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THE DEVELOPMENT OF A CESIUM-VAPOR-FILLED THERMIONIC ENERGY CONVERTER

FINAL TECHNICAL REPORT

PREPARED FOR

JET PROPULSION LABORATORIES

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA

CONTRACT NAS-7-100

P.O. NO. 950229

PREPARED BY

RADIO CORPORATION OF AMERICA

ELECTRON TUBE DIVISION

LANCASTER, PENNSYLVANIA

AUTHORS' G. Y. EASTMAN AND D. M. ERNST

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FOREWORD

This report was prepared by the Radio Corporation of America on Contract NAS-7-100, P.O. 950229, "The Development of a Cesium-Vapor-Filled Thermionic Energy Converter". The work was administered under the direction of the Jet Propulsion Laboratories of the California Institue of Technology, Pasadena, California. Mr. Arvin Smith is Project Engineer for the Laboratories.

The report covers the work applied from 18 June 1962 through 18 November 1962 and represents the efforts of Thermionic Converter Engineering of the Electron Tube Division, RCA-Lancaster. Mr. G.Y. Eastman is the Engineering Leader responsible for the technical direction and control of the project under the direct supervision of Mr. F.G. Block, Manager. Mr. Eastman was assisted in the technical direction of the program by the following engineering personnel: R.W. Longsderff, D.M. Ernst and S.W. Kessler, Jr.

This report is the Final Technical Report and it concludes the work on the subject contract.

This report is unclassified.

ABSTRACT

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This report covers a five-month program of development, fabrication and test of cesium-vapor-filled thermionic energy converters. The units were designed for use in a solar-heated space application for the Jet Propulsion Laboratories. The geometry was limited by stringent system parameters of size and temperature.

The program was directed toward the generation of twenty-five watts of output power at an emitter temperature not exceeding 2000° Kelvin. Design objectives included a service life of one year at rated capacity at an efficiency of twenty percent.

RCA has delivered five converters designed to these requirements at operating temperature of less than 2000° Kelvin. The objectives of life and efficiency have been approached by incorporating materials and fabrication techniques which will obtain the greatest reliability and performance.

The report covers the specific techniques, procedures and geometry of the converters shipped under the contract. In addition, details of problems encountered and their solutions are explained. Test data on converters shipped is included.

Author

FINAL TECHNICAL REPORT
CONTRACT NAS-7-100
PURCHASE ORDER 950229

THE DEVELOPMENT OF A CESIUM-VAPOR-FILLED
THERMIONIC ENERGY CONVERTER

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

FINAL TECHNICAL REPORT
CONTRACT NAS-7-100
PURCHASE ORDER 950229

THE DEVELOPMENT OF A CESIUM-VAPOR-FILLED
THERMIONIC ENERGY CONVERTER

SECTION I

PURPOSE

RCA will design, fabricate, test and deliver to JPL five cesium-vapor-filled thermionic energy converters, in accordance with the following design requirements, design objectives, drawings/specifications and testing requirements:

A   Design Requirements

    (1)   Electrical Power - Each converter shall deliver twenty-five watts of electrical power at rated capacity.

    (2)   Structural Constraint - The structural envelope shall conform with the constraints defined in JPL Drawing No. J-118977-1.

    (3)   Cesium Reservoir - Each converter shall be equipped with an electrically-heated cesium reservoir capable of establishing and maintaining the optimum cesium vapor pressure at any converter orientation.

    (4)   Radiator and Collector Heater - Each converter shall incorporate a fin-type radiator and electrical heater capable of establishing and maintaining the optimum collector temperature. The radiator shall be fabricated with excess radiative surface which can be reduced in successive increments to obtain optimum collector temperature without the aid of the electrical heater.

    (5)   Cavity Adapter - Four of the thermionic energy converters shall be equipped with integral emitter-cavity refractory metal adapters as detailed in JPL Drawing No. J-118977-2. One converter shall be equipped with an emitter cavity refractory metal adapter as detailed in JPL Drawing No. J-118977-3.

18 December 1962

(6) <u>Generator Attachment Ring</u> - Each thermionic energy converter shall be equipped with an electrically insulated generator attachment ring as detailed in JPL Drawing No. J-118977-1.

(7) All converters shall be instrumented with platinum - platinum + ten percent rhodium thermocouples as follows:

    a. One as close as possible to the ceramic member of the metal-to-ceramic vacuum seal.

    b. Two on the cesium reservoir as close as possible to the liquid-vapor interface.

    c. Two on the collector body as close as possible to the collector surface opposite the emitter.

    d. One on the radiator.

(8) The thermionic energy converters shall be capable of withstanding a minimum of twenty thermal cycles from room ambient to operating temperature. The half cycle from room ambient to operating temperature shall not require more than fifteen minutes. Cool-down will be accomplished by an abrupt termination of all heater power when the converter is at operating temperature except that the cesium reservoir heater may remain energized.

(9) The emitter temperature shall not exceed two thousand degrees Kelvin true temperature.

(10) Each converter shall be equipped with a "black-body hole" sufficiently near the emitter surface to permit an accurate pyrometer measurement of emitter true temperature.

B   <u>Design Objectives</u>

(1) <u>Service Life</u> - The service life of the thermionic energy converters shall be not less than one year at rated capacity.

(2) <u>Converter Efficiency</u> - Converter efficiency shall be twenty percent or greater, at rated capacity.

C   Drawings /Specifications

JPL Drawing Nos. J-118977-1, J-118977-2 and J-118977-3, "Solar Energy Thermionic Converter".

D   Testing Requirements

(1)   Minimum Electrical Testing - Each converter shall be electrically tested at operating temperature for a minimum of twenty hours prior to delivery to JPL. Converter output current and voltage, collector temperature, cesium reservoir temperature, metal-to-ceramic seal temperature, and the electrical power supplied to all heaters shall be measured continuously during the minimum electrical test period. Emitter temperature shall be measured at least three times per hour during the minimum test period.

(2)   Maximum Operating Time Above Four Hundred Degrees Centigrade
The operating time per converter above 400° Centigrade shall not exceed fifty hours prior to delivery to JPL.

(3)   Current-Voltage Characteristics - The current-voltage characteristics from 0.3 to 1.2 volts shall be obtained at the rated emitter temperature with optimum cesium vapor pressure and collector temperature.

SECTION II

CONVERTER DESIGN

A   Introduction

RCA proposed to develop a converter operable at elevated temperatures to deliver power densities equal to the maximum obtainable of the then, current, State-of-the-Art at 2000° Kelvin. In order to accomplish this objective RCA designed a unit within specific limitations of size and geometry. The final design, as developed, is shown in Figure 1.

B   Overall Converter Design

The RCA Developmental Converter A-1270, as shown in cross-section in Figure 2, was the result of compliance with the geometry and size limitations as directed by the Jet Propulsion Laboratories. This design employs four major sub-assemblies as follows: 1. Emitter; 2. Collector; 3. Cesium Reservoir; and 4. Generator Support Ring.

(1)   Emitter - Tantalum was selected as the basic material for the emitter as a result of extensive evaluation of possible metals. Figure 3 shows the emitter sub-assembly and its components.

(2)   Collector - The collector sub-assembly, as shown in Figure 4, employed a precise ratio of molybdenum-to-copper to obtain the correct emitter-collector spacing by means of differential expansion techniques.

(3)   Cesium Reservoir - The requirements for successful operation in any orientation of the cesium reservoir, and the maintenance of the correct cesium temperature with auxiliary heaters, were met without difficulty. The details of the cesium reservoir are shown in Figure 5.
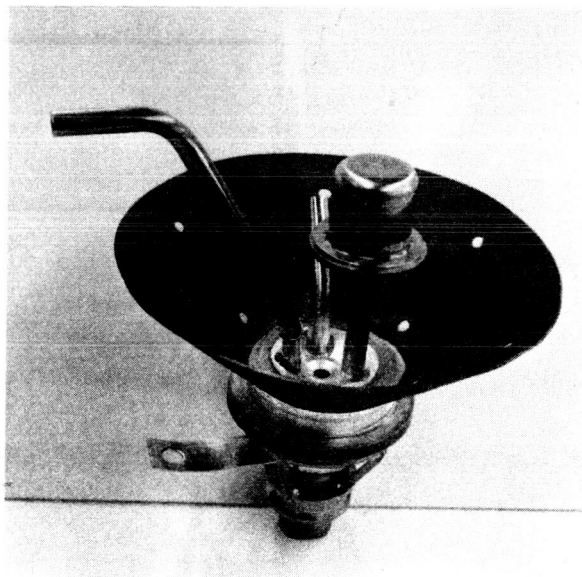
FIGURE 1 - TWO VIEWS OF THE
RCA DEVELOPMENTAL CONVERTER A-1270

Emitter

Collector

Generator
Support
Ring
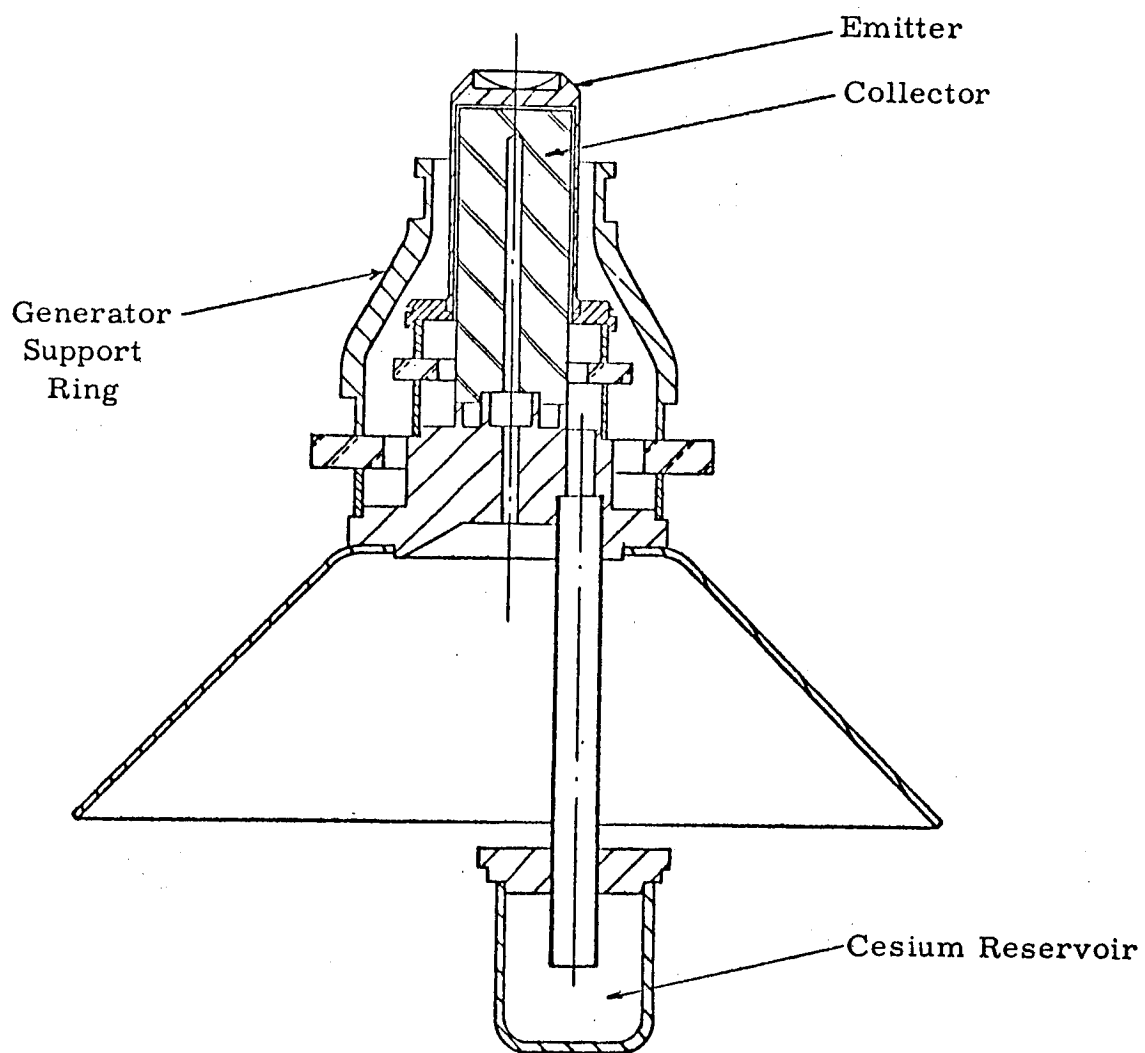
Cesium Reservoir

FIGURE 2 - CROSS-SECTION DRAWING OF THE
RCA DEVELOPMENTAL CONVERTER A-1270
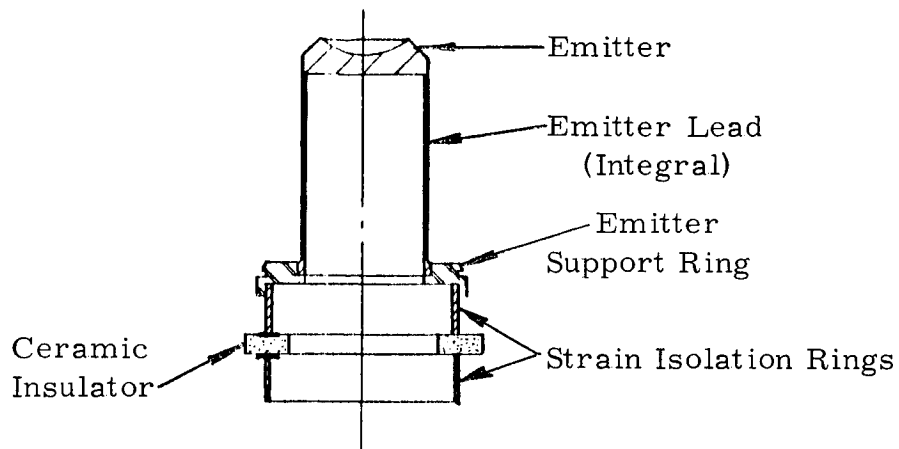
FIGURE 3 - EMITTER SUB-ASSEMBLY
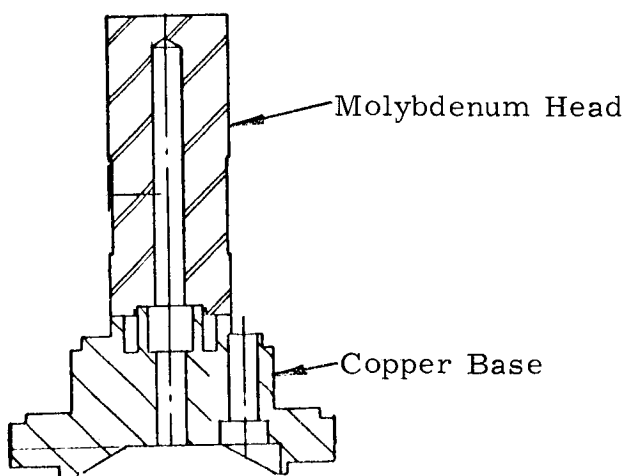
FIGURE 4 - COLLECTOR SUB-ASSEMBLY
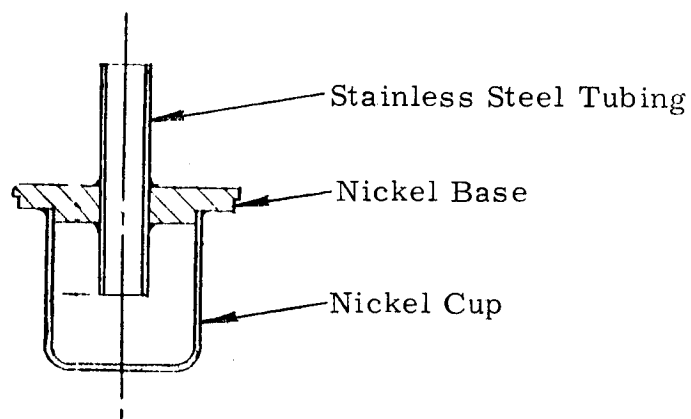
FIGURE 5 - CESIUM RESERVOIR SUB-ASSEMBLY

Stainless Steel Tubing

Nickel Base

Nickel Cup
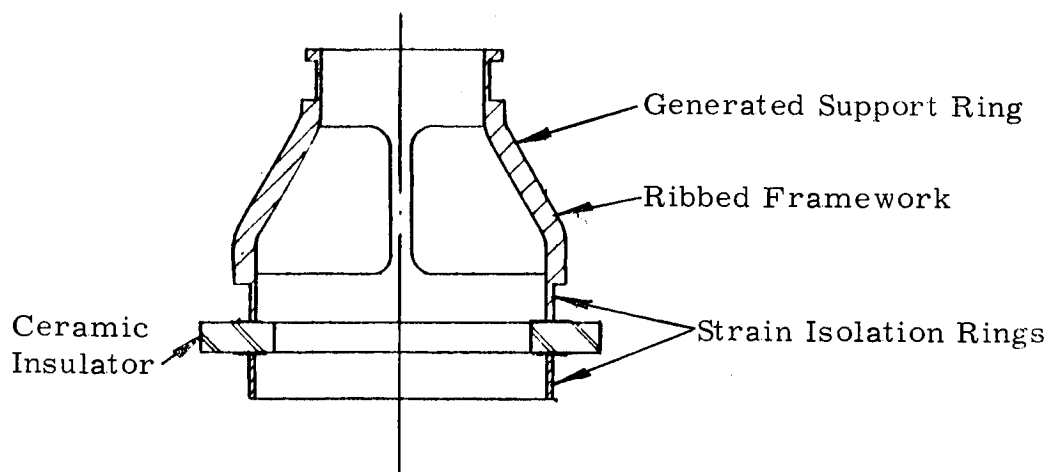
FIGURE 6 - GENERATOR SUPPORT RING SUB-ASSEMBLY

Generated Support Ring

Ribbed Framework

Strain Isolation Rings

Ceramic Insulator

(4) Generator Support Ring - The generator support ring was isolated electrically from the converter. It was designed as a ribbed framework, as seen in Figure 6, to permit maximum open area for adequate heat radiation from the inner converter parts.

The converter was thoroughly outgassed and exhausted at temperatures above operating conditions prior to cesiation, in order to enhance life expectancy and reliability.

C   Specific Converter Design

The details of the construction of the major assemblies are the results of a continuing program of refinement and modification.

(1) Emitter Subassembly - The emitter subassembly, as shown in Figure 3, consists of the one piece emitter-emitter lead, emitter support ring, ceramic insulator, and two strain isolation rings.

(a) Emitter-Emitter Lead

The emitter was fabricated from tantalum in order to utilize the low vapor pressure at the required operating temperature, to prevent the evaporation of the surface material to other internal converter components. When evaporation takes place at elevated temperatures, components are weakened by the loss of material, while those components on which the material condenses become contaminated and thus reduce operating efficiency and reliability. In an atmosphere of cesium, an emitter of tantalum demonstrates excellent thermionic emission properties.

The emitter lead was also fabricated from tantalum utilizing its favorable ratio of electrical-to-thermal conductivity and the resultant mechanical simplicity of a one piece emitter-lead structure without the need of a high-temperature joint.

However, tantalum has a limitation in that it reacts readily with carbon, nitrogen, hydrogen or oxygen at elevated temperatures. By maintaining a vacuum better than 1.5×10^{-5} torr, impurities were kept to very low levels so that this characteristic was not a limiting factor.

The one piece emitter-emitter lead was machined from tantalum rod into a cup with the required thickness on the end needed for the emitter face, and a 0.012 inch wall. The 0.012 inch wall was reduced to 0.008 inch and 0.005 inch along the lead by a rolling process. The varying wall thicknesses strengthened the lead at points of maximum stress.

The calculation of the wall thickness of the emitter lead showed that the theoretical optimum thickness was 0.004 inch. From experience, however, a minimum wall thickness of 0.005 inch was established in order to prevent failures due to crystal growth. While not necessarily leading to failure, this condition makes the structure more susceptible to stress cracking and intergranular corrosion by undesired containments in the crystal boundaries. Single crystals formed in some instances as is evident from Figure 7. However, the increased thickness prevented failure.

The emitter surface was machined according to JPL Drawing No. J-118977-2. A black body hole for optical pyrometer true-temperature readings was located in the emitter side-wall. The machined surface of the emitter was sandblasted to improve its emissivity, thereby increasing the efficiency of the emitter to absorb more thermal radiation.

The inner surface of the emitter was machined flat within 0.0005 inch, and the emitter lead was held within 0.0005 inch perpendicularity with respect to the flat surface of the emitter, thereby insuring a uniform emitter-collector spacing reference plane.
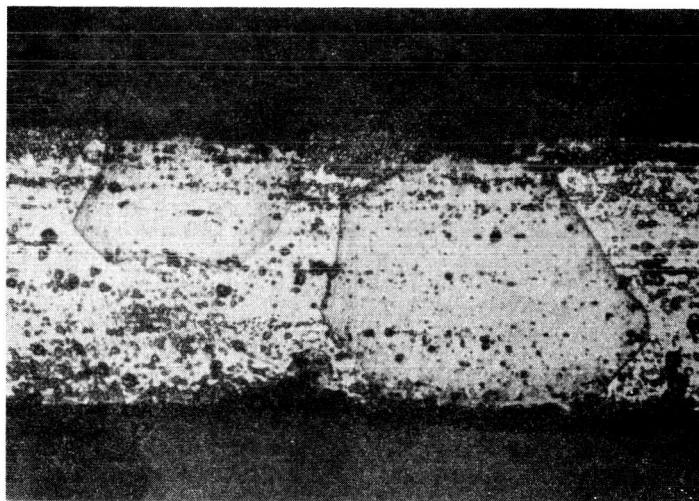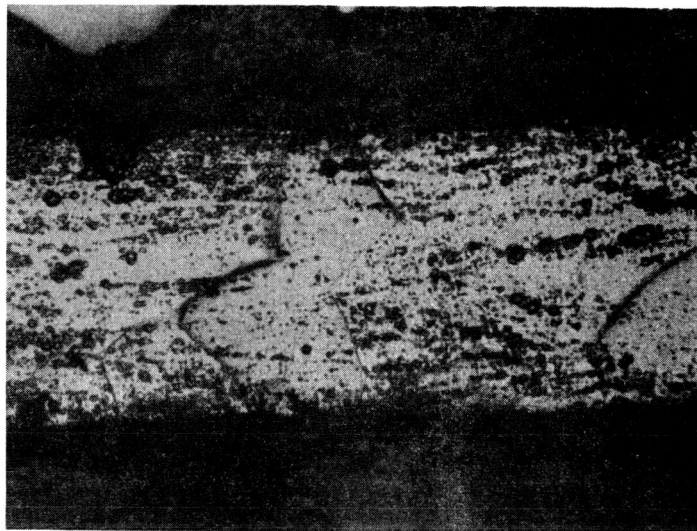
FIGURE 7 - SINGLE CRYSTAL FORMATIONS
(Tantalum 0.005 inch - Magnification X272)

(b) Emitter Support Ring

The emitter support ring was made from molybdenum because of its compatibility with cesium. Its high-thermal conductivity made it possible to distribute the thermal load uniformly around the emitter lead, minimizing temperature differences and consequent motion due to thermal expansion.

The emitter support ring was brazed to the emitter lead with zirconium as a filler, since zirconium is one of the few materials that will satisfactorily bond refractory metals.

After brazing, the emitter support ring was nickel plated taking care not to contaminate the zirconium braze area or the emitter lead with nickel, which diffuses undesirably into each of these metals at the elevated temperatures encountered during converter operation.

(c) Strain Isolation Rings

The nickel-plated, kovar, strain-isolation rings not only provided flexible members to take up the thermally-induced stresses in the ceramic-to-metal seals, but also provided low-thermal impedance paths to the ceramic. This design prevented the temperature of the ceramic from rising above a safe level during converter operation. The strain rings were nickel plated all over to prevent grain bounding penetration of the solder.

(d) Ceramic Insulator

The ceramic provides an electrical insulating portion of the vacuum envelope between the emitter and collector, so that power is not dissipated but can be utilized externally through a load.

(e) Assemblying the Emitter Subassembly

The parts were assembled on a stainless steel brazing fixture to achieve the desired parts concentricity and brazed in vacuum using copper as a filler.

(2) Collector Subassembly - The collector subassembly, as seen in Fig-4, was the result of a calculated ratio of differential expansion to obtain the correct emitter-collector spacing during converter operation. The desired spacing was obtained by selecting the ratio of the length of material in the copper base to that of the molybdenum head to utilize the differences in thermal expansion of the collector assembly to the emitter assembly.

(a) Molybdenum Head

Sintered molybdenum was used as the head of the collector so that, in conjunction with the cesium coverage during converter operation, it would provide a very low effective work-function collector. The molybdenum served as the low expansion part of the ratio of materials needed to obtain the correct emitter-collector spacing. Because of its high melting point, the molybdenum head prevented the higher temperatures of short circuit converter operation from melting the collector and short-circuiting the converter.

(b) Copper Base

Copper was used for this component to provide the high-thermal-expansion material in the collector assembly needed to obtain the desired collector-emitter spacing. Having a high-thermal conductivity, copper also provided a low-thermal-impedance path through the collector for the unused thermal power. This characteristic aided in obtaining a minimal-area radiator fin to dispose of this power.

The copper base of the collector was machined with strain isolation lands and moats to fit matching contours machined in the molybdenum head. The lands permitted a good mechanical vacuum braze. The copper structure was sufficiently flexible to absorb the stresses applied during contraction and expansion of the joint.

Four holes were placed in the outer copper land to permit proper outgassing during the vacuum brazing of the assembly. Additional holes were added to the base to accommodate the thermocouple well, the collector lead, the cesium reservoir tubulation and the exhaust line.

The surface of the collector head was machined flat to within 0.0005 inch and perpendicular to the outside diameter of the collector base to within 0.0005 inch, to insure uniform emitter-collector spacing. The collector was then machined to the required length to complement the overall dimension of the emitter subassembly for that particular converter. The copper base of the collector and the nicoro braze area was nickel plated to prevent attack by cesium.

(3) Cesium Reservoir Subassembly - The cesium reservoir subassembly consisted of a nickel cup and base and a stainless steel tubing as shown in Figure 5.

(a) Nickel Cup and Base
Nickel was selected for this application because of its compatibility with cesium and its high-thermal conductivity. The high-conductivity insured proper temperature uniformity throughout the reservoir.

(b) Stainless Steel Tubing
Stainless steel was used to permit the desired thermal isolation from the collector to control the temperature of the cesium independently. The stainless steel tubing extended into the center of the reservoir cup so that it's open end would remain above the cesium liquid level in any orientation.

(c) Assembly

The assembly was brazed with Nicrobraze 30 in a vacuum furnace.

(4) Generator Support Ring Subassembly - The generator support ring sub-assembly, as shown in Figure 5, was fabricated to fulfill the purpose of the program and electrically insulated from the converter. The assembly consisted of the kovar support ring, rib and strain isolation ring as one piece, insulation ceramic and a second kovar strain-isolation ring.

(a) Insulating Ceramic

The ceramic provided electrical insulation of the converter from its support.

(b) Kovar Support Ring

The kovar provided a high-thermal-impedance path which prevented any significant thermal interaction between the converter and its supports. The ribs were so located to permit the output ceramic seal to effectively radiate its heat to space.

(c) Assembly

The parts were assembled on a stainless steel brazing fixture and brazed with copper solder in a hydrogen atmosphere.

(5) Converter Assembly - The four subassemblies along with the radiator fin, collector lead, exhaust line, as shown in Figure 8, and the external emitter lead were assembled and brazed with silver-copper eutectic solder in a vacuum furnace.

(a) Collector Lead

Copper was used for the collector lead to minimize the electrical loss between the converter and its load.

Collector Radiator Fin
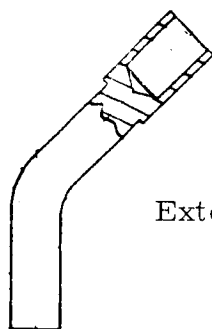
External Collector Lead
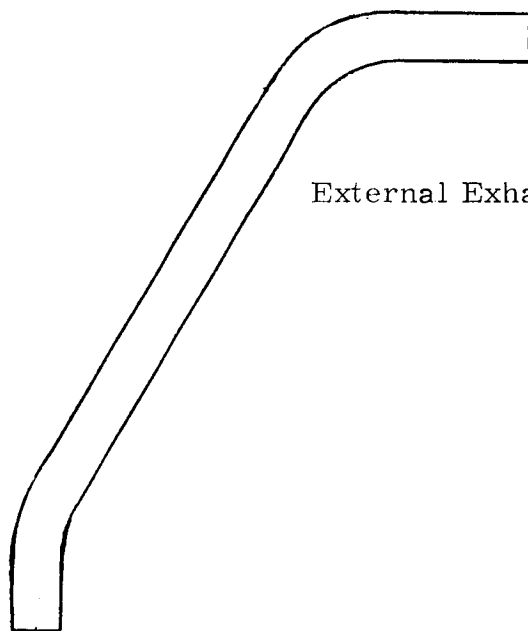
External Exhaust Tubing

FIGURE 8 - ADDITIONAL PARTS OF CONVERTER ASSEMBLY

(b) Exhaust Line

The exhaust line also employed copper which is easily pinched-off with an hydraulic press to form a leak-tight, cold-weld seal. The high-thermal conductivity of copper permitted sufficient heat flow from the collector to the pinch-off to insure operation at a temperature in excess of the cesium reservoir to prevent undesired cesium condensation.

After the final braze of the converter, the exhaust tubulation was high-frequency-induction brazed to the converter with silver-copper eutectic solder. A cesium capsule was placed in the tubing and the tubing pinched-off.

(c) Collector Radiator Fin

The collector radiator fin was a one-piece copper cone designed to fit as its smaller end onto the base of the collector. The fin was treated with a silicone-aluminum[1] coating of high-thermal emissivity to obtain maximum radiation effectiveness. Holes were placed in the fin for the attachment of the fin heater.

(d) Radiation Fin Heater

The radiator fin was wrapped with a heater made from No. 22 Nichrome V wire covered with ceramic beads. Stainless steel straps bolted to the fin held the heater in place.

(e) Cesium Reservoir Heater

The cesium reservoir heater was made by wrapping beaded No. 22 Nichrome V wire around a nickel cup. Stainless steel straps spot-welded to the cup held the heater in place. This cup was then slipped over the reservoir and held in place by bending the stainless steel straps over the cesium reservoir base. The reasons for choosing a radiation type heater are as follows:

[1]U.S. Patent No. 2,891,879 assigned to Westinghouse.

1. RCA felt it important not to make the heater an integral part of the converter so that it might be easily removed and replaced.

2. By using a radiation type heater, the ultimate application of the converter is more readily demonstrated.

(6) Exhausting and Cesiation - The converter was thoroughly exhausted at elevated temperatures prior to cesiation and pinch-off from the vacuum system.

(a) Exhausting

The procedure for exhausting the converter required the use of a dual-vacuum system. One system, employing an oil diffusion pump with appropriate baffling, was used to evacuate the converter proper. The second system, also employing an oil diffusion pump with appropriate baffling, was a vacuum chamber which served to simulate the space environment outside of the converter. It thus provided protection of the converter from the atmosphere, the proper conditions for radiation of the rejected heat from the converter and for operation of the electron-bombardment heat source.

The converter was mounted in the test chamber, connected to its exhaust manifold, and pumping started. While the converter pump-down was proceeding, thermocouples were placed on the metal-to-ceramic seal, collector fin, cesium reservoir and in the collector well. The converter emitter was grounded to provide a safe return path for the electron-bombardment power. The cesium reservoir and collector fin heaters were attached to vacuum feed-throughs. The bakeout heater was attached to an electrical feed-through and placed around the exhaust tubulation, cesium capsule appendage and exhaust manifold section. The black-body hole in the emitter side wall was positioned to observe temperature through the heat shields. High voltage to ground insulation was checked as well as continuity of the radiator-fin, cesium-reservoir and bombardment

heaters and the thermocouples. A glass bell jar was installed to close the chamber and pumping was started.

Both exhaust systems were pumped to a pressure of 50 microns or less and bake-out started on the "molecular sieve" high-vacuum traps. After an initial rise the pressure returned to its original level or less. The diffusion pumps were then activated. When the pressure dropped into the 10^{-4} torr range, bake-out of the exhaust manifolding and cesium line was started. After a brief pressure rise, heating of the converter to 400° Centigrade was intitiated. The entire system, including the converter, was kept at 400° Centigrade for approximately one hour. At this time, both "molecular sieve" traps were cooled to room temperature where their effectiveness in trapping hydrocarbons is high. When the traps had reached 200° Centigrade, cooling of the manifolding was started. When the "molecular sieve" traps and manifolding were cool, liquid nitrogen was applied to a trap in the converter system as a further safe-guard. The exhaust tubing and cesium appendage were maintained at 400° Centigrade and the converter temperature raised slowly until all points were at a temperature in excess of their normal operating condition. The emitter was raised to 2000° Centigrade. A maximum pressure limit of 10^{-5} torr was observed during this process. This condition was maintained for at least one hour until the pressure had dropped to a stable level. The converter was then cooled, the bell jar removed, and the converter pinched-off from the vacuum system. The pressure at pinch-off was typically 2×10^{-8} torr.

(b) Cesiation

The cesium capsule was crushed to admit cesium to the converter. The tubulation was heated to a temperature of 350° Centigrade for five minutes to drive the cesium into the converter where it condensed. The heater tape was then removed and the cesium tubulation was pinched off completing the cesiation process. The converter was then ready for test.

SECTION III
PROBLEM AREAS

A **Introduction**

During the course of developmental projects, the initial design is revised through a continuing program of investigation, modification and refinement. The achievement of the program objectives requires the solution of specific problems and the selection of the most effective techniques. The development of a converter for Jet Propulsion Laboratories was typical of this pattern.

B **Problem Areas**

Emphasis of effort was required in several areas of investigation as detailed below.

(1) **Emitter Assembly Braze** - The emitter lead-to-emitter support ring braze joint required the selection of a satisfactory brazing alloy.

(2) **Emitter-Lead Embrittlement** - The embrittlement of the tantalum emitter lead due to crystal growth and hydrocarbon attack required changes in design and processing.

(3) **Collector Assembly** - The braze between the copper base and the molybdenum head presented difficulties to guarantee both a vacuum-tight seal and a mechanically strong joint which would withstand the thermal expansion difference between copper and molybdenum.

By changing the design of the collector radiator fin from radial to a one-piece cone the mass of the collector was reduced and the effective radiator area increased.

(4) **Cesium Reservoir** - The change in the radiator fin increased the thermal power to the cesium reservoir and required a compensation to optimize the reservoir temperature.

(5) Converter Slump - After ten to fifteen hours of operation several of the converters tested slumped from the original power output.

C   Specific Details of Problem Solutions

(1) Emitter Assembly Braze

(a) Problem

Considerable difficulty was encountered in the selection of a suitable brazing alloy for brazing the tantalum emitter lead to the molybdenum emitter support. Initial brazing tests using Nicrobraz 30 as the filler were partially successful. However, it was not possible in practice to prevent excessive alloying with the tantalum and resultant embrittled and leaky joints. Attempts to use pure copper as the filler were also unsuccessful because of the need to nickel plate the tantalum to obtain good wetting. The plating proved unreliable. Pure nickel, nickel-molybdenum eutectic and nickel-niobium eutectic mixtures were also unsuccessful because of an excessive alloying with the molybdenum. Figure 9 shows the intergranular cracking of the molybdenum typical of these brazes.

(b) Solution

A successful procedure was established utilizing zirconium as the brazing filler alloy. The braze was carried out at 1770° Centigrade in vacuum. The quantity of zirconium was kept to a minimum. The solution reactions, with the structural materials, were carried to completion to prevent the subsequent formation of lower melting eutectic compositions.

(c) Suggested Improvement

A further improvement will result from the substitution of electron-beam welding to eliminate entirely the necessity of filler material.
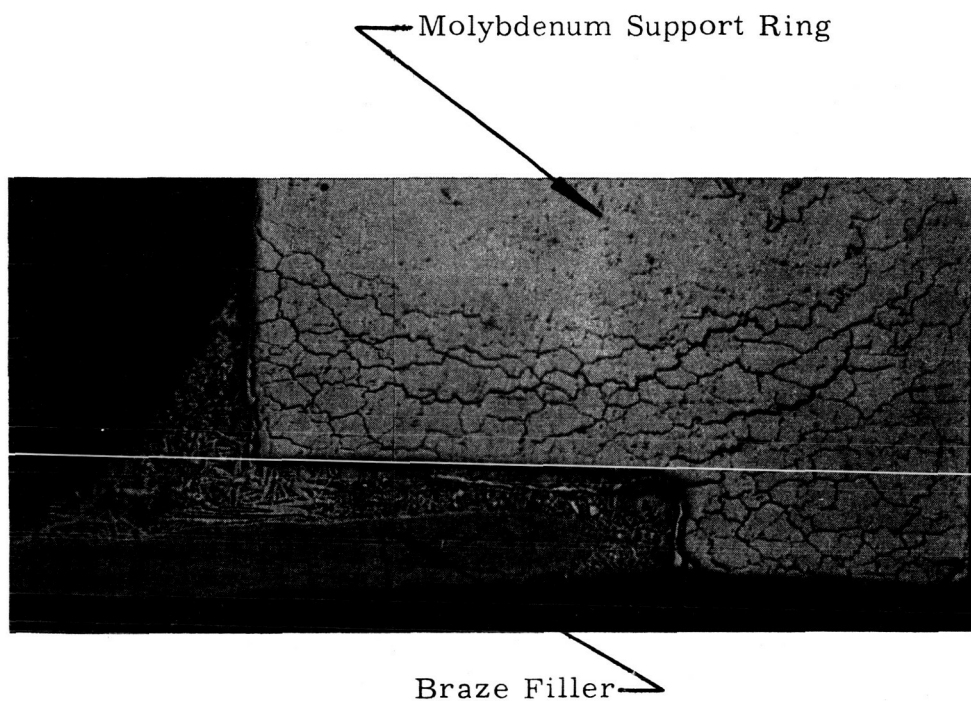
Photograph taken of cracking of molybdenum near the tantalum emitter braze joint at 38.8 magnification.

FIGURE 9 - EXAMPLE OF STRESS IN MOLYBDENUM

(2) <u>Emitter Lead Embrittlement</u>

    (a) Problem

A serious problem encountered in the fabrication process was the embrittlement of the tantalum emitter lead as shown in Figure 10. Four converters failed because of cracks and subsequent leaks from this cause. One of these was shown to be due to a water leak in the vacuum bell jar. However, analysis of the remaining three such converters showed strong evidence of hydrocarbon reaction during the exhaust cycle.

    (b) Solution

The operation of the exhaust equipment was revised to prevent any hydrocarbons from reaching the tantalum while at elevated temperatures. Both internal and external vacuum systems were maintained at pressures below 10^{-4} torr throughout bake-out and below 10^{-5} torr subsequent to bake-out. The heating cycle of the "molecular sieve" traps was modified to improve their effectiveness during converter outgassing. A liquid-nitrogen trap was added to the converter pumping line as an additional barrier to the back-streaming of diffusion pump oil vapor.

The analysis showed that the cracking of the emitter lead wall was confined to the more hightly stressed points directly above the joint to the support ring. To improve reliability without degrading converter performance, the emitter lead wall was increased in this area and reduced to the 0.005 inch wall in steps as shown in Figure 11.

No further incidence of this problem occurred. The action taken appears adequate.

(3) <u>Collector</u>
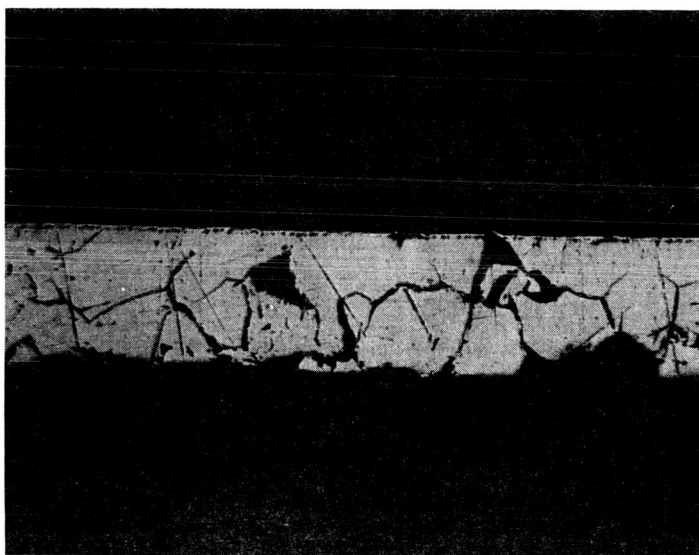
FIGURE 10 - TWO EXAMPLES OF HYDROCARBON ATTACK
ON TANTALUM EMITTER WALL
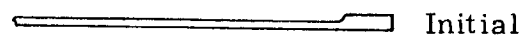
Initial

Intermediate
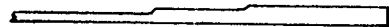
Final

FIGURE 11 - EVOLUTION OF EMITTER LEAD

(a) Problem

The initial collector braze between the molybdenum head and the copper base was unsatisfactory. Tests were made using Nicrobraz 130, and a nickel tubing as shown in the cross-section of Figure 12. However, in actual converter construction consistent difficulty was encountered in obtaining vacuum-tight joints. Poor braze quality and separation of the parts due to expansion of the nickel were both shown to exist.

(b) Solution

The nickel tubing was removed. The molybdenum head was machined so lands in the copper base would partially fit into the molybdenum moat leaving a small area for the braze to fill (Figure 13). Tight tolerances were held so the thermal expansion would help make the braze. Nicoro was substitured for the Nicrobraz.

(c) Suggested Improvement

The substitution of a one piece, all copper collector, is proposed eliminating the joint under discussion. Added benefits would improve converter weight as described below.

(4) Rejection of Collector Heat

(a) Problem

Tests of the first converter showed that the heat rejection characteristics of the radiator were marginal.

(b) Solution

By reducing the length of the thermal path in the collector and incorporating a conical, one-piece fin the efficiency of the radiator was increased. A worthwhile reduction in mass also resulted. The radiator emissivity was improved with the addition of a black
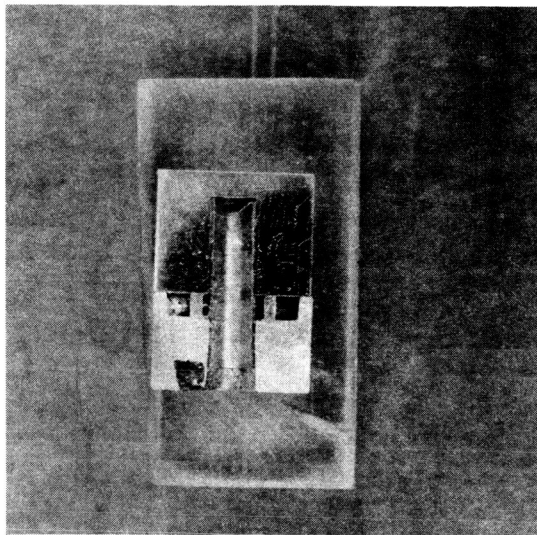
FIGURE 12 - INITIAL COLLECTOR BRAZE
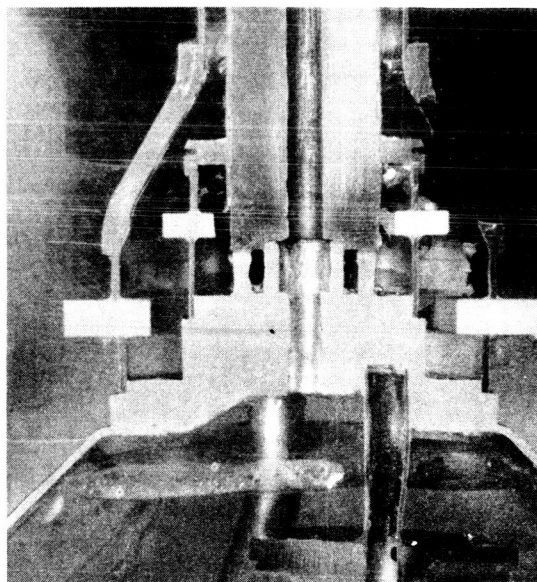
FIGURE 13 - FINAL COLLECTOR BRAZE

coating. Aquadag was used at first, but was replaced in later converters with a more adherent, stable, silicone-aluminum coating.

(c) Suggested Improvement

A substantial increase in radiator effectiveness and reduction in converter weight would result from the use of an all copper collector.

(5) Cesium Reservoir Assembly

(a) Problem

The equilibrium temperature of the cesium reservoir in the first converter was somewhat higher than desired, and limited test flexibility particularly at high collector and radiator temperatures.

(b) Solution

A shield was designed to protect the cesium reservoir from radiated heat. This modification together with the revised fin design resulted in the desired operating condition which required heater power to maintain correct reservoir temperature at all times.

(c) Suggested Improvement

The current solution is considered adequate.

(6) Degradation of Converter Performance

(a) Problem

The slumping of converter power output after several hours operation was a serious problem. Of the seven converters which were operated for the twenty hour period, four slumped. In one case a vacuum leak was shown to be the cause. The remaining three were very similar in behavior. After initially producing approximately 24 watts of power output, the converters operated ten to

fifteen hours at a relatively constant level and then began to deteriorate. During this slumping period the output dropped to approximately 15 watts while the emitter temperature remained unchanged and the collector temperature rose while the power input was maintained at an approximately constant level. It was noted that in at least one case the deterioration was proportionally greater at the high-current end of the volt ampere curve than at the high-voltage end. It is felt that different ionization mechanisms may prevail at these points: the "Ball-of-Fire" arc mode in the high-current region and the contact ionization mode in the high-voltage region. If a difference in effect does exist between the modes, the cause may well lie in the plasma, since a change in work function would affect the two modes similarly.

It has been shown in previous work at RCA that the presence of certain gases can interfere with the photon trapping essential to the "Ball-of-Fire" operation and cause slumping. The presence of such a gas could also account for the increased heat transfer between emitter and collector as described.

(b) Solution

Several steps were taken to alleviate the problem. Higher temperatures were used during the original firing of the parts and during exhaust the temperature at which the converter parts were processed was higher than any during converter operation.

(c) Suggested Improvement

Higher exhaust processing temperatures should be employed for even longer periods of time. A cesium "still" should be introduced during the exhaust process to allow actual converter operation while removing any gases released. Mass spectrometer measurements should be carried out to determine the identity of gases

released in the converter. Converters which show slumping output should be opened, re-exhausted and recesiated. Many converters thus reprocessed at RCA have shown marked improvement. Materials, such as tantalum, which are likely to getter and give up gases as temperatures change should be avoided where possible.

SECTION IV

TEST DATA

A Introduction

After exhaust and cesiation, the converter was tested in the same vacuum
chamber used for exhaust. The converter was optimized at a load point
and a D.C. load curve was taken from 0.3 volts to 1.2 volts. The output
of the converter was reoptimized and the twenty hours life test started.

The test data presented covers the information observed from the five con-
verters shipped to JPL and two additional converters of initially high power
output in which degradation was seen.

B Overall Test Procedures and Data

(1) Preparation for Converter Test

(a) Preliminary

The converter was set-up in the vacuum chamber, as seen in Fig-
ure 14, being held in place by a base plate and three clamps, as
seen in Figure 15. Thermocouples and leads were checked and the
system was evacuated.

(b) Warm Up of the Converter

When the pressure in the environmental system was in the 10^{-5}
torr range, the converter was gradually heated and the optimum
cesium reservoir collector temperatures determined.

(2) Load Curve

After the converter was optimized, a D.C. load curve from 0.3 to 1.2
volts was taken.

(3) History of the Converters

The construction, relating to material and brazing alloys, output data
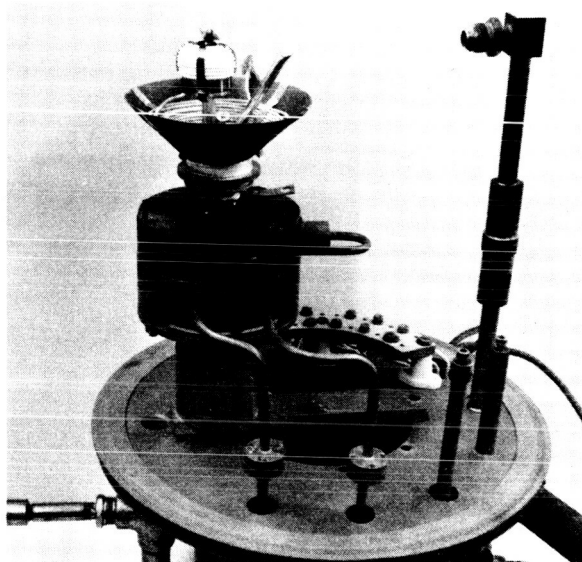
FIGURE 14 - CONVERTER BEING PREPARED FOR TEST
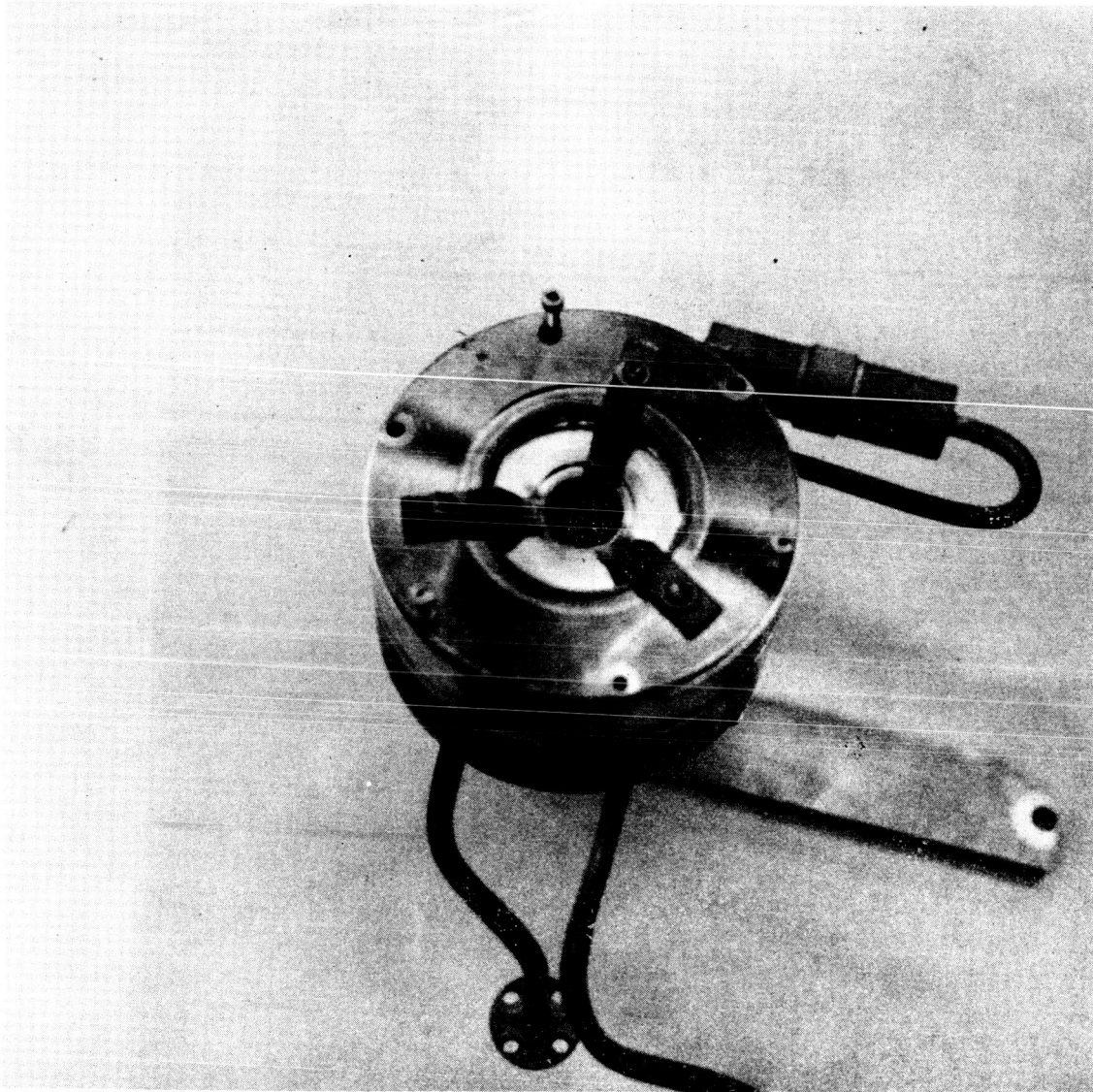
FIGURE 15 - CONVERTER SUPPORT ASSEMBLY

and final conditions of the eighteen converters fabricated for the subject program will be detailed.

(4) Test Data

The output characteristic of seven pertinent converters had been prepared in detail.

C Specific Testing of Converters

(1) Set-Up of Converter

The converter was tested in the same vacuum environment used for exhaust procedures as shown in Figure 14. It was held in place by three stainless steel fingers clamping the generator support ring to a stainless steel baseplate, as seen in Figure 15. The baseplate was made variable in its vertical position so the outer surface of the emitter could be positioned as desired with respect to the electron bombardment heater.

The six thermocouples and the leads to the cesium reservoir and fin heaters were then placed on the converter and spot welded to the feedthroughs. The voltage and current leads were connected to the converter with the emitter grounded to provide a safe return for the electron bombardment power.

The black body hole in the emitter was aligned with holes in the heat shields around the heater. The high-voltage leads were inspected for shorts to ground. The continuity of the thermocouples and heaters was verified.

(2) Warm-Up of Converter

The environmental system was evacuated to a pressure in the 10^{-5} torr range which was maintained throughout the testing period. At that vacuum, the electron bombardment filamentary heater (thoriated tungsten) was energized. When the temperature of the

heater reached 2000° Kelvin, the high voltage was applied and heating of the converter emitter started. At the same time, a current of approximately three amperes was passed through the cesium reservoir heater.

The emitter temperature was raised by increasing the bombardment power until all temperatures were sufficient to produce an open circuit voltage of 2.5 volts. The converter was then connected to a variable electrical load set at approximately the optimum value.

The emitter was then heated to an equilibrium temperature of approximately 1700° Centigrade, off-setting the rising electron cooling of the emitter with increased bombardment power.

From this point, the cesium reservoir temperature was varied up and down until an optimum pressure was determined. The load was then varied to find the optimum load point keeping the cesium pressure constant. When the optimum load was found, the cesium pressure was again optimized.

(3) Load Curve

The load curve was then taken by varying the load from optimum to open circuit condition and back to optimum load. The emitter temperature was maintained constant by adjusting the bombardment heater power. Then the load was decreased to the short circuit condition. The emitter temperature was not allowed to drop below 1700° Centigrade during this operation at low load resistance in order to insure against accidental contact with the collector as it expanded due to its increased thermal dissipation. Pertinent data are presented in Table I through VI for pertinent converters at three load points on the load curve.

TABLE I

TEST DATA SHEET FOR RCA CONVERTER A-1270
SERIAL NUMBER 6

Temperatures	Open Circuit		Optimum		Short Circuit	
Temitter	1700° C		1695° C		1700° C	
Tcollector	637° C		765° C		820° C	
Tcesium reservoir	265° C		340° C		385° C	
Tceramic seal	400° C		460° C		435° C	
Tfin	310° C		425° C		350° C	
Input Power						
E_f	7.0	volts	6.95	volts	7.0	volts
I_f	35.0	amps	34.5	amps	35.0	amps
E_b	950.0	volts	1000.0	volts	1125.0	volts
I_b	0.26	amp	0.31	amp	0.32	amp
I_{cs}	2.7	amps	3.0	amps	2.9	amps
Output						
E_o	1.35	volts	0.66	volts	0.28	volts
I_o	2.5	amps	34.0	amps	70.0	amps
P_o	3.3	watts	22.5	watts	19.6	watts

TABLE II

TEST DATA SHEET FOR RCA CONVERTER A-1270
SERIAL NUMBER 11

Temperatures	Open Circuit		Optimum		Short Circuit	
Temitter	1705° C		1720° C		1710° C	
Tcollector	543° C		675° C		733° C	
Tcesium Reservoir	370° C		378° C		379° C	
Tceramic Seal	400° C		435° C		429° C	
Tfin	310° C		346° C		345° C	

Input Power						
E_f	8.1	volts	8.1	volts	8.1	volts
I_f	37.0	amps	37.0	amps	37.0	amps
E_b	760.0	volts	830.0	volts	880.0	volts
I_b	0.28	amps	0.32	amps	0.35	amps
I_{cs}	3.0	amps	3.0	amps	2.8	amps

Output						
E_o	1.2	volts	0.52	volts	0.23	volts
I_o	2.5	amps	21.5	amps	45.5	amps
P_o	3.0	watts	11.2	watts	10.4	watts

TABLE III

TEST DATA SHEET FOR RCA CONVERTER A-1270

SERIAL NUMBER 12

Temperatures	Open Circuit		Optimum		Short Circuit	
Temitter	1707° C		1720° C		1710° C	
Tcollector	605° C		795° C		835° C	
Tcesium reservoir	384° C		400° C		392° C	
Tceramic seal	410° C		485° C		460° C	
Tfin	390° C		435° C		435° C	

Input Power

	Open Circuit		Optimum		Short Circuit	
E_f	7.0	volts	7.0	volts	7.0	volts
I_f	34.0	amps	34.0	amps	34.0	amps
E_b	760.0	volts	940.0	volts	940.0	volts
I_b	0.28	amps	0.35	amps	0.36	amps
I_{cs}	2.9	amps	3.0	amps	2.9	amps

Output

	Open Circuit		Optimum		Short Circuit	
E_o	1.20	volts	0.49	volts	0.33	volts
I_o	5.2	amps	48.8	amps	62.0	amps
P_o	6.3	watts	23.9	watts	20.4	watts

TABLE IV
TEST DATA SHEET FOR RCA CONVERTER A-1270
SERIAL NUMBER 14

Temperatures	Open Circuit		Optimum		Short Circuit	
Temitter	1715° C		1711° C		1700° C	
Tcollector	598° C		805° C		930° C	
Tcesium reservoir	387° C		390° C		390° C	
Tceramic seal	427° C		470° C		480° C	
Tfin	330° C		365° C		375° C	

Input Power						
E_f	7.7	volts	7.6	volts	7.7	volts
I_f	35.0	amps	35.5	amps	35.5	amps
E_b	920.0	volts	1030.0	volts	1070.0	volts
I_b	0.25	amps	0.30	amps	0.31	amps
I_{cs}	3.0	amps	3.1	amps	3.0	amps

Output						
E_o	1.2	volts	0.68	volts	0.35	volts
I_o	7.0	amps	35.0	amps	55.0	amps
P_o	8.4	watts	23.8	watts	19.3	watts

TABLE V
TEST DATA SHEET FOR RCA CONVERTER A-1270
SERIAL NUMBER 15

Temperatures	Open Circuit	Optimum	Short Circuit
Temitter	1700° C	1720° C	1710° C
Tcollector	545° C	790° C	830° C
Tcesium reservoir	388° C	390° C	405° C
Tceramic seal	415° C	470° C	470° C
Tfin	310° C	355° C	355° C

Input Power						
E_f	7.6	volts	7.6	volts	7.6	volts
I_f	35.0	amps	35.0	amps	35.0	amps
E_b	890.0	volts	1100.0	volts	1120.0	volts
I_b	0.25	amps	0.30	amps	0.35	amps
I_{cs}	3.2	amps	3.0	amps	3.2	amps

Output						
E_o	1.20	volts	0.61	volts	0.38	volts
I_o	5.0	amps	40.0	amps	62.0	amps
P_o	6.0	watts	24.4	watts	23.5	watts

TABLE VI

TEST DATA SHEET FOR RCA CONVERTER A-1270

SERIAL NUMBER 16

Temperatures	Open Circuit	Optimum	Short Circuit
Temitter	1725° C	1720° C	1725° C
Tcollector	600° C	820° C	820° C
Tcesium reservoir	385° C	395° C	390° C
Tceramic seal	420° C	470° C	515° C
Tfin	300° C	330° C	350° C

Input Power						
E_f	7.7	volts	7.7	volts	7.7	volts
I_f	35.0	amps	35.0	amps	35.0	amps
E_b	1000.0	volts	1160.0	volts	1190.0	volts
I_b	0.245	amps	0.290	amps	0.310	amps
I_{cs}	2.9	amps	3.0	amps	2.7	amps

Output						
E_o	1.18	volts	0.65	volts	0.35	volts
I_o	8.5	amps	43.0	amps	58.5	amps
P_o	10.0	watts	28.0	watts	20.4	watts

(4) Converter Histories

The final converter design had an effective emitter area of 2.07 square centimeters and an emitter-collector spacing of approximately 0.002 inch. The emitter-collector spacing was determined for the optimum operating conditions. Variation in output current resulted in a change in collector temperature and changed the spacing. The spacing was obtained by the difference in the differential expansion of the emitter and collector. In short circuit operation the spacing was greater than optimum.

(a) Standardized Construction Techniques

The ceramic seal braze of the emitter employed copper as a standard filler.

The copper collector base and Nicoro braze joints were nickel plated.

The generator support ring sub-assembly was brazed with copper and the cesium reservoir assembly was brazed with Nicrobraz 30.

The first four converters were constructed with a very large copper collector base and radial radiator fins. The remaining converters had a much smaller collector base and a one-piece cone-shaped radiator fin. All of the fins were hydroblasted to raise their emissivity and converters, Serial Numbers 11 and 12, had a coating of Aquadag sprayed on the fin to improve its emissivity. The Aquadag often peeled during testing. The remaining converters were treated with a high-emissivity silicone-aluminum coating. Unless otherwise noted, the power output figures given were obtained at emitter temperatures of slightly less than 2000° Kelvin.

(b) Specific Construction Details

Each converter incorporated certain individual construction details which are itemized below and referenced to converter serial numbers:

(1) The tantalum emitter was brazed to the molybdenum support with Nicrobraz 30. The converter leaked after brazing. The leak was sealed with copper. The collector assembly employed nickel tubing and Nicrobraz 130 as described in Section III, above. This assembly also leaked. The overall converter assembly was continued however in order to obtain fabrication, spacing and temperature distribution information.

Final converter was brazed with Nicrobraz. The converter was used for spacing tests between emitter and collector. No definite spacing was determined with the cathetometer. The unit was electrically shorted at all times and therefore scrapped.

(2) The tantalum emitter was brazed to the molybdenum support with Nicrobraz 30. The joint leaked. The leak was sealed with copper during ceramic seal braze.

The molybdenum head-to-copper base junction, employing nickel tubing, was brazed with Nicrobraz 130. The molybdenum head was nickel plated. The collector was damaged and brazed area leaked. The assembly was completed to gain further information.

The final converter was brazed with Nicrobraz L. M. The converter was used for spacing tests. Spacings of 0.002 inch to 0.008 inch between emitter and collector, depending on electrode temperatures, was observed with a cathetometer. The converter was scrapped.

(3)   The tantalum emitter was brazed to the molybdenum sup-
      port with copper.

      The molybdenum head was brazed to the copper base em-
      ploying nickel tubing and using Nicoro. The molybdenum
      was also nickel plated.

      The converter assembly was brazed with silver-copper eu-
      tectic solder. The emitter-collector spacing was approxi-
      mately 0.003 inch under optimum operating conditions. The
      output was 5.2 watts at 0.41 volt and 12.7 amperes. The
      collector shorted to the emitter after five hours of opera-
      tion. Analysis showed nickel deposits on the tantalum emit-
      ter. The converter was scrapped.

(4)   The tantalum emitter was brazed to the molybdenum sup-
      port with copper. The junction leaked. The leak was sealed
      with Nicoro brazing material.

      The molybdenum head was brazed to the copper base em-
      ploying nickel tubing with Nicoro.

      The final converter assembly was brazed with silver-copper
      eutectic solder.

      The emitter-collector spacing was approximately 0.005 inch
      at operating conditions. The output was 10.5 watts at 0.92
      volt and 11.5 amperes. An output of 19.7 watts was achieved
      at an emitter temperature of 1850° Centigrade. The unit is
      in storage after 25 hours of test.

(5)   The tantalum emitter was brazed to the molybdenum support
      using copper as a filler.

The molybdenum collector was brazed to the copper base employing nickel tubing with Nicoro.

The final converter was brazed with silver-copper eutectic solder. The unit leaked on exhaust at the copper braze in the emitter sub-assembly. The converter was analyzed and then scrapped.

(6) The tantalum emitter was brazed to the molybdenum support with nickel-molybdenum eutectic solder.

The molybdenum head of the collector was brazed to the copper base employing nickel tubing and using Nicoro.

The final converter was brazed with silver-copper eutectic solder. The emitter collector spacing was approximately 0.002 inch at operating conditions. The output was 22.5 watts at 0.66 volt and 34 amperes. An output of 25.9 watts at 0.7 volt and 37 amperes was achieved at an emitter temperature of 1750° Centigrade. After twenty-one hours of test, the unit was shipped.

The remaining twelve converters had the same type of collector braze. The nickel tubing was eliminated and an additional moat was machined in the molybdenum head to give a better seal when brazed with Nicoro.

(7) The tantalum emitter was brazed to the molybdenum support with copper.

The final converter was brazed with silver-copper eutectic solder. The emitter lead was damaged on exhaust. The converter was scrapped after analysis.

(8) The Fansteel 60 emitter was brazed to the molybdenum support with copper.

The final converter was brazed with silver-copper eutectic solder. The emitter lead was damaged on exhaust. The converter was scrapped after analysis.

(9) The tantalum emitter was brazed with zirconium.

The final converter was brazed with silver-copper eutectic solder. The spacing was approximately 0.002 inch under operating conditions. An output of 13.9 watts was obtained at 0.59 volt and 23 amperes. The emitter lead became embrittled and leaked after five hours operation due to external hydrocarbon attack of the emitter lead. The converter was scrapped after analysis.

(10) The tantalum emitter was brazed with zirconium.

The final converter was brazed with silver-copper eutectic solder. The spacing was approximately 0.002 inch under operating conditions. An output of 18.7 watts was obtained at 0.58 volt and 32.5 amperes. The emitter lead became embrittled and leaked after four hours of operation due to internal hydrocarbon attack of emitter lead. The converter was scrapped after analysis.

(11) The 0.012 inch thick wall at the base of the tantalum emitter lead was extended from 0.060 inch to 0.125 inch length and brazed with zirconium.

The final converter was brazed with silver-copper eutectic solder. The spacing was approximately 0.002 inch under

operating conditions. An output of 20.4 watts was obtained at 0.68 volt and 30 amperes. The output slumped after fifteen hours of operation. The converter was shipped after twenty hours of operation.

(12)   The tantalum emitter lead of 0.012 inch was further extended and the thickness of 0.008 inch for 0.125 inch was maintained before the 0.005 inch wall was fabricated.

The emitter-support ring was made with zirconium. The final converter was brazed with silver-copper eutectic solder. The spacing was approximately 0.0015 inch under operating conditions. An output of 23.9 watts was obtained at 0.49 volt and 48.75 amperes. The unit was tested for twenty-five hours and then shipped.

Converter Serial Number 12 was the only unit built with the flat emitter surface, JPL Drawing Number 111977-3. The final six converters were assembled in the same manner as Serial Number 12, except as noted below.

(13)   The spacing was approximately 0.002 inch. An output of 24.6 watts was obtained at 0.625 volt and 39.6 amperes. The converter slumped after twenty hours of operation. In the process of recesiation, a collector leak developed. The converter was scrapped.

(14)   The spacing was approximately 0.002 inch. An output of 23.6 watts was obtained at 0.67 volt and 35 amperes. After a twenty-five hour test, the converter was shipped.

(15)   The spacing was approximately 0.002 inch. An output of
        24.4 watts was obtained at 0.61 volt and 40 amperes. An
        output of 25.2 watts was achieved at an emitter temperature
        of 1735° Centigrade. The unit then slumped to 14 watts.
        However, the converter was shipped after twenty-two hours
        of testing.

(16)   The spacing was approximately 0.002 inch. An output of 28
        watts was obtained at 0.65 volt and 43 amperes. The con-
        verter slumped to 16 watts after twenty hours. The original
        copper braze of the ceramic leaked and was sealed with
        silver-copper eutectic solder during final converter braze.
        The converter was decesiated and re-exhausted, but during
        re-exhaust a leak developed at the ceramic seal. The con-
        verter was scrapped.

(5) Test Data

Converters, Serial Numbers 6 and 11 through 16, were tested. Data
were compiled into volt-ampere and volt-power curves.

In addition to the standard meters for observing voltage and power, the
temperature was closely controlled and monitored.

The electron-bombardment heater, as detailed on print 344-14078,
was shielded to improve the heat transfer to the emitter. The spacing
between the heater and the face of the emitter varied between 0.150
inch and 0.200 inch. Optical pyrometers (Leeds & Northrup, Catalogue
No. 8622-C) were checked against standards and the correction applied
in use. The temperature correction for reading through the bell jar
was measured and found to be approximately 15° at 1700° Centigrade.
This correction was also applied in determining true operating temper-
atures.

The continuous temperature of the emitter was observed with a radiation pyrometer (Radiation Electronics Company Type Thermodot, Model TD-6, Radiation Thermometer).

The data obtained from the thermocouples and the cesium reservoir and collector heaters together with voltage output, current output and emitter temperature were continuously recorded with a Honeywell-Brown Electronic Recorder (Model No. Y153X89-(C)-II-W7-16).
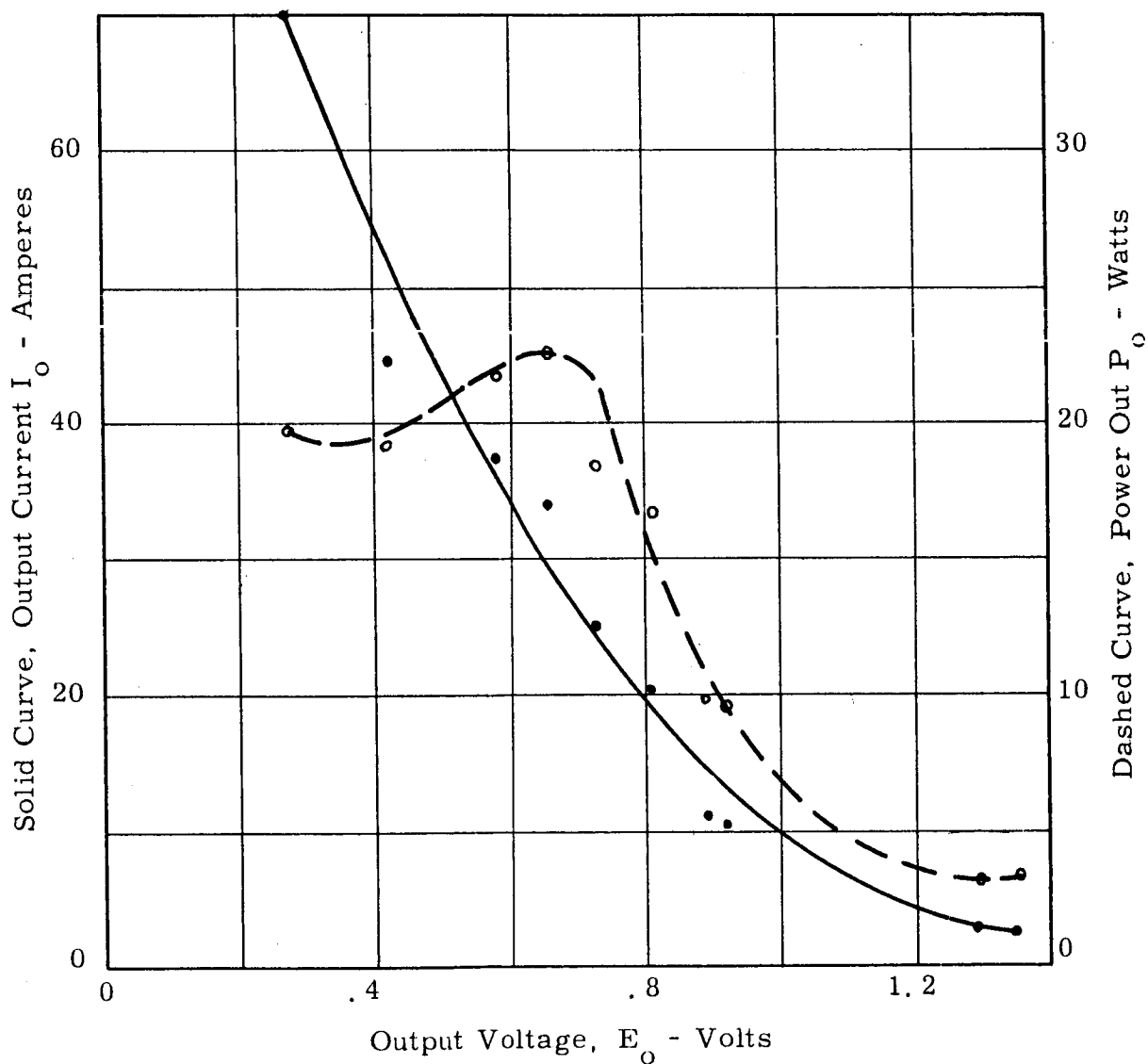
			Test Data	

Operating Conditions		E_O - Volts	I_O - Amps	P_O - Watts
$T_{emitter}$	1715°C	0.28	70.0	19.6
		0.42	44.5	19.1
$T_{collector}$	750°C	0.58	37.2	21.6
		0.66	34.0	22.5
T_{cesium}	375°C	0.73	25.0	18.3
		0.81	20.5	16.6
		0.89	11.2	10.0
		0.92	10.5	9.7
		1.28	2.5	3.2
		1.35	2.5	3.3

VOLT-AMPERE CURVE, VOLT-POWER CURVE
THERMIONIC CONVERTER
TYPE A-1270, SERIAL NUMBER 6

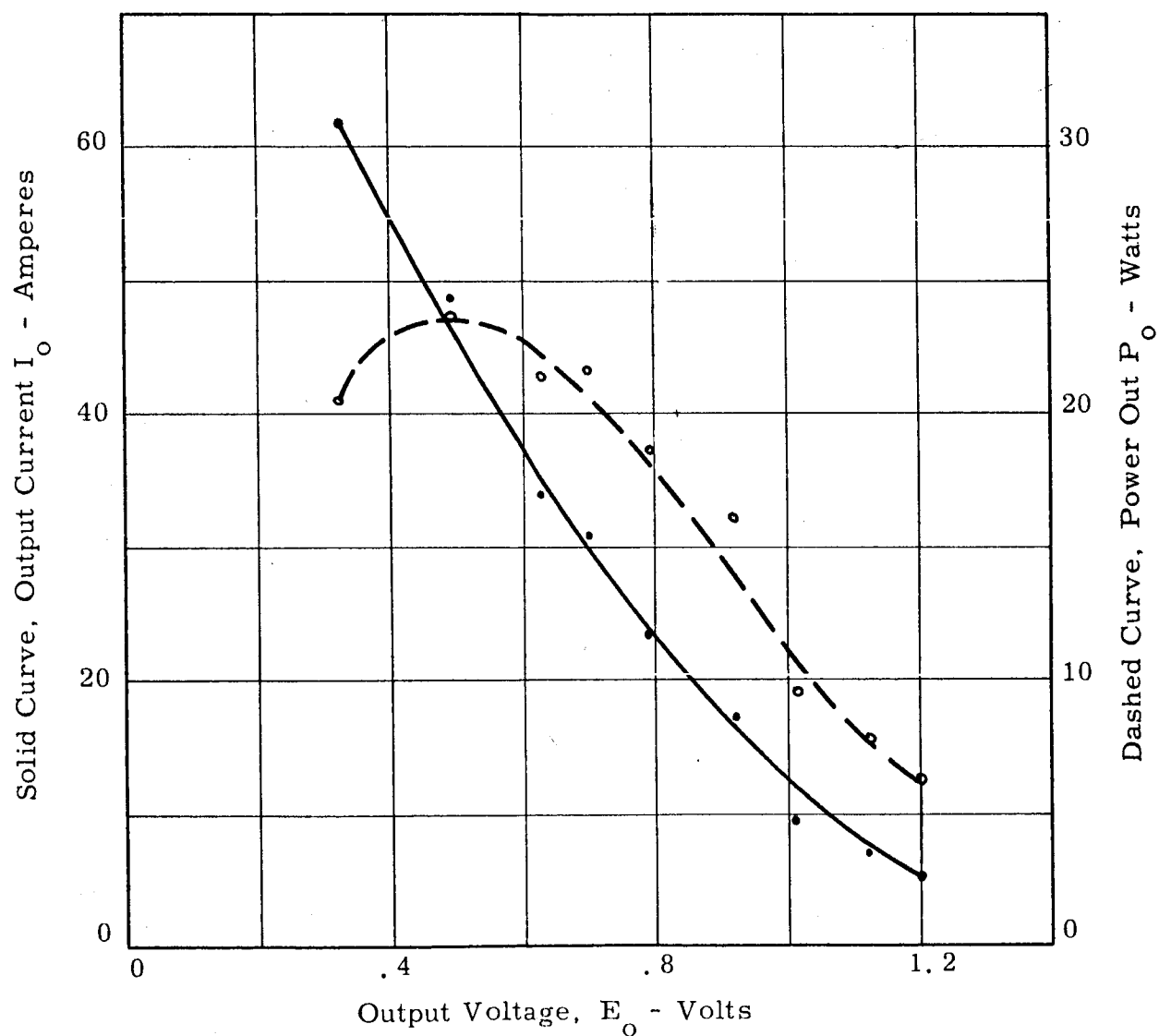| Operating Conditions			Test Data		
			E_O - Volts	I_O - Amps	P_O - Watts
$T_{emitter}$	1715°C		0.23	45.5	10.4
			0.42	26.5	11.1
$T_{collector}$	650°C		0.52	21.5	11.2
			0.63	16.0	10.1
T_{cesium}	375°C		0.69	13.0	9.0
			0.77	9.5	7.3
			0.87	5.5	4.8
			1.00	5.0	4.5
			1.10	3.8	4.2
			1.20	2.5	3.0
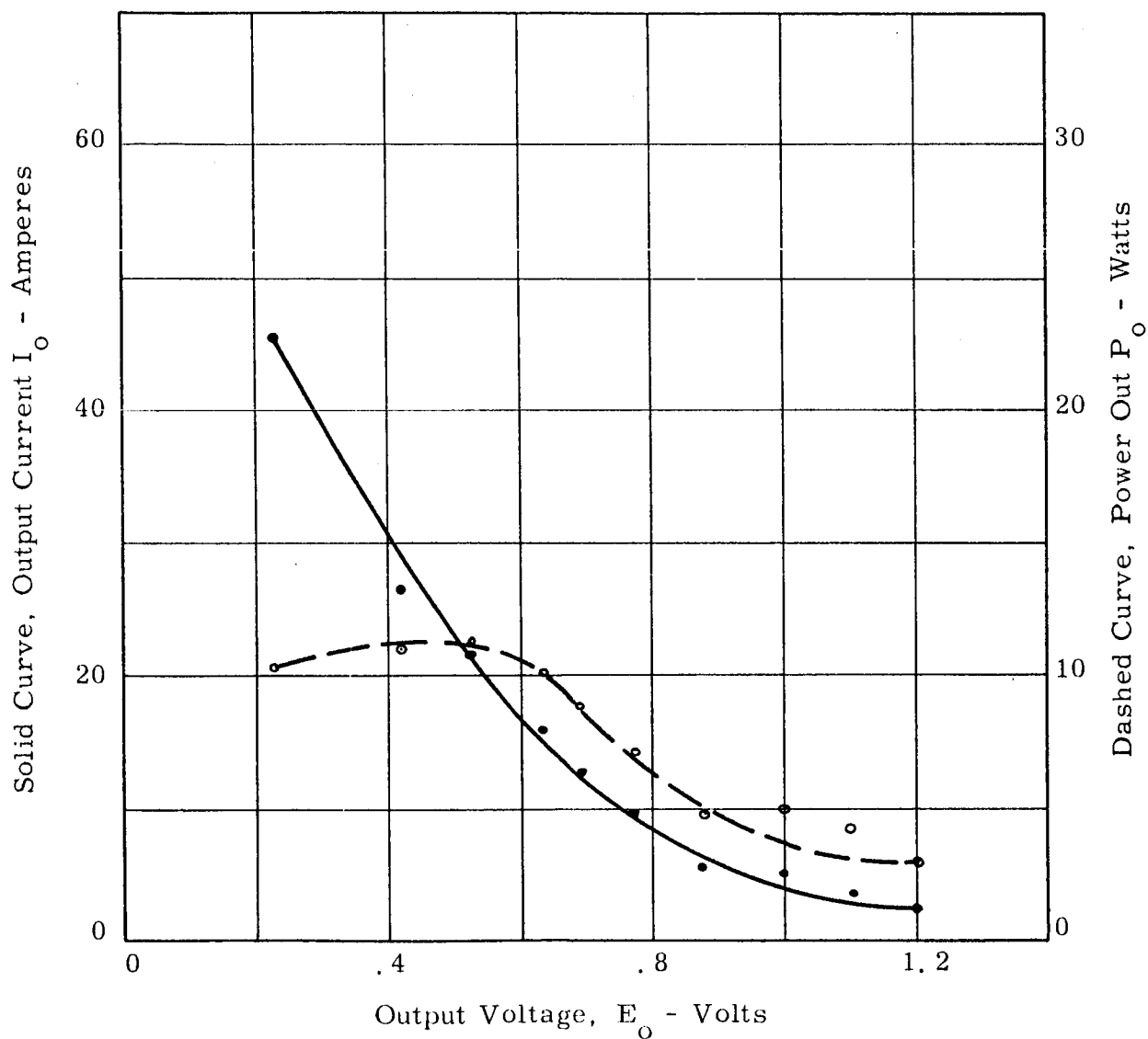
VOLT-AMPERE CURVE, VOLT-POWER CURVE
THERMIONIC CONVERTER
TYPE A-1270, SERIAL NUMBER 11

Operating Conditions		Test Data		
		E_O - Volts	I_O - Amps	P_O - Watts
$T_{emitter}$	1725°C	0.33	62.0	20.4
		0.49	48.8	23.9
$T_{collector}$	750°C	0.63	34.0	21.4
		0.70	31.0	21.7
T_{cesium}	385°C	0.79	23.5	18.6
		0.92	17.5	16.1
		1.01	9.5	9.6
		1.12	7.0	7.8
		1.20	5.2	6.3

VOLT-AMPERE CURVE, VOLT-POWER CURVE
THERMIONIC CONVERTER
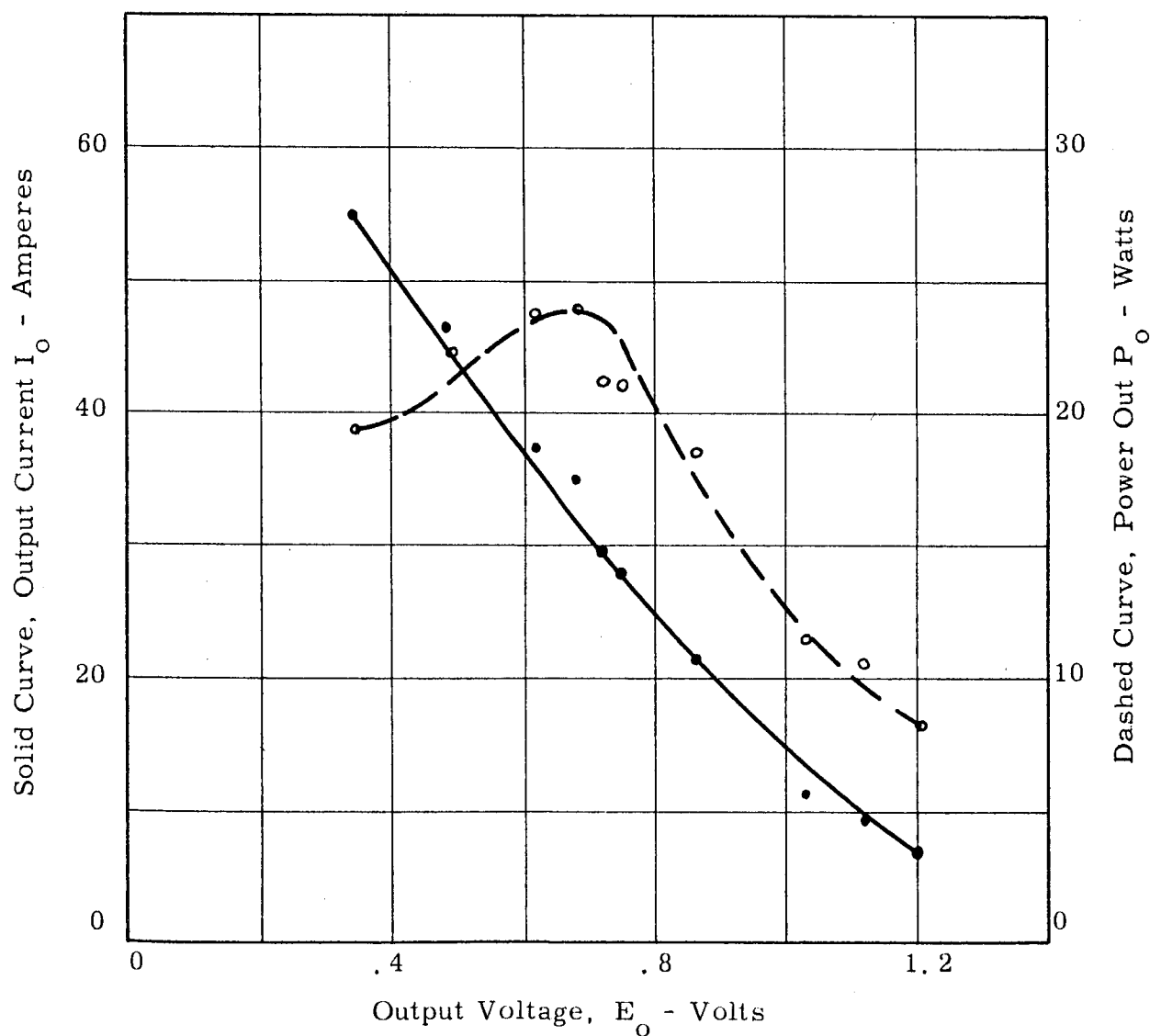TYPE A-1270, SERIAL NUMBER 12

Operating Conditions		Test Data		
		E_o - Volts	I_o - Amps	P_o - Watts
$T_{emitter}$	1720°C			
$T_{collector}$	725°C	0.30	46.0	13.8
		0.60	40.0	24.0
T_{cesium}	385°C	0.63	39.6	24.6
		0.66	37.0	24.3
		0.72	33.0	23.7
		0.89	21.5	19.2
		0.92	17.0	15.6
		0.96	13.5	13.0
		1.00	10.0	10.0
		1.04	9.5	9.8
		1.15	8.0	9.4
		1.23	6.5	8.0

VOLT-AMPERE CURVE, VOLT-POWER CURVE
THERMIONIC CONVERTER
TYPE A-1270, SERIAL NUMBER 13

Final Technical Report
Contract NAS-7-100
18 December 1962

Operating Conditions		Test Data		
		E_O - Volts	I_O - Amps	P_O - Watts
$T_{emitter}$	1720°C	0.35	55.0	19.3
		0.48	46.5	22.3
$T_{collector}$	750°C	0.62	37.5	23.6
		0.68	35.0	23.8
T_{cesium}	385°C	0.72	29.5	21.2
		0.75	28.0	21.0
		0.86	21.5	18.5
		1.03	11.5	11.9
		1.12	9.5	10.6
		1.20	7.0	8.4

VOLT-AMPERE CURVE, VOLT-POWER CURVE
THERMIONIC CONVERTER
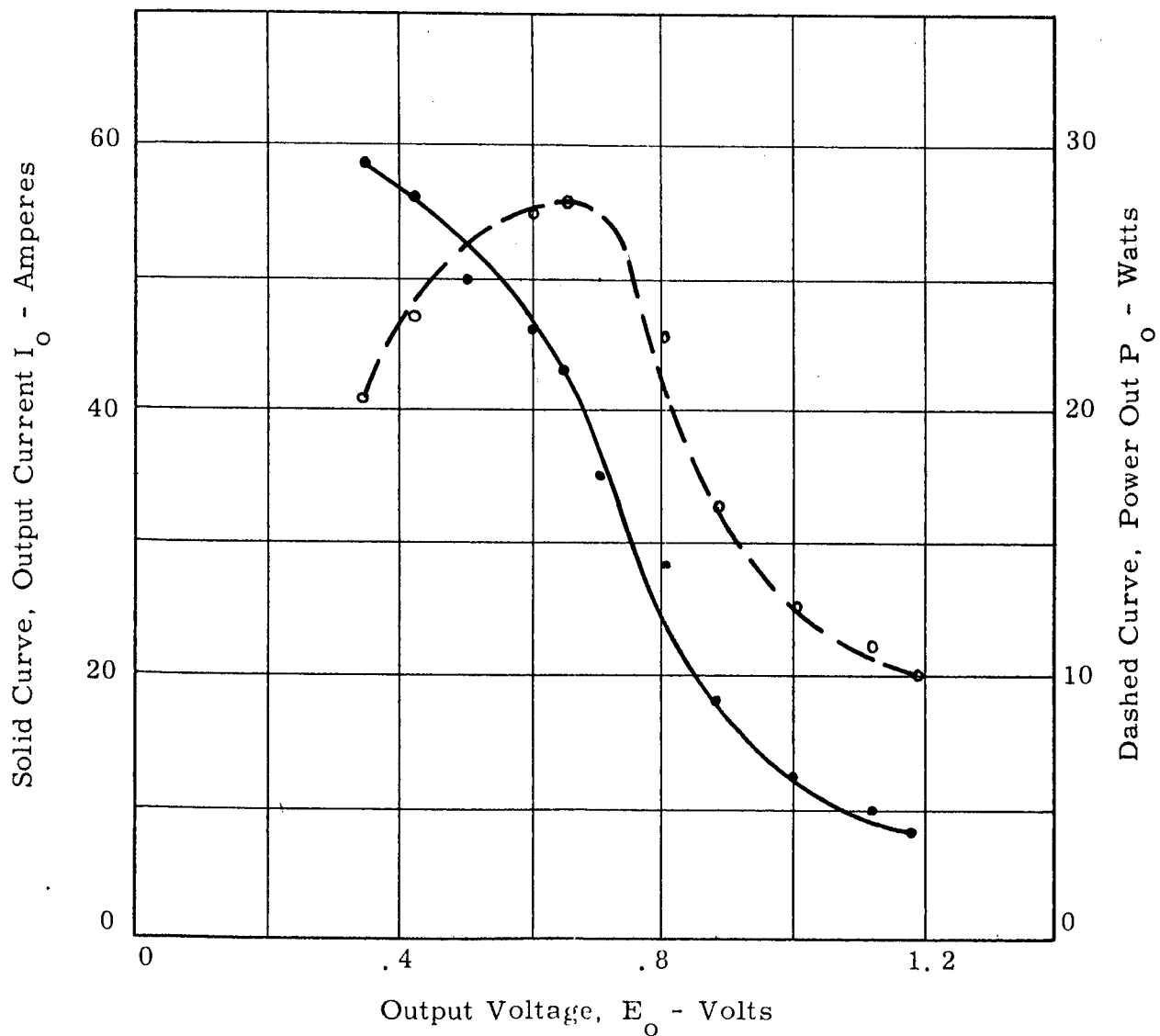TYPE A-1270, SERIAL NUMBER 14

Operating Conditions		Test Data		
		E_o - Volts	I_o - Amps	P_o - Watts
$T_{emitter}$	1720°C	0.38	62.0	23.5
$T_{collector}$	750°C	0.61	40.0	24.4
		0.68	31.0	21.1
T_{cesium}	390°C	0.76	28.0	18.7
		0.85	22.0	18.7
		0.95	13.0	12.3
		1.05	11.3	11.9
		1.20	5.0	6.0
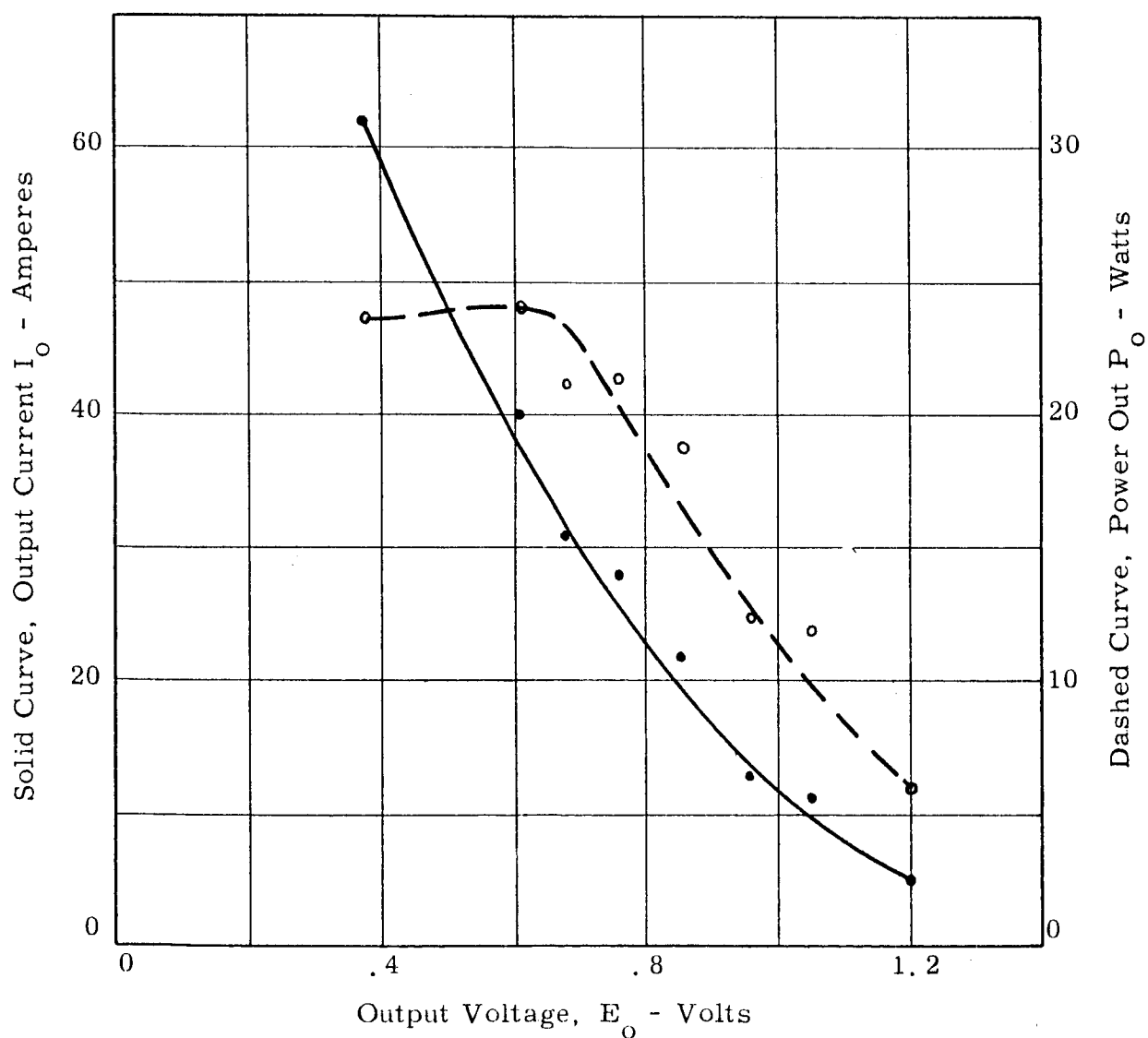
VOLT-AMPERE CURVE, VOLT-POWER CURVE
THERMIONIC CONVERTER
TYPE A-1270, SERIAL NUMBER 15

Operating Conditions		Test Data		
		E_o - Volts	I_o - Amps	P_o - Watts
$T_{emitter}$	1700°C	0.35	58.5	20.4
$T_{collector}$	775°C	0.42	56.0	23.5
		0.51	50.0	25.0
T_{cesium}	390°C	0.60	46.0	27.5
		0.65	43.0	28.0
		0.72	35.0	25.0
		0.81	28.5	22.8
		0.88	18.5	16.3
		1.00	12.5	12.5
		1.12	10.0	11.2
		1.18	8.5	10.0

VOLT-AMPERE CURVE, VOLT-POWER CURVE
THERMIONIC CONVERTER
TYPE A-1270, SERIAL NUMBER 16

APPENDIX A

HEAT LOSS DETERMINATIONS

RCA DEVELOPMENTAL CONVERTER TYPE A-1270

Prepared For:

JET PROPULSION LABORATORIES
California Institute of Technology
Pasadena, California

CONTRACT NAS-7-100
P. O. NO. 950229

APPENDIX A

HEAT·LOSS DETERMINATIONS

A Emitter Lead Loss

$T_k = 1700°$ C $\qquad$ P_{T_a} at $1100°$ C $= 59 \times 10^{-6}$ ohm-cm

$T_{\text{Heat Dam}} = 600°$ C

$\qquad$ K_{T_a} at $1100°$ C $= 0.65$ watts/cm °C

$I = 33.2$ Amps

$\qquad$ $N_o = 15$ o/o $\qquad$ $\Delta T = 1100°$ C

$$\frac{A}{L} = I \left(\frac{\rho}{K \Delta T \, N_o} \frac{(1 - N_o)}{2} \right)^{1/2}$$

$$\frac{A}{L} = 33.2 \left(\frac{59 \times 10^{-6}}{(0.65)(1100)(0.15)} \frac{(1 - 0.15)}{2} \right)^{1/2}$$

$$\frac{A}{L} = 33.2 \left(0.508 \times 10^{-6} \right)^{1/2}$$

$$\frac{A}{L} = \underline{\underline{0.0236}} \quad \frac{cm^2}{cm}$$

Assume $L = 2.5$ cm.

then $\quad A = 2.5 \times 0.0236 = 0.059 \, cm^2$

If $\quad A = \pi DS$ where $D = 0.665$ in $\times 2.54 \dfrac{cm}{in}$

$\qquad\qquad\qquad$ $S =$ thickness of heat dam wall,

then

$$S = \frac{A}{\pi D} = \frac{0.059 \, cm^2}{(3.14)(0.665)(2.54)} = 0.0111 \text{ cm}$$

$$S = \underline{\underline{0.00438 \text{ inches}}}$$

A heat dam of 0.0028 inch thickness is considered undesirably thin by RCA for reasons of mechanical strength. Therefore, to prevent excessive weakness a 0.005 inch wall thickness was used.

1. Heat Flow Down Emitter Lead

Emitter Diameter = 0.661 inch x 2.54 cm/in

Emitter Wall (S) = 0.005 inch x 2.54 cm/in

Emitter Length (L) = 2.54 cm

Thermal Conductivity at T_a at 1100° C = 0.65 watts/cm^2

A = 0.067 cm^2

ΔT = 1700 - 600 = 1100° C

$$W = \frac{KA\Delta T}{L} = \frac{(0.65)(0.067)(1100)}{2.5} = \underline{\underline{19.3 \text{ watts}}}$$

Since the modification of the emitter lead was in the low temperature area, relatively small changes in the losses from the emitter lead were encountered. Temperature measurements taken at the ceramic seal area for converters of the modified and unmodified type show no change. Therefore, the change in heat flow is considered to be negligible and emitter heat loss after modification was determined to be the same as the initial heat loss.

B   Collector Heat Losses

The following calculated heat energy must be considered transferred to the collector.

1. Electron Heating

$$P_e = I\left(\phi_c + \frac{2KT}{2}\right) \quad \text{where} \quad \frac{2K}{e} = 1.723 \times 10^{-4} \text{ watts/amp}$$

$$P_e = 13.3 \frac{\text{amps}}{\text{cm}^2}\left(1.86 \text{ V} + 1.723 \times 10^{-4} \frac{\text{watts}}{\text{amp °K}} \times 2000° \text{ K}\right)$$

$$P_e = 24.7 \frac{watts}{cm^2} + 4.6 \frac{watts}{cm^2} = 29.3 \ watts/cm^2$$

$$P_e = 29.3 \ watts/cm^2 \times 2.07 \ cm^2 = \underline{\underline{60.5 \ watts \ total}}$$

2. Radiation Loss

   a. Radiation Loss (Emitter Force)

$$P_R = \sigma \in eff \ A \ (T_2^4 - T_1^4)$$

$$P_R = 5.67 \times 10^{-12} \times 0.12 \times$$
$$2.07 \ (2000^4 - 900^4)$$

$$P_R = 21.6 \ watts \ total$$

$\sigma = 5.67 \times 10^{-12} \ watts/cm^2 \ °K$

$A = 2.07 \ cm^2$

$T_c = 2000° \ K$

$T_A = 900° \ K$

$\in eff = (\frac{1}{c} + \frac{1}{A} - 1)^{-1}$

$\in eff = 0.12$

   b. Radiation Loss (Emitter Wall - 1 cm lg from face)

$$P_R = 5.67 \times 10^{-12} \times 5.3$$
$$(1600^4 - 900^4)$$

$$P_R = 21 \ watts \ total$$

$\sigma = 5.67 \times 10^{-12} \ watts/cm^2 \ °K$

$A = 0.66/in \times 17 \times 2.54 \ \frac{cm}{in} \times 1 \ cm$

$A = 5.3 \ cm^2$

$T_c = 1600° \ K$

$T_A = 900° \ K$

$\in eff = 0.12$

3. Ionization Loss

   Ion Power = arc drop x current density
   assume arc drop = 0.5 volt

   Ion Power = 0.5 volt x 13.3 amp/cm^2 = 6.6 $watts/cm^2$
   or 13.6 watts total

4. Cesium Cooling Losses

   a. Gas Transfer

   As cooling occurs at 7 $watts/cm^2$

   7 watts x 2.07 = $\underline{\underline{14.5 \ watts}}$

Summing up:

1	Electron Heating	60. 5 watts
2a	Radiation Loss	21. 6 watts
2b	Radiation Loss	21. 0 watts
3	Ionization Loss	13. 6 watts
4a	Gas Transfer	14. 5 watts
	Total	130. 2 watts

C. Radiator Change and Reduction of Collector Copper

1. Modified Collector and Radiator Design

What is temperature drop to collector end assuming $T_{collector}$ of 700° Centigrade ?

Heat to Anode = 150 watts (130 w plus 20 w safety factor)
Ther. Cond. Mo = 0. 29 (4. 19) watts/cm^2
Ther. Cond. Cw = 0. 93 (4. 19) watts/cm^2

$$W = \frac{KA\Delta T}{L}$$

$$\Delta T\, Mo = \frac{W\, L_{Mo}}{K_{Mo}\, A_{Mo}}$$

$$\Delta Tcu_1 = \frac{W\, L_1}{Kcw\, A_1}$$

$$\Delta Tcu_2 = \frac{W\, L_2}{Kcw\, A_2}$$

$$\Delta Tcu_3 = \frac{W\, L_3}{Kcw\, A_3}$$

$$\Delta Tcu_4 = \frac{W\, L_4}{Kcw\, A_4}$$

$$\Delta Tcu_5 = \frac{W\, L_5}{Kcw\, A_5}$$
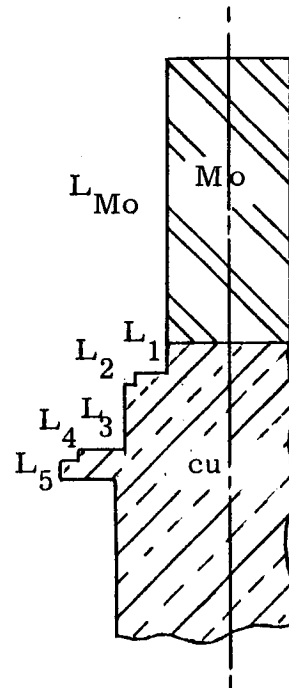
See Drawing 344-3213

$$\Delta T_{Mo} = \frac{(150)\,(1.5)\,(2.54)}{(0.29)\,(4.19)\,(3.14)\,(0.322)^2\,(2.54)^2} = 220° \text{ C}$$

$$\Delta T_{cu_1} = \frac{(150)\,(0.20)\,(2.54)}{(0.934)\,(4.19)\,(3.14)\,(0.322)^2\,(2.54)^2} = 9.25° \text{ C}$$

$$\Delta T_{cu_2} = \frac{(150)\,(0.050)\,(2.54)}{(0.934)\,(4.19)\,(3.14)\,(0.50)^2\,(2.54)^2} = 0.96° \text{ C}$$

$$\Delta T_{cu_3} = \frac{(150)\,(0.35)\,(2.54)}{(0.934)\,(4.19)\,(3.14)\,(0.65)^2\,(2.54)^2} = 3.99° \text{ C}$$

$$\Delta T_{cu_4} = \frac{(150)\,(0.05)\,(2.54)}{(0.934)\,(4.19)\,(3.14)\,(0.75)^2\,(2.54)^2} = 0.425° \text{ C}$$

$$\Delta T_{cu_5} = \frac{(150)\,(0.90)\,(2.54)}{(0.934)\,(4.19)\,(3.14)\,(0.60)^2\,(2.54)^2} = \underline{12° \text{ C}}$$

$$\text{Total} = 247° \text{ C}$$

Therefore, temperature at point of anode radiator attachment = 700° C - 247° C = $\underline{\underline{453° \text{ C}}}$

Assume no more than 10° drop down anode radiator tolerable.

Therefore, we radiate 150 watts at 450° Centigrade.

$$P_R = \sigma A \, \epsilon_{eff}\,(T_2^4 - T_1^4)$$

ϵ radiator = 0.9

ϵ glass = 0.7

ϵ eff = $\left(\dfrac{1}{0.9} + \dfrac{1}{0.7} - 1\right)^{-1}$ = 0.655

T_1 = 50° C = 323° K

T_2 = 450° C = 723° K

σ = 5.67 x 10^{-12} w/cm^2 °K

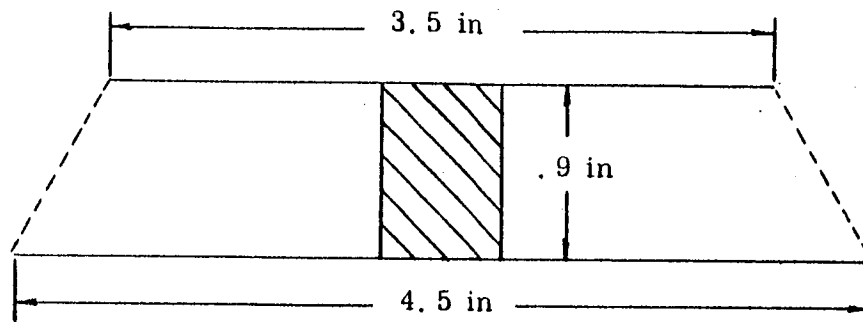P_R = 150 watts

$$A = \frac{P}{\sigma \, \epsilon_{eff}\,(T_2^4 - T_1^4)}$$

$$A = \frac{150}{5.67 \times 10^{-12} \, (0.655) \quad 723^4 - 323^4}$$

$A = \underline{155 \text{ cm}^2}$ of radiator area needed to radiate 150 watts at 450° C.

2. Radiator Geometry

Radiator Average Dia. $= \dfrac{4.5'' + 3.5''}{2} = 4''$ or 16.16 cm

Radiator Length = 1 inch or 2.54 cm

Average Projected Area $(A_1) = \pi dL = (3.14)(10.16)(2.54) = \underline{81 \text{ cm}^2}$

Area of Large Fin $(A_2) = \pi R^2 = (3.14)(5.72)^2 = 102.5 \text{ cm}^2$

$$R = \frac{4.5 \times 2.54}{2}$$

$$R = 5.72 \text{ cm}$$

$A_2 = 102.5 - \text{Area of Cs. Res. } (5.1) = \underline{97.4 \text{ cm}^2}$

Radiator can radiate from projected area (A_1) and large fin Area (A_2), as follows:

$P_1 = \sigma \epsilon \text{ eff } A_1 \, (T_2^4 - T_1^4) = 5.67 \times 10^{-12} \, (0.655)(81)(723^4 - 323^4)$
$P_1 = 80 \text{ watts}$

$P_2 = \sigma \epsilon \text{ eff } A_2 \, (T_2^4 - T_1^4) = 5.67 \times 10^{-12} \, (0.655)(97.4)(723^4 - 323^4)$
$P_2 = 91 \text{ watts}$

Therefore, with collector temperature of 700° C a radiator of geometry described can radiate a total of 80 + 91 = 171 watts. Since the actual calculated power loss to the collector is 130 watts, such a radiator should be sufficient.

Considering the ratio of slot depth to fin spacing, it is seen that seven fins provide an 8:1 ratio which should give an emissivity of 0.9.

Then for the A_1 radiator area, approximately 10 watts/fin must be radiated. In other words, 10 watts/fin x 7 fins = 70 watts + 90 watts radiated by the A_2 radiator area should be sufficient. Assuming copper fins, no more than 20° C drop across fin.

$$A = \frac{WL}{K\Delta T} = \frac{10(3.56 \text{ cm})}{(0.943)(4.19)(20)}$$

$$A = 0.45 \text{ cm}^2$$

W = 10 w/fin
Ave. L = 1.4 in x 2.54 $\frac{\text{cm}}{\text{in}}$
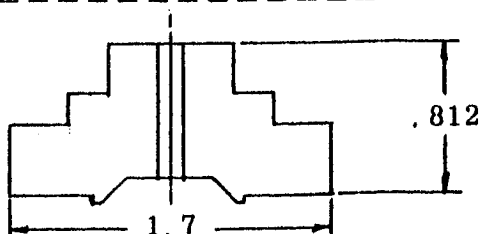Ave. L = 3.56 cm
Kcu at 20°C = 0.943 x 4.19 w/cm°C
ΔT = 20° C

then:

$A = \pi ds$ where d = ave. fin length

$$d = \frac{4.5 + 3.5}{4} = 2 \text{ inches or } 5.08 \text{ cm}$$

$$S = \frac{A}{\pi d} = \frac{0.45}{3.14 \times 5.08} = 0.028 \text{ inch}$$

Therefore, if 0.030 copper is used for fins no more than 20° C drop will occur from the center of the fin to the outer diameter of the fin.

3. New Copper Section of Anode

.812

See Drawing 344-2101

1.7

ΔT_1 down copper to fin attachment area ?

$$W = \frac{KA\Delta T}{L} \qquad \Delta T = \frac{WL}{KA}$$

Assume Ave. A
W = 150 watts
L = 0.7 in

$$\Delta T_1 = \frac{(150)\ (0.7)\ (2.54)}{(0.934)\ (4.19)\ (0.625)^2\ (2.54)^2}$$

$$\Delta T_1 = 28° C$$

ΔT_2 = drop down Mo section of anode = 225° C

Temperature at radiator = 800° C - (225° C + 28° C)

Temperature at radiator = 550° C or 825° K

$$P_R = \sigma \in \text{eff } A\ (T_1^4 - T_2^4)$$

$$A = \frac{P_R}{\sigma \in \text{eff } (T_1^4 - T_2^4)} = \frac{150}{5.67 \times 10^{-12}\ (0.655)\ (825^4 - 324^4)}$$

$A = 95.5 \text{ cm}^2$ or $\approx$ 15 in^2 of radiator area.
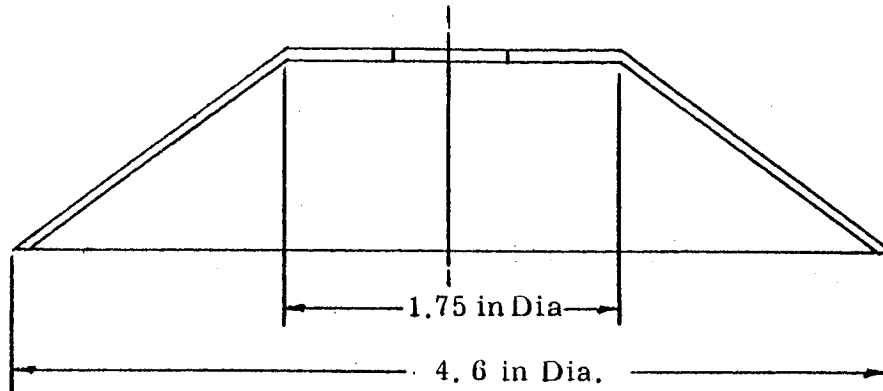
If cone shaped design used -
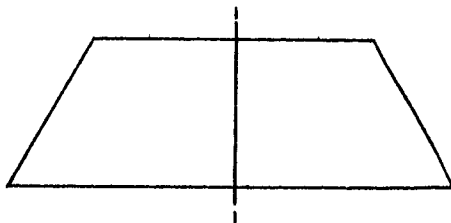
See Drawing 344-2100

Area Cone = ave. dia. x π x lg. of one side

15 = D ave. x π x 1.5 in   assume 1.5

$$\text{d ave.} = \frac{15" \text{ sq.}}{(3.14)\ (1.5 \text{ in})} = \underline{3.18" } \text{ ave. dia.}$$

Therefore, radiator of a geometry as follows, will radiate 150 watts at a collector temperature of 800° C.

4. <u>Cesium Reservoir Lead</u>

Assume - stainless steel tubing 0.010" wall x 1/4" O.D. for lead.

(a) What power can the reservoir proper radiate assuming a ΔT = 100° Centigrade ?

$$P_R = \sigma \sum eff \, A \, (T_2^4 - T_1^4)$$

$$P_R = 5.67 \times 10^{-12} \, (0.114) \, (5.1) \quad (623)^4 - (293)^4$$

$$P_R = 0.254 \text{ watts}$$

$$\sigma = 5.67 \times 10^{-12} \text{ w/cm}^2 \text{ °K}$$

$$\epsilon \, eff = (\frac{1}{.12} + \frac{1}{.7} - 1)^{-1} = .114$$

$$A = 5.1 \text{ cm}^2$$

$$T_2 = 623° \text{ K}$$

$$T_1 = 293° \text{ K}$$

Assuming lead length = 1.5 inches, what ΔT will result if we assume that 0.254 watts is conducted down lead ?

$$\Delta T = \frac{WL}{KA} = \frac{0.254 \times 1.5 \times 2.54}{0.058 \times 0.05 \text{ cm}^2}$$

$$K_{ss} = 0.058 \text{ w/cm °C at 400° C}$$

$$A = \pi DS = 0.05 \text{ cm}^2$$

$$\Delta T = 334° \text{ C}$$

APPENDIX B

BILL OF MATERIALS

RCA DEVELOPMENTAL CONVERTER A-1270

Prepared For:

JET PROPULSION LABORATORIES
California Institute of Technology
Pasadena, California

CONTRACT NAS-7-100
P.O. NO. 950229

Final Technical Report
18 December 1962

Drawing Title	Drawing Number	Material	Page Number
Complete Converter Assembly	344-3230	-	B-2
Crossection Drawing	344-2233	-	B-3
Emitter Assembly	344-2042	-	B-4
Emitter, Blunt End	344-2150	Tantalum	B-5
Emitter, Rolled Blunt End	344-2149	Tantalum	B-6
Emitter, Blank Blunt End	344-2148	Tantalum	B-7
Emitter	344-2087	Tantalum	B-8
Emitter, Rolled	344-2088	Tantalum	B-9
Emitter, Blank	344-2089	Tantalum	B-10
Emitter Support	344-2030	Molybdenum	B-11
External Emitter Lead	344-2048	Nickel	B-12
Insulator Assembly	344-2103	-	B-13
Strain Isolation Ring, Small	344-2037	Kovar	B-14
Ceramic Insulator	344-2043	Ceramic	B-15
Strain Isolation Ring	344-2038	Kovar	B-16
Generator Support Ring Assembly	344-2049	-	B-17
Generator Support Ring	344-2050	Kovar	B-18
Generator Support Ring Blank	344-2099	Kovar	B-19
Solder Washer	344-2054	Copper	B-20
Strain Isolation Ring, Large	344-2039	Kovar	B-21
Ceramic Insulator	344-2051	Ceramic	B-22
Collector Assembly	344-2271	-	B-23
Collector Head	344-2123	Molybdenum	B-24
Collector Base	344-2101	Copper	B-25
Collector Radiator Fin	344-2100	Copper	B-26
Collector Lead	344-2055	Copper	B-27
Exhaust Line Tubing	344-2122	Copper	B-28
Cesium Reservoir Assembly	344-2047	-	B-29
Cesium Reservoir Cup	344-2044	Nickel	B-30
Cesium Reservoir Base	344-2046	Nickel	B-31
Cesium Reservoir Pipe	344-2045	St. Steel	B-32
Cesium Reservoir Heater Assembly	344-2058	-	B-33
Cesium Reservoir Heater Cap	344-2071	Nickel	B-34
Emitter Shield	344-2270	Bakelite	B-35
Pinch-Off Protector Sleeve	344-2225	St. Steel	B-36
Pinch-Off Protector Split Ring	344-2226	St. Steel	B-37
Pinch-Off Protector Clamping Ring	344-2227	St. Steel	B-38

Test Mount, Jigs and Fixtures

Drawing Title	Drawing Number	Material	Page Number
Test Bottle	14059	-	B-39
Connector	14060	St. Steel	B-40
Exhaust Tubing	14061	OFHC Cpr.	B-41
Exhaust Joint	14062	OFHC Cpr.	B-42
Cesium Tubing	14063	OFHC Cpr.	B-43
Mount Bar	14064	St. Steel	B-44
Insulator Adaptor	14065	St. Steel	B-45
Exhaust Line	14066	St. Steel	B-46
Bottle Gasket	14067	Rubber	B-47
Base Plate	14068	St. Steel	B-48
Ion Gauge Adaptor	14069	St. Steel	B-49
Exhaust Pipe	14070	St. Steel	B-50
Converter Connector	14071	OFHC Cpr.	B-51
Clamp	14072	St. Steel	B-52
Seat Mount	14073	St. Steel	B-53
Seat	14074	Kovar	B-54
Heat Shield Assembly	14077	Ta-Nickel	B-55
Electron Bombardment Heater	14078	Thoriated Tungsten	B-56
Heater Terminal	14079	OFHC Cpr.	B-57
Cylinder	14080	St. Steel	B-58
Bearing	14082	St. Steel	B-59
Bearing Mount	14083	St. Steel	B-60
Heater Water Terminal	14084	OFHC Cpr.	B-61
Collector Terminal	14085	OFHC Cpr.	B-62
Emitter Terminal	14086	OFHC Cpr.	B-63
Exhaust Line Fitting	14087	St. Steel	B-64
Manifold Assembly	14088	-	B-65
Exhaust Assembly	14089	-	B-66
Insulator Adaptor	14090	St. Steel	B-67
Thermocouple Stand-Off	14091	Teflon	B-68
Terminal Assembly	14092	-	B-69
Finished Machine Drawing	14093	-	B-70
Exhaust Line Expansion	14094	OFHC Cpr.	B-71

Drawing Title	Drawing Number	Material	Page Number
Punch Blank	14101	Vasco Supreme	B-72
Punch	14102	Vasco Supreme	B-73
Punch Hob	14103	Vasco Supreme	B-74
Punch Guide	14104	Vasco Supreme	B-75
Punch Barrel	14105	Vasco Supreme	B-76
Weight	14123	St. Steel	B-77
Brazing Jig	14124	-	B-78
Weight	14125	St. Steel	B-79
Split Ring	14126	St. Steel	B-80
Base	14127	St. Steel	B-81
Brazing Base	14131	St. Steel	B-82
Brazing Jig	14132	St. Steel	B-83
Rubber Die Solder Washer	14143	Rubber	B-84
Brazing Jig	14144	-	B-85
Emitter Weight	14145	St. Steel	B-86
Generator Support Ring, Weight	14146	St. Steel	B-87
Split Ring	14147	St. Steel	B-88
Base	14148	St. Steel	B-89
Grinding Fixture	14151	St. Steel	B-90

Brazing Materials:

Zirconium

OFHC Copper

Nicrobraze 30 - 19% Cr - 10% Si - 15% C - Bal Ni
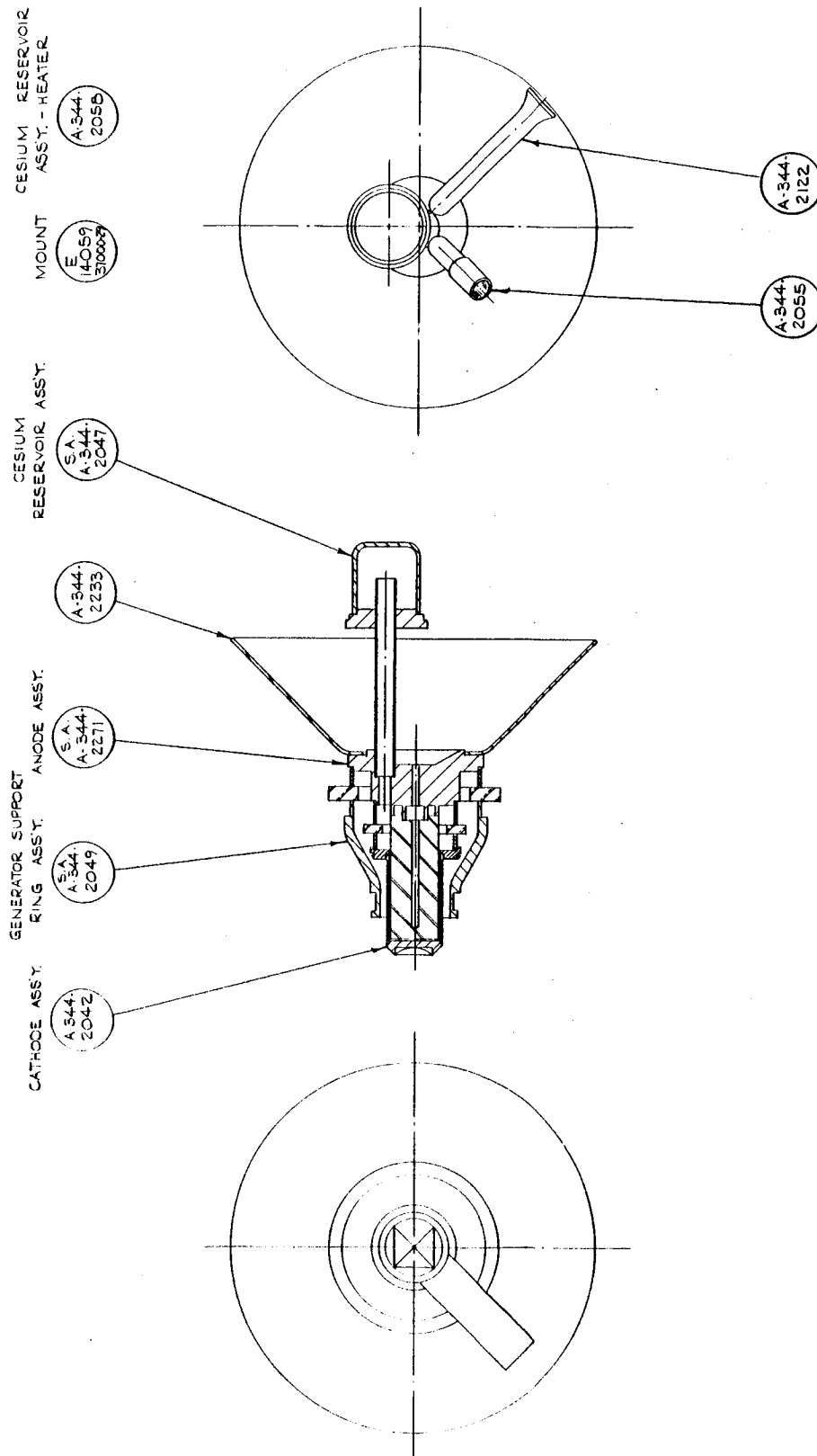
Nicoro Braze - 3% Ni - 35% Au - Bal. Cu

BT - Silver - Copper Eutectic - 28% Copper - 72% Silver

STANDARD TOLERANCE			
BASIC DIM.		FRAC.	DEC.
UP TO 6"	±	1/64	.005
ABOVE 6"	±	1/32	.010
ABOVE 24"	±	1/16	.015
ANGULAR DIM. ± 1/2°			

NOTE: THREADS EXTERNAL, CLASS 2A: INTERNAL, CLASS 2B (AMERICAN STDS) UNLESS OTHERWISE SPECIFIED.

SURFACE ROUGHNESS OF 500 MICRO-INCHES OR STOCK FINISH ACCEPTABLE UNLESS OTHERWISE SPECIFIED.

NOTE: SUPPLY ALL SCREWS, NUTS, BOLTS, RIVETS, WASHERS, DOWELS, TAPER PINS, COTTER PINS & WOODRUFF KEYS WITH PART.

CESIUM RESERVOIR ASSY. - HEATER

A-344-2058

MOUNT

E (4-O59 3700027)

A-344-2122

A-344-2055

CESIUM RESERVOIR ASSY.

S.A. A-344-2047

A-344-2233

GENERATOR SUPPORT RING ASSY.

ANODE ASSY.

S.A. A-344-2271

S.A. A-344-2049

CATHODE ASSY.

A-344-2042

NOTES:
1. ASSEMBLY MUST BE VACUUM TIGHT.

COMPLETE CONVERTER ASSEMBLY

344-3230

CROSSECTION DRAWING

344-2233

CESIUM RESERVOIR

RADIATOR FIN

INSULATOR

INSULATOR

GENERATOR SUPPORT RING

CATHODE

ANODE

A-344-2037

A-344-2043

A-344-2054

S.A.
A-344-2050

S.A.
A-344-2087
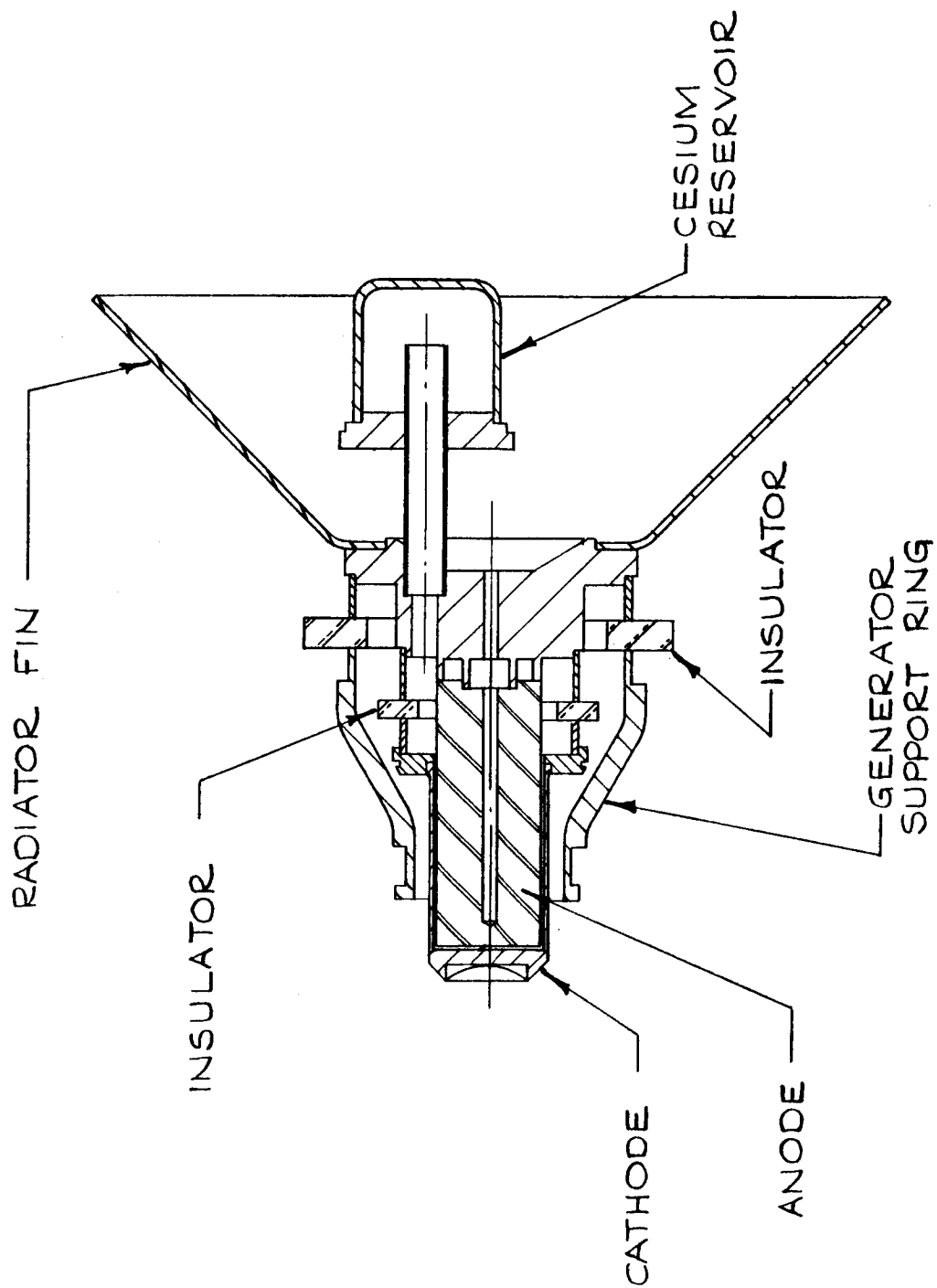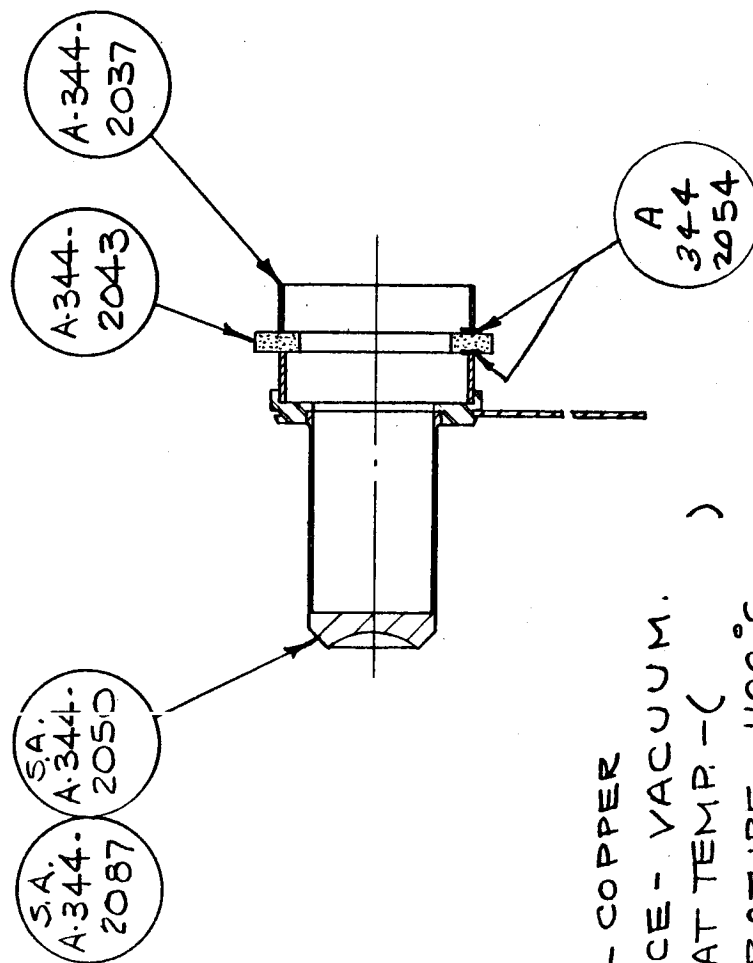
BRAZE - COPPER
FURNACE - VACUUM.
TIME AT TEMP. - (   )
TEMPERATURE 1100°C.
JIG N° 37000-T7 -29.
JIG N° 37000-T4-29.

NOTE: BRAZED ASSY. MUST BE VACUUM TIGHT.

EMITTER ASSEMBLY

344-2042

NOTES:
1. WASH W612.
2. FIRE VACUUM 2000°C (1) MIN.
3. STORE IN CLEAN CONTAINER.

45°

32

45°

32

.665 ±.002

.096 ±.002

.171 ±.002

.470 ±.002

.470 ±.002
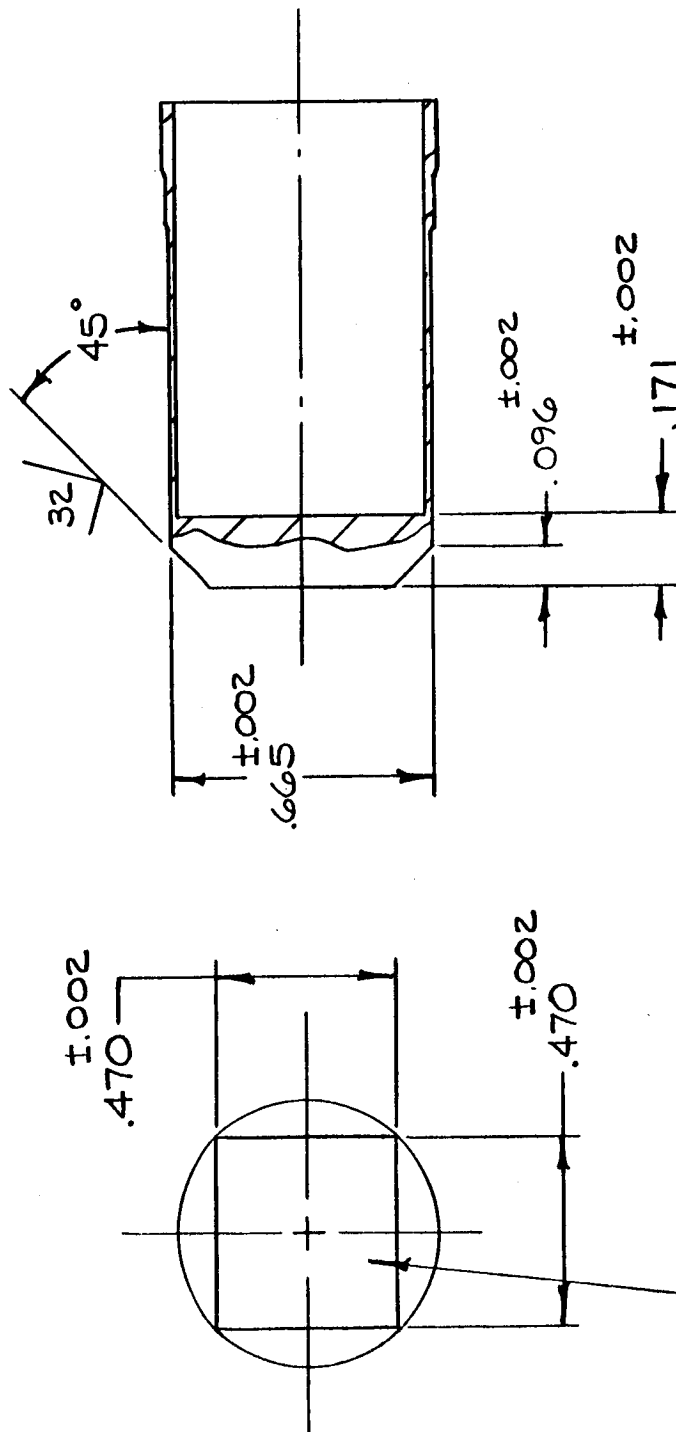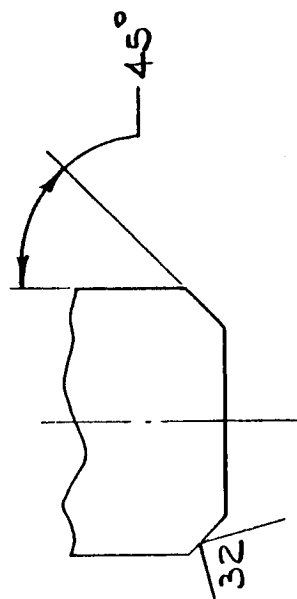
SANDBLAST END OF PART EXCEPT (4) CHAMFERS

EMITTER, BLUNT END

344-2150
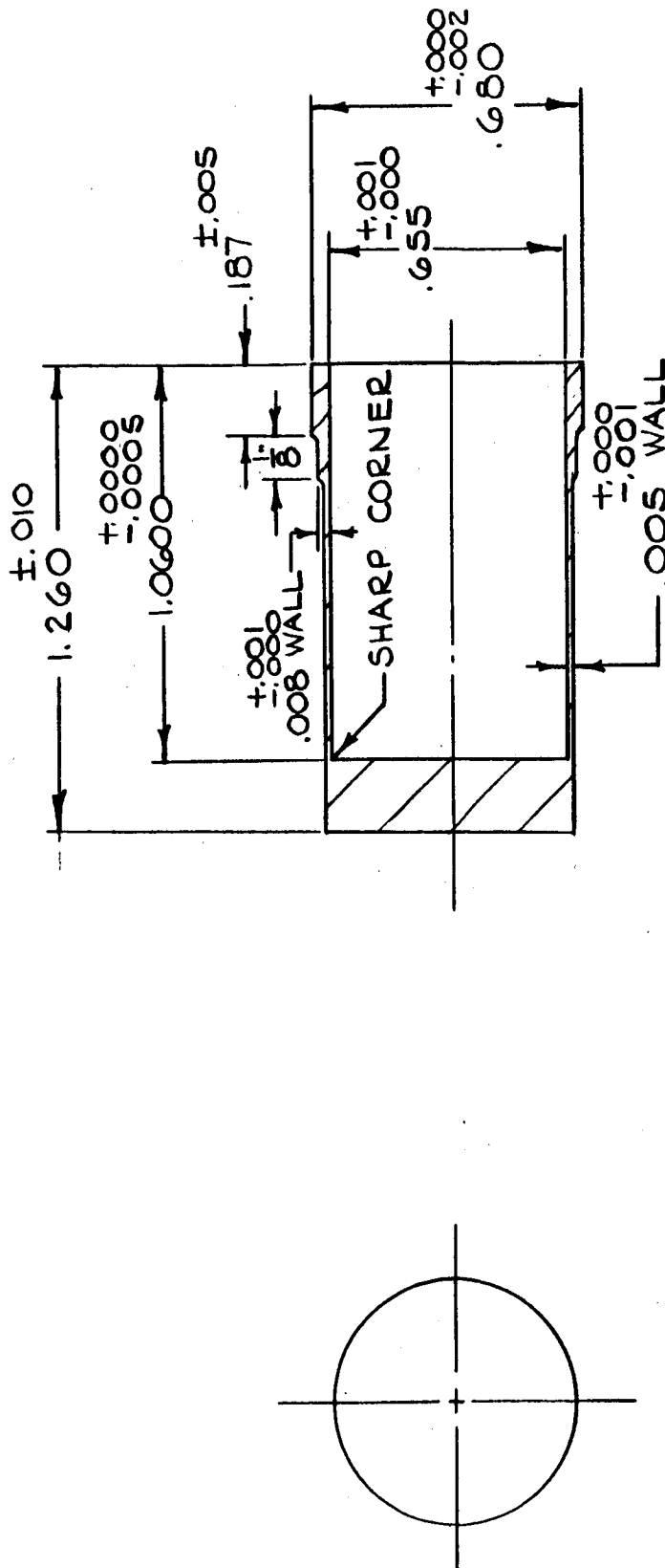
EMITTER, ROLLED BLUNT END

344-2149

NOTES:

1. PART MUST BE VACUUM TIGHT.

.015 WALL REF.

.680 ±.002

.650 +.001 −.000

.750 ±.010

.550 ±.010

32

NOTES 1 & 2

NOTES:
1. THIS SURFACE TO HAVE A ⌴.
2. THIS SURFACE TO BE PERPENDICULAR TO I.D. OF PART WITHIN .001.
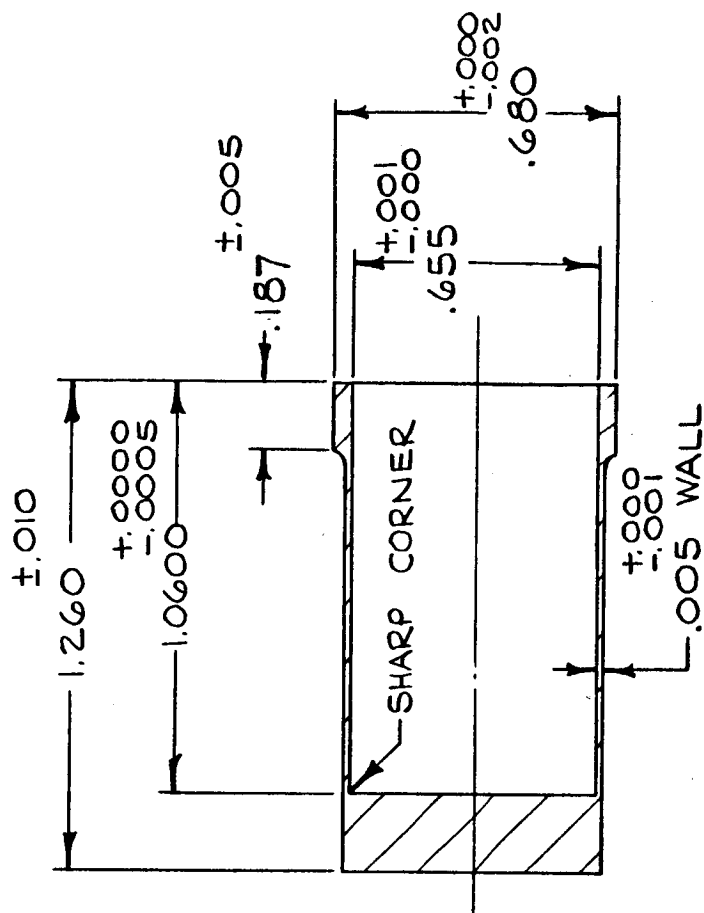
EMITTER, BLANK BLUNT END

344-2148

NOTES:
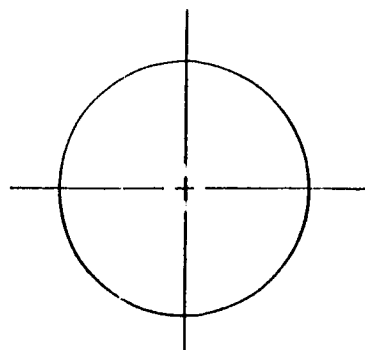1. WASH W612.
2. FIRE VACUUM 2000°C (1) MIN.
3. STORE IN CLEAN CONTAINER.

45°

32

.333 RAD. ±.002

32

45°

.333 R. ±.002

.665 ±.002

.096 ±.002

.171 ±.002

.470 ±.002

.470 ±.002
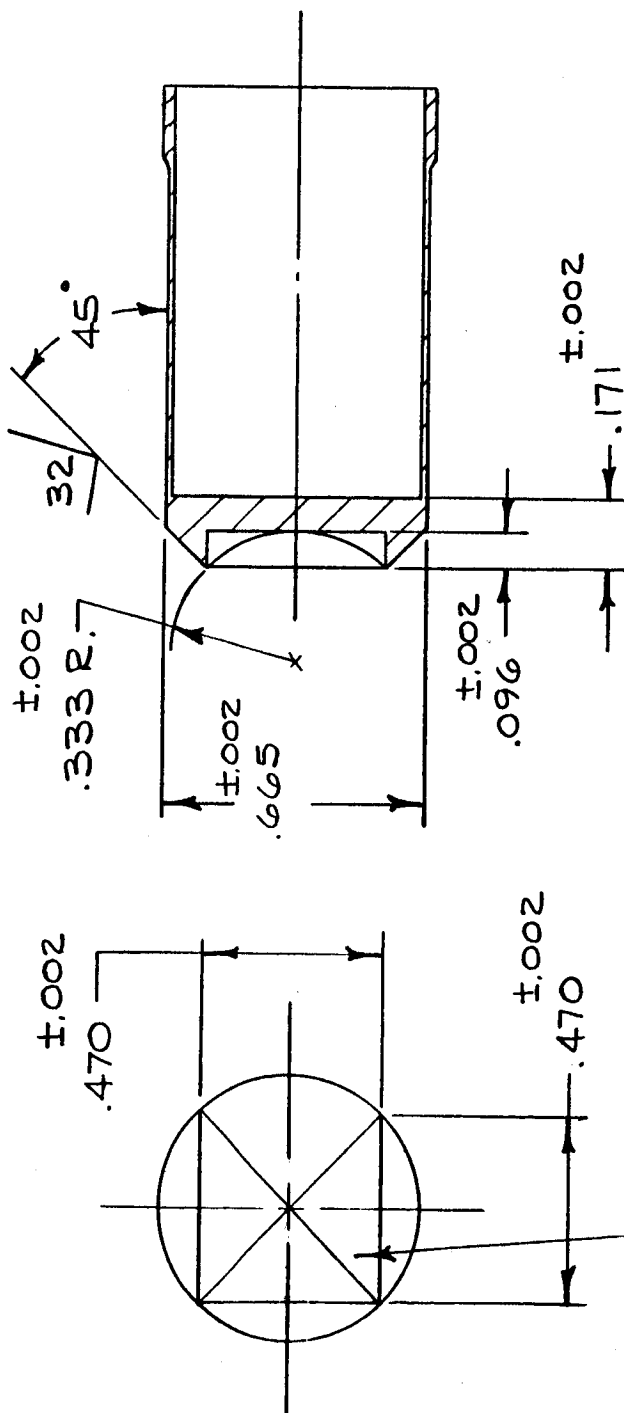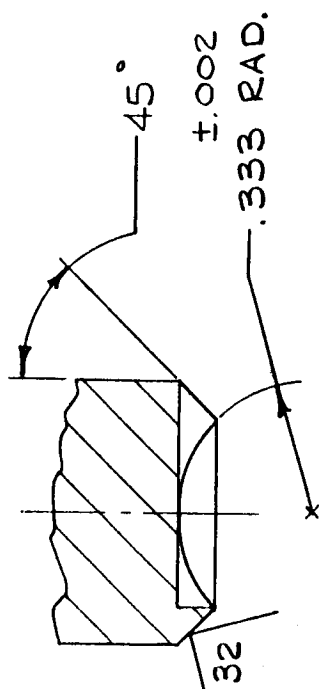
SANDBLAST END OF
PART EXCEPT (3) CHAMFERS.

EMITTER
344-2087

SHARP CORNER

.005 WALL

.680 +.000 -.002

.655 +.001 -.000

.187 ±.005

1.0600 +.0005 -.00
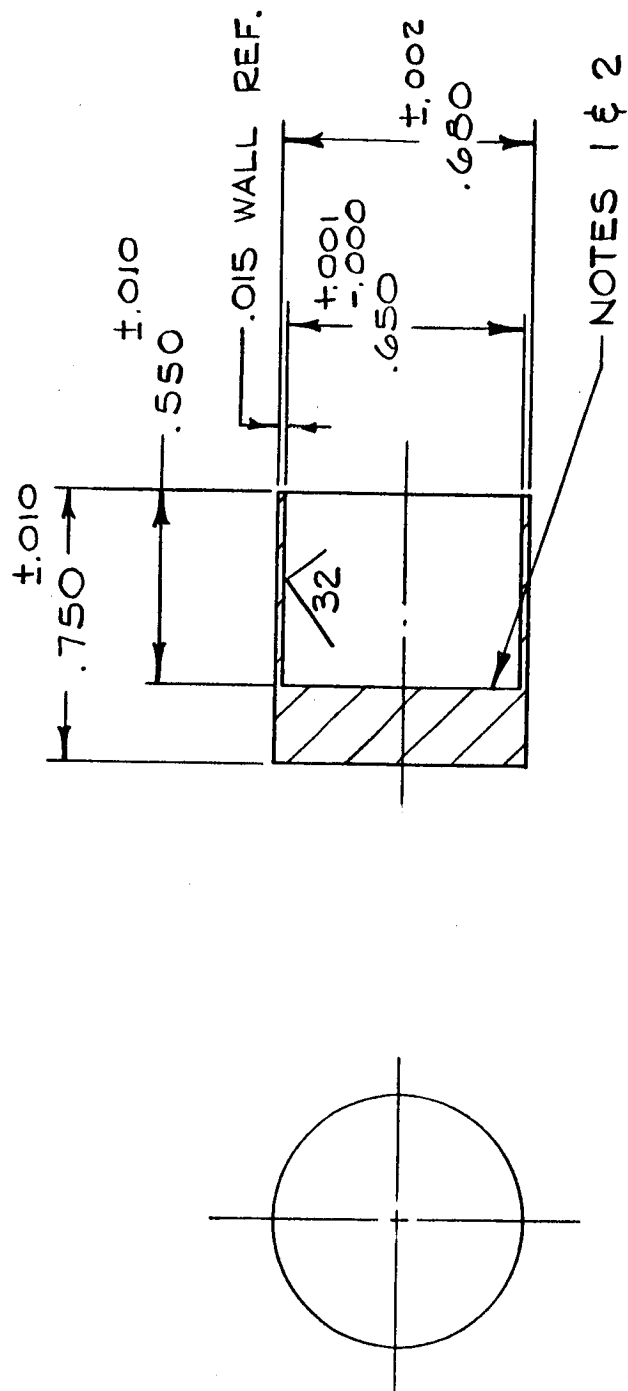
1.260 ±.010

+.000 -.001

EMITTER, ROLLED

344-2088

NOTES:

1. PART MUST BE VACUUM TIGHT.

EMITTER, BLANK

344-2089

NOTES:
1. THIS SURFACE TO HAVE A $\sqrt{16}$.
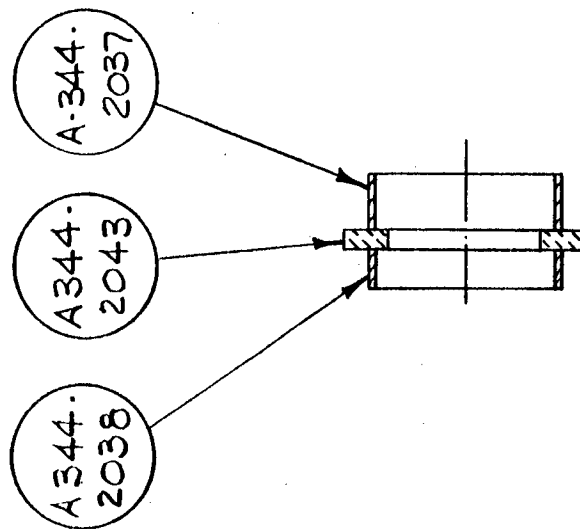2. THIS SURFACE TO BE PERPENDICULAR TO I.D. OF PART WITHIN .001.

(1) MOAT ±.001
.015 WIDE & DP.

.031 +.000/-.001

1.008 +.002/-.000

.658 +.001/-.000

.050

.150

.065

.005 ±

.020 ±.005

.681 +.002/-.000

.060 ±.002

1.050 ±.010

30°

(1) MOAT 1/16" DP. FROM O.D.

NOTES:
1. WASH W612.
2. FIRE – VACUUM 1200°C, FOR (10) MINS.
3. STORE IN CLEAN CONTAINER.

EMITTER SUPPORT

344-2030

STOCK.

$\frac{1}{2}"$

$1\frac{1}{2}"$

$\frac{15}{32}"$ R.

NOTES:
1. WASH W612.
2. STORE IN CLEAN CONTAINER.

EXTERNAL EMITTER LEAD

344-2048

A-344. 2037

A344. 2043

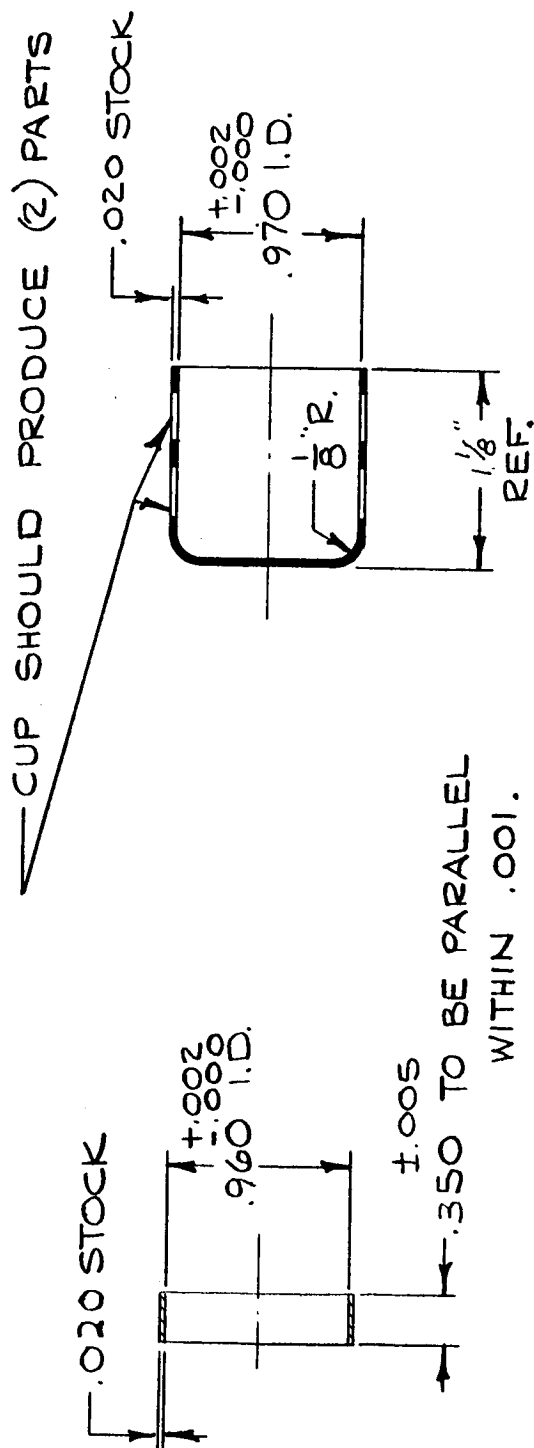A344. 2038

NOTES:
1. PLANE OF ENDS TO BE PARALLEL WITHIN .001.
2. WASH W412 ALL PARTS
3. BRAZE - COPPER
4. VACUUM
5. TEMPERATURE - 1100°C

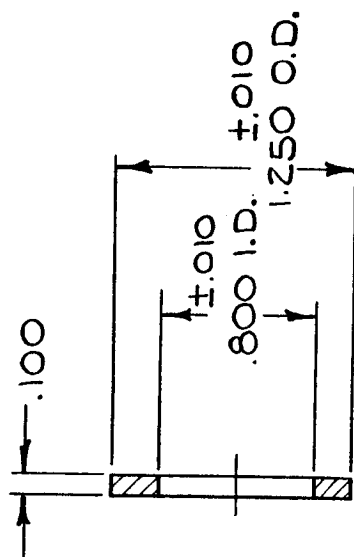CUP SHOULD PRODUCE (2) PARTS

.020 STOCK

.970 I.D. $+.002 -.000$

$\frac{1}{8}$ R.

$\frac{1}{8}$" REF.

.020 STOCK

.960 I.D. $+.002 -.001$

.350 ±.005 TO BE PARALLEL WITHIN .001.

NOTES:
1. WASH W612.
2. FIRE DRY H$_2$, 1020°C, FOR (10) MINS.
3. DULL NICKEL PLATE .0001-.0002, ALL OVER.
4. FIRE LINE H$_2$, 1020°C, FOR (10) MINS.
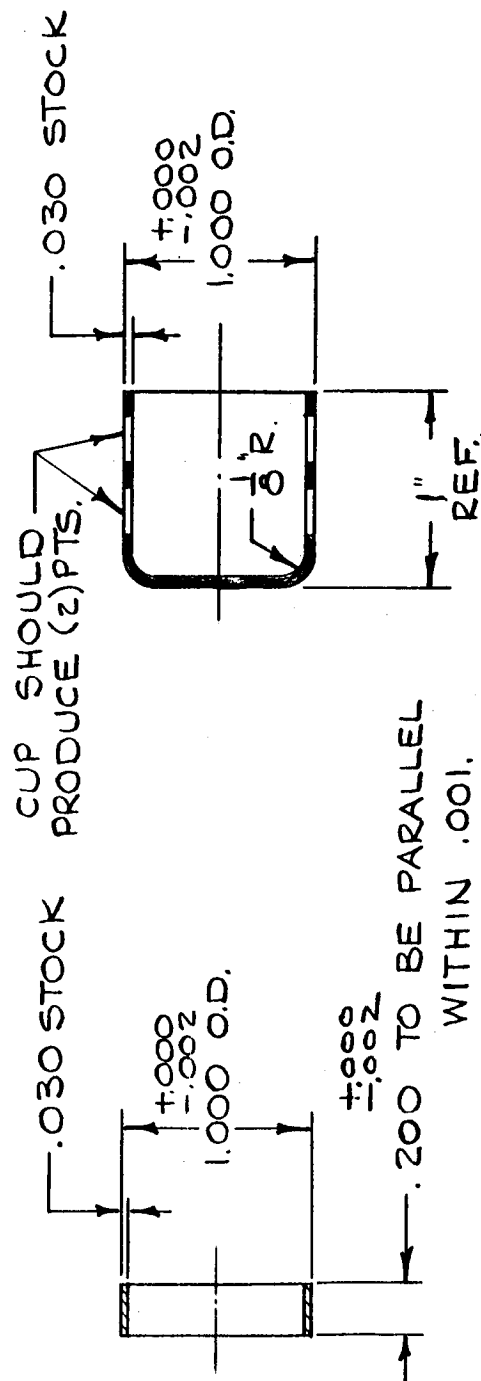5. STORE IN CLEAN CONTAINER.

ISOLATION RING, SMALL

344-2037

NOTE: METALIZE FULL (BOTH SIDES).

.100

.800 I.D. ±.010

1.250 O.D. ±.010

CERAMIC INSULATOR

344-2043

.030 STOCK

1.000 O.D. $^{+.000}_{-.002}$

CUP SHOULD
PRODUCE (2) PTS.

$\frac{1}{16}$" R.

1" REF.

.030 STOCK

1.000 O.D. $^{+.000}_{-.002}$

.200 $^{+.000}_{-.002}$ TO BE PARALLEL WITHIN .001.

STRAIN ISOLATION RING

344-2038

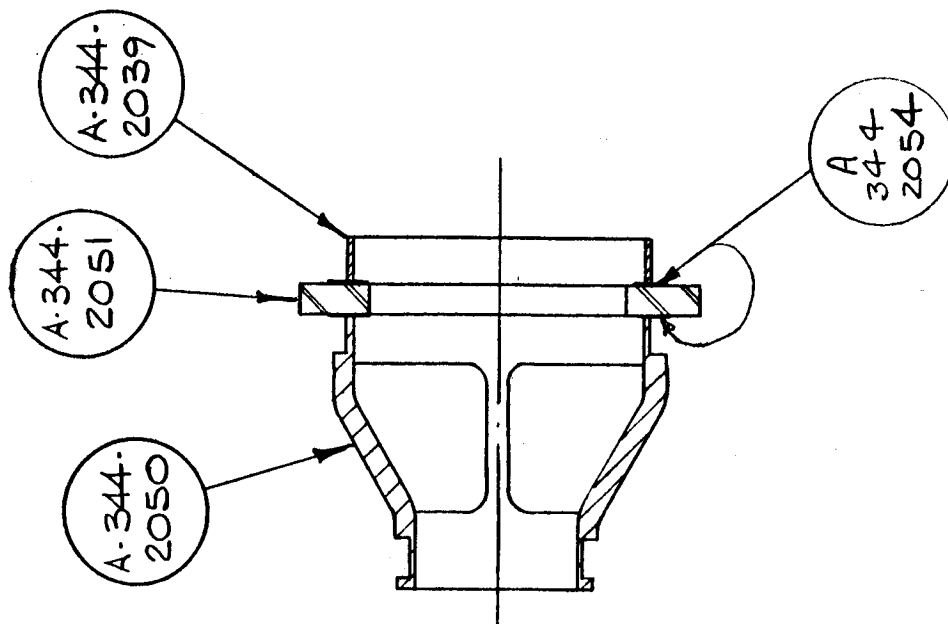NOTES:
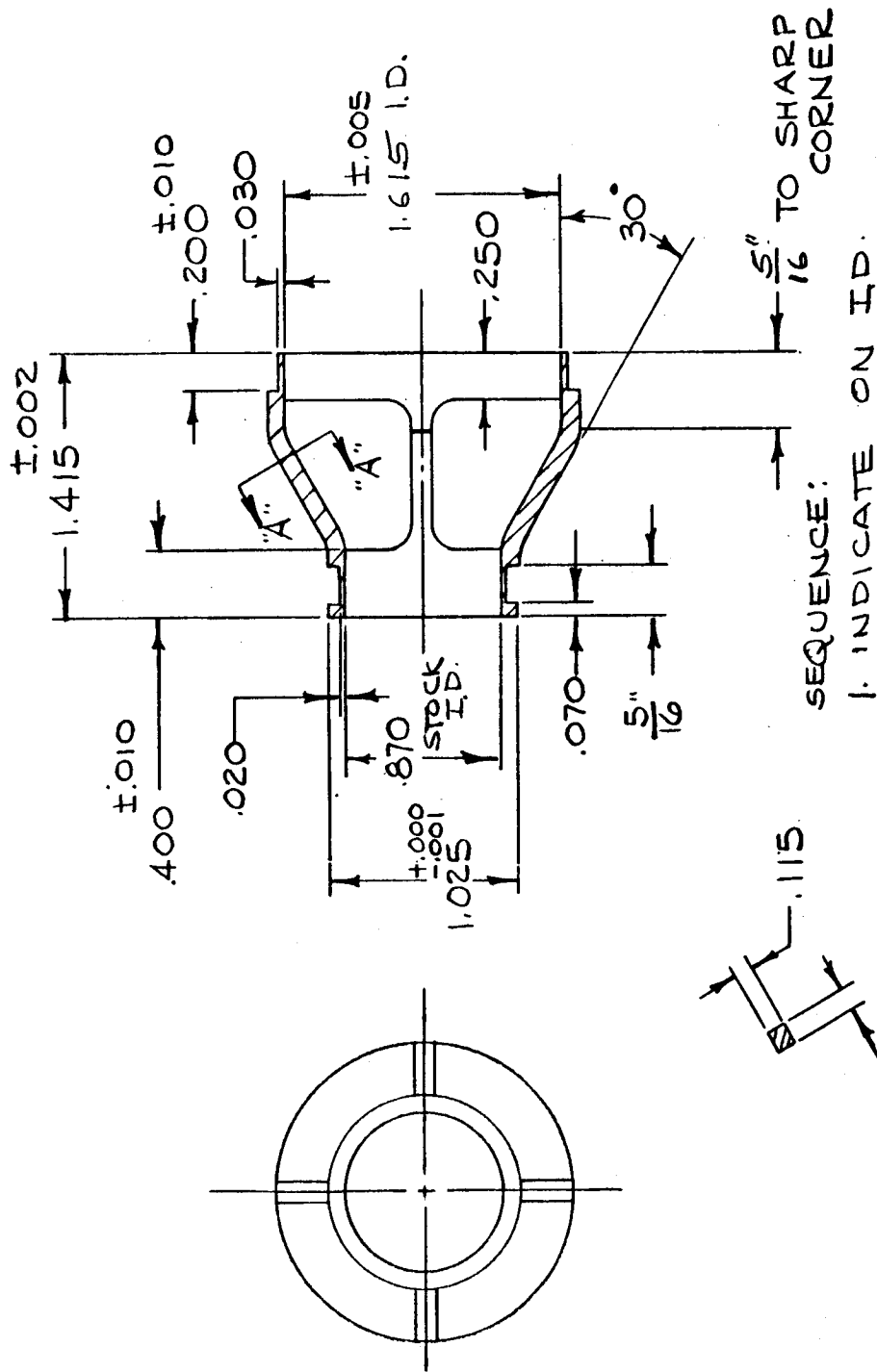
1. WASH W612.
2. FIRE DRY H₂, 1020°C, FOR (10) MINS.
3. DULL NICKEL PLATE .0001-.0002 ALL OVER.
4. FIRE LINE H₂, 1020°C, FOR (10) MINS.
5. STORE IN CLEAN CONTAINER.

A.344.2039

A.344.2051

A.344.2050

A 344 2054

BRAZE - COPPER
FURNACE - HYDROGEN
TIME AT TEMP. (   )
TEMPERATURE - 1100°C.

GENERATOR SUPPORT RING ASSEMBLY

344-2049

GENERATOR SUPPORT RING

344-2050

SECTION "A":"A"

Dimensions shown: ±.010 .200, .030, ±.005, 1.615 I.D., ±.002 1.415, ±.010 .400, .020, .870 STOCK I.D., 1.025 +.000 -.001, "A", .250, 30°, .070, $\frac{5"}{16}$, $\frac{5"}{16}$ TO SHARP CORNER, INDICATE ON I.D., .115, .090

SEQUENCE:
1. INDICATE ON I.D.
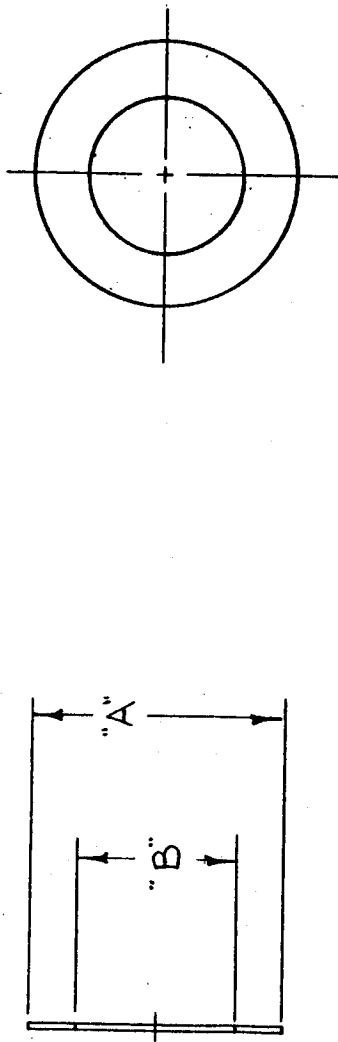2. FACE .010 TO .015" OFF LARGE END.
3. HOLD 1.415 BY FACING REMAINING MATERIAL OFF SMALL END.
4. FINISH MACHINE.

NOTES:
1. ALL RADII TO BE APPROX. $\frac{1"}{8}$.
2. WASH W612.
3. STORE IN CLEAN CONTAINER.
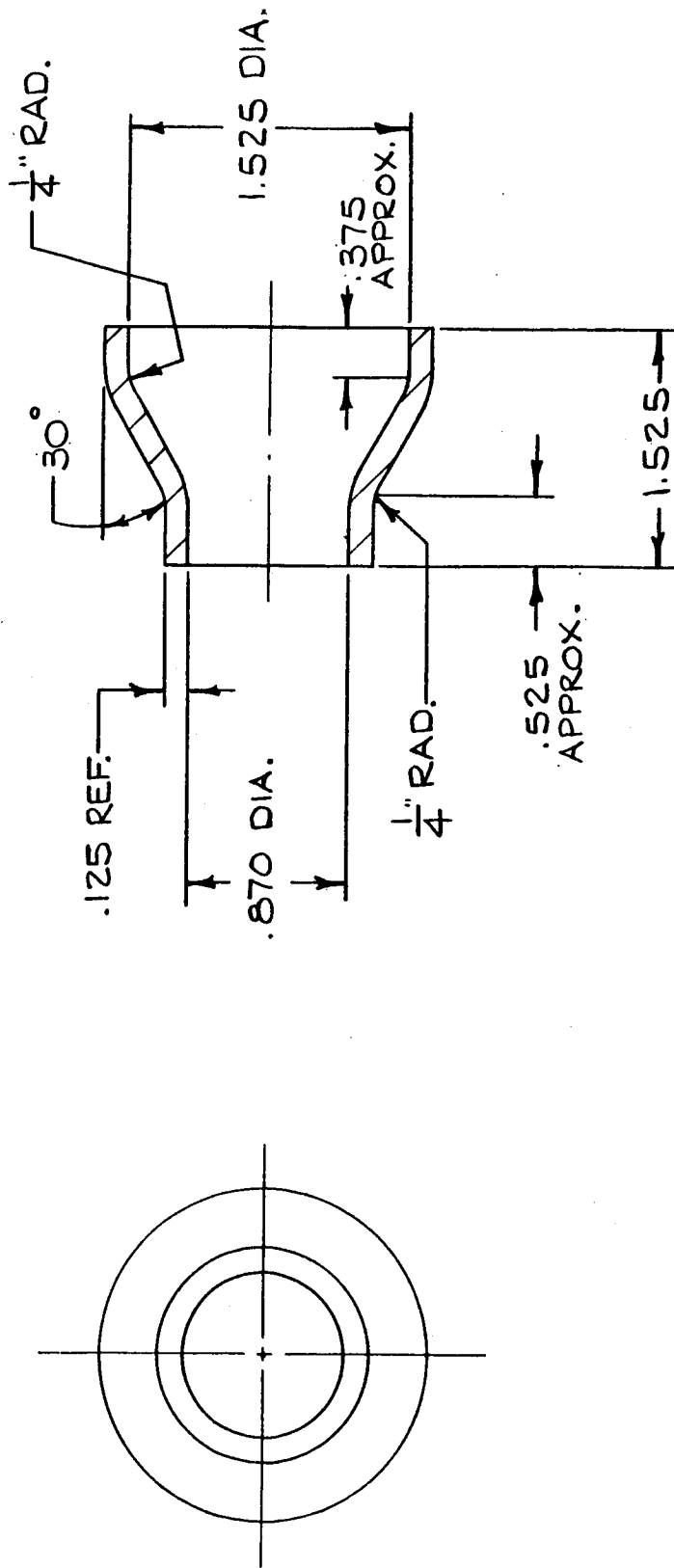
GENERATOR SUPPORT RING BLANK
344-2099

NOTES:

1. FIRE - HYDROGEN 1000°C TO STRESS RELIEVE.

PT.	"A"	"B"	TOOL #
2	2.100 ±.005	1.355 ±.005	37000-T8-29-1
1	1.250 ±.005	.800 ±.005	37000-T8-29-2

SOLDER WASHER
344-2054

NOTES:
1. WASH W612.
2. RINSE WITH ACETONE.
3. STORE WRAPPED IN KIMWIPES.

STRAIN ISOLATION RING, LARGE
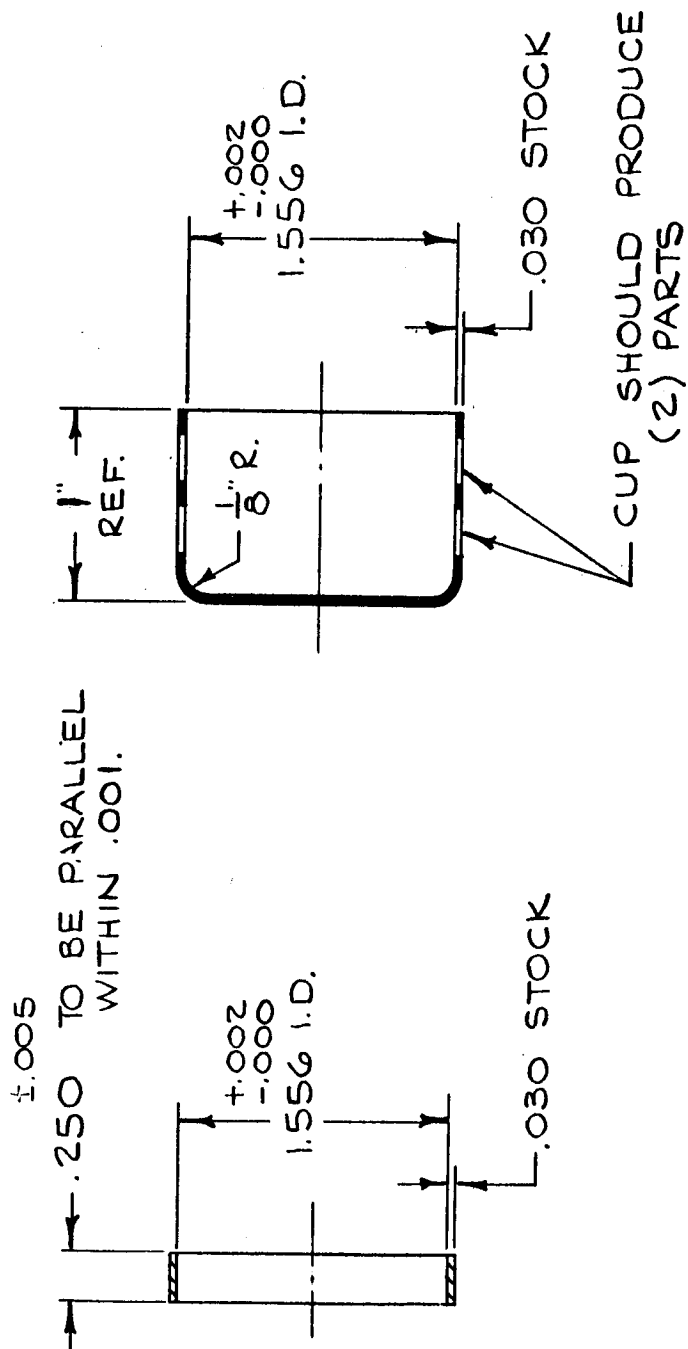
344-2039

1.556 I.D. +.002 -.000

.030 STOCK

CUP SHOULD PRODUCE (2) PARTS

$\frac{1}{8}$" R.

1" REF.

±.005

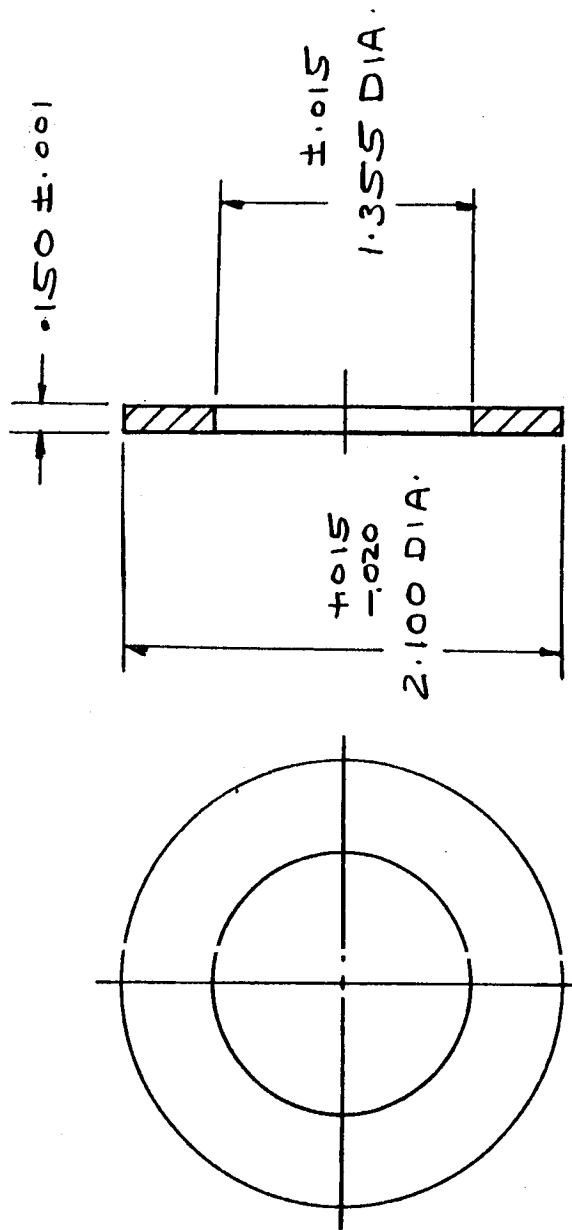.250 TO BE PARALLEL WITHIN .001.

1.556 I.D. +.002 -.000

.030 STOCK

NOTES:

1. WASH W612.

2. FIRE DRY H₂, 1020°C, FOR (10) MINS.

3. DULL NICKEL PLATE .0001-.0002 ALL OVER.

4. FIRE LINE H₂, 1020°C, FOR (10) MINS.

.150 ±.001

1.355 DIA. ±.015

1.020 +.015 DIA.

2.100 DIA.

NOTE:

METALIZE FULL (BOTH SIDES).

CERAMIC INSULATOR

344-2051

COLLECTOR ASSEMBLY - 344-2271

$\frac{3}{4}$ B.C.

.166 DIA. REF.

90°

135°

(2) $\frac{5}{32}$ DRILL X .600 DP. $\pm$.010
REDRILL .251 $^{+.001}_{-.000}$ DIA. X .280 DP.
REDRILL $\frac{3}{8}$" DIA. X .155 $\pm$.005 DP.

(1) $\frac{5}{32}$ DRILL X .400 DP. $\pm$.010
REDRILL .251 $^{+.001}_{-.000}$ DIA.
X .280 $\pm$.010 DP. $\pm$.005
REDRILL $\frac{3}{8}$" DIA. X .155 DP.

A-344-2101

A-344-2123-2

.500 DIA. $\pm$.010

1.700 DIA. $\pm$.005

1.202 DIA. $^{+.000}_{-.002}$

1.005 DIA. $\pm$.005

.030 $^{+.005}_{-.000}$

.155 $\pm$.005

30°

ENGR. SPEC.

2.100 $\pm$.005

.050

ENGR. SPEC.

.075

1.548 DIA. $^{+.000}_{-.002}$

.949 DIA. $^{+.000}_{-.002}$

.636 DIA. $^{+.000}_{-.001}$

.005

$\frac{3}{4}$

$\frac{1}{2}$

1.060 DIA. $\pm$.005

32

SEQUENCE:
1. MACHINE
2. WASH WG12.
3. DULL Ni PLATE .0001-.0002. COPPER ONLY
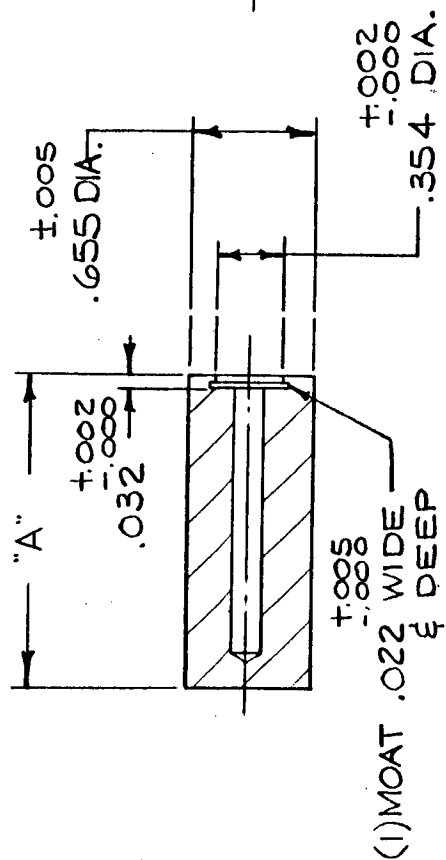4. FIRE - H₂ 750°C (10) MINS.
5. STORE IN CLEAN CONTAINER.

SEQUENCE:
1. MACHINE
2. WASH - W612.
3. FIRE - VACUUM 1200° TO 1500°C (5) MIN.
4. STORE IN CLEAN CONTAINER.

(1) HOLE #19 (.166) DIA.
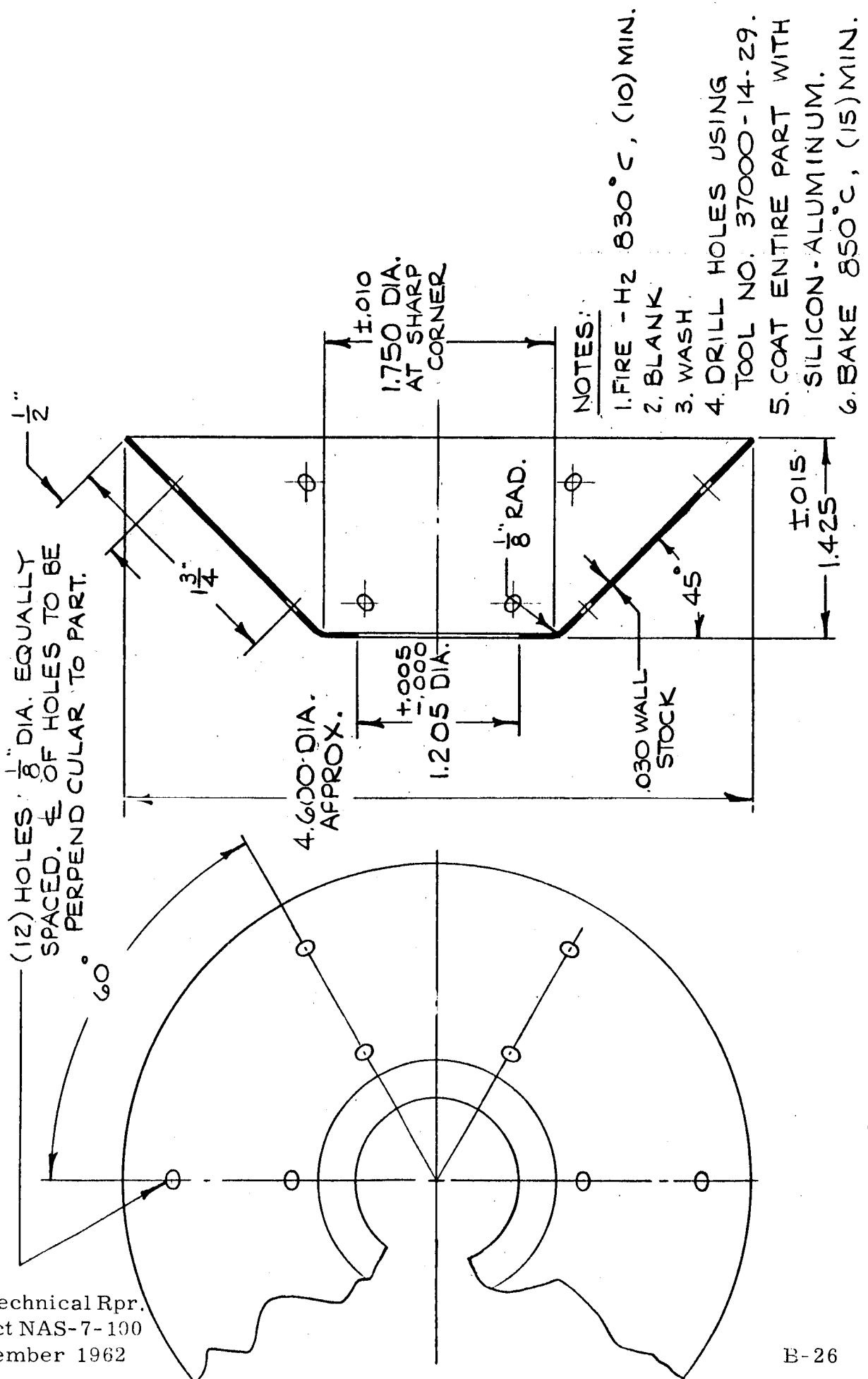X "B" DEEP TO POINT
OF DRILL.

.655 DIA. ±.005

.354 DIA. +.002 −.000

"A"

.032 +.002 −.000

(1) MOAT .022 WIDE
ξ DEEP +.005 −.000

COLLECTOR HEAD

344-2123

PT.	"A"	"B"	CATH. MAT'L.
1.	1.550 ±.003	1 3/8"	MOLY
2.	1.600 ±.003	1 3/8"	TANTALUM

COLLECTOR BASE

344-2101

1.700 DIA ±.005

1.202 DIA. +.002 -.002

.500 DIA. ±.010

.070 ±.010

30°

.155 ±.005

PLATE IN THIS DIM. ONLY. SEE NOTE 4.

.812 ±.010

.230 ±.010

.130 ±.005

.050 ±.010

.350 DIA. +.002 -.002

.250 DIA. +.002 -.002

.100 ±.005

.650 DIA. ±.010

.500 DIA. ±.010

#19 DRILL (.166) DIA. THRU

(4) HOLES: 1/16" DIA. EQUALLY SPACED THRU TO .500 ±.010 DIA. ONLY.

SEQUENCE
1. MACHINE
2. WASH W612.
3. FIRE - HYDROGEN 1020°C. (10)MIN.
4. PLATE - DULL Ni .0002-.0005 THK.
5. FIRE - SAME AS NOTE 3.
6. STORE IN CLEAN CONTAINER.

NOTES:
1. FIRE – H₂ 830°C, (10) MIN.
2. BLANK
3. WASH
4. DRILL HOLES USING TOOL NO. 37000-14-29.
5. COAT ENTIRE PART WITH SILICON-ALUMINUM.
6. BAKE 850°C, (15) MIN.

1.750 DIA. ±.010 AT SHARP CORNER

1.425 ±.015

⅛" RAD.

45°

.030 WALL STOCK

1.205 DIA. +.005 -.000

4.600 DIA. APPROX.

1¾"

½"

(12) HOLES ⅛" DIA. EQUALLY SPACED. ₵ OF HOLES TO BE PERPENDICULAR TO PART.

60°

COLLECTOR RADIATOR FIN
344-2100

B-26

COLLECTOR LEAD

344-2055

NOTES:

1. WASH WG12.
2. FIRE IN DRY OR LINE H_2 IC20°C, FOR (5) MINS.

EXHAUST LINE TUBING

344-2122

PEEN AT PROPER HEIGHT BEFORE BRAZING

CIRCULAR BEAD OF NICRO-BRAZE 30 PAST.

A 344 2045

A 344 2046

A 344 2044

.375 ±.010
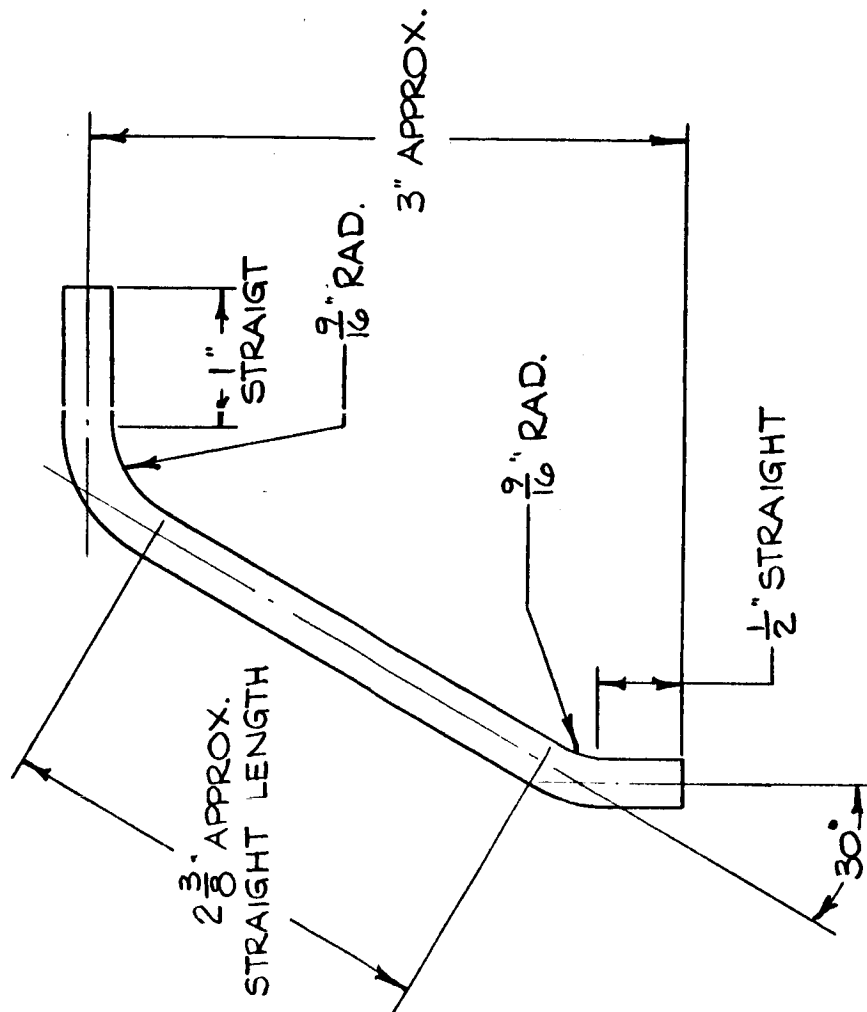
NOTE: MUST BE A VACUUM TIGHT ASSY.
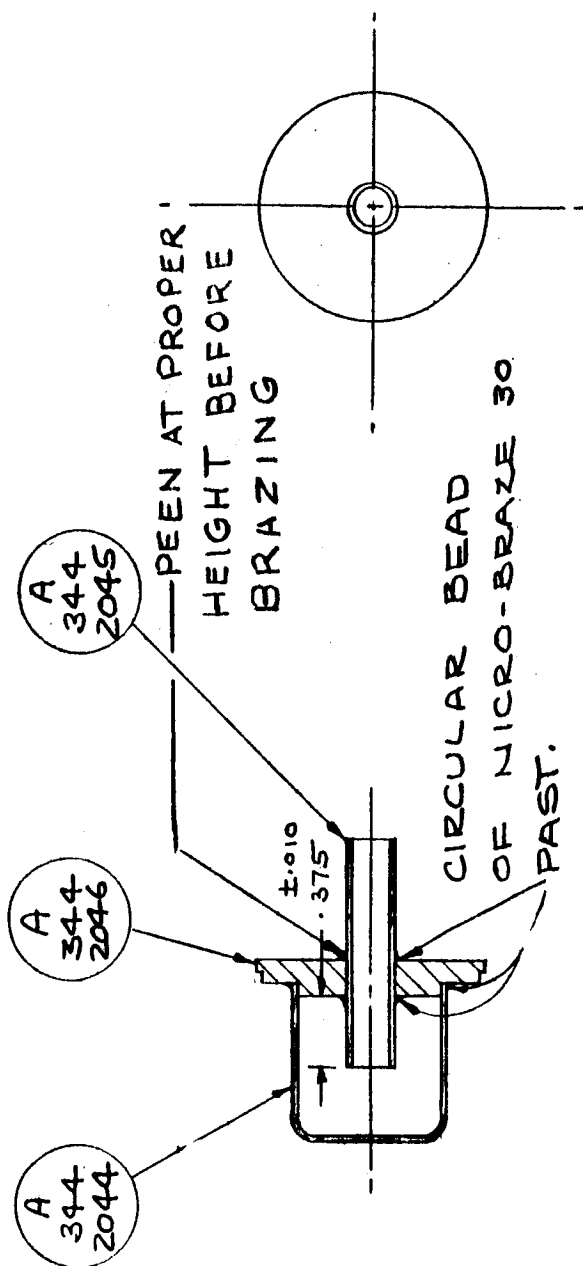
BRAZE - NICRO BRAZE 30.
FURNACE - VACUUM.
TIME AT TEM. - (   )
TEMPERATURE - 1135°C

CESIUM RESERVOIR ASSEMBLY

344-2047

CESIUM RESERVOIR CAP

344-2044

.800 ±.010

.750 +.005 -.000

3/32 R.

.030 STOCK

NOTES:

1. WASH WG12.

2. FIRE DRY H₂, 1100°C, FOR (5) MINS.

3. STORE IN CLEAN CONTAINER.

.100

.050

(1) .252 DIA. THRU $^{+.002}_{-.000}$

CESIUM RESERVOIR BASE

344-2046

$\frac{3"}{16}$

SHARP CORNERS

.748 $^{+.000}_{-.002}$

1.120 $^{+.000}_{-.005}$

$1\frac{3"}{16}$

NOTES:
1. WASH WG12.
2. FIRE DRY H₂, 1100°C, FOR (5)MINS.
3. STORE IN CLEAN CONTAINER.

.010 STOCK

$\frac{1}{4}"$ STOCK

$2\frac{5}{16}"$

NOTES:
1. WASH W612.
2. STORE IN CLEAN CONTAINER.

CESIUM RESERVOIR PIPE

344-2045

SPOTWELD
(4) TABS

A-344-
2071

.030 STOCK

$+.005$
$-.000$

1.125

$\frac{1}{4}$ RAD.

$\pm.010$

1.000

(4) HOLES - 90° APART
DRILL #36 (.106) DIA.
TAP #6-32

.900 ±.010

1.035 ±.005

1.300 ±.010

.125 ±.010

1.125 ±.010

EMITTER SHIELD

344-2270

(4) SLOTS : EQUALLY SPACED $\frac{1}{16}$ WIDE x DP. SHOWN

.625 DIA. $+.002 / -.000$

.740 DIA. $+.002 / -.000$

.925 $\pm.010$

.860 $\pm.010$

$\frac{3}{80}$

.030 MAX. RAD.

PINCH-OFF PROTECTOR SLEEVE

344-2225

(1) HOLE : .250 DIA ±.002

CUT APART - 180° APART
USING $\frac{1}{32}$ - $\frac{1}{16}$" WIDE
CUTTER.

.623 DIA. $^{+.000}_{-.002}$

.725 DIA. ±.005

$\frac{1}{4}$"

$\frac{1}{16}$"

PINCH-OFF PROTECTOR SPLIT RING

344-2226

(1) HOLE : DRILL #36 (.106) DIA. THRU COUNTERDRILL #23 (.154) DIA. × $\frac{1}{4}$" DP. TAP #6-32 × $\frac{1}{2}$" DP.

.250 $^{+.010}_{-.000}$
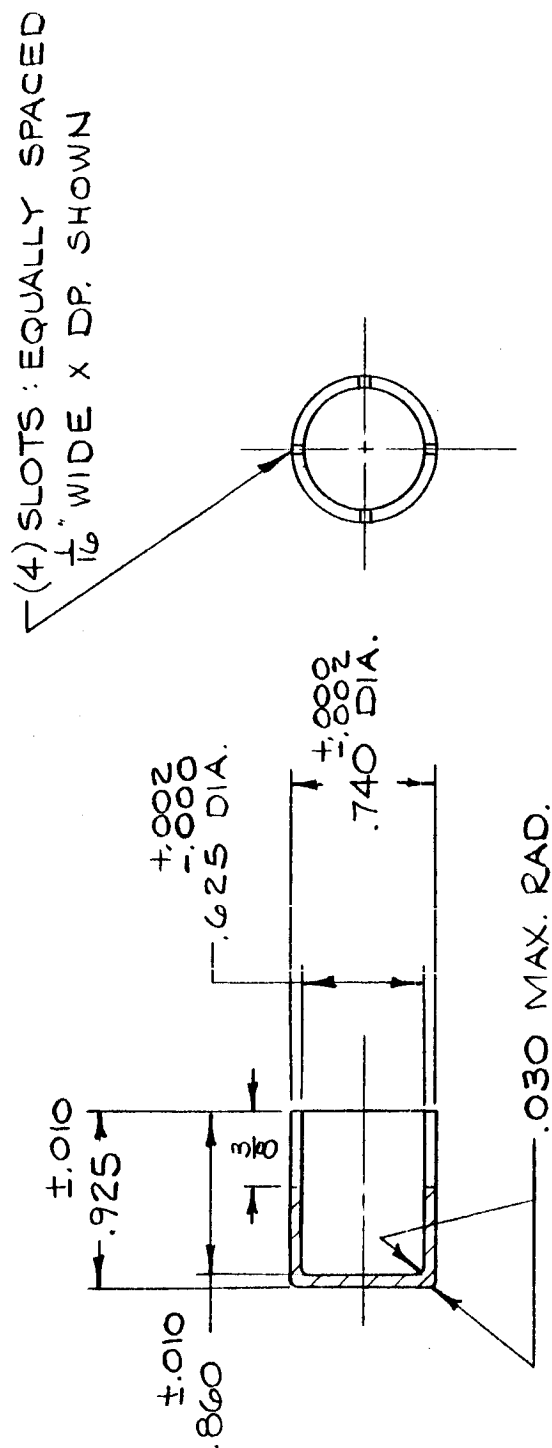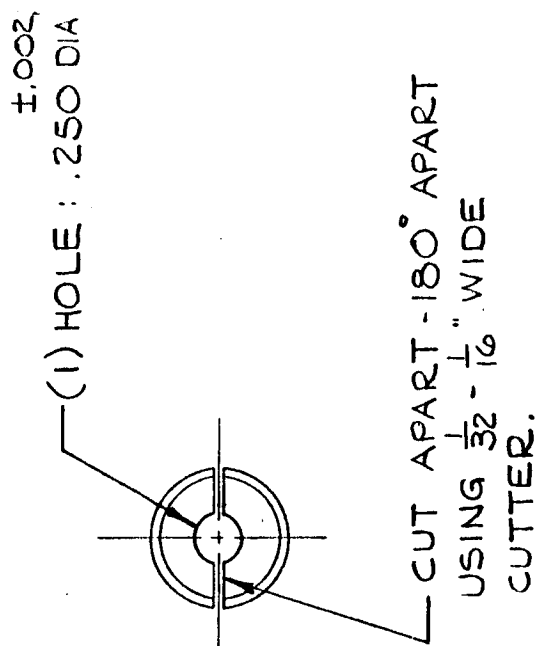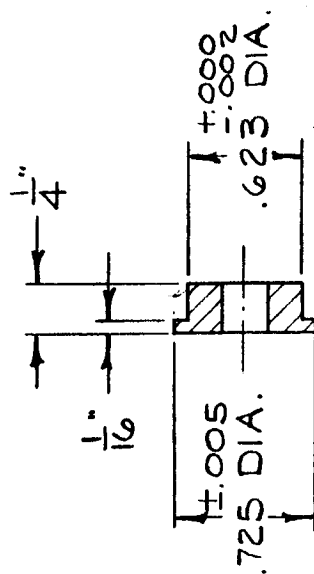
CUT APART ONE PLACE ONLY

(1) SLOT - $\frac{1}{32}$" - $\frac{1}{16}$" WIDE × .125 $\pm$.005 DP. FROM I.D.

.360 $^{+.000}_{-.010}$

$1\frac{1}{4}$" O.D.

.742 DIA. $^{+.002}_{-.000}$

$\frac{1}{8}$"

$\frac{1}{4}$"

PINCH-OFF PROTECTOR CLAMPING RING

344-2227

TEST BOTTLE A-14059
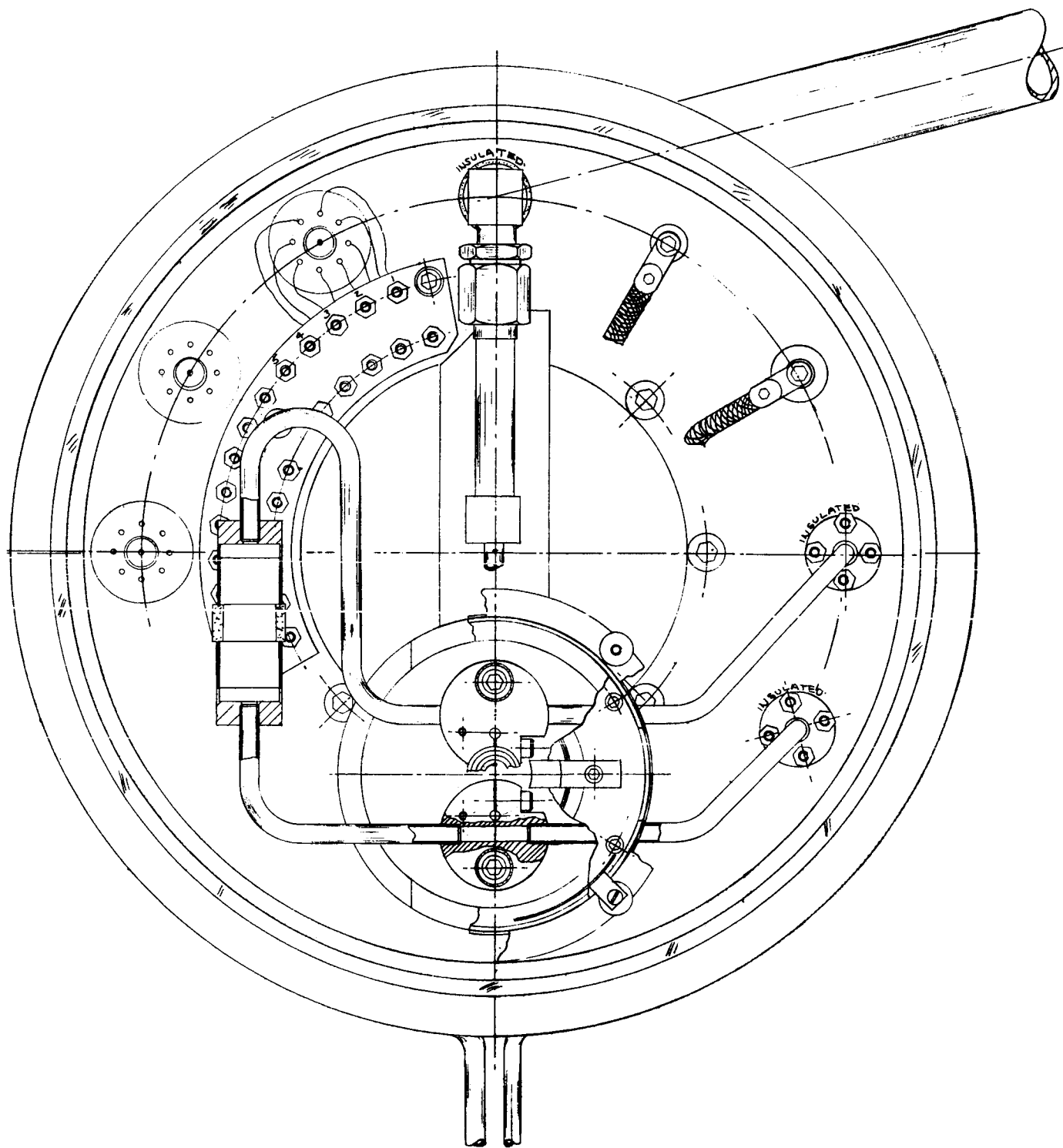
TEST BOTTLE B-14059
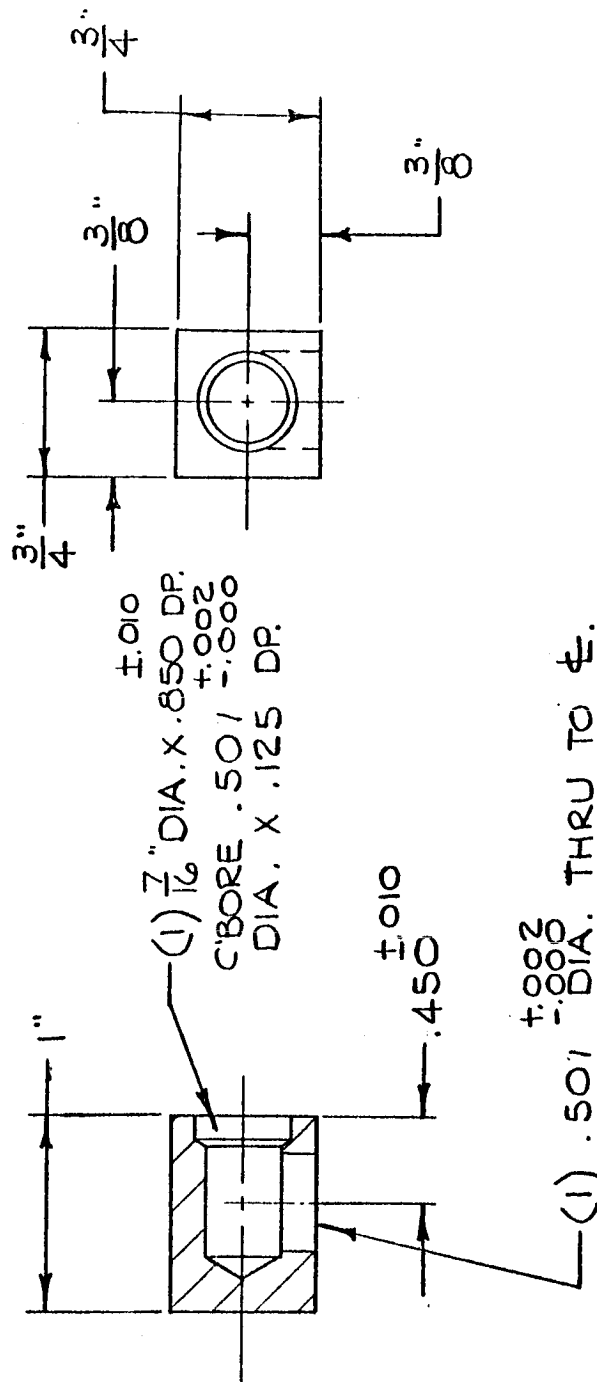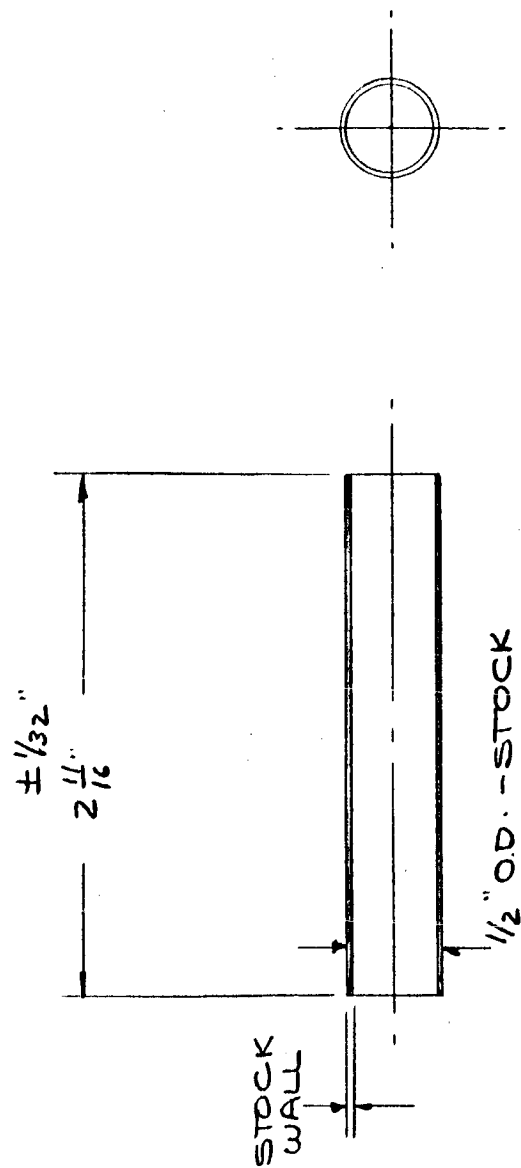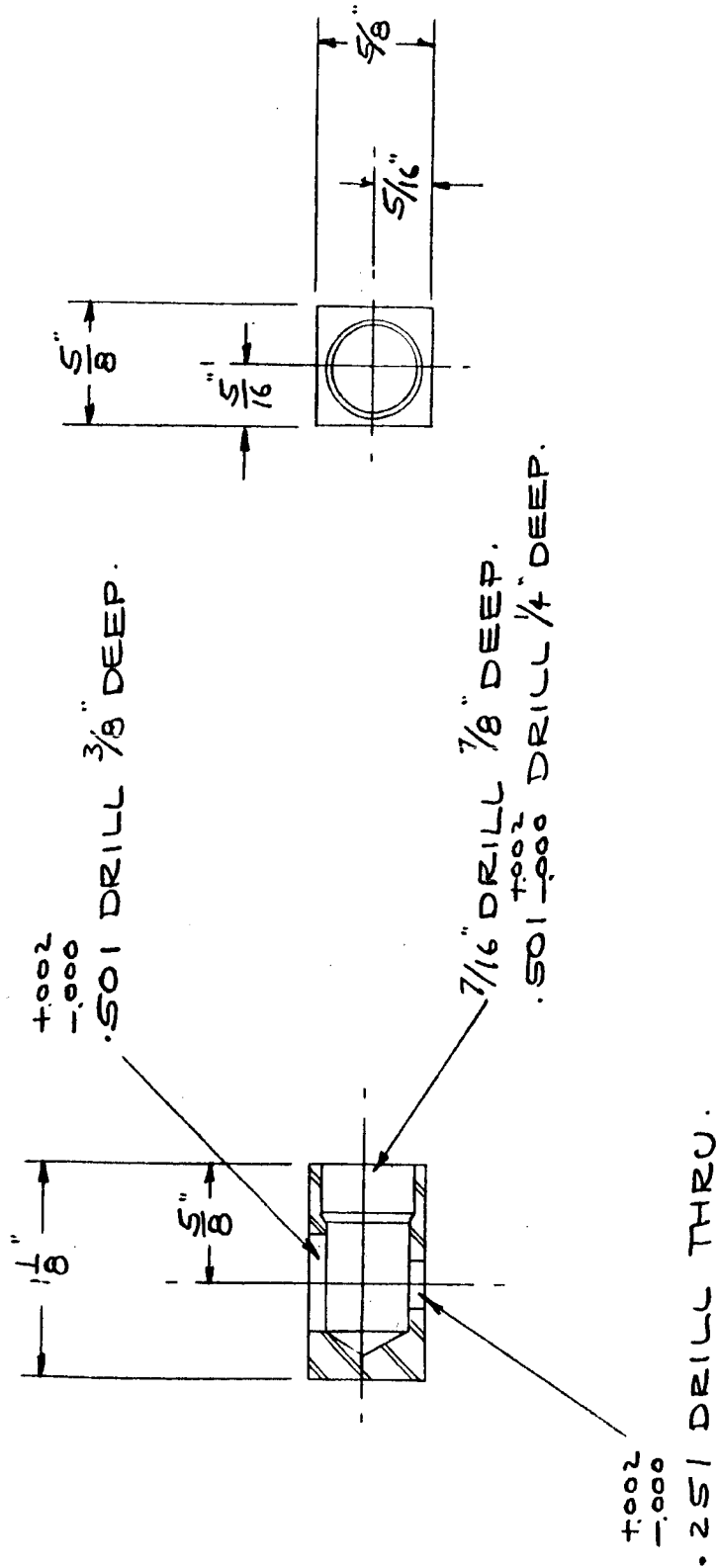
B-39B

CONNECTOR

14060

(1) $\frac{7}{16}$" DIA. x .850 DP.

C'BORE .501 $+.002 \atop -.000$ DIA. x .125 DP.

$\pm .010$

.450 $\pm .010$

(1) .501 $+.002 \atop -.000$ DIA. THRU TO ₵.

EXHAUST TUBING

14061

$\pm \frac{1}{32}''$

$2\frac{11}{16}''$

$\frac{1}{2}''$ O.D. - STOCK

STOCK WALL

5/8"

5/16"

5/8"

5/16"

EXHAUST JOINT

14062

.501 DRILL 3/8" DEEP.
+.002
-.000

7/16" DRILL 7/8" DEEP.

.501 +.002 DRILL 1/4" DEEP.
-.000

1/8"

5/8"

.251 DRILL THRU.
+.002
-.000

CESIUM TUBING

14063

± ¼"

7 ½"

STOCK O.D.

⅟₈ WALL.

MOUNT BAR
14064

Dimensions (as labeled):
- 3/4"
- 3/16"
- 3/4"
- 1/2" STOCK.
- 30°
- 1 1/2"
- 3/4"
- 5 5/8"
- 7 1/4"
- (2) 21/64" DRILL THRU.

INSULATOR ADAPTOR

14065

$\frac{3}{4}$" DRILL × $\frac{1}{4}$" DP.

.875 DIA. ±.005

.800 DIA. ±.002

$\frac{1}{16}$"

$13\frac{1}{16}$"

$\frac{7}{16}$" DRILL THRU.
.501 ±.002 DIA.
CT. BR. 1/8" DEEP.

STOCK WALL

½" O.D. - STOCK

4"
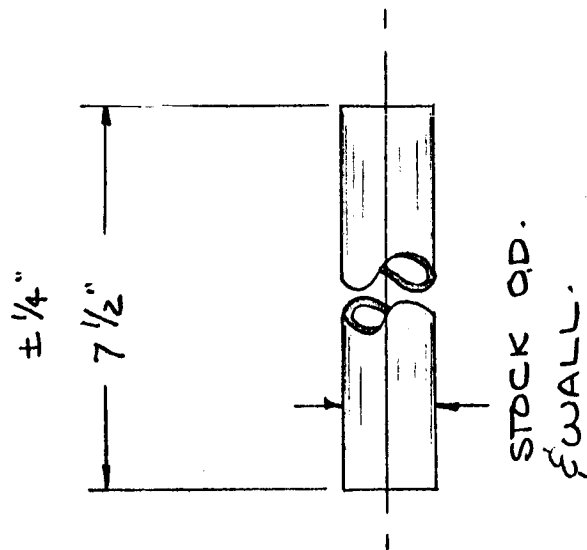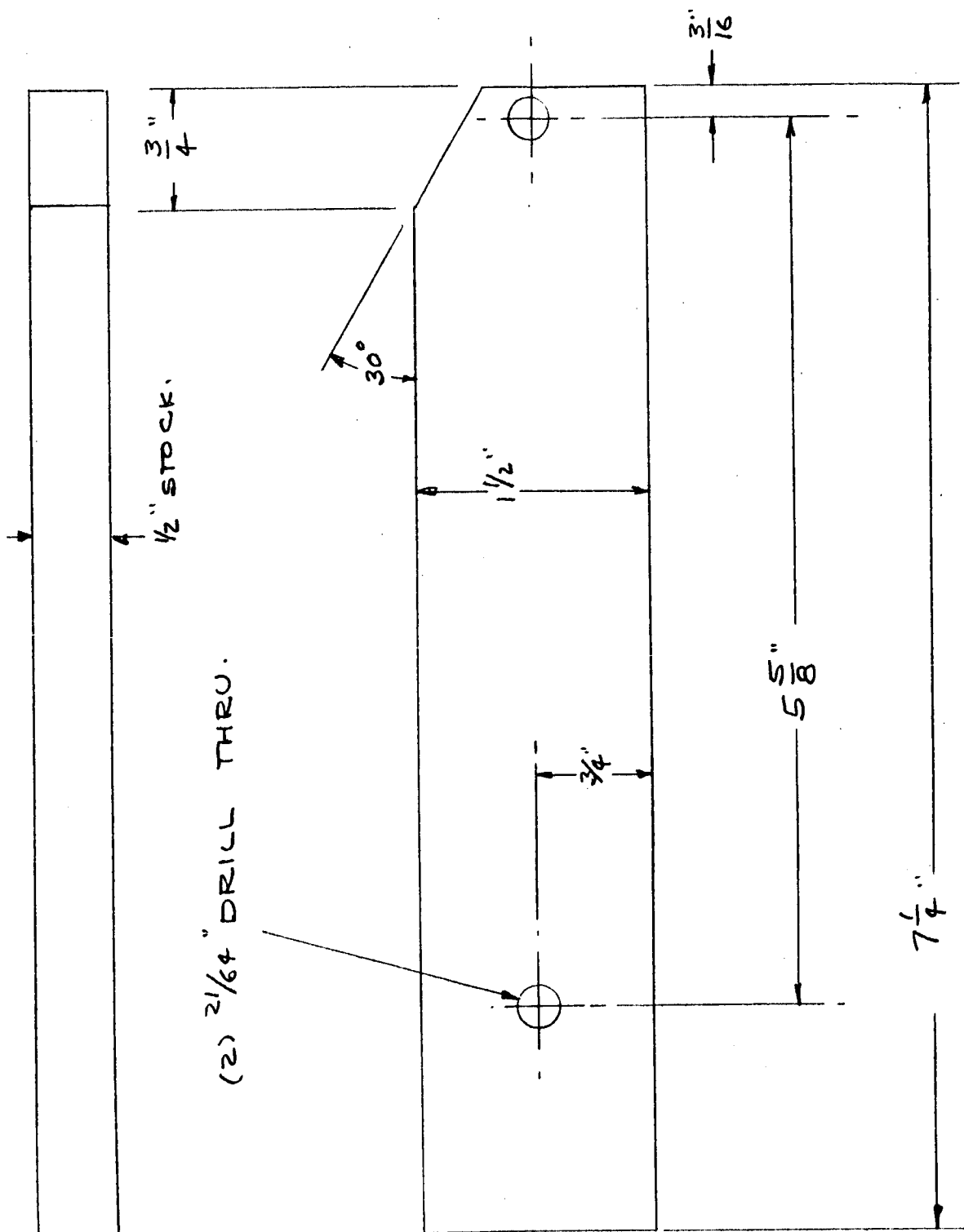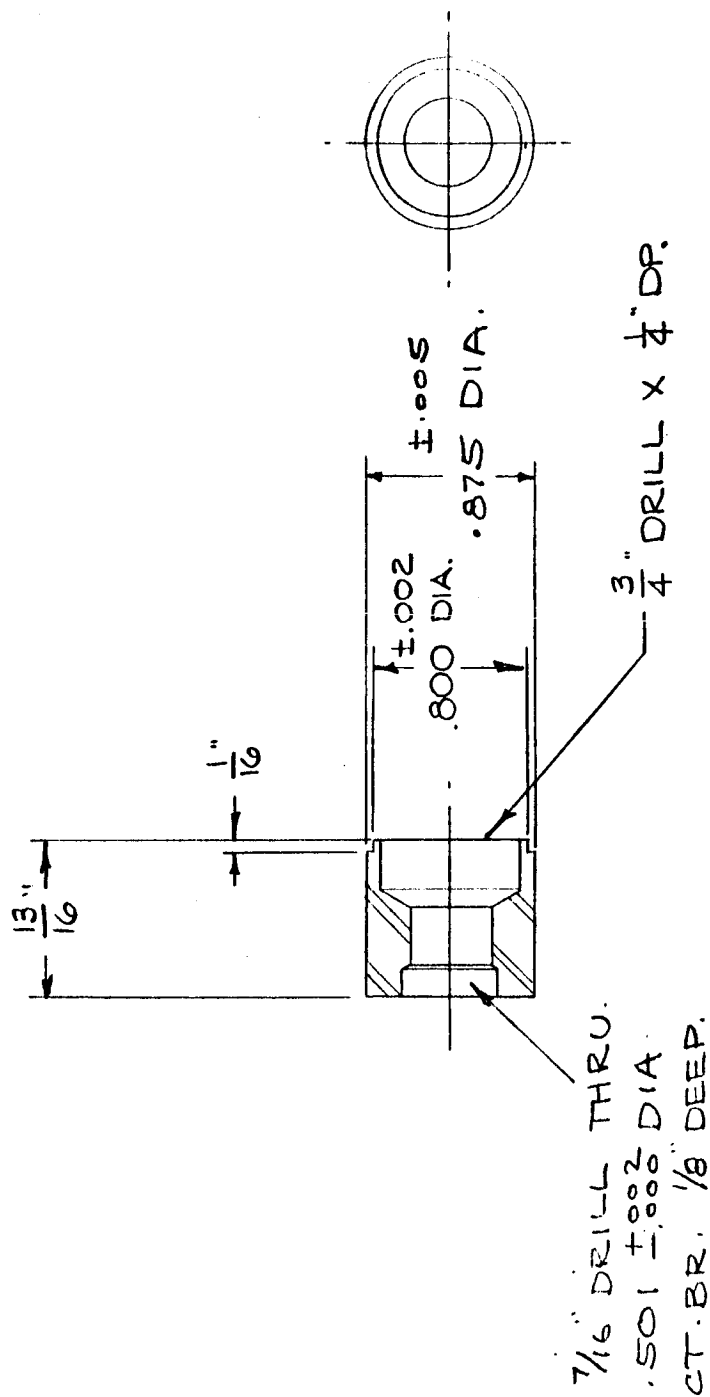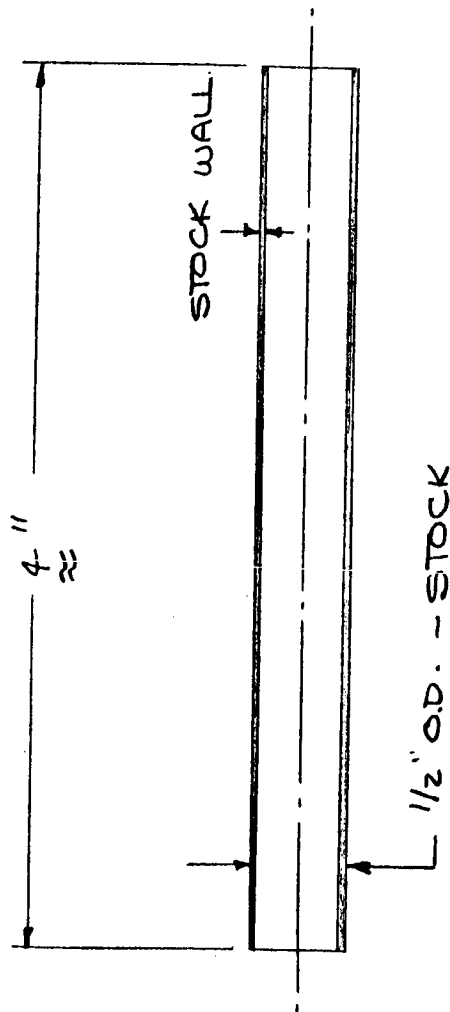
EXHAUST LINE

14066

BOTTLE GASKET

14067

¼" - STOCK

13" O.D.

11 ⅛" I.D.

BASE PLATE

14068
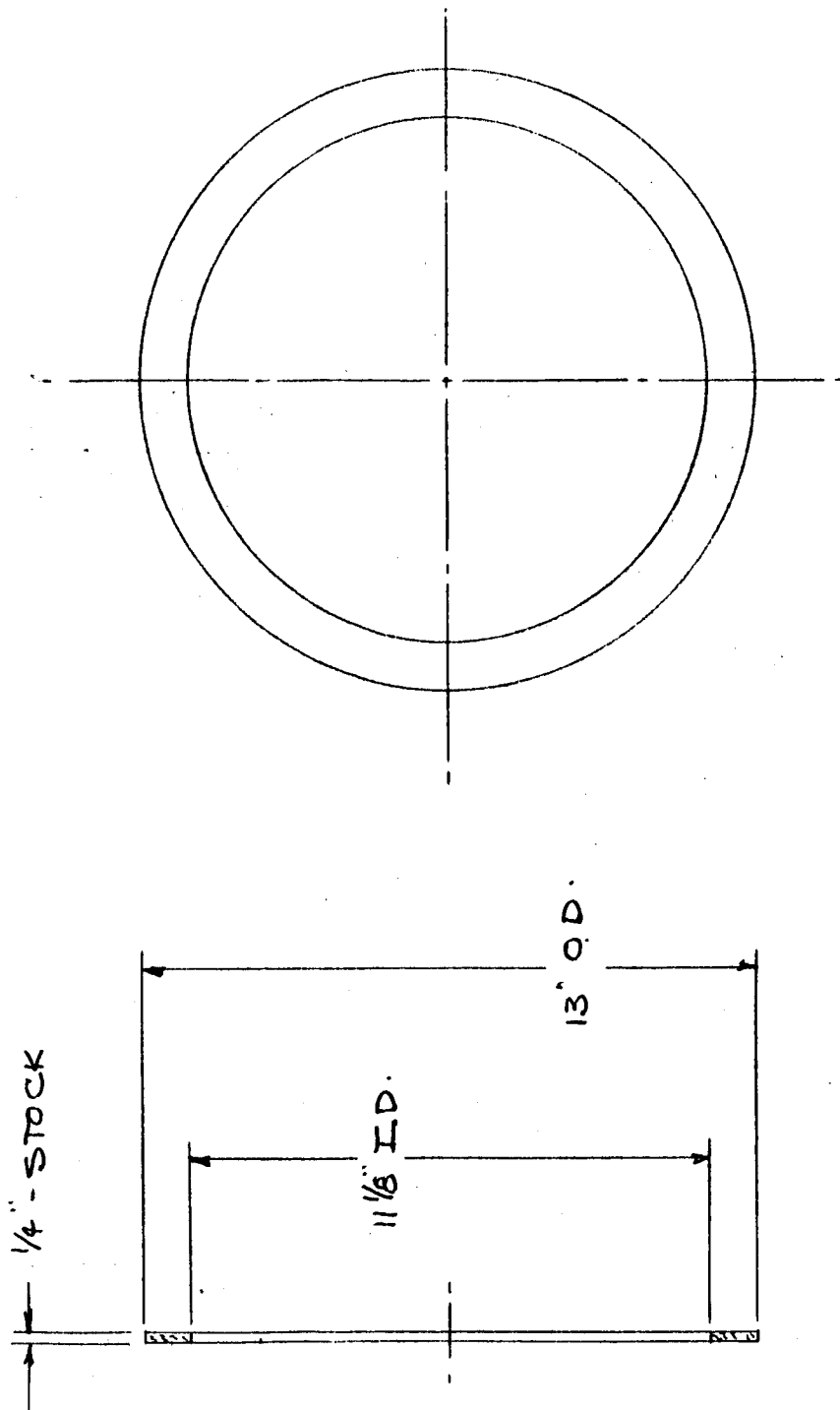
NOTE: FUSION ARC WELD INTO A-14070. ENTIRE ASSY. MUST BE VACUUM TIGHT.

1" DIA. OR STOCK

23/32" DRILL THRU. 1/2"-14 N.P.T. 3/4" DEEP. ± 1/16".

ION GAUGE ADAPTOR

14069

.990 DIA. $^{+.000}_{-.002}$

1"

x 1/2"

STOCK (BOTH PCS.)

.065 STOCK WALL (BOTH PCS.)

7"

FUSION ARC WELD—TO BE VACUUM TIGHT
((TO BE DONE IN DEPT. 95E))

1"

45°

45°

$1\frac{1}{4}$"

$.992$ DIA. BORE.
$\begin{array}{l}+.002\\-.000\end{array}$

$1\frac{1}{2}$"
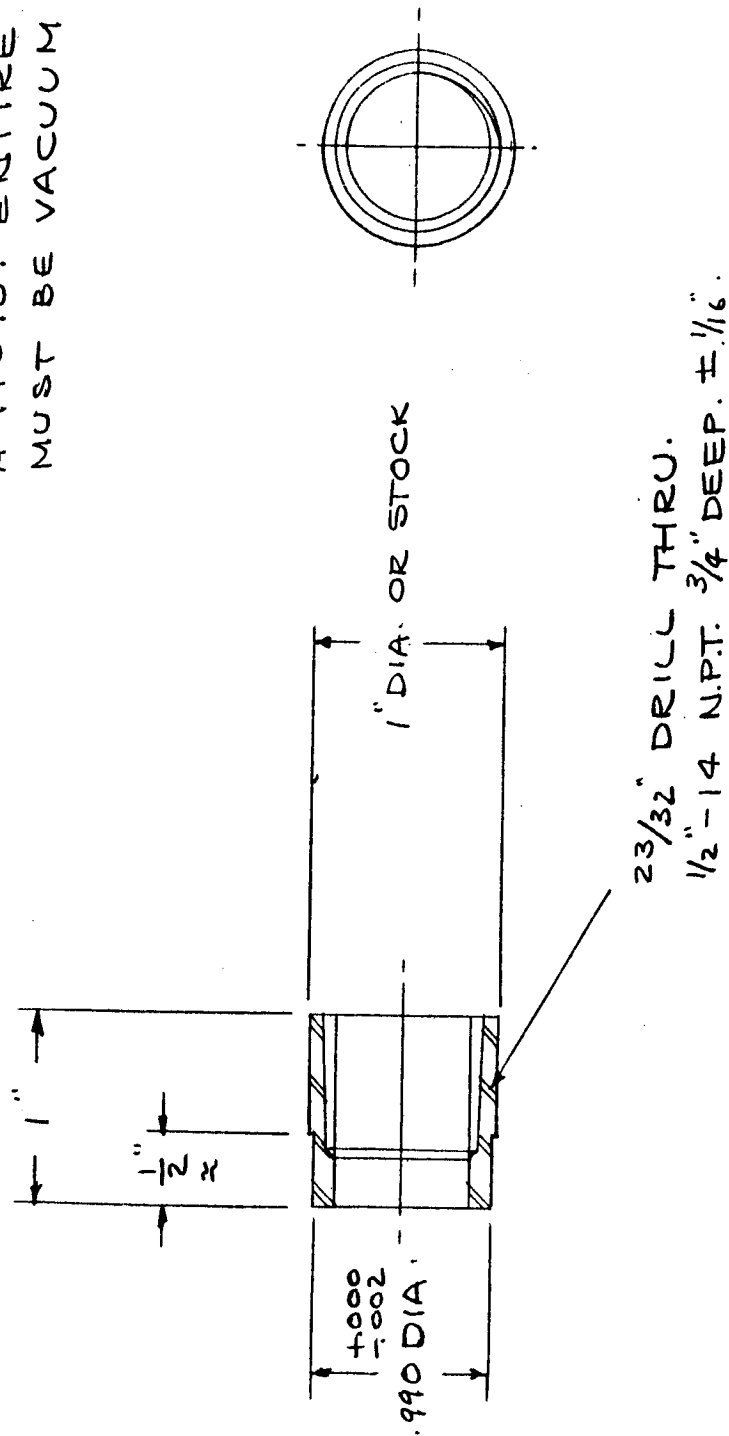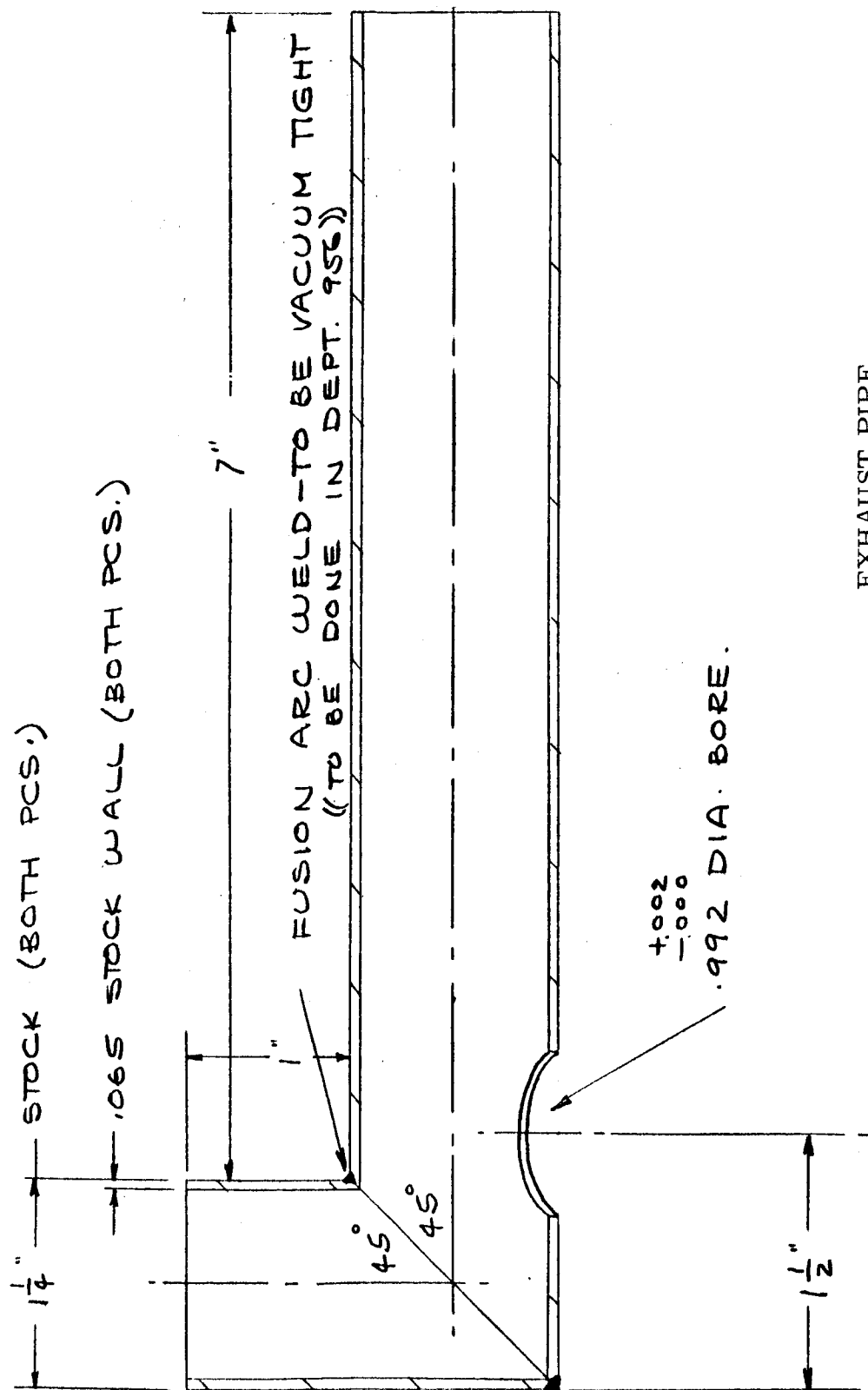
EXHAUST PIPE

14070

CONVERTER CONNECTOR

14071

CLAMP

14072

ON 2¾" DIA. B.C.
(6) #16 (.177) DRILL
THRU. EQ. SP'ED.

ALL (6) PARTS.

3½" DIA.

3¼" DIA.

1⅜" DIA.

⅛" TO 5/32" RAD.

.305 ±.005

.060 / .070

7/16"

1/32"

8°

1.000 ±.005 .912 DIA.

11/16" DIA.

60°

CUT (6) EQUAL PIECES FROM CIRCULAR PART AS SHOWN

3/16"

3/8"

4¼" DIA.

3⅝" DIA

2.000 DIA. $^{+.001}_{-.000}$

½"

1/16" TO 1/8" RAD.

1/16"

±1/16 7/16" DIA. 2"

2.065 DIA. ±.005

1/8"

NOTE:
SEE A-14093 FOR FINISH MACHINE DIMENSIONS.

SEAT MOUNT

14073

SEAT
14074

1.999 DIA. +0.000 / -0.001

⅛"

7/16"

1.934 DIA. ±0.005

1/16" TO ⅛" RAD.
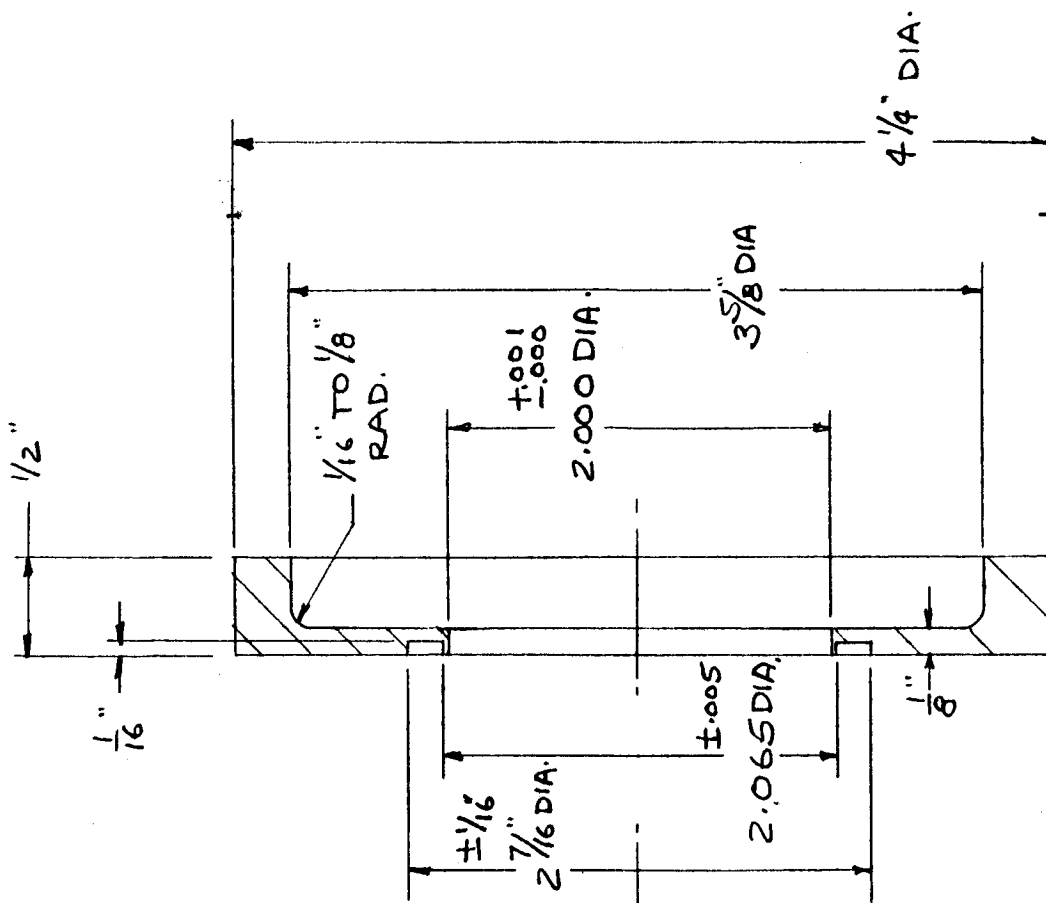
5/8" HOLE

NOTE: SEE A-14093 FOR FINISH MACHINE DIMENSIONS.

Final Technical Report
Contract NAS-7-100
18 December 1962

B-54

(2) #26 (.147) DRILL

7/16

9/16

1 1/8

HEAT SHIELD ASSEMBLY

14077

NI.

(3) INNER SHIELDS ARE TA.

1 3/4" DIA.

1/8 Ø.

7/8 Ø.

1 Ø.

1"

3/4"

1/4 DIA.

SPOT WELD (4) CYLINDERS TOGETHER WITH LITTLE U-SHAPED PIECES OF TA. (8) BETWEEN EACH CYLINDER ON EACH END.

ELECTRON BOMBARDMENT HEATER

14078

OVERALL LENGTH $1\frac{3}{8}$

$\frac{3}{8}$ CENTER TO CENTER

.030

TUNGSTEN.
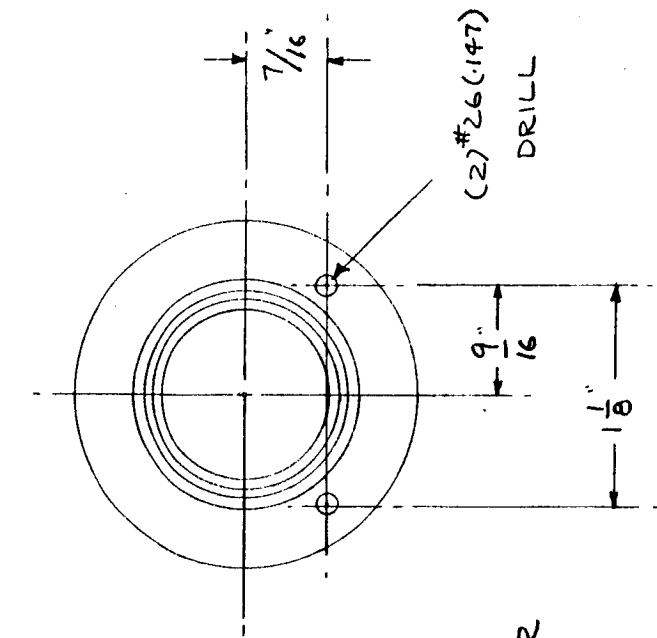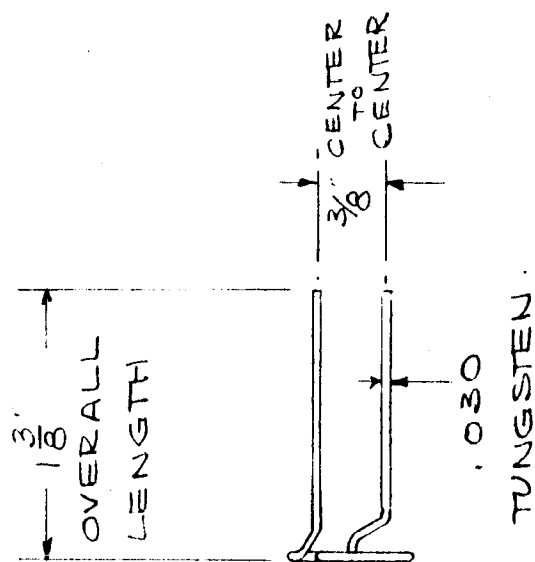
SPIRAL CONTAINING (2) COMPLETE TURNS. FROM START TO FINISH.

$\frac{1}{16}$ GAP

$1.020 \begin{smallmatrix}+.000\\-.000\end{smallmatrix}$ O.D.

.725 O.D.

HEATER TERMINAL

14079

37000-29

CYLINDER

14080

25°

25°

2 1/4"

1 1/8"

±.005
ON 3.937 DIA. B.C.
(4) #36(.1065)
DRILL 1/2" DEEP
6-32 TAP 3/8"
DEEP.

BREAK SHARP EDGE

CAN BE SHARP CORNERS

1"

2 1/2"

1"

1/2"

UNDERCUT FACE ONLY

+.000 -.005
4.220 DIA.

1/4"

5/8"

4 1/4" O.D. TO 4 3/8" O.D.

+.003 -.000
4.125 DIA.

±.005
ON 3.875 DIA. B.C.
(3) #36(.1065) DRILL 1/2"
DEEP. 6-32 TAP 3/8" DEEP.

3.500 I.D.

120°
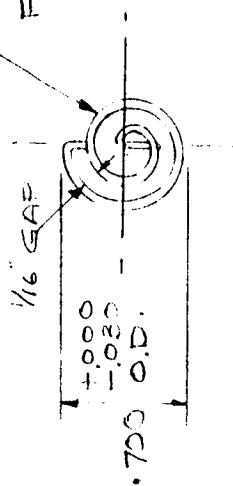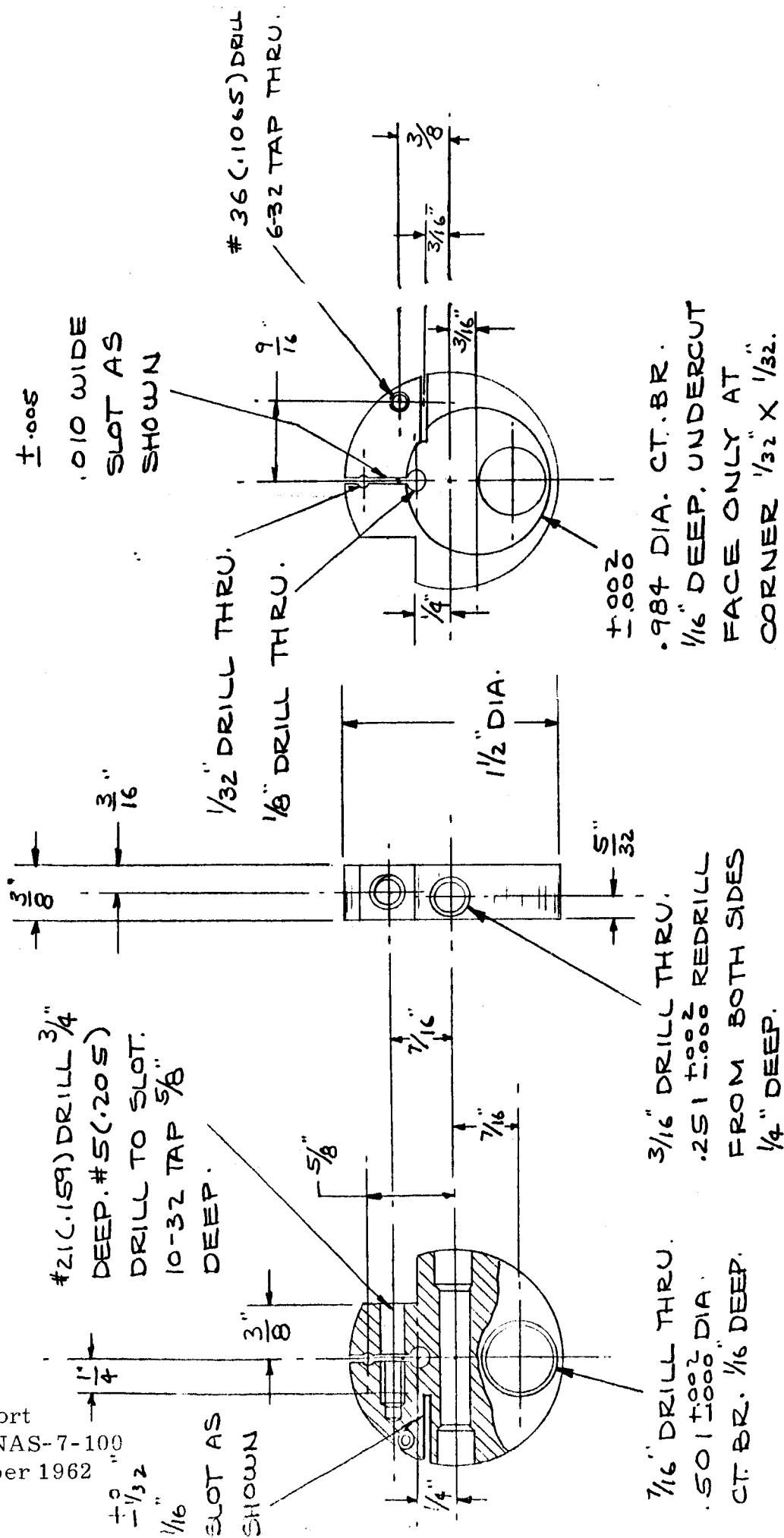
NOTE TACK WELD THIS PART ON BOTTOM OF PART N°
B-14081 AS SHOWN.

PART N° B-14081
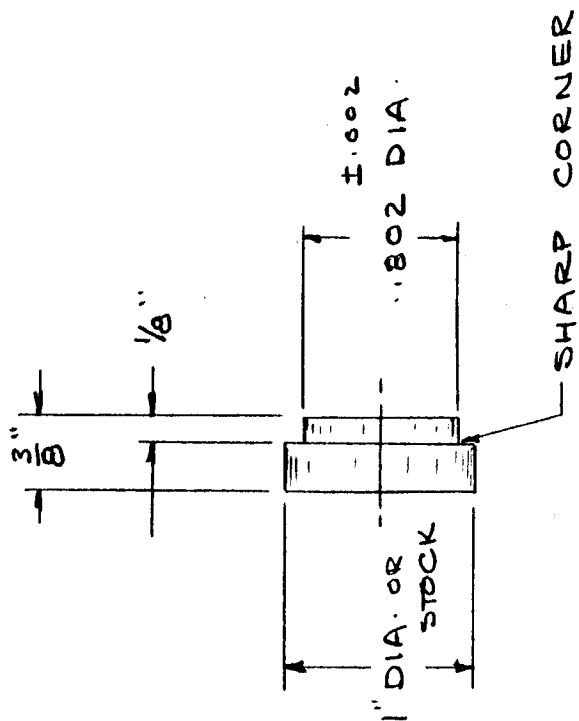
$\frac{1}{32}$" TO $\frac{1}{16}$" RAD.

2" ± $\frac{1}{16}$"

$\frac{1}{8}$"

1.437 DIA $^{+.000}_{-.002}$

$1\frac{1}{4}$" OR LESS I.D. - STOCK.

$1\frac{1}{2}$" O.D.

BEARING
14082

BEARING MOUNT

14083

.376 THRU. $\pm{}^{.002}_{.000}$

HEATER WATER TERMINAL

14084

.802 DIA. $\pm .002$

SHARP CORNER

¹⁄₈"

³⁄₈"

1" DIA. OR STOCK

BREAK SHARP
EDGE - BOTH
ENDS.

3/8"-16 THREAD.

$1\frac{1}{2}$"

THREADED
LENGTH

3/8" DIA.
STOCK

$9"$ $\pm\frac{1}{16}"$

#21(.159) DRILL 3/4" DEEP.
10-32 TAP 5/8" DEEP.

COLLECTOR TERMINAL

14085

BREAK SHARP. EDGE BOTH ENDS

2" THREADED LENGTH

1/2" – 13 THREAD.

1/2" DIA. STOCK.

#21 (.159) DRILL 3/4" DEEP.
10 – 32 TAP. 5/8" DEEP.

7" ± 1/16"
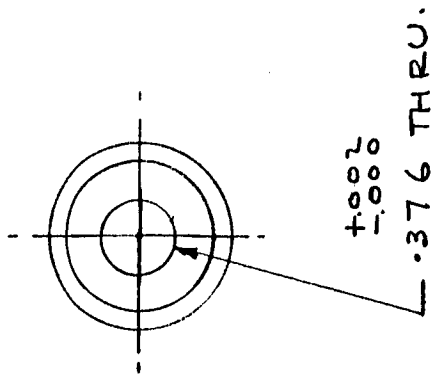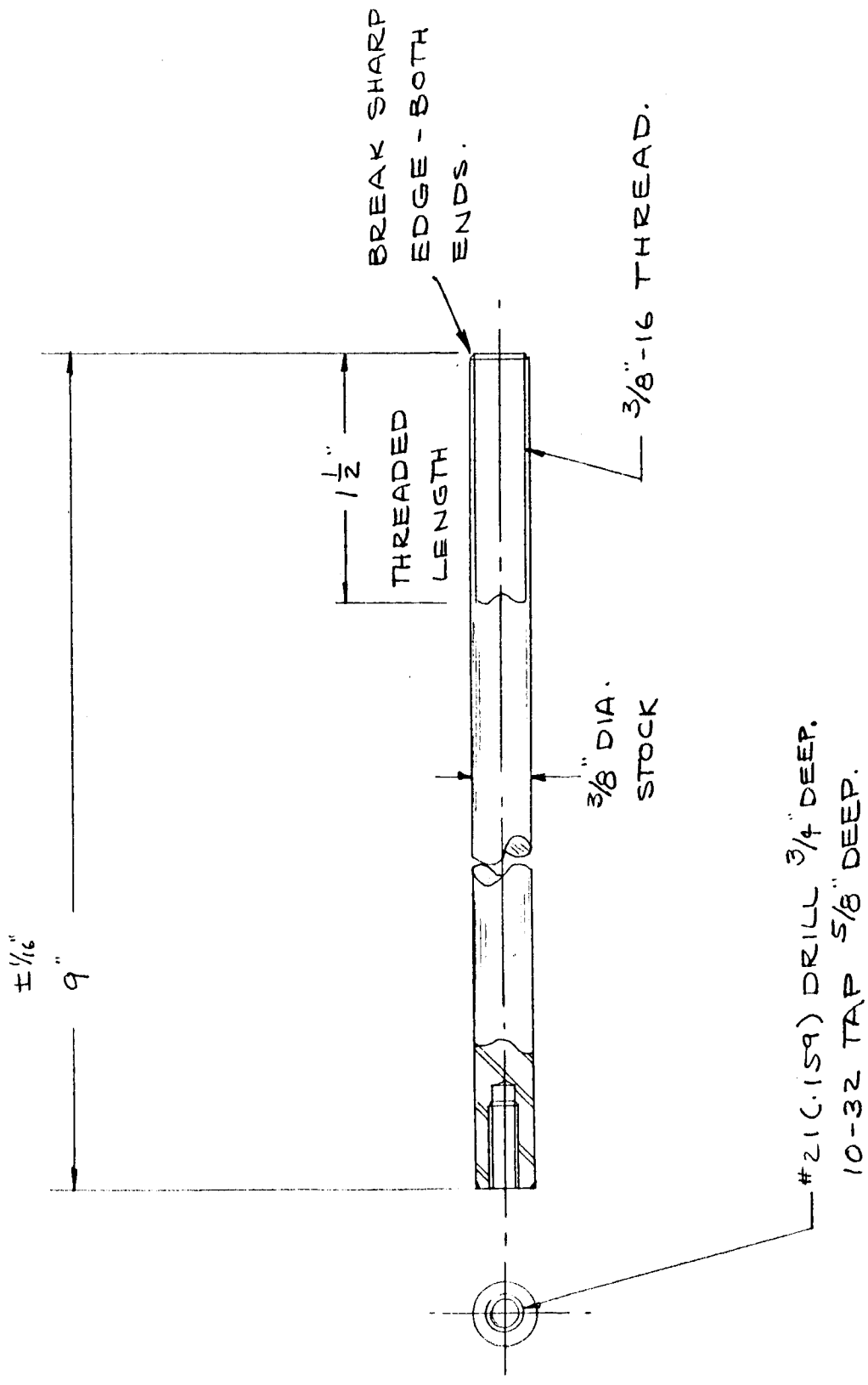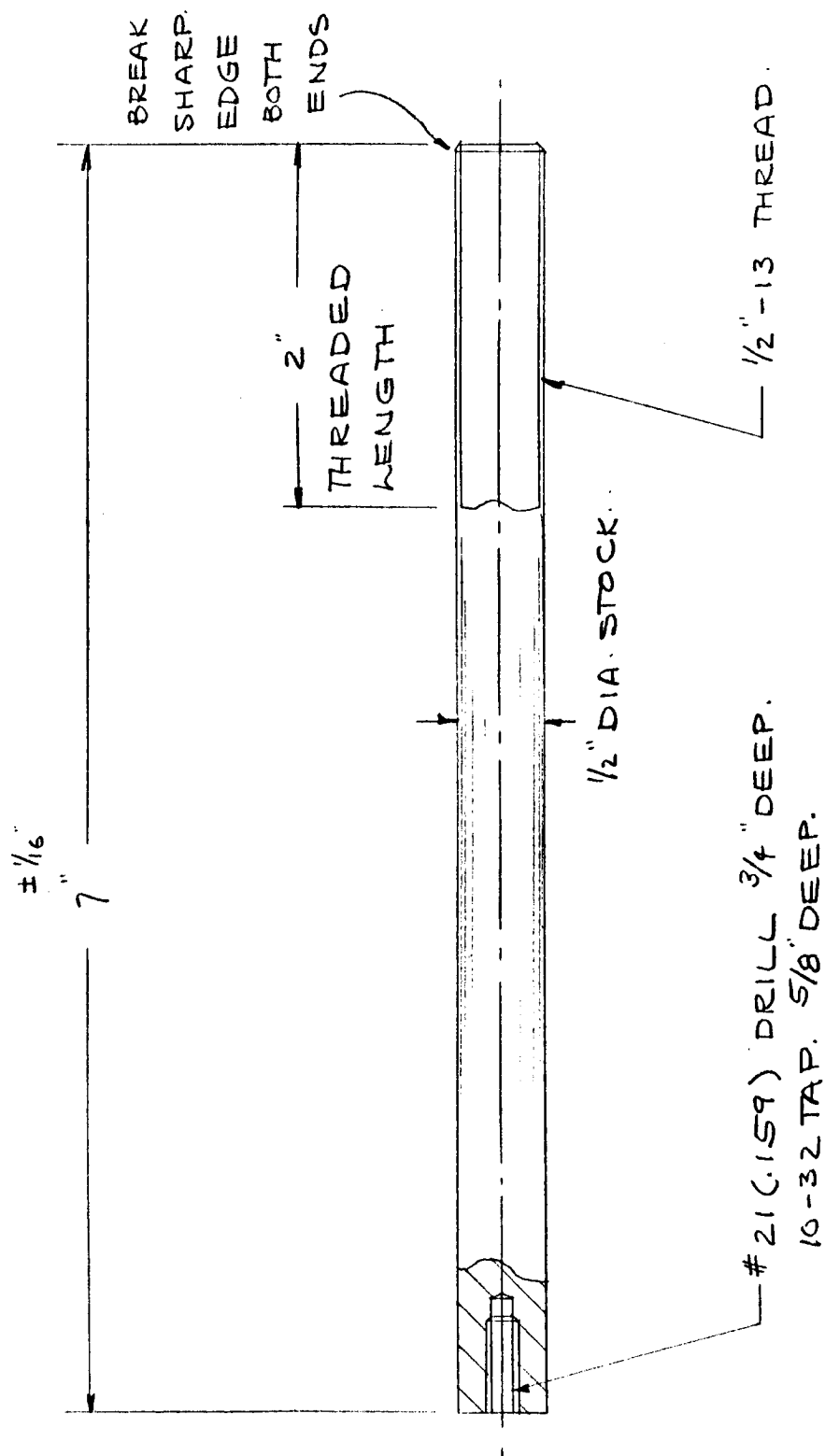
EMITTER TERMINAL

14086

EXHAUST LINE FITTING

14087

A-14066

A-14065

WELD

WELD

A-14092

WELD

A-14065

WELD

A-14066

WELD

A-14060 A-14087

WELD

WELD

WELD

± 1/16"
11 1/4"

± 1/32"
2"
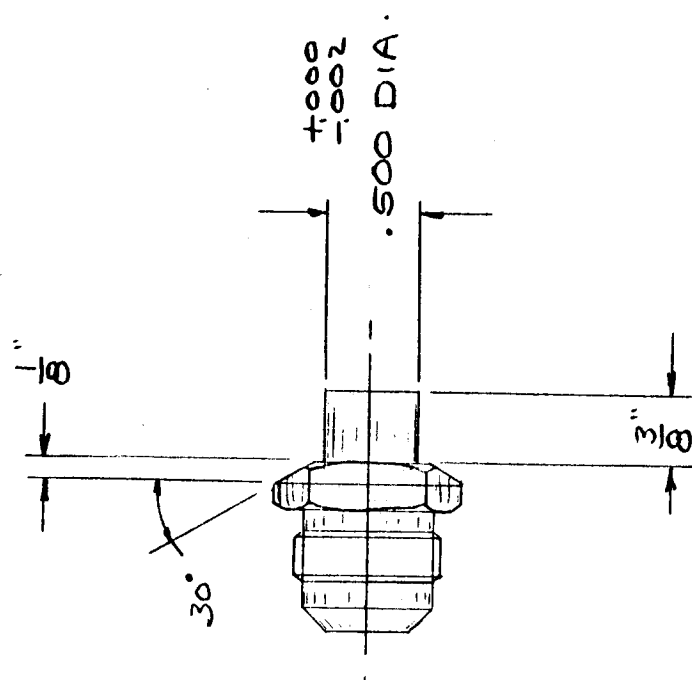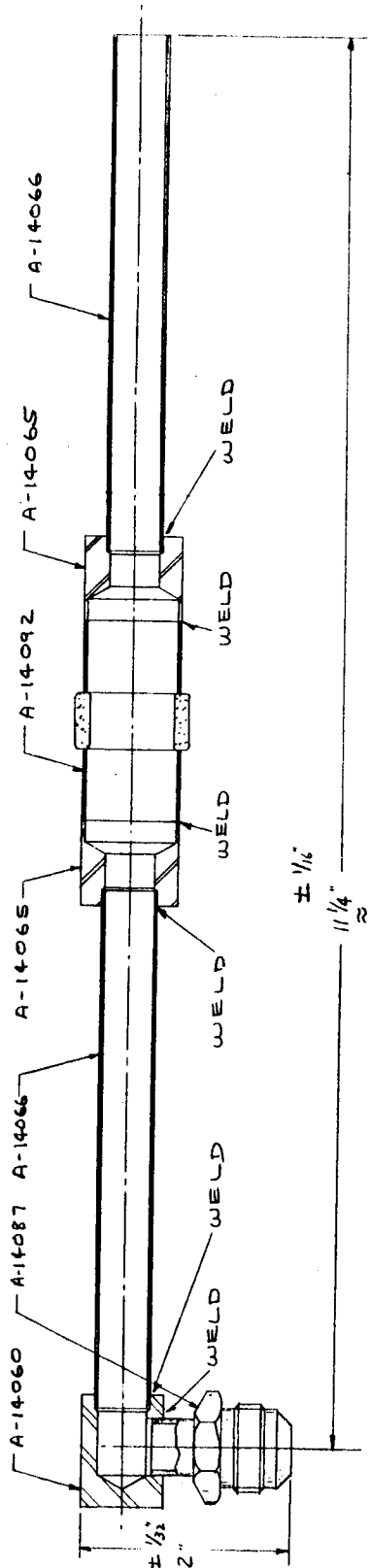
NOTE: ALL JOINTS MUST BE VACUUM TIGHT.
ALL WELDS ARE FUSION ARC WELDS.

MANIFOLD ASSEMBLY

14088

A-14061

COLLAR - FROM ½" PARKER.

NUT - FROM ½" PARKER.

A-14062

A-14094

SQUEEZE

A-14063

R.F. BRAZE POINT.

A-14071

2 13/16" ±1/16

13/16
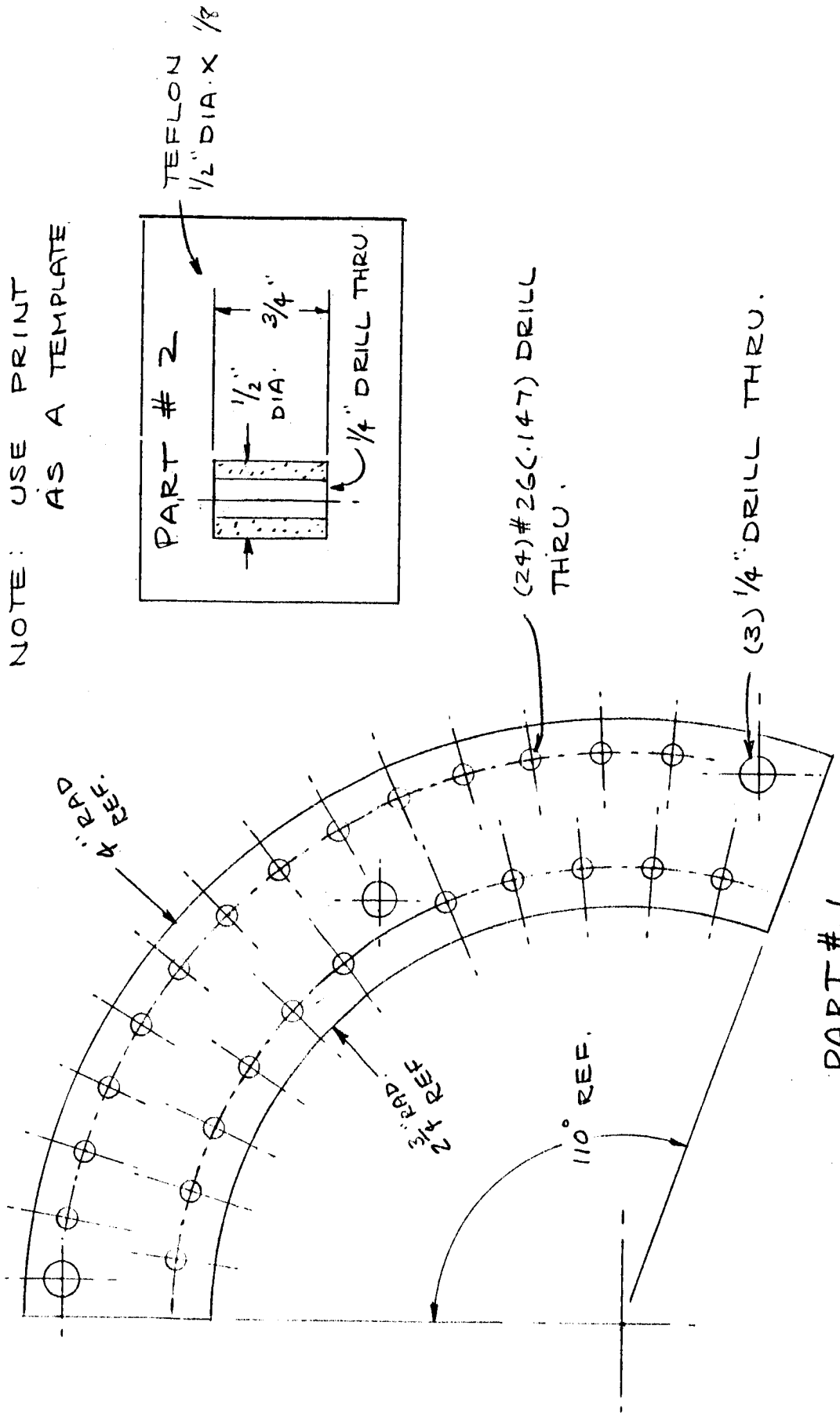
3 3/8" ±1/8

9 ½" ±1/8
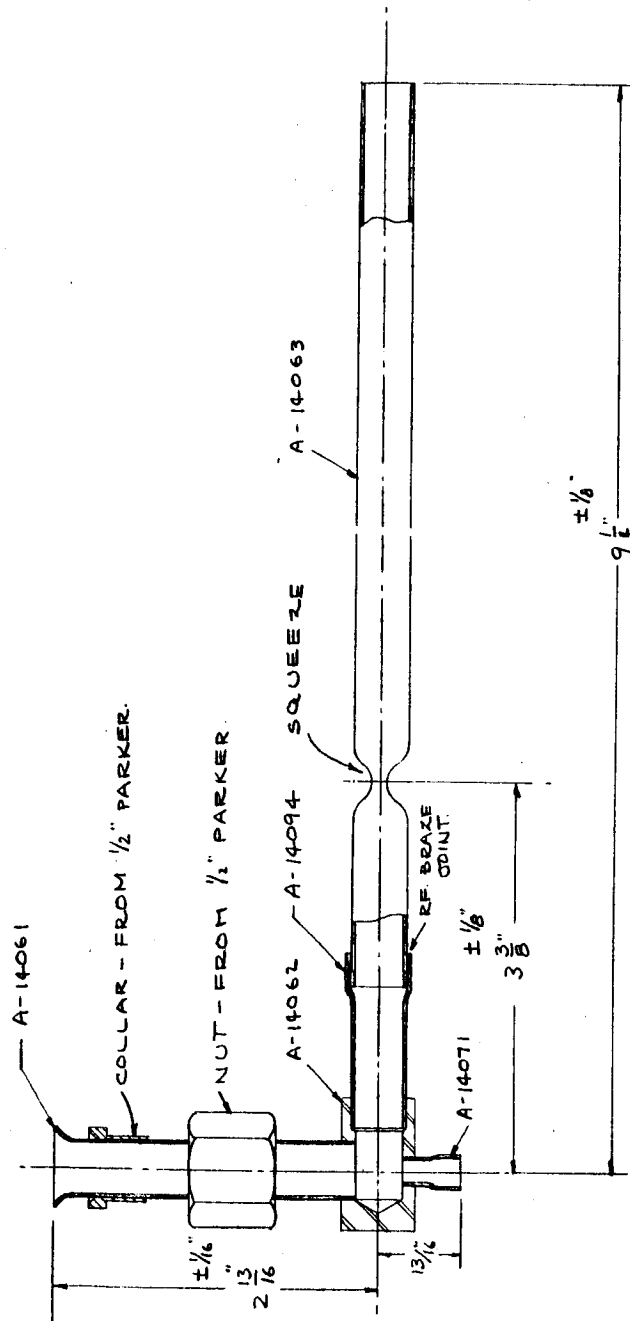
NOTES:

1. CLEAN PARTS THOROUGHLY.

2. B.T. BRAZE 830°C & LEAK CHECK.

3. ASSEMBLE COLLAR & NUT, FLARE AS SHOWN

4. R.F. BRAZE PART No A-14063 TO ASSY, & LEAK CHECK.

5. SQUEEZE PART No A-14063 TO RETAIN CESIUM CAPSULE.
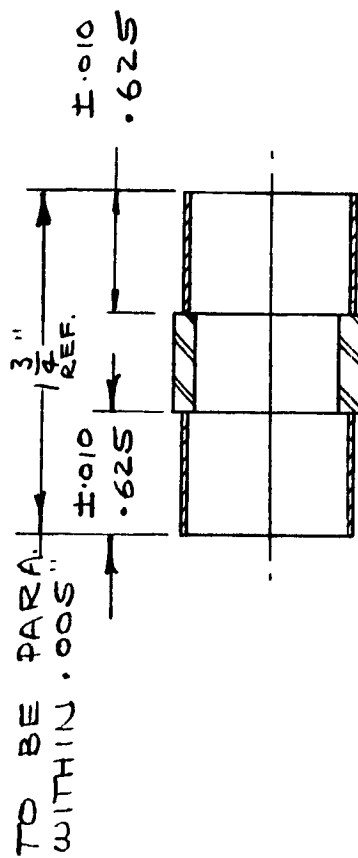
EXHAUST ASSEMBLY

14089

INSULATOR ADAPTOR

14090
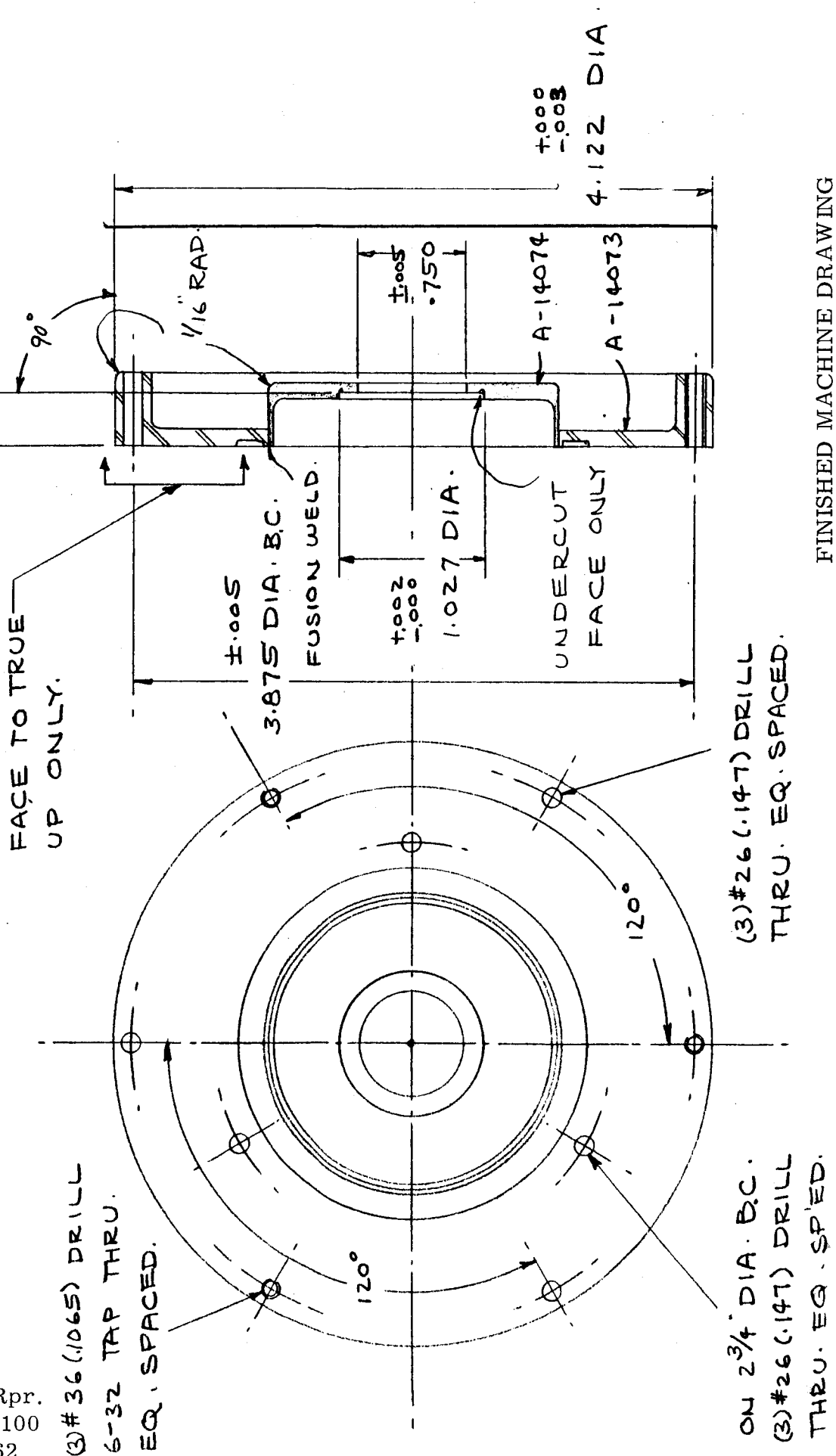
±.005 .875 DIA.

±.002 .800 DIA.

.030 -.040 WALL

3/16" DRILL THRU. .251 +.002 -.000 DIA. C'T.BR. 1/4" DEEP.

1/4"

1/16"

9/16"

NOTE: USE PRINT
AS A TEMPLATE

PART # 2

TEFLON
1/2" DIA. X 1/8

1/2"
DIA.

3/4"

1/4" DRILL THRU.

(24)#26(.147) DRILL
THRU.

(3) 1/4" DRILL THRU.

1" RAD
& REF.

3/4 RAD
2 1/4 REF

110° REF.

PART # 1
(1) PIECE TEFLON
1/4" THICK X 3" X 7"

THERMOCOUPLE STAND-OFF
14091

.625
±.010

.625
±.010

3"/4 REF.

TO BE PARALLEL WITHIN .005"

TERMINAL ASSEMBLY

14092

FINISHED MACHINE DRAWING

14093

4.122 DIA. $^{+.000}_{-.003}$

.375 ±.005

90°

1/16 RAD.

.750 ±.005

A-14074

A-14073

FACE TO TRUE UP ONLY.

3.875 DIA. B.C. ±.005

FUSION WELD.

1.027 DIA. $^{+.002}_{-.000}$

UNDERCUT FACE ONLY

(3) #26 (.147) DRILL THRU. EQ. SPACED.

120°

120°

(3) #36 (.1065) DRILL 6-32 TAP THRU. EQ. SPACED.

ON 2 3/4" DIA. B.C.
(3) #26 (.147) DRILL THRU. EQ. SPED.

STOCK WALL

½" STOCK O.D.

EXPAND TO .501 $^{+.003}_{-.000}$ I.D.

$\frac{1}{2}$"

$\pm \frac{1}{16}$"

$\frac{5}{16}$" EXPANDED LENGTH.
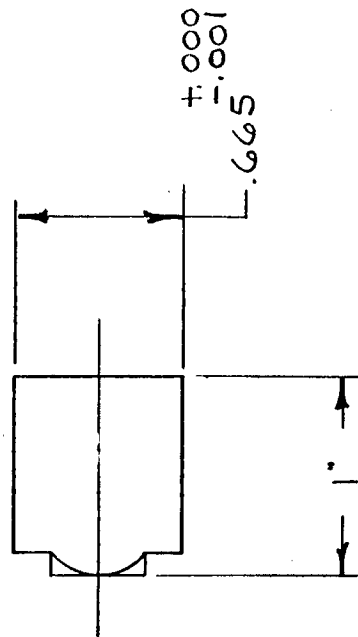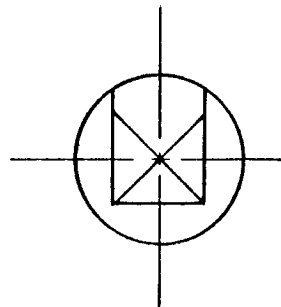
2"

2" DIA.
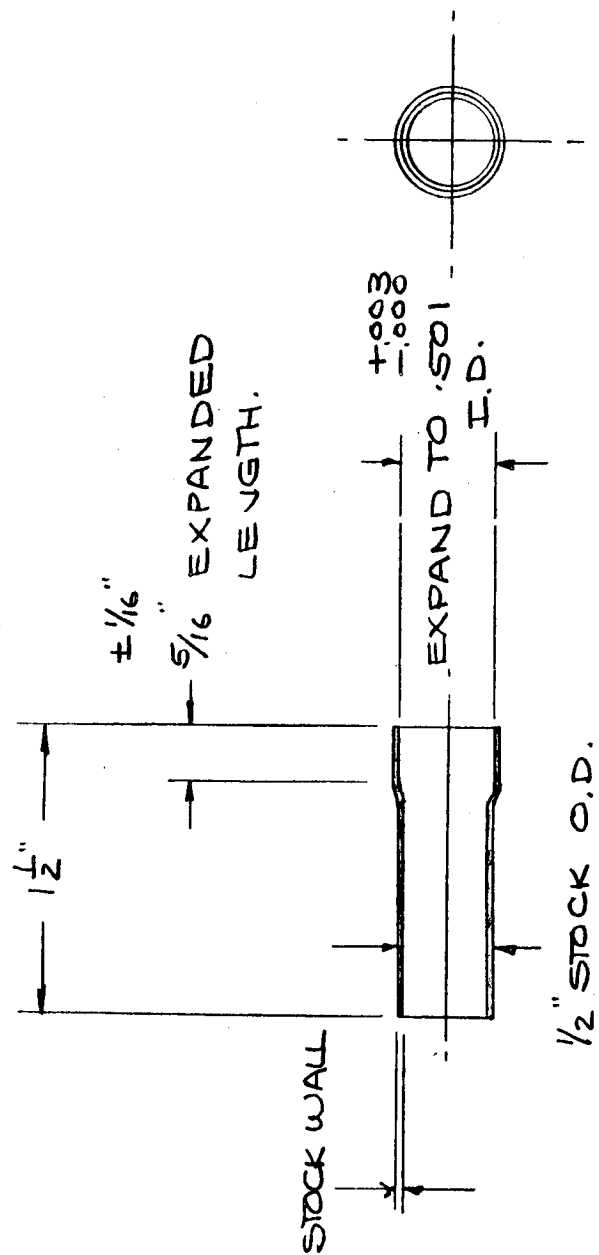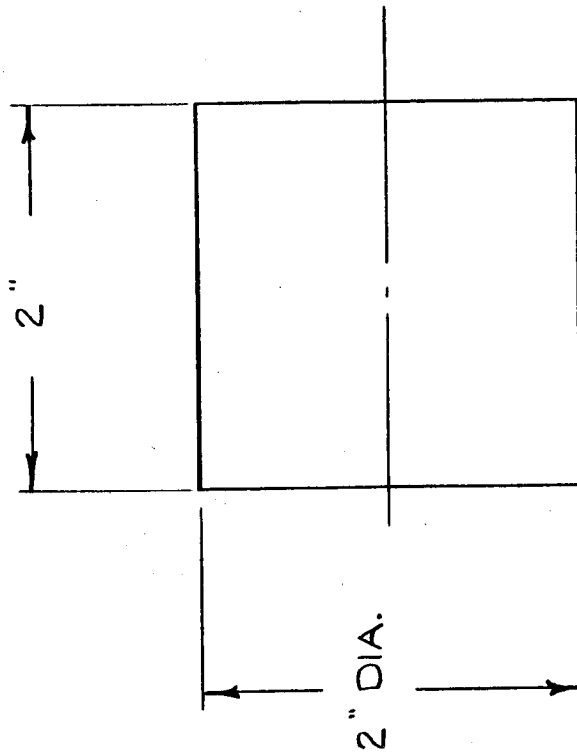
NOTES:
1. ENDS OF PART TO BE PARALLEL WITHIN .001.
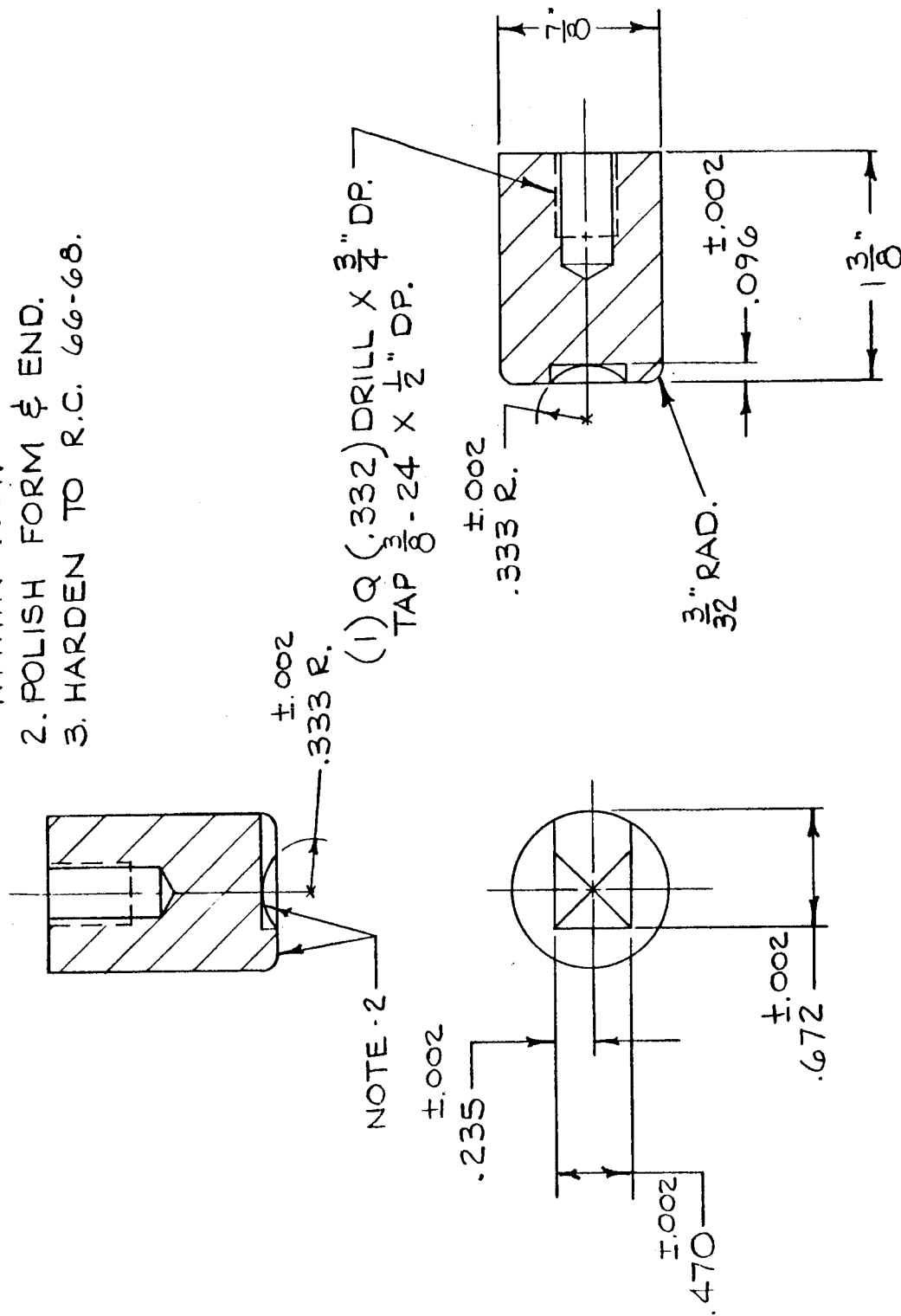
PUNCH BLANK

14101
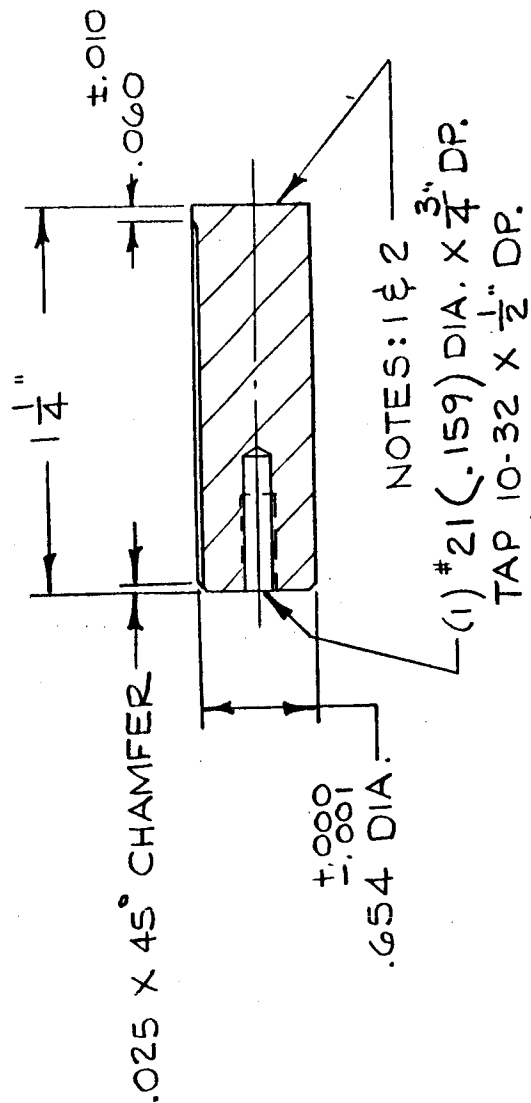
NOTES:
1. O.D. TO BE GROUND.
2. HARDEN TO R.C. 66-68.

.665 +.000 -.001

1"

PUNCH
14102

NOTES:

1. ENDS OF PART TO BE PARALLEL WITHIN .001.
2. POLISH FORM ₵ END.
3. HARDEN TO R.C. 66-68.

.333 R. ±.002

(1) Q (.332) DRILL X ¾" DP.
TAP ⅜-24 X ½" DP.

.333 R. ±.002

.096 ±.002

1 3/8"

7/10"

3/32" RAD.

NOTE-2

.235 ±.002

.470 ±.002

.672 ±.002

PUNCH HOB
14103

(1) .015 WIDE X .015 DP. SLOT
TO DEPTH SHOWN.

.060 ±.010

1 $\frac{1}{4}$"

.025 X 45° CHAMFER

NOTES: 1 & 2

(1) #21 (.159) DIA. X $\frac{3}{4}$" DP.
TAP 10-32 X $\frac{1}{2}$" DP.
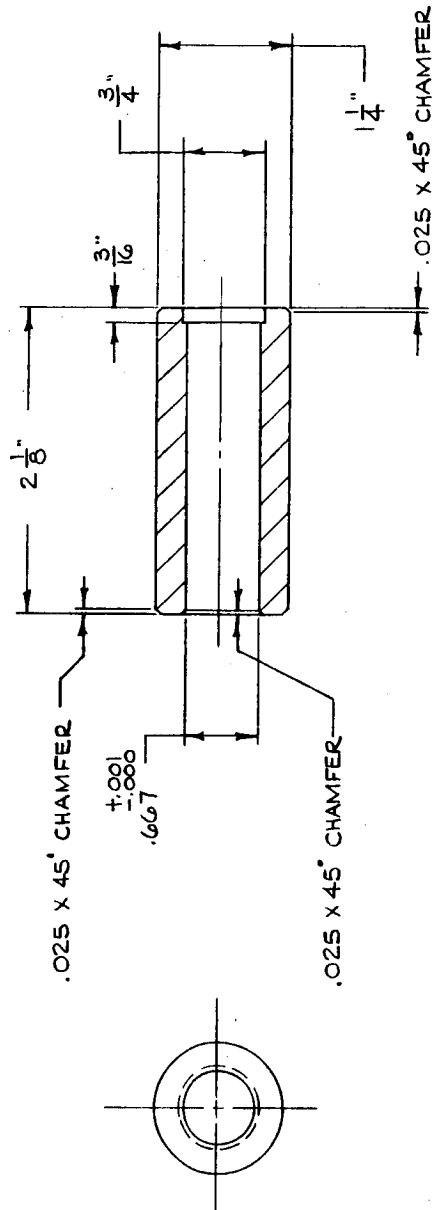
.654 DIA. $^{+.000}_{-.001}$

NOTES:
1. THIS SURFACE TO HAVE A GROUND & POLISHED FINISH.
2. THIS SURFACE TO PERPENDICULAR TO O.D. WITHIN .001.
3. HARDEN TO R.C. 66-68.

PUNCH GUIDE
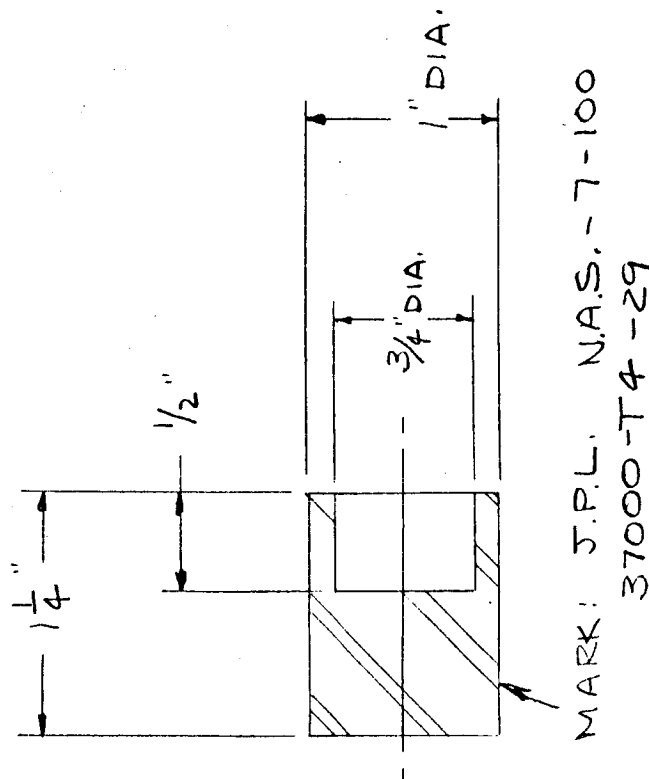
14104

PUNCH BARREL

14105

$\frac{3''}{4}$

$\frac{3''}{16}$

$2\frac{1}{8}''$

$\frac{1}{4}''$

.025 X 45° CHAMFER

.025 X 45° CHAMFER

.025 X 45° CHAMFER

$.667 \begin{smallmatrix}+.001\\-.000\end{smallmatrix}$

NOTES:
1. I.D. TO HONE FINISH.
2. HARDEN TO R.C. 66-68.

1" DIA.

3/4" DIA.

1/2"

1 1/4"

MARK: J.P.L. N.A.S.-7-100
37000-T4-29

BRAZING JIG
14124
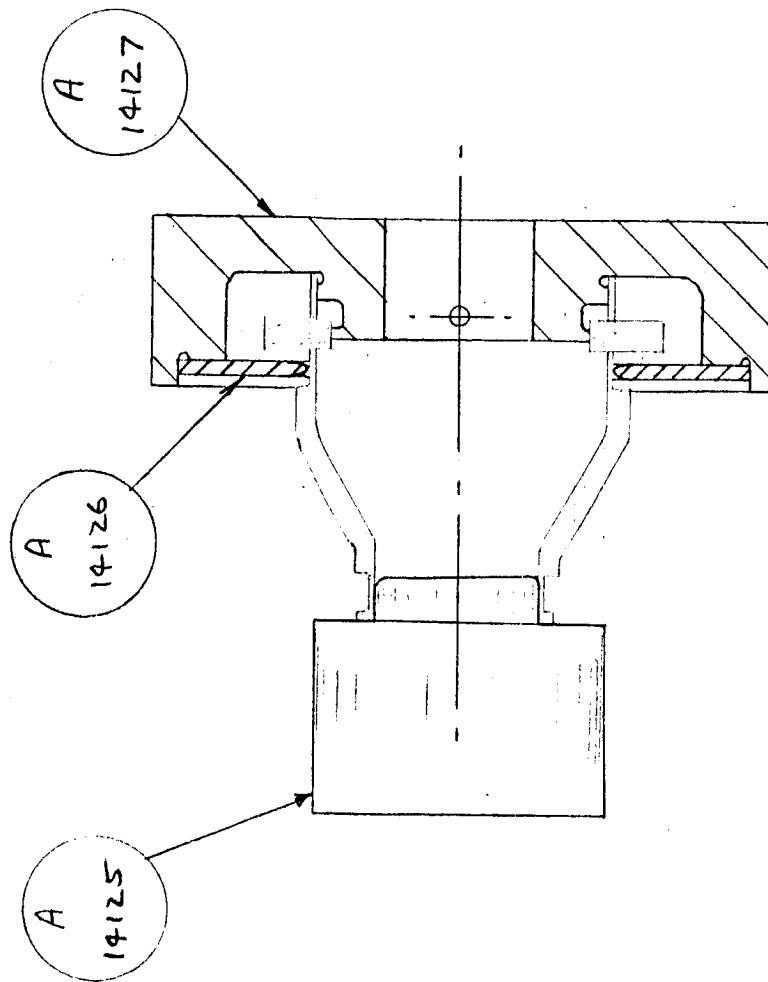
A 14127
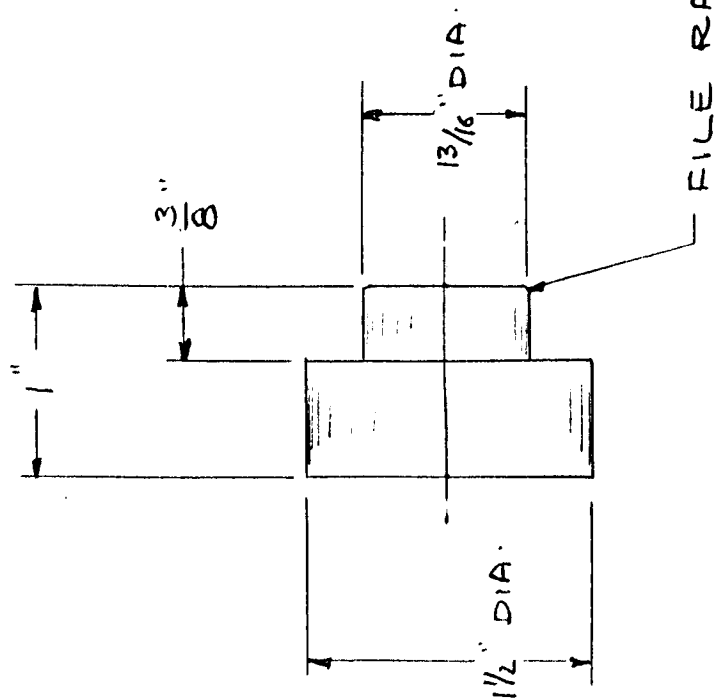
A 14126

A 14125

STAMP: J.P.L. N.A.S. 7-100 37000-TS-29

WEIGHT

14125

MARK BOTH PCS:
J.PL. N.A.S. 7-100
37000-TS-29.

DO-ALL SAW
IN HALF.

2.748 DIA. TO
BE CONC.
WITH 1.620 ID.
WITHIN .003 T.I.R.

NOTE: REMOVE ALL SHARP EDGES.

FIRE-HYDROGEN. 1020°C (1) HOUR
TO OXIDIZE.

SPLIT RING
14126

¾" HOLE THRU.

UNDERCUT FACE

CAN BE SHARP CORNER OR UP TO ⅛ RAD.

2.750 DIA. $^{+.002}_{-.000}$

1.548 DIA. $^{+.002}_{-.002}$

1.325 DIA. $^{+.000}_{-.000}$

UNDERCUT 1.325 DIA. AS SHOWN.

NOTE: 1.325 DIA., 1.548 DIA., & 2.750 DIA. TO BE CONC. WITHIN .003" T.I.R.

FIRE - HYDROGEN 1020°C (1) HOUR TO OXIDIZE

BASE - 14127

STAMP:
JPL NAS
7-100
37000-TS-29

⅝"
½"
17/64"
7/8"

UNDERCUT DIA.

15/32"

5/32"

1/16"
1/16"

2½ DIA.

3" O.D. ≈

⅛" DRILL THRU O.D. TO CENTER.

Final Technical Report
Contract NAS-7-100
18 December 1962

B-81

1/4" DRILL THRU.

BRAZING BASE

14131

1 1/4" DIA.

1 1/16" DIA.

UNDERCUT DIA. ONLY

1/8"

1/4"

MARK: S.P.L. NAS. 7-100

37000-T6-29

NOTE: .646 DIA., 779 DIA., & .960 DIA. TO BE CONC. WITHIN .001" T.I.R.

¼" DRILL THRU.

.960 DIA. +.000 -.001

.779 DIA. +.000 -.002

.646 +.000 -.001 DIA.

.010/.030 RAD.

¼"

UNDERCUT DIA. ONLY

9/16" DIA.

(2) ⅛" DRILL THRU.

3/4"

1½"

.285 ±.005

.030 ±.005

1/16"

29/64"

1"

⅛"

1¼" O.D.

MARK:
J.P.L. N.A.S. 7-100
37000-T7-29

BRAZING JIG
14132

.200 - .250
.025 - .030

STAMP

SHARP GROUND EDGES BUT NO BURRS

(1) $\frac{1}{4}$ DRILL THRU.

PT.	"A"	"B"	"C"	TOOL # STAMP	MATERIAL
1	2 $\frac{3}{20}$"	2.100 ±.005	1.355 ±.005	37000-TB-29-1	(1) PC. GA. ST. $\frac{1}{4}$" TK. X 2 $\frac{1}{2}$" SQ.
2	1 $\frac{7}{8}$"	1.250 ±.005	.800 ±.005	37000-TB-29-2	(1) PC. GA. ST. $\frac{1}{4}$" TK. X 2" SQ.

RUBBER DIE SOLDER WASHER

14143

BRAZING JIG

14144

A 14148
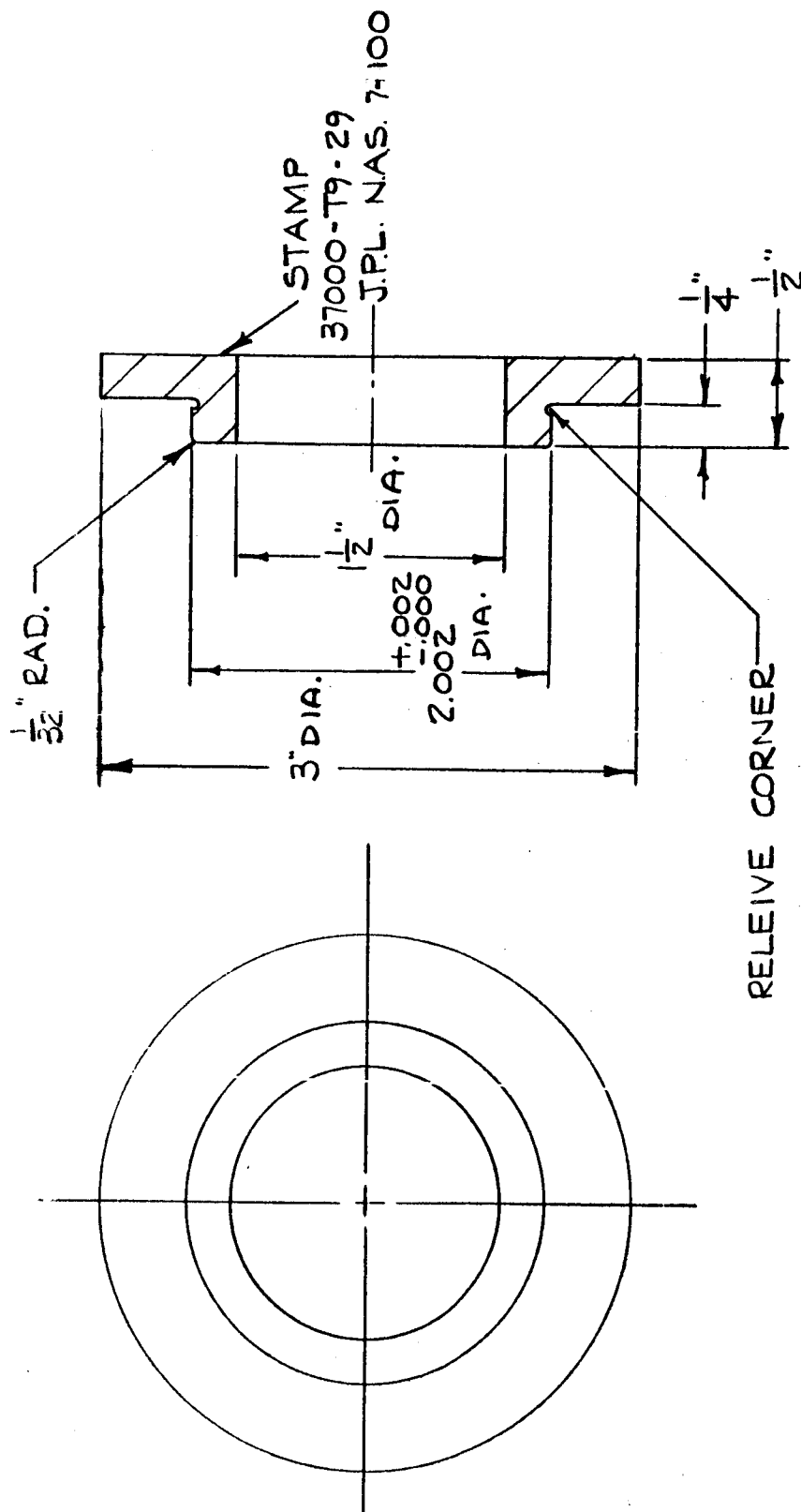
A 14147

A 14146

A 14145

EMITTER WEIGHT

14145

.670 DIA. $^{+.005}_{-.000}$

$1\frac{1}{4}$" DIA.

$\frac{5}{16}$"

1"

STAMP 37000-T9-29
JPL. NAS. 7-100

(1) $\frac{11}{16}$" DIA. THRU.

$2\frac{1}{2}$" DIA.

$\frac{3}{8}$" DIA.

$\frac{3}{8}$"

$\frac{1}{2}$"

STAMP 37000-T9-29
J.P.L. N.A.S. 7-100

2.005 DIA. +.002 -.000

3/16

1 7/16" +1/16 -0

2"

1 5/8"

3" DIA.

1.204 +.002 -.004

1 1/8"

.040 +.005

3/16

(2) SLOTS ~ 90° APART

(2) MOATS 1/16" WIDE × 1/16" DP. ANY SHAPED BOTTOM

STAMP 37000-T9-29 J.P.L. N.A.S. 7-100

SPLIT RING

14147

3/8"

CUT APART 180° APART DO-ALL SAW

BASE
14148

± .010
1.220 DIA.

± .000
- .005
.790 DIA.

± .000
- .005
.285

STAMP 37000-T10-29
J.P.L. N.A.S. 7-100

APPROX. 2"

(1) #21 (.159) DIA. DRILL X $\frac{3}{4}$" DP.
TAP #10-32 X $\frac{1}{2}$" DP.

#10-32 SCREW X $\frac{1}{2}$" LG.

CERAMICS

GRINDING FIXTURE

14151