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DEVELOPMENT OF AN ENCAPSULATED THERMIONIC POWER GENERATOR

QUARTERLY TECHNICAL PROGRESS REPORT

FOR THE PERIOD

NOVEMBER 1 THROUGH JANUARY 31, 1963

Contract AF33(657)-10077
Project Number: 8173
Task Number: 817305-20

Prepared for:

Aeronautical Systems Division
Air Force Systems Command
U. S. Air Force
Wright-Patterson Air Force Base, Ohio

Prepared by:

Martin Marietta Corporation
Nuclear Division
Baltimore 3, Maryland

February 15, 1963

MND-2945-1

The work covered by this report was accomplished under Air Force Contract AF33(657)-10077, but this report is being published and distributed prior to Air Force review. The publication of this report, therefore, does not constitute approval by the Air Force of the findings or conclusions contained herein. It is published for the exchange and stimulation of ideas.

INTRODUCTION

This program, Development of an Encapsulated Thermionic Power Generator, Contract AF33(657)-10077, is designed to performance test and evaluate a two-converter thermionic generator containing fuel bearing emitters. In addition, fuel elements with dimensions comparable to those of the emitters will be thermally endurance tested. Progress achieved thus far includes initiation of fabrication of several generator components and fabrication of a fuel element and its vacuum test chamber.

SUMMARY

PRESENT WORK

The engineering design of the double diode thermionic power generator has been completed. Fabrication of several component parts has been initiated. The parts for the fueled emitters are almost completely fabricated with only assembly and final machining remaining. The manufacture of other generator components including the collector temperature control assembly and the ceramic-to-metal seals has been initiated.

The engineering design of the clad fuel elements has been completed and the first element, similar in configuration to the fueled emitter, has been fabricated. This element will be used to determine the changes in the vacuum emission characteristics over a 200 hour test period. The vacuum test chamber has been fabricated and is undergoing preliminary outgassing.

FUTURE WORK

During the next reporting period, fabrication of the fueled emitters will be completed. Fabrication of the remaining generator components and the back-up device will continue. The vacuum emission test will be conducted and the remaining fuel elements for the 200-hour endurance test will be fabricated and a pretest examination performed.

TECHNICAL DISCUSSION

I. Fabrication of the Fueled Clad Double Diode Thermionic Generator

The engineering design of the double diode thermionic generator containing fuel bearing emitters has been completed. An assembly drawing of the device is shown in Figure 1 (Martin Drawing No. 390-0790116, Sheet 1). The device has been given the Martin designation FDM-1. During this reporting period, the fabrication of some of the FDM-1 components was initiated. These efforts are described below.

A. Fueled Emitter Fabrication

Fabrication of the fueled emitters was begun in January. A minor design change in the end cap of the top cathode was made during this quarter and is reflected in Figure 1. The end cap of the upper cathode was redesigned to provide a ductile lip for crimping to the intermodule electrical lead. The redesigned end cap consists of a 0.146 inch tantalum plate bonded to the exterior face of a 0.020 inch molybdenum plate. A bi-metallic end was resorted to in order to maintain a continuous molybdenum barrier for the uranium dioxide-molybdenum cermet fuel while simultaneously providing a ductile lip for crimping to the anode lead of the next diode.

Exploratory development work showed that this bi-metallic end cap could be made by hot press bonding a disc of tantalum to a disc of molybdenum - 1/2% titanium alloy, and then machining the resulting bi-metallic slug to the diameter and thickness required for the fueled emitter fabrication operation. The hot press bonding operation required to produce a satisfactory metallurgical bond between the two metals was a three (3) minute hold at 2150°C under a pressure of 5000 psi in a graphite die. This time-temperature relationship required the use of a flame sprayed zirconium oxide protective coating on all exterior surfaces of the discs to prevent excessive carbide formation on the surfaces. Figure 2 is a photomicrograph of the interface between the tantalum and molybdenum - 1/2% titanium alloy discs and illustrates the degree of bonding attained in this operation

Fabrication of the component parts for both the upper and lower cathodes is now being completed. These parts include the cermet fueled bushing, center mandrels, exterior cladding sleeves, bi-metallic end caps for the top cathode and the standard end caps. The next phases of the program are fitting and assembling of the components into the fueled emitter configuration, flame spraying of the exterior surfaces with zirconium oxide, and hot pressing the assembly into fueled emitters. These fabrication operations will be followed by radiographic inspection, final machining, and incorporation in the generator assembly.

B. Fabrication of Other Generator Components

Work was initiated on the fabrication of components for the collector temperature control assembly. This assembly permits variation of the collector temperature so that its effect on thermionic performance may be investigated. These parts are similar in nature to those used successfully in past Martin devices and for which elaborate manufacturing procedures have been established.

Components for the ceramic-to-metal seals are being manufactured. It is expected that the seals will be assembled during the month of February. Procedures for the seal component manufacture and assembly have been standardized. Past experience with these seals has been excellent. One seal operated successfully in a device for over 2000 hours and showed no sign of deterioration at device failure.

During the next quarterly period, fabrication of components for the FDM-1 and its back-up components will continue.

II. Evaluation of Clad Fuel Elements

The engineering design of the clad fuel elements has been completed and an assembly drawing is shown in Figure 3 (Martin Drawing No. 390-0790122). The progress achieved during this reporting period in this portion of the program is described below.

A. Fuel Element Fabrication

Fabrication of the fuel element to be used to determine quantitative changes in the thermionic emission properties over a 200-hour test at design temperature has been completed. This vacuum emitter element is similar in configuration to the fueled thermionic emitter with the following exceptions: the fueled section is 0.104 inches thick (with an equivalent U-235 density of 6.75 grams/cc) and the pellet has a 1/8 inch diameter through hole drilled concentric with the long axis. The purpose of this hole is to permit heating of the element in a vacuum chamber by the use of an electron bombardment heater that passes completely through the element. The fueled section of this vacuum emitter pellet is provided with a .040 inch inner cladding of molybdenum - 1/2% titanium to extend heater life and obtain more uniform heating of the fueled section.

Radiographs of the vacuum emitter after the hot press fabrication operation showed it to possess good quality metallurgical bonding between all components. Radiographs taken upon completion of the mandrel drilling operation and surface finishing operation revealed no loss of bond integrity due to the drilling or machining operations. Each radiographic operation was conducted using three 120° rotations about the long axis of the emitter in order to ensure complete coverage. The radiographs are not included in this report because of their poor reproducibility. Figure 4 shows the fueled vacuum emitter after completion of all fabrication operations.

During the next quarterly period, the fuel elements for the 200-hour endurance test will be fabricated and a pre-test examination conducted.

B. Vacuum Emission Test

In order to observe possible changes in the vacuum thermionic emission properties of a refractory metal clad fueled emitter, a vacuum test chamber has been fabricated and is undergoing preliminary outgassing. The test chamber is a water cooled metallic tube which will provide a high vacuum environment in which the fueled emitter element will be heated by electron bombardment. The 15 cm^2 fueled emitter will be heated to 1600°C and a cylindrical guard ring anode structure will be used to draw saturated thermionic emission current. After brief preliminary operation in the range of 1450 to 1700°C to determine the emission characteristics and thermal characteristics of the emitter structure (with respect to temperature gradients), the emitter will be operated for 200 hours at 1600°C. During this time the output current will be monitored and periodic checks will be made of the thermionic emission characteristics. At the completion of the 200-hour test, a metallurgical examination will be conducted to determine the extent of any structural changes.

In making the emission measurements, particular care will be taken to insure that the emitter structure is operated at a constant temperature and that any effects of the diffusion of fuel constituents are detected. The diffusion of low-work function materials such as uranium metal or uranium dioxide to the surface is expected to greatly enhance the vacuum emission of the molybdenum - 0.5% titanium surface. If, on the other hand, diffusion takes place along grain boundaries and the fuel components evaporate from the emitter before a surface coverage is accomplished, then the influence on emission may be very small. Even if no change is seen in the thermionic emission, alpha radiation counters will be used to detect the presence of uranium compounds on the surface prior to metallurgical examination.

The effect which the presence of fuel material on the emitter surface will have on the performance characteristics of the vapor-filled converter is not clearly defined at this point. From thermionic considerations, materials which have high vacuum work functions have demonstrated superior performance in cesium vapor-filled converters. Hence the presence of low-work function fuel materials might be expected to lower the performance of the converter. This will be a point of particular interest in the vacuum emission test and in the prolonged operation of the fueled emitters in the FDM-1 device.

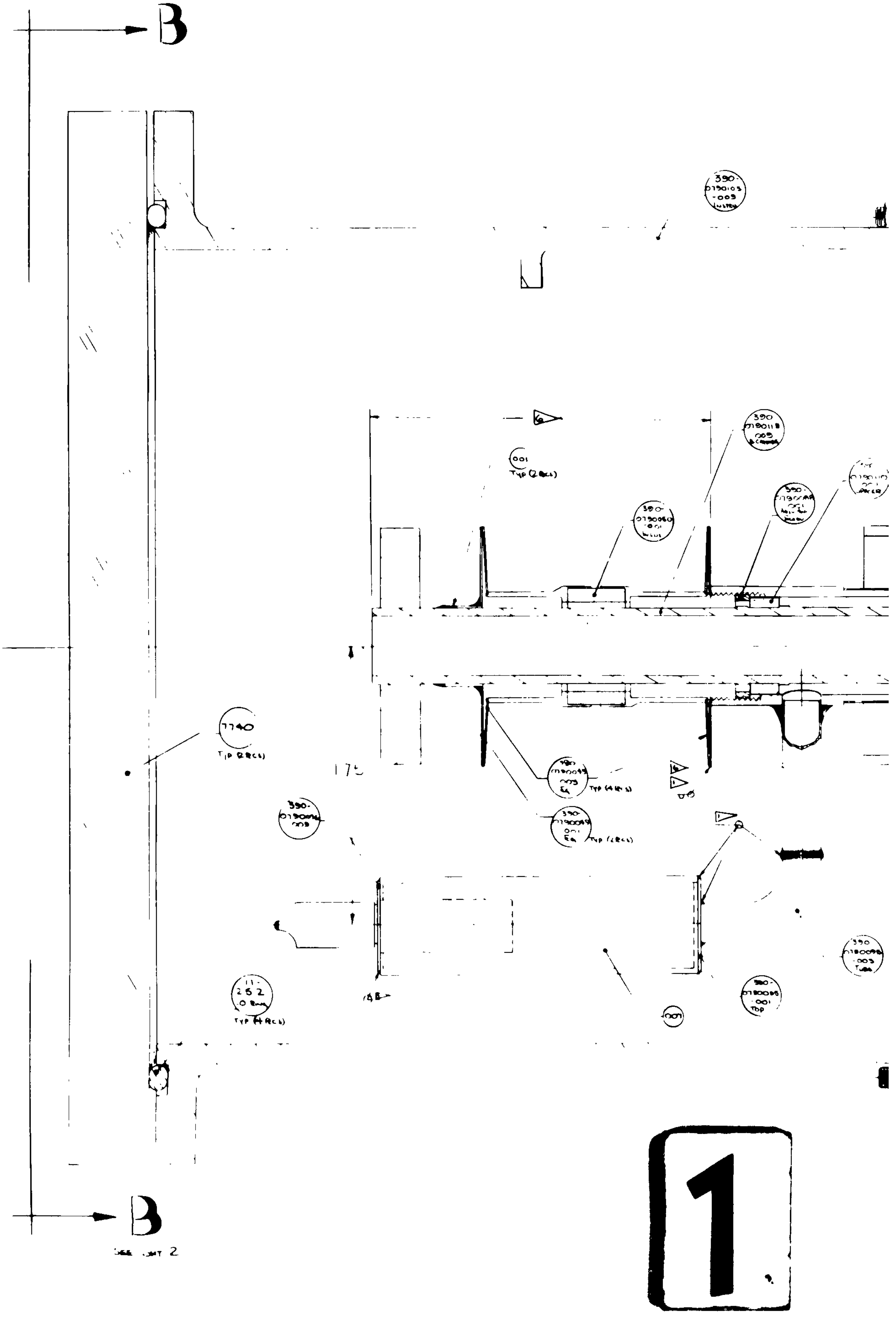
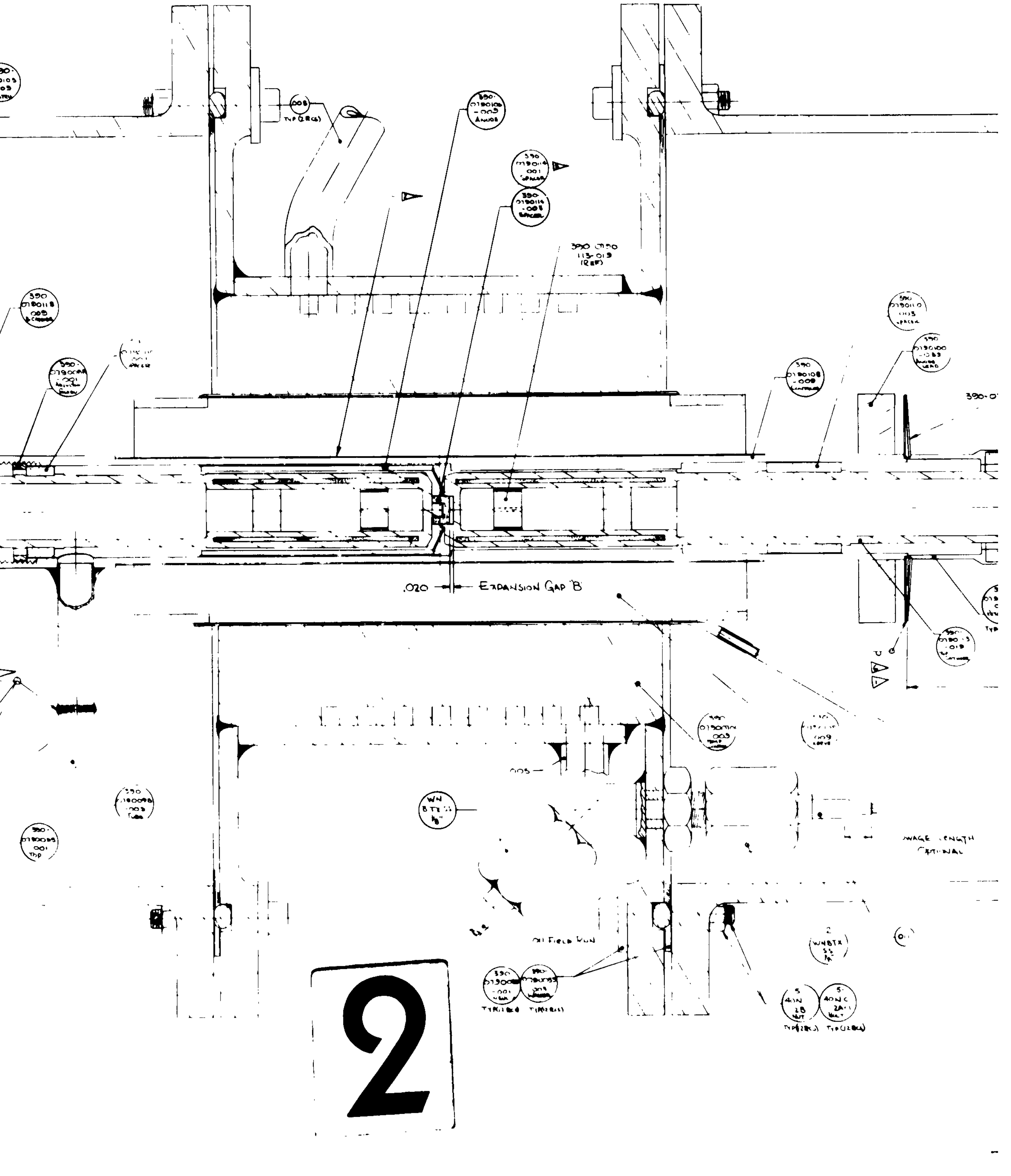
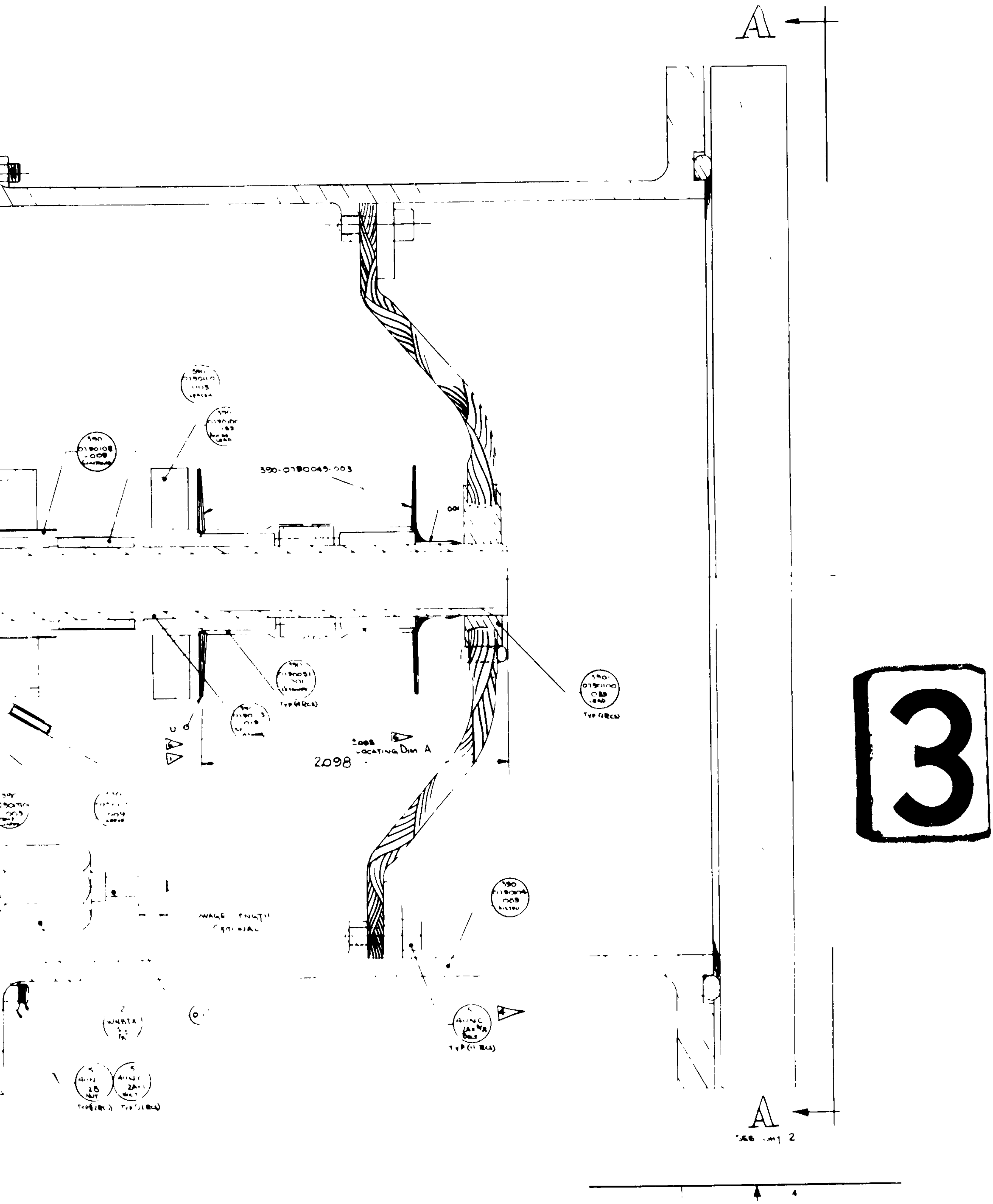


FIGURE 1 (Cont.)



.020
EXPANSION GAP 'B'
.005
2



A
390-0790049-003
2098
LOCATING DIM A
A
SEE SHT 2
3

SYM	ZONE	REVISIONS DESCRIPTION	DATE	APPROVED

Notes:

7. All Parts As Described By Vendor Or Equal.
6. After Aquiring Top (Location Dim A') Make Top Seal Weld. Drive Adjustment (390-0790088) Until (390-0790114) Bottoms Then Reverse Procedure To Achieve Expansion Gap 'B'. Followed By The Final Seal-Weld In Assy.
5. Use Of 390-0790114-001 Optional
4. Part To Be Match Drilled At Assy. - 5-40NC-2B × 3/8
2. Al_2O_3 Coating See Dwg 390-0790108-009.
1. Before Welding Or Brazing Contact Don Stoffel (Dept 1571) For Instr.

390-0790116

Qty Reqd	Part No	Description	Stock Size	Note	Material or Vendor	Material Specification
	390-0790114-003	Spacers				
1	1/8" White-33	45° Bend Fitting	1/8"	7	Ruller Tube Co	Cat 4300 Pg 26
12	5-40NC 2B	Nut		7	McMasters & Carr	Cat 67 Pg 8
12	5-40NC 2A × 5/8	Socket Head Cap Screw		7		Pg 1571
12	5-40NC 2A × 1			7	McMasters & Carr	
4	11-252	O Ring		7	Auburn Co	Neoprene Rubber
2	7740	View P	1 × 1 × 1/8	7	Corning Glass	Bulletin [illegible]
4	390-0790100-025	Terminal Lead				
1	100-033	Terminal Lead				
1	210-003	Temp Control				
2	100-003	Thermal Sleeve				
1	104-003	Instru. Assy Top				
1	104-005	Bottom				
12	058-003	Teflon Washer				
12	059-001	Teflon Insulator				
1	276-002	Cesium Supply Assy				
	099-003	Cesium Tube				
1	097-001	Top Reservoir				
1	098-001	Adjustment Screw				
	108-009	THD Container				
1	106-009	Anode Assy				
1	113-019	Top Cathode				
1	113-009	Bottom Cathode				
5	114-001	Intermodule Spacer	Be → Ac			
4	051-001	Insul Retainer				
2	050-001	Al_2O_3 Insul				
1	121-001	Pre Test Fixture				
1	110-001	Spacers				
4	049-003	Flange Q				
2	390-0790088-001	Flange R				
1	390-0790109-021	Blank Base	See Sht 2			
	390-0790114-003	Intermodule Spacer	Al_2O_3			
1	011	Helium Tube	1/8 × .028 × 20"		Ta Tube	Comm
1	007	Reservoir Tube	.50 × .010 × 2"		Tantalum Tube	
1	005	Coolant Tube	1/8 × .035 × 2"		Copper Tube	
2	001	Welding Sleeve	[illegible]		Tantalum Tube	Comm.

QUANTITY/DASH NO SHOWN — PART NO EVEN DASH NO OPP — ZONE — SH — NOTE — DESCRIPTION — STOCK SIZE — MATERIAL OR VENDOR — MATERIAL SPECIFICATION — FINISH — CHG

LIST OF MATERIAL

CALC WT	DASH NUMBER	NEXT ASSY	USED ON	FINAL ASSY	TEST
	-003	-	CRP	1	

APPLICATION — QTY REQD

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND ARE AFTER PLATING. TOLERANCES ON FRACTIONS, DECIMALS, ANGLES. MACHINED SURFACES REF MIL STD 10. MIL I 8500 STATUS: INTERCHANGEABLE / REPLACEABLE / UNCONTROLLED ✓

Drawn by	R.E. Lowary	Dept 1574	12-72-62
Checked	[illegible]		12-4-62
Stress Engr	[illegible]		
Wt Engr			
Mat'l Engr	L.W. Stoffel		12-27
Reliability			
QA Engr			
Program Ref	[illegible]		
Cust Ref	W. C. [illegible]		

MARTIN COMPANY
THE AEROSPACE DIVISION OF MARTIN MARIETTA CORPORATION
FRIENDSHIP INTERNATIONAL AIRPORT, MARYLAND

FUELED DOUBLE MODULE #1
THERMIONIC MODULE (TYPE) II
CMD

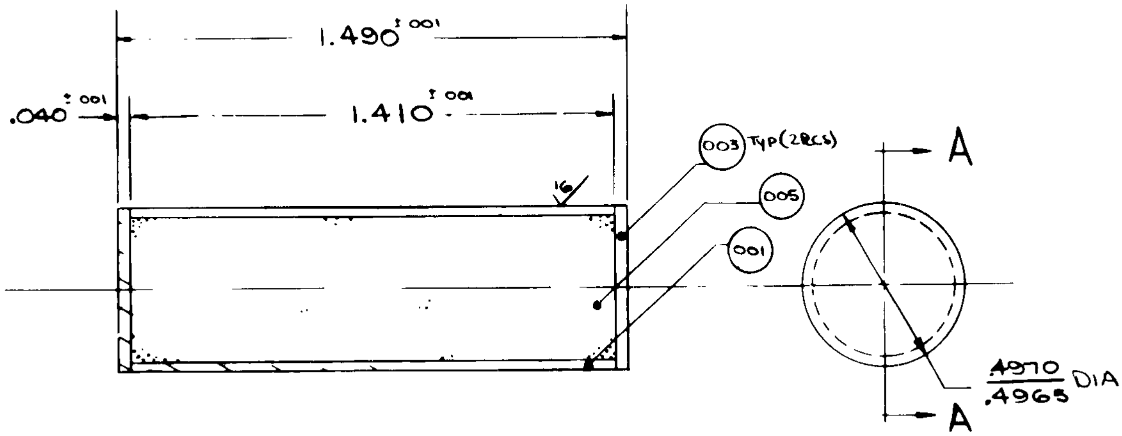
CODE IDENT NO 38597 — SIZE J — 390-0790116
SCALE 1/1 — Nuclear Division — SHEET 1 OF 2

FIGURE 1

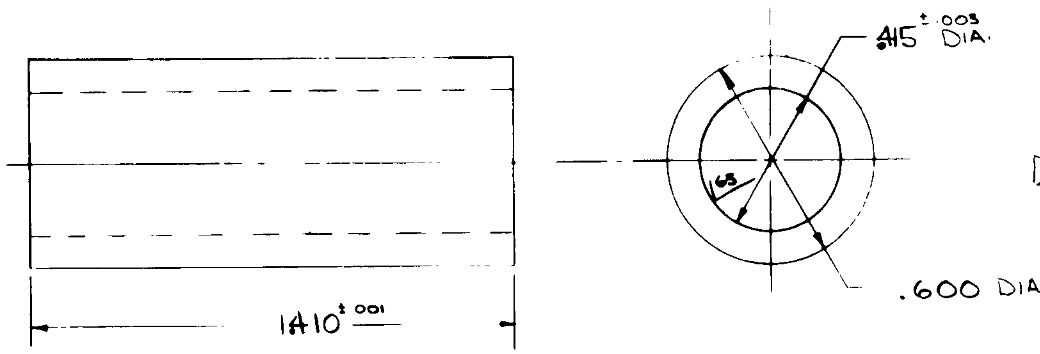
Figure 2

Bimetallic end cap of the top cathode of the FDM-1 device showing the bonding zone between the tantalum and the molybdenum - ½% titanium alloy. Hot pressed for 2½ minutes at 5000 psi and 2150°C. Tantalum (on top) etched with mixed acids. Magnification: 400X

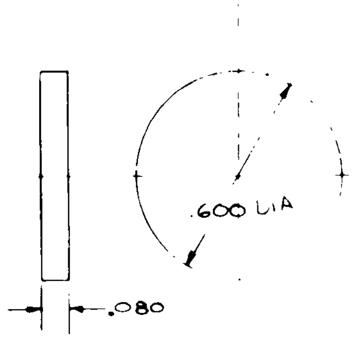
390-0790122 | SH | CHG A



SECTION A-A -009 ASSY. [1]



DETAIL -001



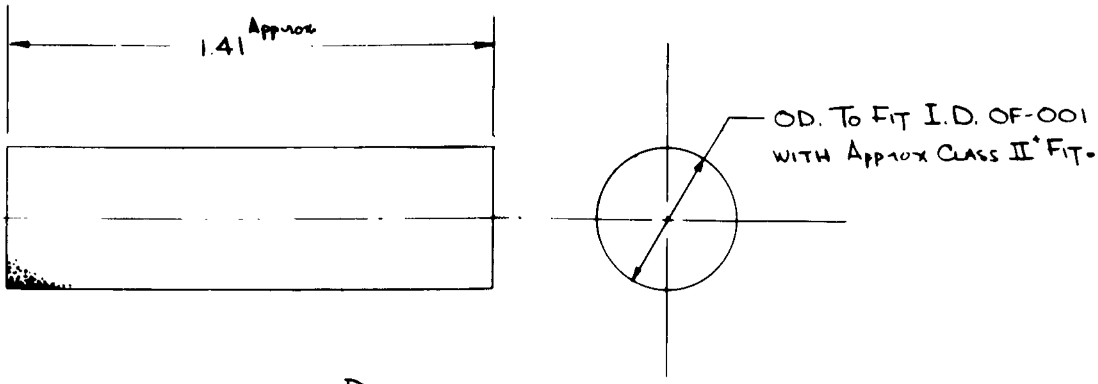
DETAIL -003

2 ALL MACH
[1] 1. FOR HOT P

CALC WT	DASH NUMBER	
	-009	39

390-0790122 | SH | CHG A

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVED
A	USAGE	ADDED 390-0790124	1-18-63	J. Monroe



DETAIL-005

2

2. All Mach Surfaces 125 Except As Noted.
1. For Hot Pressing Instru. Contact J. Monroe (Dept 1571).

PART NO.	DESCRIPTION	STOCK SIZE	MATERIAL OR VENDOR	MATERIAL SPECIFICATION
-005	Fuel UO2-Mo Cermet (A)	60% Ge Eqv. U235 Rich		COMM
-003	End Plug	3/4 Φ x 1/8 LG	Mo-.5% Ti	COMM
-001	Emitter Sleeve	3/4 Φ x 1.50 LG	Mo-.5% Ti	COMM
-009	Fuel Pellet			

LIST OF MATERIAL

DASH NUMBER	NEXT ASSY	USED ON
-009	(A) 390-0790124	CRP

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND ARE AFTER PLATING. TOLERANCES ON FRACTIONS ± 1/32; DECIMALS .X ± .1, .XX ± .03, .XXX ± .010; ANGLES ± 1/2°

MACHINED SURFACES REF MIL-STD-10: Noted

MIL-I-8500 STATUS: INTERCHANGEABLE / REPLACEABLE / UNCONTROLLED

DRAWN BY R.E. LOWRY, DEPT. 1654, DATE 12-27-62

CHECKER 12-27-62

THE MARTIN COMPANY, BALTIMORE, MARYLAND

FUEL PELLET ASS'Y.

THERMIONIC MODULE CRP

CODE IDENT NO. 38597 | SIZE D | 390-0790122

SCALE 4/1 | NUCLEAR DIV. | SHEET 1 OF 1

FIGURE 3

390-0260/03
390-0219/R

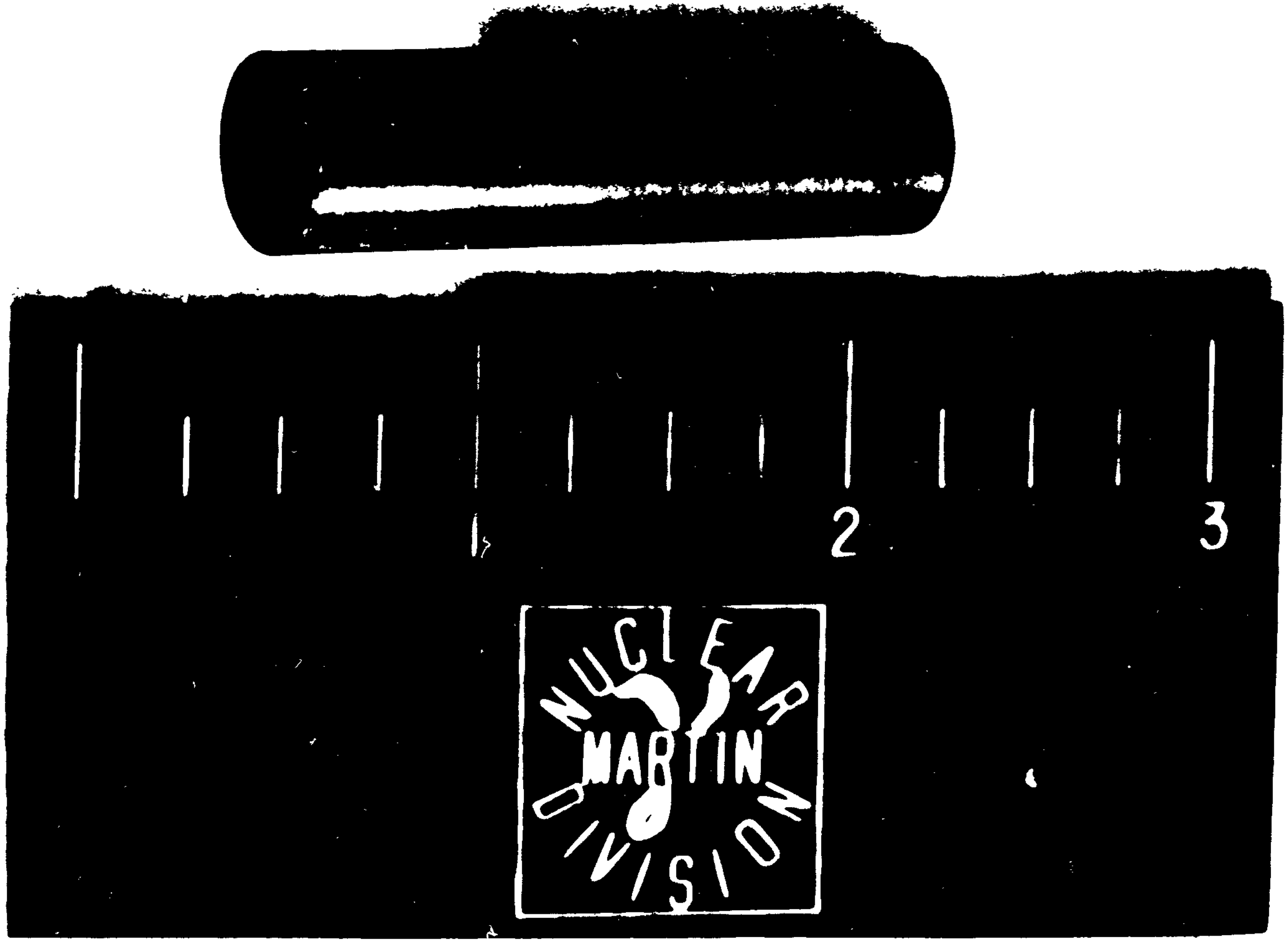


Figure 4

Finished fueled vacuum emitter test element. Central hole is drilled completely through the pellet. Fuel thickness is 0.104 inches and the equivalent U-235 density in the fuel section is 6.75 gm/cc.

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