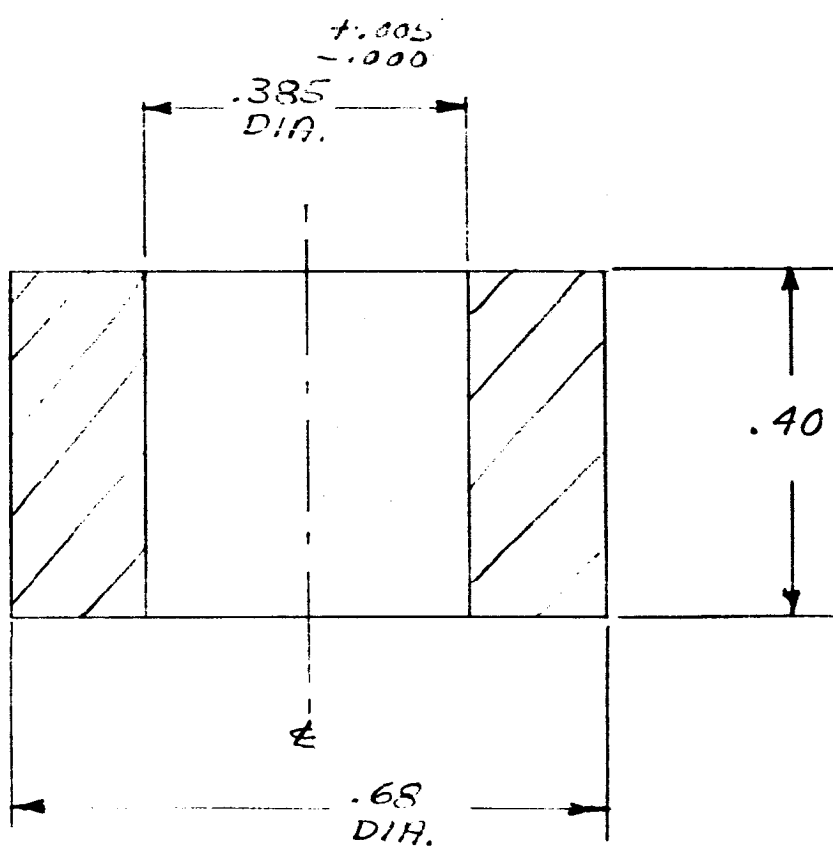
MAT'L	REQ
A1203	1

NO. OF HOLES	DESCRIPTION	DBC	REV	DESCRIPTION	DATE	BY	APPR

Technical drawing of a cylindrical part with a hole. The hole has a diameter of .377 with a tolerance of +.002 / -.000. The cylinder has an outer diameter of .778 with a tolerance of +.000 / -.002. The wall thickness of the cylinder is .080.

UNLESS OTHERWISE SPECIFIED		THERMO ELECTRON ELECTRICAL CORPORATION 80 FIRST AVENUE - WALTHAM, MASS. 019	
DECIMAL: $\pm .03$, $\pm .01$, $\pm .005$	FILLET RADIUS: O.D. MAX	DRAWN	CHECKED ENGINEER
THREADS: CLASS 2	ADDITIONAL TOLERANCES	MN 8/9/46	8/2/46
ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED	SURFACES TO BE PAR WITHIN .005" TIR	TITLE: INSULATING WASHER	
HOLE ANGULAR TOL. 0-10° MAX	3.0-4.0 RAD. $\pm .01$ "		
ALL OTHER ANGULAR TOL. TO BE $\pm .01$ "			
REMOVE ALL BURRS AND EDGES			
SCALE: 5X 1	FINISH	SIZE	DRAWING NUMBER
		B	549-018
MAT'L	REQ	NEXT ASSY.	SIMILAR TO
Al ₂ O ₃	1		

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
 FILLET RADIUS: .010 MAX
 THREADS: CLASS 2
 * DIA. CONC. WITHIN ____ T.I.R.
 ALL OTHER DIA. CONC. WITHIN .005 ____ T.I.R.
 SURFACES TO BE PERP. WITHIN .005 ____ T.I.R.
 SURFACES TO BE PAR. WITHIN .005 ____ T.I.R.
 HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9'
 2.0-4.0 RAD. ± 0° 5'
 ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
 REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
 ENGINEERING CORPORATION
 85 FIRST AVENUE • WALTHAM, MASS. 02154

DRAWN **CHECKED** **ENGINEER**

MN 8/2/54 6/9/54

TITLE:
 WASHER LOCATING

MAT'L	REQ	SCALE:	FINISH:	SIZE	DRAWING NUMBER	SHEET	REV
	1	NEXT ASSY.	SIMILAR TO	A	549-019		

NOLE	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR

$.57$
 $.100$
 $.248 \pm .002$ DIA
 $3/8-16$ THD

UNLESS OTHERWISE SPECIFIED DECIMAL: $X \pm .03$, $XX \pm .01$, $XXX \pm .005$ FILLET RADIUS: $Q10$ MAX THREADS: CLASS 2 * DIA CONC. WITHIN TIR ALL OTHER DIA. CONG. WITHIN .005 SURFACES TO BE PER. WITHIN .005 SURFACES TO BE PA. WITHIN .005 HOLE ANGULAR TOL. $0-2.0$ RAD $\pm 0.8^\circ$ ALL OTHER ANGULAR TOL. TO BE $0-30^\circ$ REMOVE ALL BURRS AND EDGES		THERMO ELECTRON 100 STATE STREET 2ND FLOOR WALTHAM, MASS. 02154	
DRAWN	CHECKED	ENGINEER	
MV 9/2/65	8/1/65		
TITLE: TERMINAL STUD			
SCALE: SX/	FINISH: 63 RMS	SIZE: B	DRAWING NUMBER: 549-021
NEXT ASSY.	SIMILAR TO	REV	
MAT'L	REQ		
Ta	1		

NO.	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR

1.50

1.50

.40

.200

.500

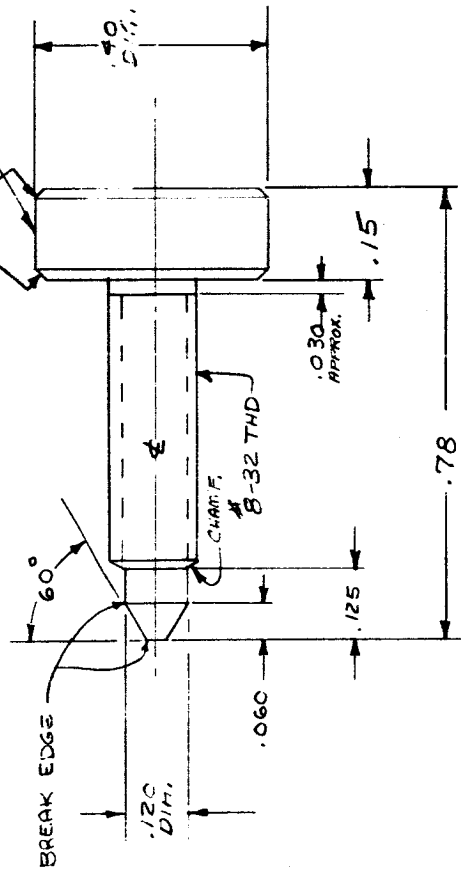
A-A

8-32 THD. THRU

UNLESS OTHERWISE SPECIFIED		THERMO ELECTRON ELECTRONIC CORPORATION 20 FIRST AVENUE - WALTHAM, MASS 01981	
DECIMAL: X+.03, XX+.01, XXX+.005	FILLET RADIUS: .010 MAX	DRAWN	CHECKED
THREADS: CLASS 2	# DIA CONC. WITHIN .005	MIN 8/25/85	ENGINEER
ALL OTHER DIA. CONE WITHIN .005	SURFACES TO BE PAR WITHIN .005	TITLE:	
HOLE ANGULAR TOL. C-3.0 RAD. 10°-90°	ALL OTHER ANGULAR TOL. TO BE 10°-90°	SUPPORT (ADJUSTMENT SCREW)	
SCALE: 5 X 1	FINISH: 63 RMS	SIZE: DRAWING NUMBER: SHEET: REV	
NEXT ASSY.	SIMILAR TO	B 549-023	

HOLE	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR

.015 x 45° CHAMF MED. DIAMOND KNURL



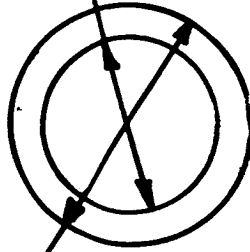
THERMO ELECTRON	
DESIGN	ENGINEER
CHECKED	ENGINEER
DRAWN BY: 8/5/58 JDS	
TITLE: CLAMP THUMB SCREW	
UNLESS OTHERWISE SPECIFIED	
DECIMAL: X.03, .XX ±.01, .XXX ±.005	
FILLET RADIUS: .010 MAX	
THREADS: CLASS 2	
HOLE ANGLES: 60° UNLESS OTHERWISE SPECIFIED	
SURFACES TO BE FINISHED WITHIN .005" TIR	
SURFACES TO BE FINISHED WITHIN .005" TIR	
HOLE ANGULAR TOL: 0-1.0° MAX	
ALL OTHER ANGULAR TOL: TO BE ±0° 30'	
REMOVE ALL BURRS AND EDGES	
SCALE: 5X	FINISH: ~
NEXT ASSY.	SIMILAR TO
MAT'L	REQ
S.S.	4
SIZE DRAWING NUMBER: B 549-024	

REV	DESCRIPTION	DATE	BY	APPR

.295
+ .000
- .005

O. D.

+ .005
- .000
.255 I. D.



☒ BRAZE WASHER

USE: .003..... THK. SHEET STOCK

☐ BRAZE RING

USE DIA. WIRE

/		FE 75		NOTES	
PART	SIZE	LOC	REQ	MAT'L	
UNLESS OTHERWISE SPECIFIED					
DEC. ± 1 .XX $\pm$.01 .XXX $\pm$.005					
SCALE: None					
ANGLES $\pm$ 0°30'		FINISH		✓ MAX	
FILLET RAD .010 MAX					
THREADS: CLASS 2					
ALL DIAS. CONCENTRIC WITHIN .005 TIR					
REMOVE ALL BURRS & SHARP EDGES					
NEXT ASSY		SIM TO		SIZE	NUMBER
				A	549-2006
				REV	

THERMO ELECTRON
ENGINEERING CORP.
WALTHAM 54, MASS.

DR MN 3/9/65 ENG 24.000 2.20.65
CHK 6/65 8/7/65 APP

TITLE

WASHER

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3.0 Assembly Data for Generator and Electron Bombardment Unit

3.1 List of Suggested Materials Vendors

Tantalum:	Kawecki Chemical 220 East 42nd Street New York, New York
Tungsten:	Universal Cyclops Steel Drawer 153 Bridgeville, Pennsylvania
	Kawecki Chemical 220 East 42nd Street New York, New York
Driver Harris 142:	Driver Harris 202 Middlesex Street Harrison, New Jersey
O.F.H.C. Copper:	Utility Brass & Copper 116 King Street Brooklyn, New York
Molybdenum :	Universal Cyclops Steel Drawer 153 Bridgeville, Pennsylvania
	Climax Molybdenum of Michigan 2170 Avenue of the Americas New York, 20, New York
Niobium :	Kawecki Chemical 220 East 42nd Street New York, New York
	National Research Corporation Metals Division 45 Industrial Place Newton, Massachusetts

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Nickel:	The International Nickel Co., Inc. Huntington 17, W. Virginia
Aluminum Oxide:	McDaniel Refractory (material only) Post Office Box 560 Beaver Falls, Pennsylvania
	Technical Ceramics (machinery only) 65 Walnut Street Peabody, Massachusetts
	Western Gold & Platinum 525 Harbor Boulevard (machine & material) Belmont, California
	Raytheon Company (metallizing) Micro Wave & Power Tube Division Foundry Avenue Waltham, Mass.
Stainless Steel:	Industrial Stainless Steels, Inc. Subsidiary of Eastern Stainless Steel Corp. 255 Bent Street Cambridge 41, Massachusetts
	or 270 Madison Avenue New York 16, New York
Igepal:	General Aniline & Film Corporation Dyestuff & Chemical Division 435 Hudson Street New York, New York
Alconox:	Standard Scientific Supply Company 808 Broadway, Dept. 5 New York, New York
Springs:	Lee Spring Company Division of Lectronics, Inc. 30 Main Street Brooklyn, New York

PROPRIETARY

Heli-Coils:

Heli-Coil

Division of Topp Industries, Inc.
Danbury, Connecticut

3.2 Suggested Cleaning Procedures

3.2.1 Chemical Cleaning

All materials are subjected to the following steps except Al_2O_3 , Copper, and Stainless Steel.

1. Scrub the part mechanically and rinse in tap water, then in acetone.
2. Vapor degrease.
3. Clean ultrasonically in hot solution of 0.05% Igepal.
4. Rinse in hot water.
5. Rinse in cold water.
6. Rinse in acetone.

3.2.2 Firing

Firing time for all materials is 20 minutes minimum.

Tantalum:	Fire at 1400 to 1500°C in vacuum
Tungsten:	Fire at 1000 to 1100°C in wet H_2 *
Molybdenum:	Fire at 1150 to 1350°C in wet or dry H_2 or vacuum
Niobium:	Fire at 1250 to 1350°C in vacuum
Nickel:	Fire at 1000 to 1100°C in wet H_2
DH 142:	Fire at 800°C in wet H_2

* Dew point is over 10 deg. C for wet H_2 .

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3.2.3 Procedure for O.F.H.C. Copper

1. Scrub the part mechanically and rinse in tap water, then in acetone.
2. Vapor degrease.
3. Bright dip 1 to 2 minutes in:
 - 275 ml Phosphoric Acid
 - 125 ml Acetic Acid
 - 100 ml Nitric Acid
 - 2.5 ml Hydrochloric Acid
4. Dip directly into neutralizer (10% ammonia) then rinse in tap water, then in distilled water, then in acetone.

3.2.4 Processing of Stainless Steel

1. Scrub the part mechanically and rinse in tap water and acetone.
2. Vapor degrease.
3. Clean ultrasonically in hot solution of 0.05% Igepal.
4. Rinse in hot water.
5. Rinse in cold water.
6. Rinse in acetone.

After heliarc welding, most of the oxidation can be removed by swabbing weld area with warm solution of 50% hydrochloric acid. The part should then be rinsed well with water, then in acetone.

3.2.5 Cleaning of Aluminum Oxide

1. Scrub part mechanically and rinse in tap water.
2. Boil in Alconox and tap water for 1/2 hour.
3. Rinse in tap water for 5 minutes.
4. Fire in air 15 minutes at 1200°C

3.3 Generator Assembly

Figure 24 shows the generator assembly flow chart, and Figure 25 that of the generator support. The flow chart references the following assembly procedures.

1. The cable should extend $1/8$ to $5/32$ of an inch beyond lead sleeve. It is then melted down into a puddle, level with the end of the lead sleeve.
2. After welding, the leads will be oxidized. They are cleaned by submerging them in a solution of 50% HCL and tap water rinse. Follow with the procedure for cleaning copper, starting with the bright dip solution. The final water rinse should be ultrasonic for an extensive period of time, frequently changing the water, to insure that all chemicals are removed from the cable strands.
3. When the lead ends are welded, they tend to become rounded. Before brazing the ends should be flattened.
4. Only the shield support and the shoe piece shields are placed on the converter at this time. They will later be held in their proper position by the converter shield when it is wrapped in place.
5. Special care should be used in wrapping the converter shield so as not to flatten out the dimples. It should be snug but not tight. Also, when applying the clamping wire, care should be taken to make it snug but not so tight as to crush the converter shield.
6. All six converters which will be used in the generator should be ready for installation at this time.

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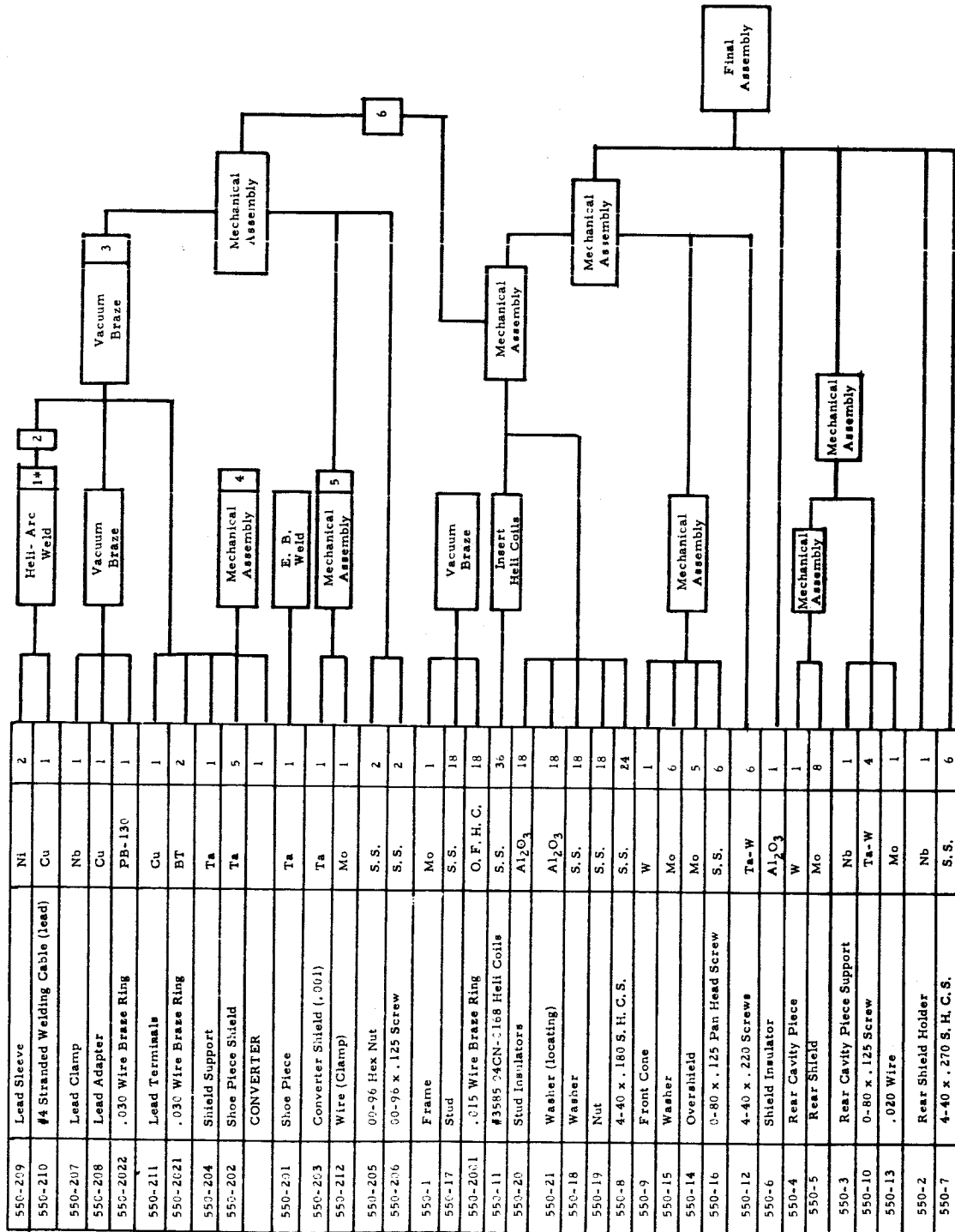


Figure 24. Generator Assembly Flow Chart

PROPRIETARY

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PROPRIETARY

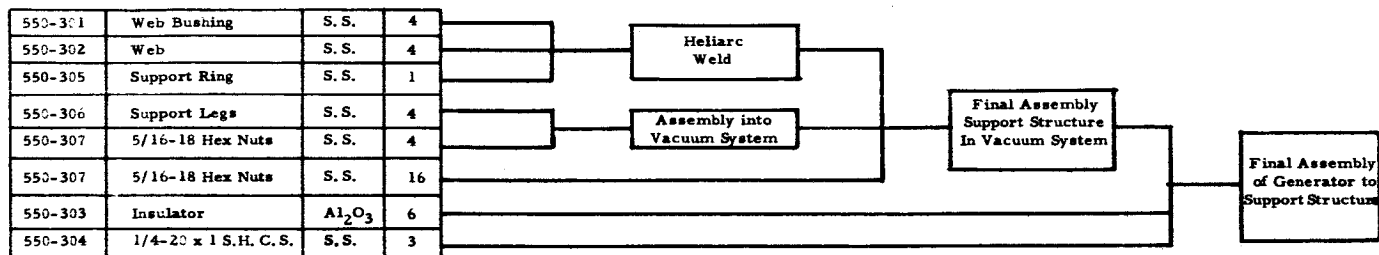


Figure 25. Generator Support Fabrication

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3.4 Electron Bombardment Unit

Figure 26 shows the electron bombardment unit flow chart which references the following assembly procedures:

1. After welding, most oxidation can be removed by swabbing welded areas with a 50% solution of HCL. If a cleaner surface is desired, the following process may be used:

Solution 1:	70% water
	25% HCL
	5% HNO_3

Solution 2:	80% water
	20% HNO_3

Heat both solutions to 70-80°C. Place part in solution No. 1 till it acquires a black color. Then place directly into solution No. 2.

Repeat until desired oxidation removal is obtained. Then rinse thoroughly in tap water, distilled water and acetone, in that order.

2. Care should be taken to jig the parts so as to maintain proper alignment during brazing.
3. To properly insert the filaments, the straight ends should be inserted into part No. 12 first, then the bent ends into part No. 16. Screw No. 15 should be tightened first, then screw No. 13.

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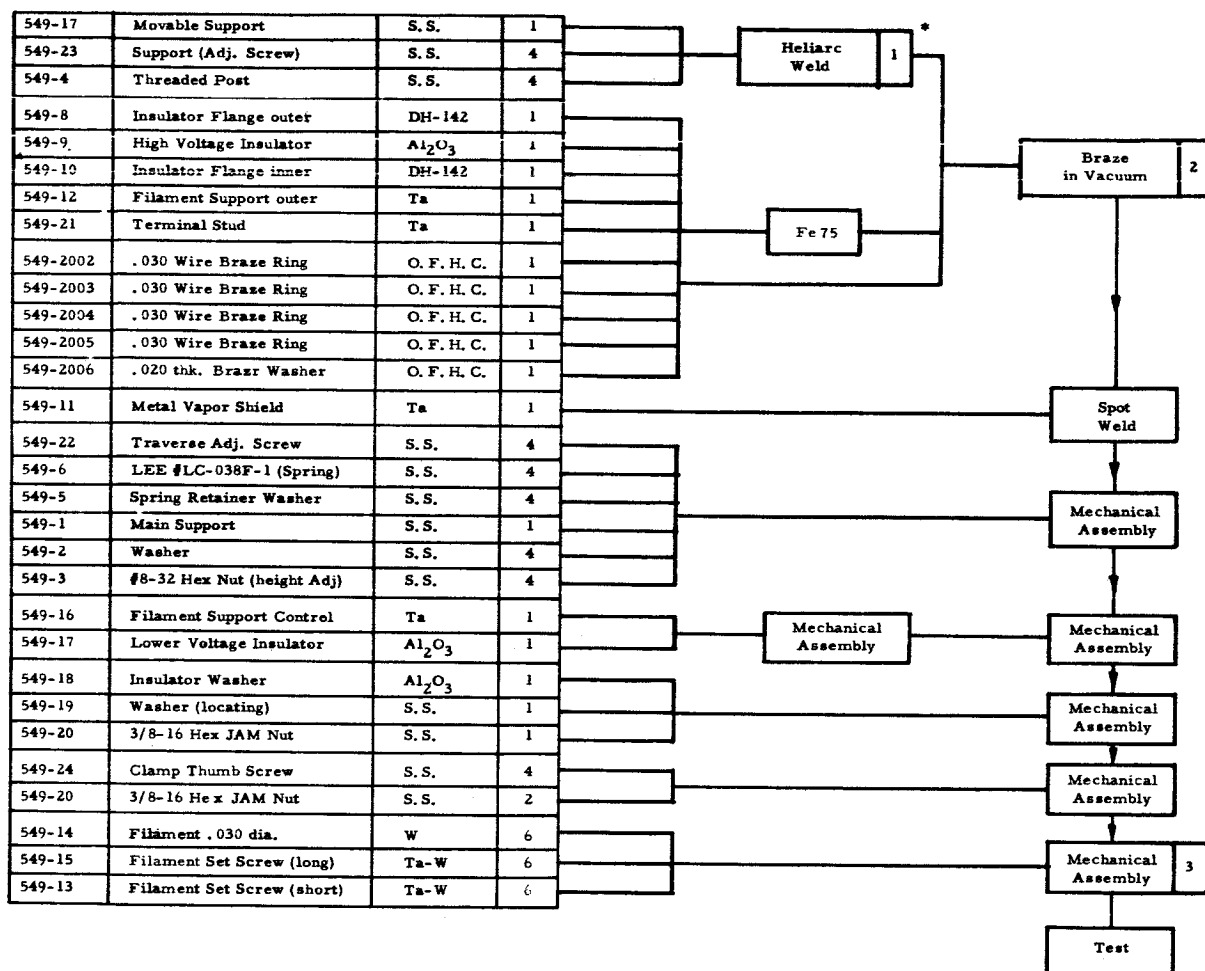


Figure 26. Electron Bombardment Unit Assembly Flow Chart

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APPENDIX A

Ideal Radiation Heat Transfer Through N Shields

Assumptions:

Edge effects are not taken into account

Conduction through shield contacts is neglected

Source surface and all shield surfaces have the same emissivity ϵ

Each surface has a uniform temperature distribution

Temperature drop across each shield is neglected

Planar geometry, all shields have the same area

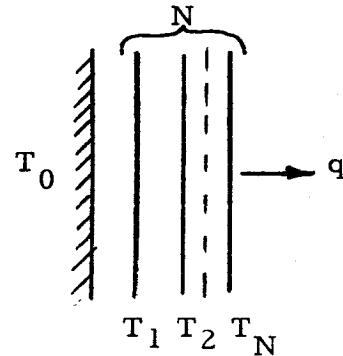
Using the nomenclature of the sketch, the heat transfer per unit area can then be expressed as:

$$(1) \quad q = \sigma \epsilon (T_0^4 - T_1^4)$$

$$(2) \quad q = \sigma \epsilon (T_1^4 - T_2^4)$$

$$(N) \quad q = \sigma \epsilon (T_N^4 - T_{N+1}^4)$$

$$(N + 1) \quad q = \sigma \epsilon T_N^4$$



Equating the sum of all left-hand members to the sum of all right-hand members we obtain

$$q(N + 1) = \sigma \epsilon T_0^4$$

$$\text{or,} \quad q = \frac{\epsilon}{N + 1} \sigma T_0^4$$

In other words the shielded surface radiates with an effective emissivity equal to $\epsilon / (N + 1)$. The value of effective emissivity as a function of surface emissivity ϵ and the number of shields N is given in Figure A-1.

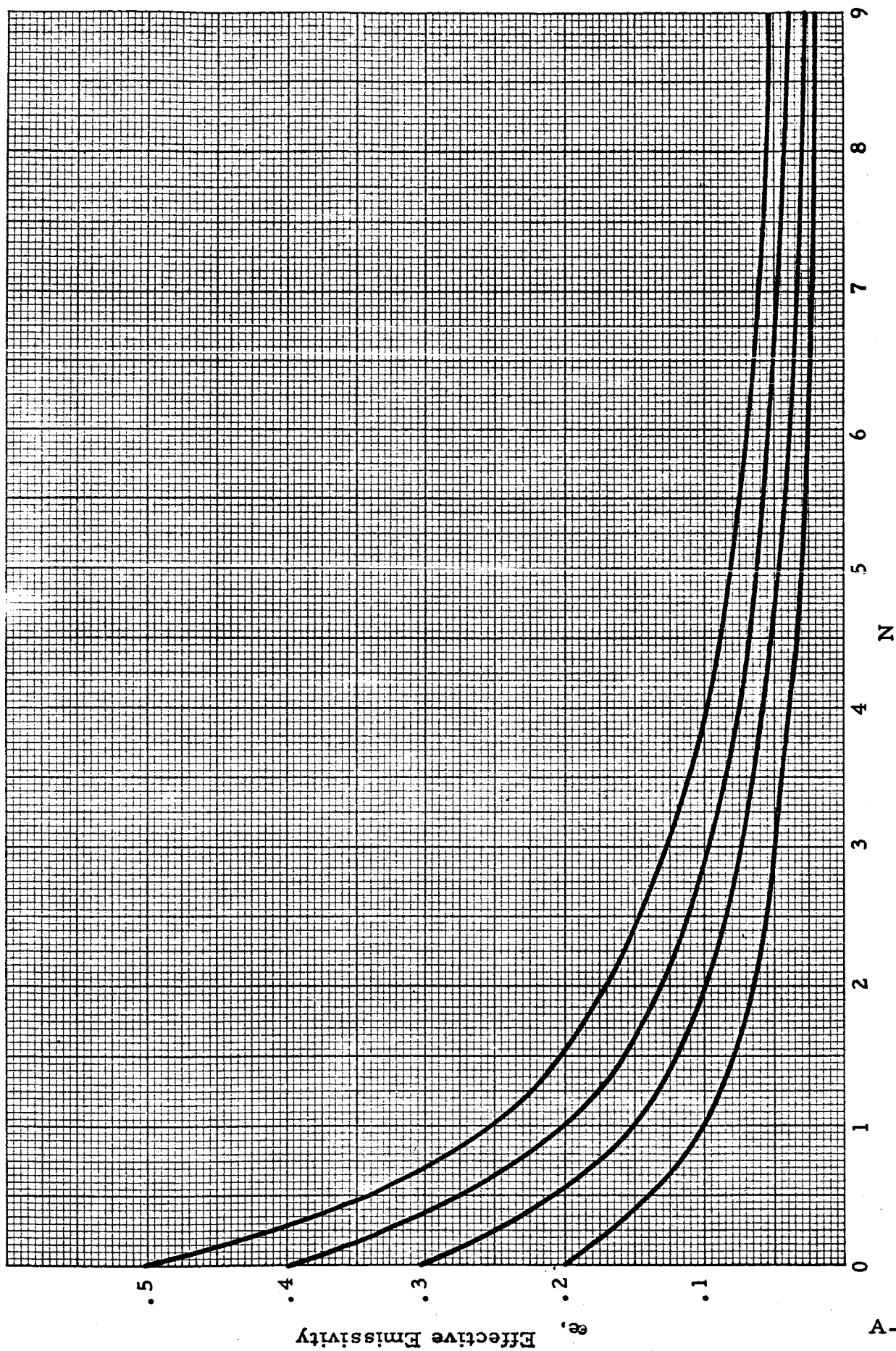


Figure A-1.