ENGINEERING REPORT ON PHASE II

HIGH SHOCK FM TRANSMITTER

CONTRACT NUMBER NAS1-5042

7061/R1

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COMPUTING DEVICES
OF CANADA LIMITED
AN AFFILIATE OF THE BENDIX CORPORATION

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SECTION 1

INTRODUCTION

N66-33974

1 This report details the specifications of the High Shock FM Transmitter (Computing Devices' Type YTX-1-2) built as part of the program and provides the engineering data necessary to construct similar units. The engineering drawings of the various mechanical components are included along with electrical assembly drawings and a circuit diagram. Assembly photographs of the transmitter at various stages of construction are also included to supplement and clarify the assembly drawings. A component parts list is also included.

Author

SECTION 2

HIGH SHOCK FM TRANSMITTER TYPE YTX-1-2

PROVISIONAL SPECIFICATION

1.	FREQUENCY.	240 to 245 MHz.
2.	NOMINAL POWER OUTPUT.	100 mW into 50 ohms.
3.	MINIMUM POWER OUTPUT.	Greater than 60 mW into 50 ohms under worst voltage and temperature conditions (-16 volts and $0^{o}C$)
4.	SHORT TERM FREQUENCY STABILITY (AFTER WARM UP)	Less than ± 0.004 per cent per 5 minutes at constant case temperature.
5.	WARM UP	Less than 2 minutes at constant case temperature.
6.	FREQUENCY CHANGE WITH TEMPERATURE.	± 0.1 per cent over temperature range.
7.	FREQUENCY CHANGE WITH VOLTAGE.	±0.005 per cent per volt for power supply variations of ±20 per cent.
8.	FREQUENCY CHANGE WITH LOAD.	±0.05 per cent for open or short circuited load.
9.	MODULATION SENSITIVITY.	50 ± 5 kHz/volt.
10.	MODULATION LINEARITY.	Sensitivity will not change by more than ± 2 per cent for deviations from 2.5 to 250 kHz.
11.	MODULATION BANDWIDTH.	(-3 dB), 0 and 100 kHz. Linear to within ± 0.5 dB; 0 to 10 kHz.
12.	MAXIMUM DEVIATION.	250 kHz.
13.	INPUT IMPEDANCE.	≥100 kΩ
14.	POWER SUPPLY VOLTAGE.	-20V.D.C. ± 20 per cent.

15.	POWER SUPPLY CURRENT.	40 mA D.C. ± 15 per cent.
16.	NOMINAL EFFICIENCY.	18 per cent.
17.	SPURIOUS RADIATION.	At least 40 dB down on fundamental power level.
18.	TEMPERATURE RANGE.	0°C to 60°C.
19.	VACUUM.	Performance unaffected by vacuum of 10^{-6} mm of Hg.
20.	VIBRATION.	Performance unaffected by sinusoidal vibrations:- .5 - 10 Hz 1 inch D.A. 10 - 55 Hz 34 i.p.s. 55-2000 Hz 30G.
21.	SHOCK.	Frequency shifts of +80 ±40 kHz along any axis for impacts into hard concrete when encapsulated in a fibreglass reinforced ball and fired at velocities between 100 and 150 feet/second. The transmitter is capable of surviving 20 such impacts without appreciable degradation of performance. At velocities below 100 feet/second, under similar test condition, the frequency shift will be less than +60 kHz during impact period.
22.	SIZE.	The physical size of the YTX-1-2 transmitter is a cylinder 1-3/4 inches in diameter by 1-1/8 inches in length. Three miniature co-axial leads: signal in; power in; and, power out; are provided at one end of the case.
23.	WEIGHT.	3.7 ozs.

SECTION 3

TRANSMITTER ASSEMBLY

INTRODUCTION

1 This section briefly outlines the various steps taken in constructing the High Shock FM Transmitters. The drawings referred to are the engineering drawings associated with the manufacture and assembly and are to be found in Section 5.

ASSEMBLY JIG

2 The assembly jig, shown in drawing number 501168 performs several useful functions.

(a) It forms a convenient holding fixture for the small chassis during the construction and tuning phases of the transmitter assembly.

(b) The plastic support tube, used while tuning the transmitter, simplifies the tuning procedure when tubular trimmer capacitors are used, by giving clear access to them and by providing a low capacity, high resistance isolation from the work bench, bench vise, etc.

(c) It provides an accurately centred fixture for machining the excess plastic away after the various potting operations, thus allowing the use of non-precision molds.

(d) The assembly jig can be used in conjunction with the r.f. test cap to provide a complete r.f. shield around the transmitter during the tuning operation. The cap acts as a gauge to insure that all the components will be inside the finished transmitter module as well.

TRANSMITTER CHASSIS

3 The transmitter chassis is made from 1/32 inch, one ounce (0.0014 inch) copper clad epoxy fibreglass board and is shown in drawing number 501165. The bottom of the chassis, detail B, is cemented to the assembly jig before the partitions are soldered to it. This prevents the bottom board from warping during the soldering process. The slots in the partitions serve to limit the size of the eddy current path around the r.f. coils. The partitions are narrower than the base diameter for the same reason.

RADIO FREQUENCY COIL

4 The r.f. coil is made by depositing silver on an almost pure alumina substrate. The substrate used is a 99.9 per cent Al_2O_3 polycrystalline alumina called Lucalox and made by General Electric's Lamp Glass Department, Cleveland, Ohio.

5 The coil is made by first depositing five or six coatings of Hanovia Liquid Silver No. 467 to a depth of 0.001 to 0.0015 inch on the substrate, each baked at 871 degrees Celsius for ten minutes. The coil is formed by first covering the silver to be removed with a plastic tape of suitable width. The tape is carefully stripped away and the exposed silver is then etched from the substrate with acid.

6 The Q of the coil should be at least 140, measured at a frequency greater than 200 MHz. Lead attachment to the silver is done with a low temperature silver bearing solder. Drawing number 501172 is the assembly drawing for the r.f. coil.

TEMPERATURE COMPENSATING CAPACITORS

7 To improve the silver dielectric bond the N750 disc type capacitors, and to decrease their volume the dielectric disc must be re-silvered using Hanovia Liquid Silver No. 467. The final capacitance value can be varied to suit the transmitter requirements by adjusting the size of the electrodes on either side of the dielectric disc. Low temperature silver bearing solder is used when attaching leads.

POWER OUTPUT TRANSISTOR

8 The 2N3866 transistor which is used in power output amplifier is packaged in a TO-39 case. To reduce the size of this case for use in the high shock transmitter the case is partially removed and the cap shown in drawing number 501169 soldered in its place. The wall of the original transistor is cut back so that the edge of the cap rests on the flange at the bottom of the transistor. The soldering is done at as low a temperature as possible and seals the transistor sufficiently well to prevent solvents from entering during the cleaning procedures prior to potting.

9 The power output transistor is inverted and attached to the top of the r.f. coil. The mechanical arrangement is shown in the side elevation of the power amplifier in the electronic assembly drawing number 501170. The transistor case is sweat soldered directly to the top of the r.f. coil.

DIODE STRESS RELIEF

10 The stress relief material on the PD6008A diodes is General Electric RTV60 with 5 per cent diluent. A thin layer of silastic is applied to the diode body and 1/16 inch of the leads.

TRANSMITTER ASSEMBLY

11 The assembly of the transmitter is carried out in accordance with Computing Devices' General Specification, GS956001, covering shop practice and workmanship when applicable. Exact compliance with portions of this specification is not possible because of the conditions imposed on the transmitter by the limited space available, the r.f. circuit layout requirements and the high shock conditions.

12 Inspection under a times seven viewing microscope is carried out frequently during all steps of the assembly by a representative of Computing Devices' Quality Control department. The assembly of the components of the transmitter is carried out in the following steps, and in conjunction with the tuning procedure outlined in paragraph 13 below. Component location and orientation are as shown in drawing number 501170 and the assembly photographs.

(a) The coaxial leads are attached to the chassis by soldering their shield conductors to the upright partitions where they enter the chassis.

(b) The r.f. coils are soldered to the bottom of the chassis. The location of these coils determines the location of most of the components in each compartment. Care is taken to follow drawing number 501171 exactly.

(c) Each section is then assembled according to drawing number 501171. The tuning capacitors are omitted from each section and extra lead length is provided in the transmitter for their attachment after potting.

(d) After the initial tuning and check out as described in paragraph 13, the transmitter is potted except for the trimmer capacitors which are replaced with silastic plugs.

(e) The remaining steps required to complete the electronic assembly consist primarily of tuning the transmitter. This is covered below.

1. VOLTAGES (V)		
Voltage across CR1	5.2 ± 0.3	
Voltage across CR2	5.2 ± 0.3	
Voltage at junction of R5 & R6	2.9 ± 0.2 above supply voltage	
Voltage at junction of R6 & R7	1.4 ± 0.2 above supply voltage	
2. CURRENTS (mA)		
	Supply Voltage -16.0V ± 0.2V	Supply Voltage -24.0V ± 0.2V
Current through CR1	1.6 ± 0.2	3.5 ± 0.2
Current through CR2	3.5 ± 0.5	3.5 ± 0.5
Current through Q1 emitter	4.5 ± 1.5	4.5 ± 1.5
Current through Q2 emitter	2.5 ± 0.5	2.5 ± 0.5
Current through Q3 emitter	3.5 ± 0.5	3.5 ± 0.5
Current through Q4 emitter	8.0 ± 2.0	8.0 ± 2.0
Current through Q5 emitter	25 ± 3	25 ± 3
3. POWER OUTPUTS (mW)		
	Supply Voltage -16.0V ± 0.2V	Supply Voltage -24.0V ± 0.2V
Power output of the Oscillator	0.5 ± 0.1	0.5 ± 0.1
Power output of the 1st Amplifier	1.5 ± 0.5	1.5 ± 0.5
Power output of the 2nd Amplifier	15 ± 5	21 ± 9
Power output of the Power Amplifier	120 ± 20	170 ± 50

Table 1. Typical Voltages, Currents and Power Outputs in the High Shock FM Transmitter YTX-1-2.

TRANSMITTER TUNING

13 The transmitter performance is critical with regard to circuit layout and component values. Many components cannot easily be replaced once they have been mounted and for this reason the tuning and assembly steps must be carried out together. Tuning should be carried out as follows.

(a) After assembly, the oscillator is tuned to approximately 245 MHz u using a 5.2 volt external DC power supply. Adjustable trimmer capacitors are used during the initial tuning steps. If the value of C1 required for tuning the oscillator is small compared with C2 there will be insufficient temperature compensation. This is counteracted by replacing the r.f. coil with one of lower inductance permitting a larger value of C1 to be used.

(b) The DC conditions in the remainder of the circuit are adjusted by selecting values of R5, R6 and R7 which will give the required DC currents in each section. These values are given in Table 1.

(c) The transmitter is adjusted for maximum output power at 245 MHz, using adjustable trimmer capacitors in place of C9, C13 and C18. If necessary adjustments can be made to C7 and C12 to increase the current gain in the first and second amplifiers. The currents, voltages and power levels given in Table 1 represent the typical conditions to be expected in the transmitter.

(d) The buffering is checked for open and short circuit loads. Buffering can be improved by adjusting C7 and C12 and in some cases by adjusting C8, C17 and C20.

(e) Once properly tuned the trimmer capacitors are replaced with fixed capacitors and the performance of the transmitter is measured with the test cap placed over the transmitter. Fixed capacitors are chosen on a trial and error basis until equivalent performance for each stage is obtained. Fixed capacitors are substituted for each adjustable trimmer capacitors one at a time. Care is exercised to prevent the trimmer capacitors C11, C13 and C18 from becoming too small. With too small values of these capacitors the temperature compensation could be insufficient and difficulties in trimming the transmitter after potting could result. To increase the size of these capacitors it is necessary to replace the r.f. coil with units having lower inductance. The large values of the temperature compensating capacitors C10, C14 and C19 do not permit small changes in value of these capacitors to be made. In addition to frequency, power output, and buffering, the temperature compensation of the transmitter is checked in an oven.

(f) If the preceding tests are satisfactory the tuning capacitors C1, C7, C9, C12, C13 and C18 are removed and their values recorded. Silastic plugs are put in their place and the transmitter is then cleaned, potted and machined to its final diameter as described in paragraphs 14, 15 and 16. R2 is also removed and replaced with a small silastic plug.

(g) After potting and machining the capacitors are replaced and adjusted as necessary to bring the transmitter back to its original performance.

(h) The oscillator and power amplifier tuning capacitors are next potted.

(j) The transmitter performance is rechecked and the remaining tuning capacitors are potted.

(k) The modulation resistor is adjusted to give the required modulation sensitivity and potted.

CLEANING PRIOR TO POTTING

14 To ensure effective bonding between the electronic components and the Stycast 1090 potting compound, the transmitter module must be cleaned before each potting operation. Cleaning is done to accepted cleaning standards using either Freon TF or Isopropal Alcohol.

POTTING PROCEDURE AND MACHINING

15 Emerson and Cuming Stycast 1090 is used to pot the transmitter. The plastic is glass microballoon ("Eccosphere") filled.

16 Curing is done at a low rate to decrease the potting stresses. The best curing schedule allows the plastic to cure for 24 hours or more at room temperature and then for 28 hours at 60 degrees Celsius. A faster cure of 8 to 14 hours at 71 degrees Celsius can also be used, with an increase in potting stress. By using an oversize mold, 30 to 40 per cent larger than the final diameter, and machining off the excess plastic, the effect of surface stress is eliminated. A very fast cure of several hours of 93 degrees Celsius could be used but is recommended for potting small volumes only.

17 The molds for potting the trimmer capacitors are made oversize to allow all air to escape from the trimmer capacitor cavity. Excess plastic is removed by machining. Vacuum potting techniques are also used.

RADIO FREQUENCY SHIELD

18 An r.f. shield, bonded to the potted transmitter module is required to prevent the relative movement of the transmitter assembly with respect to the outer case from shifting the frequency of the oscillator. The r.f. shield is formed in the following manner:

(a) A narrow band of copper at the top edges of the partitions and around the bottom of the chassis is exposed.

(b) Emerson and Cuming Eccoband Solder 56C with catalyst number 11 conducting epoxy is applied to a fairly thick layer over the sides and top of the transmitter module. The bond between the copper on the transmitter chassis and the conducting epoxy is made as uniform and strong as possible. The plastic is cured for several hours at 100 degrees Celsius.

(c) After curing, the conducting epoxy is carefully machined down to produce a uniform layer approximately 0.007 inches thick.

(d) A layer of silver 0.005 inches is next applied to the conducting epoxy using standard electroplating procedures.

FINAL ASSEMBLY

19 A uniform spacing of approximately 0.062 inch between the transmitter and the outer case is produced by using 1/16 inch square strips of neoprene rubber, see drawing number 501171. The transmitter module is then inserted into the outer case which has been partially filled with Dow Corning 501 silastic. The case lid is then screwed on. The excess silastic plastic is allowed to flow out of the two threaded holes in the lid. The bottom treated holes are plugged with 6-32 allen setscrews before potting and the top holes are plugged with similar setscrews after potting.

SECTION 4

ASSEMBLY PHOTOGRAPHS

1 The following photographs show stages in the assembly of the High Shock FM Transmitter YTX-1-2. The drawings referred to are the Computing Devices' engineering drawings reproduced in Section 5 of this report.

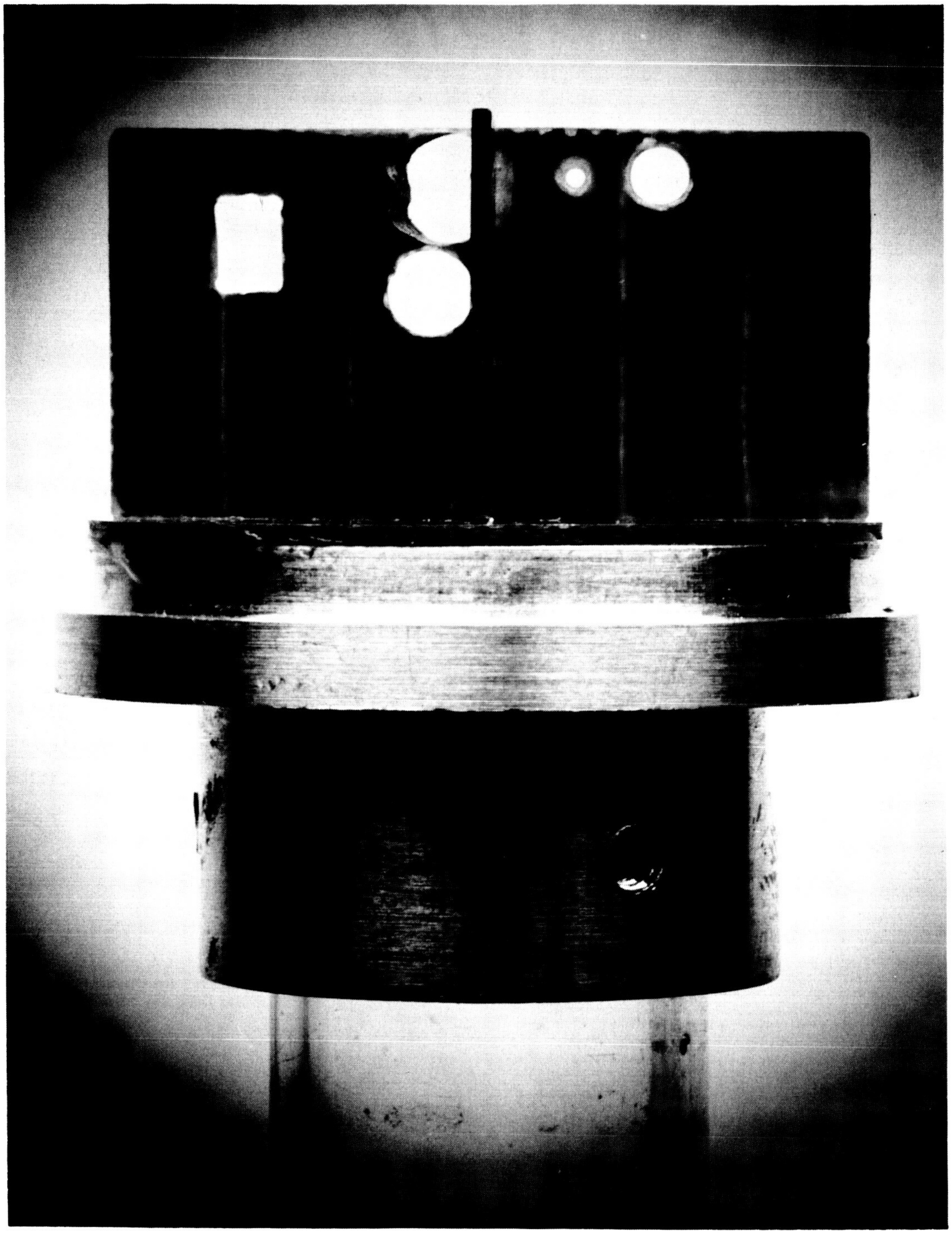


Figure 1. Photograph Showing Transmitter Chassis Attached to Assembly Jig as shown in Drawing No. 501168

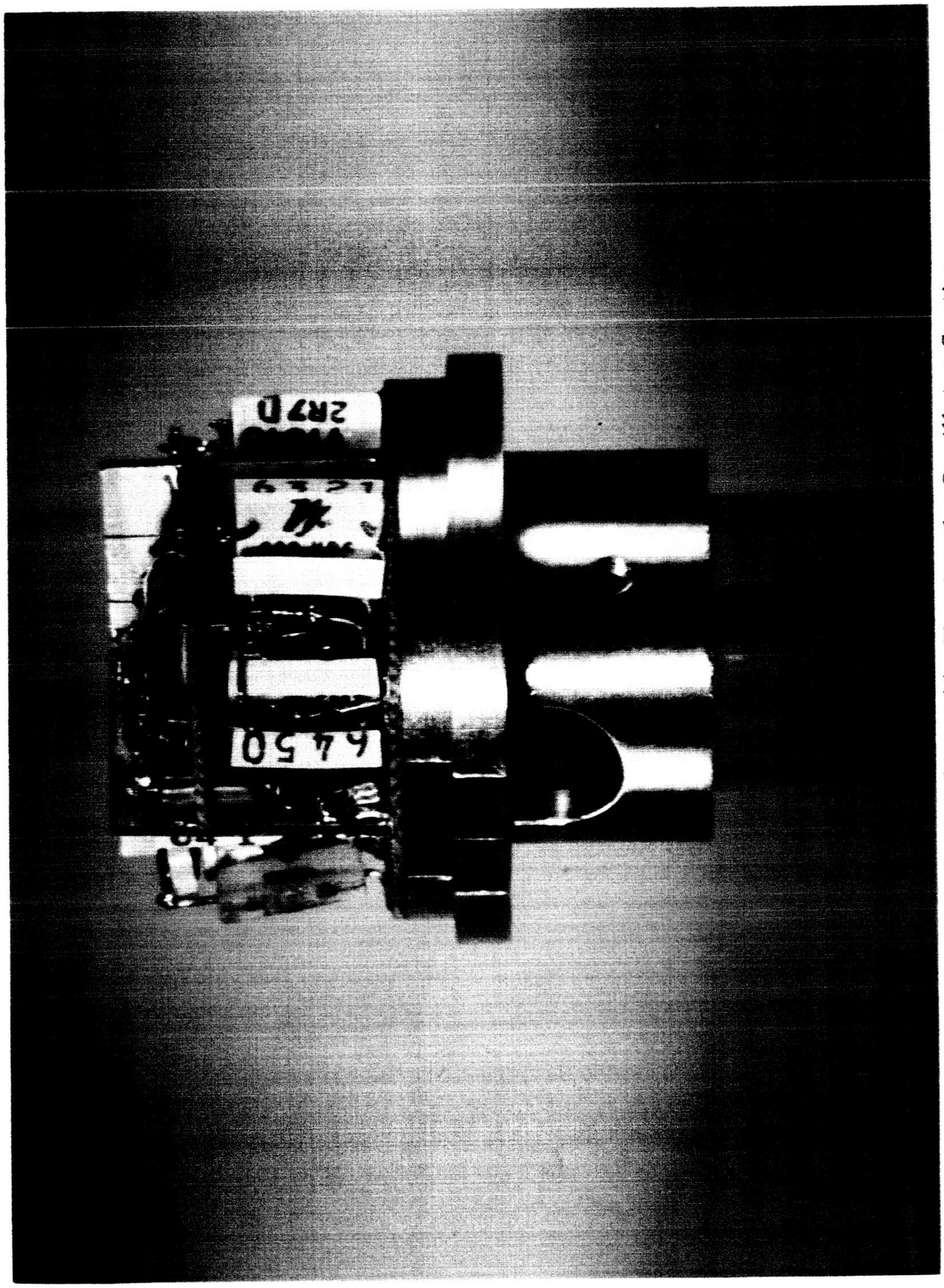


Figure 2. Component Assembly Showing the Oscillator Section

Figure 2.

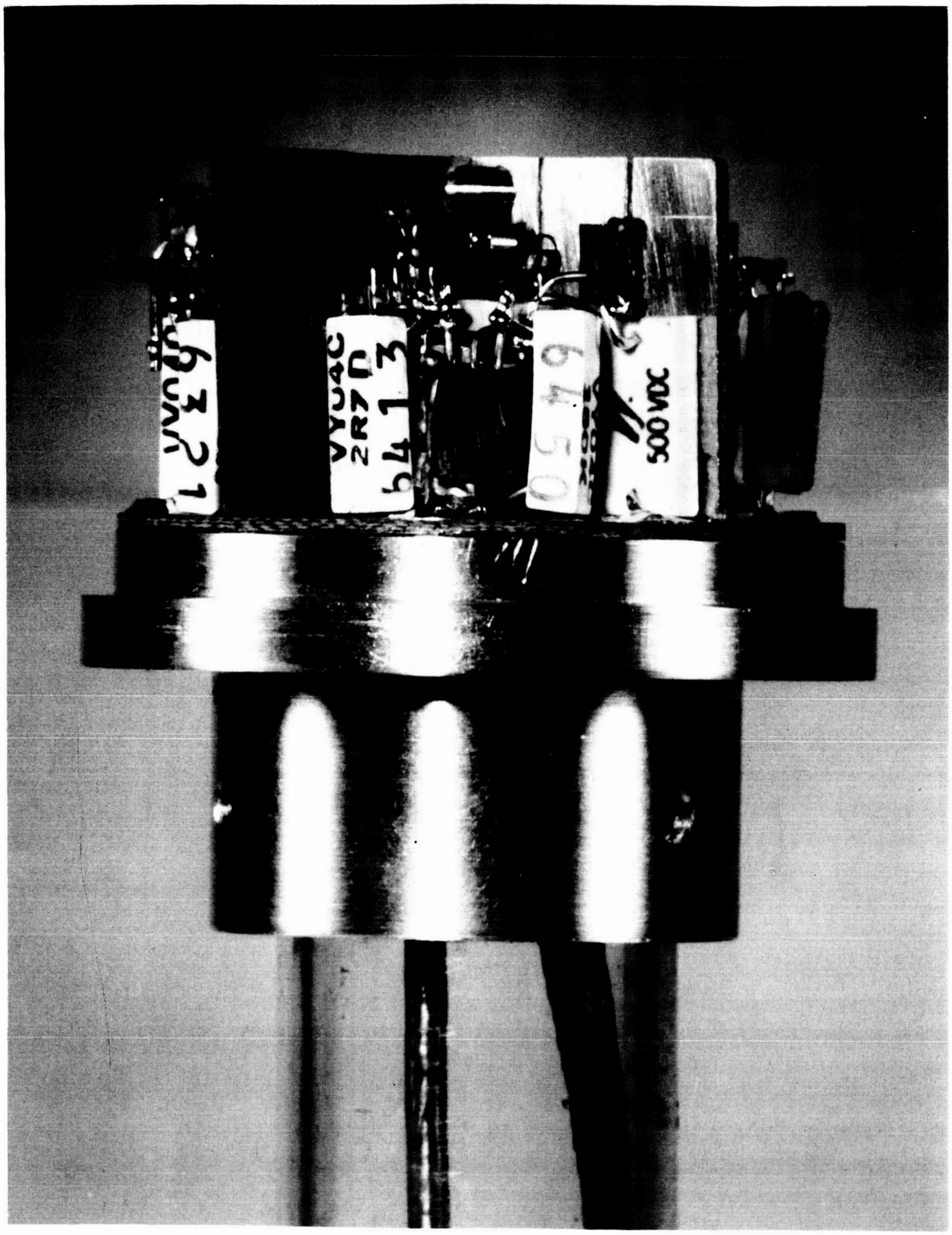


Figure 3. Component Assembly Showing the Final Amplifier

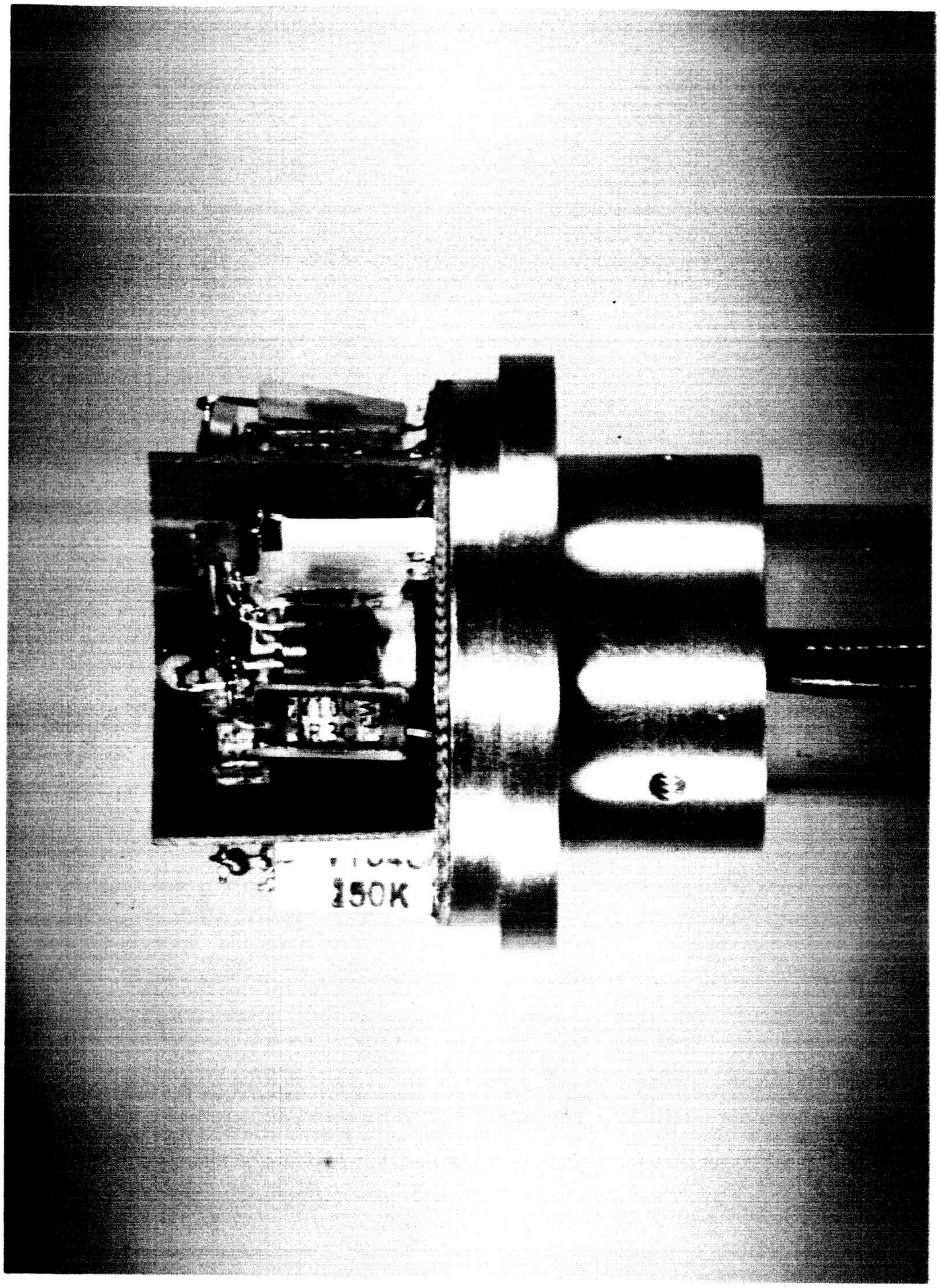


Figure 4. Component Assembly Showing the Second Amplifier

Figure 4.

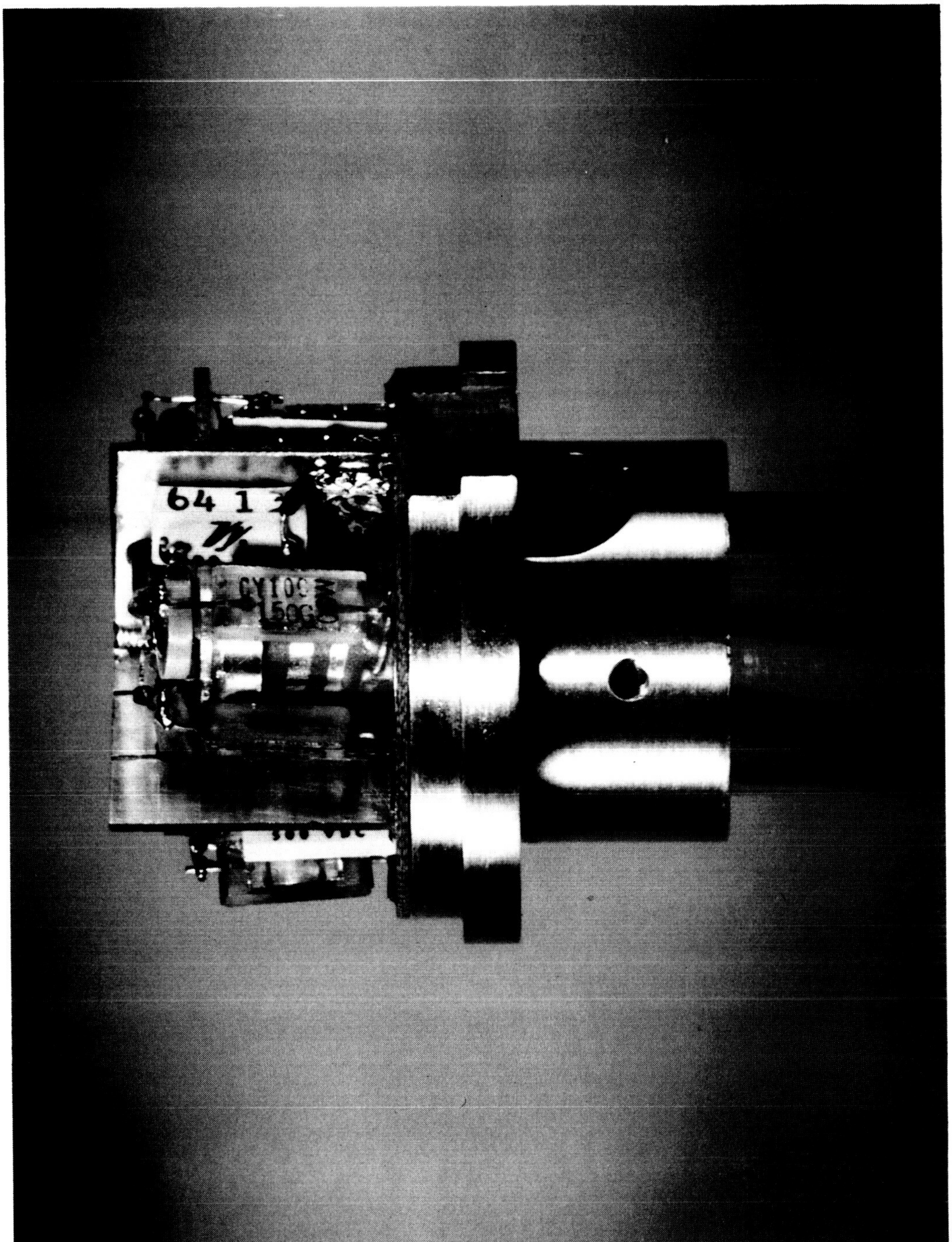


Figure 5. Component Assembly Showing the Power Amplifier

Figure 5.

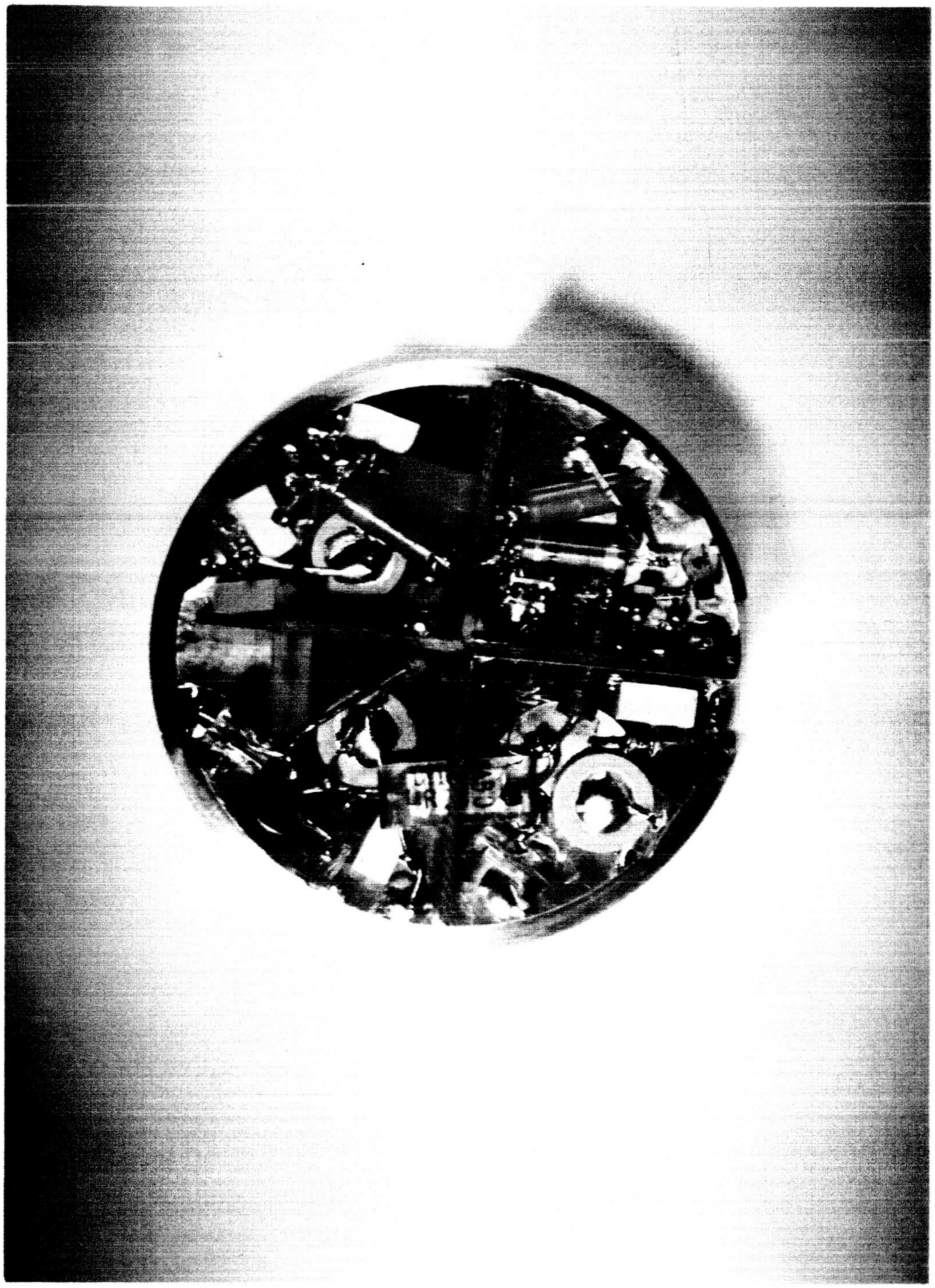


Figure 6. Top View of the High Shock FM Transmitter

Figure 6.

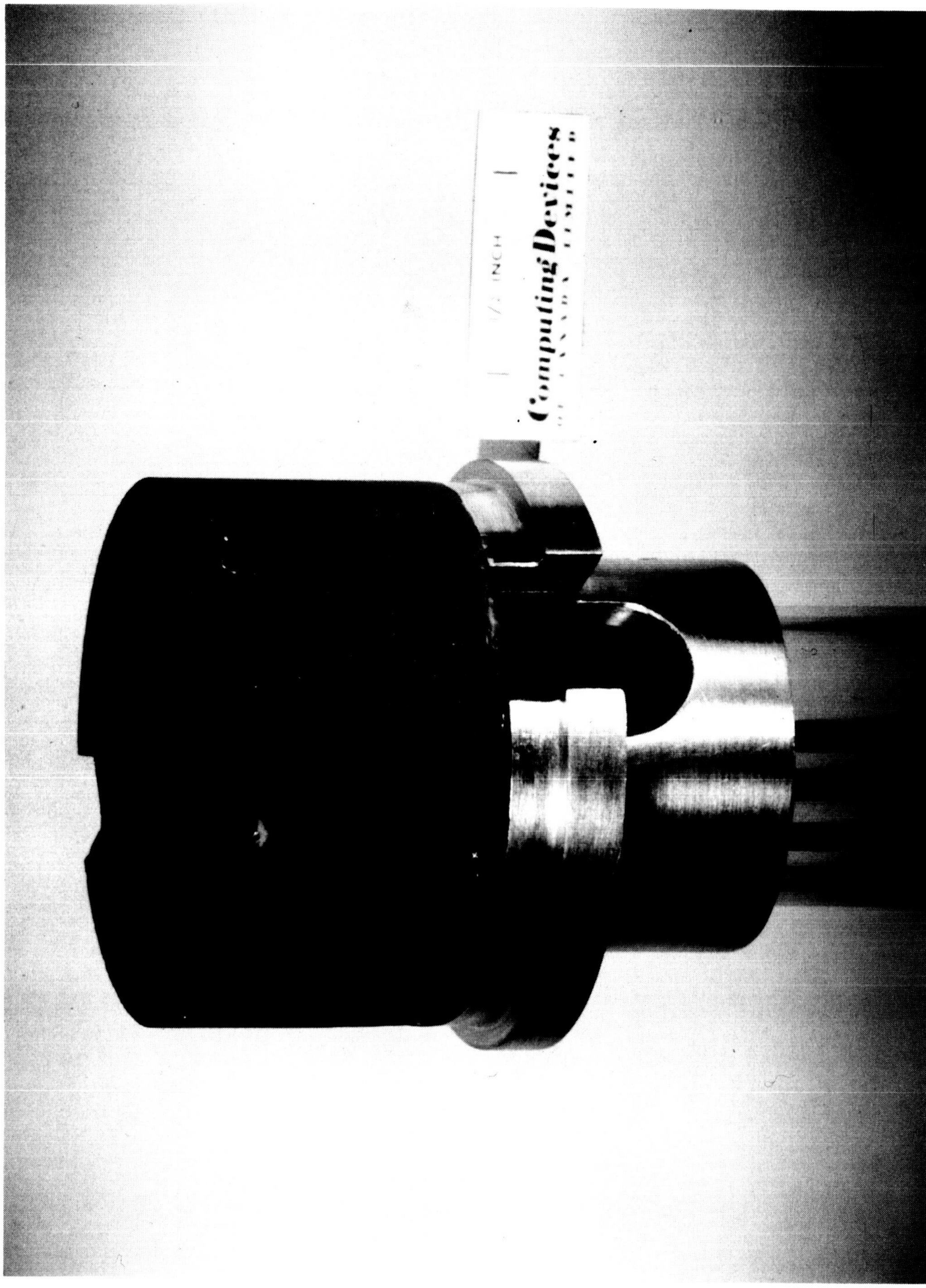


Figure 7. High Shock FM Transmitter after First Potting

Figure 7.

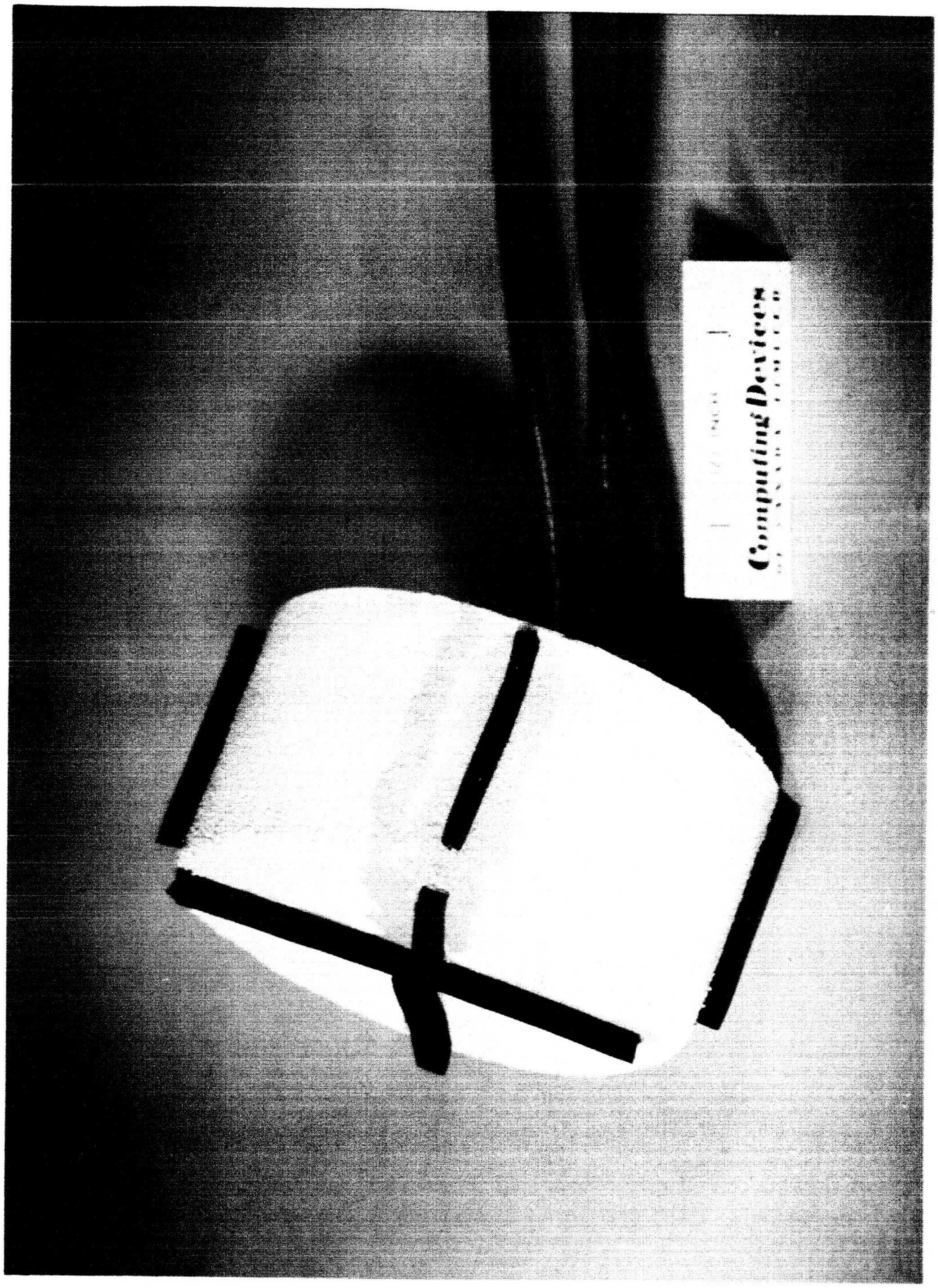


Figure 8. High Shock FM Transmitter after Silver Plating and with Neoprene Spacers in Place

Figure 8.

Figure 9. Completed High Shock FM Transmitter YTX-1-2

Figure 9.

SECTION 5

ENGINEERING DRAWINGS AND PARTS LIST

1 The following drawings are Computing Devices' engineering drawings produced for the manufacture and assembly of the High Shock FM Transmitter YTX-1-2. A parts list is also included as Figure 17.

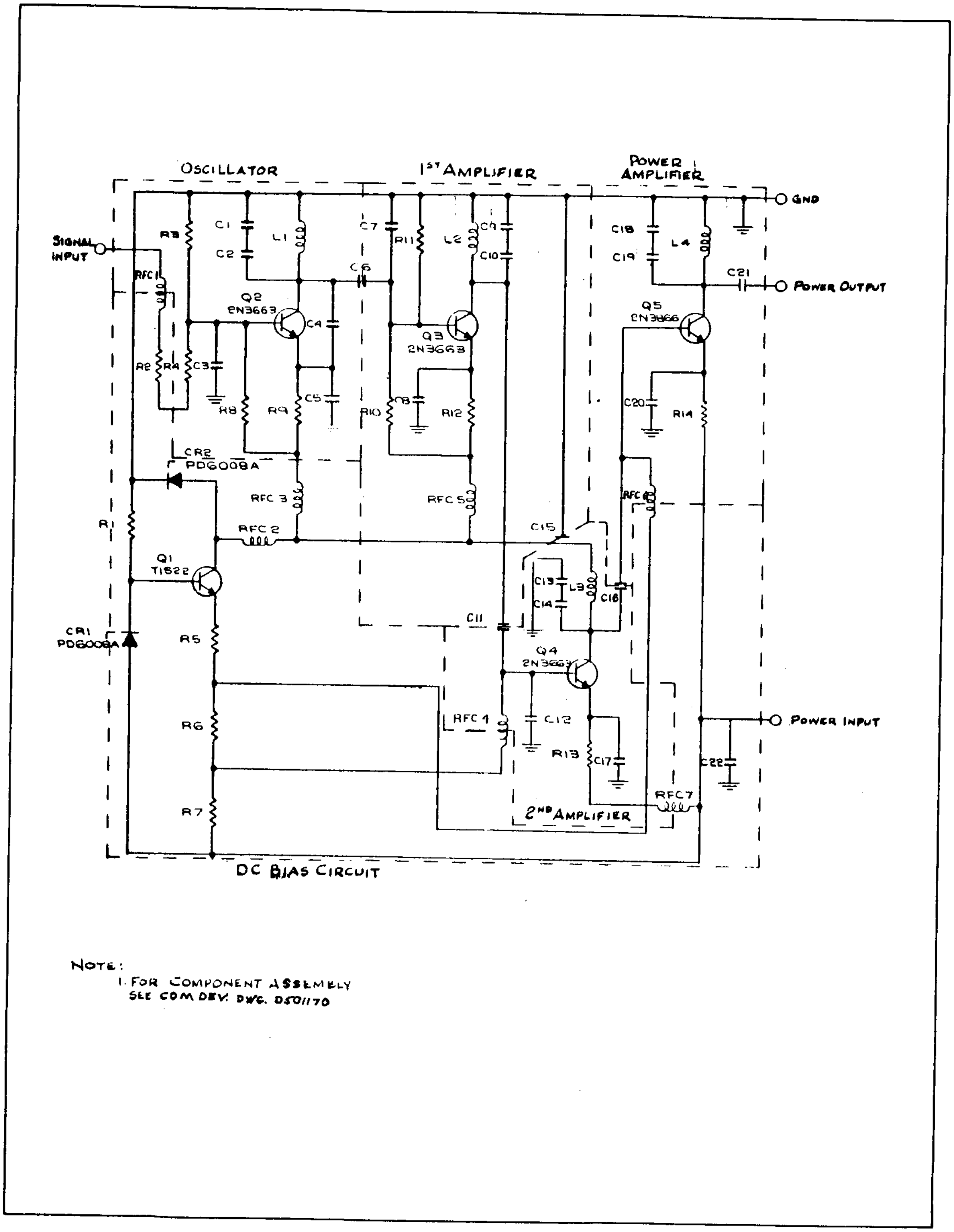


Figure 10. Schematic Diagram, Computing Devices Drawing No. 501163

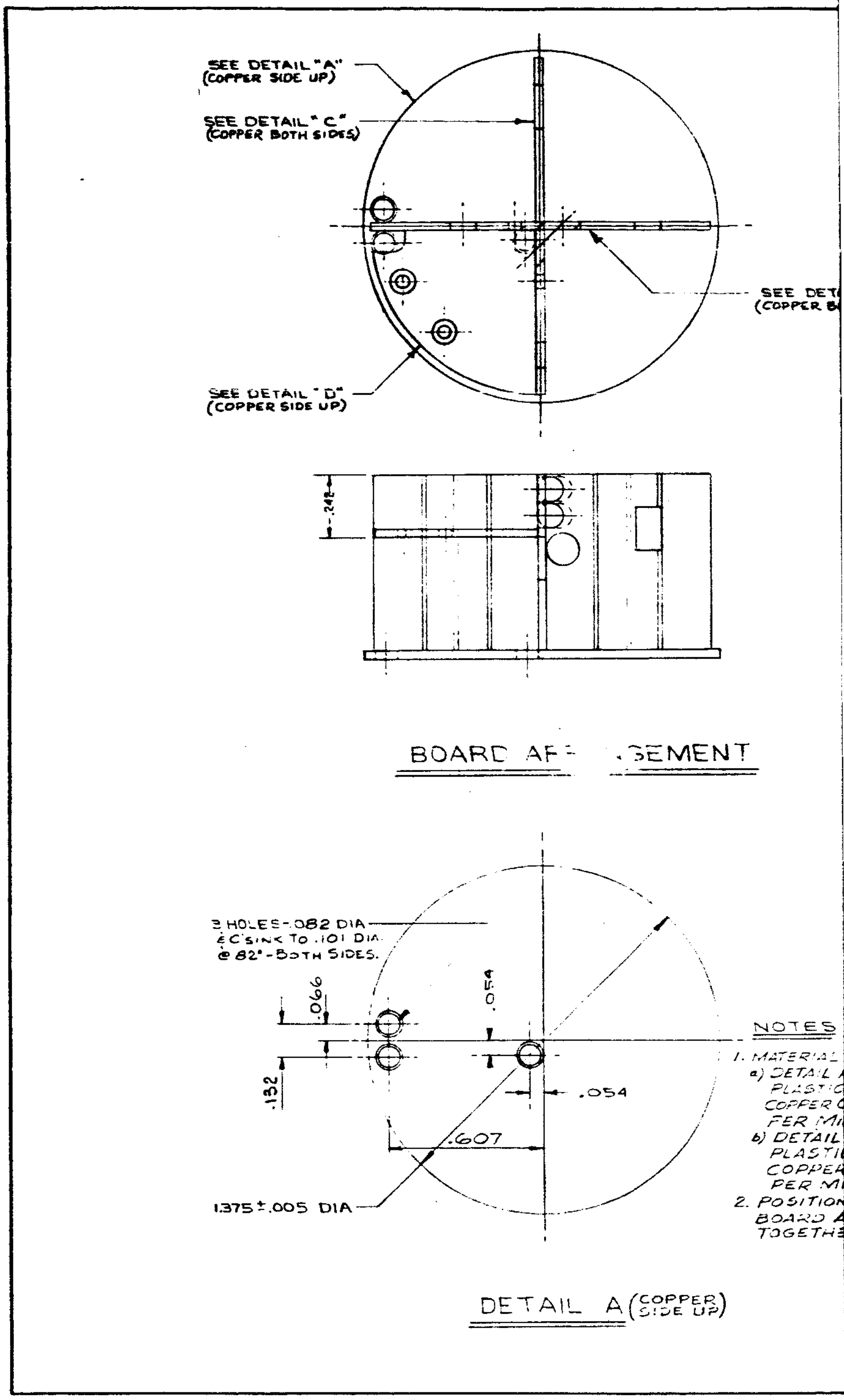

SEE DETAIL "A"
(COPPER SIDE UP)
SEE DETAIL "C"
(COPPER BOTH SIDES)
SEE DETAIL "D"
(COPPER SIDE UP)
.248
BOARD AR   GEMENT
3 HOLES-.082 DIA
& C'SINK TO .101 DIA.
@ 82°-BOTH SIDES.
.066
.054
.132
.054
.607
1.375±.005 DIA
NOTES
DETAIL A (COPPER SIDE UP)

Figure 11.

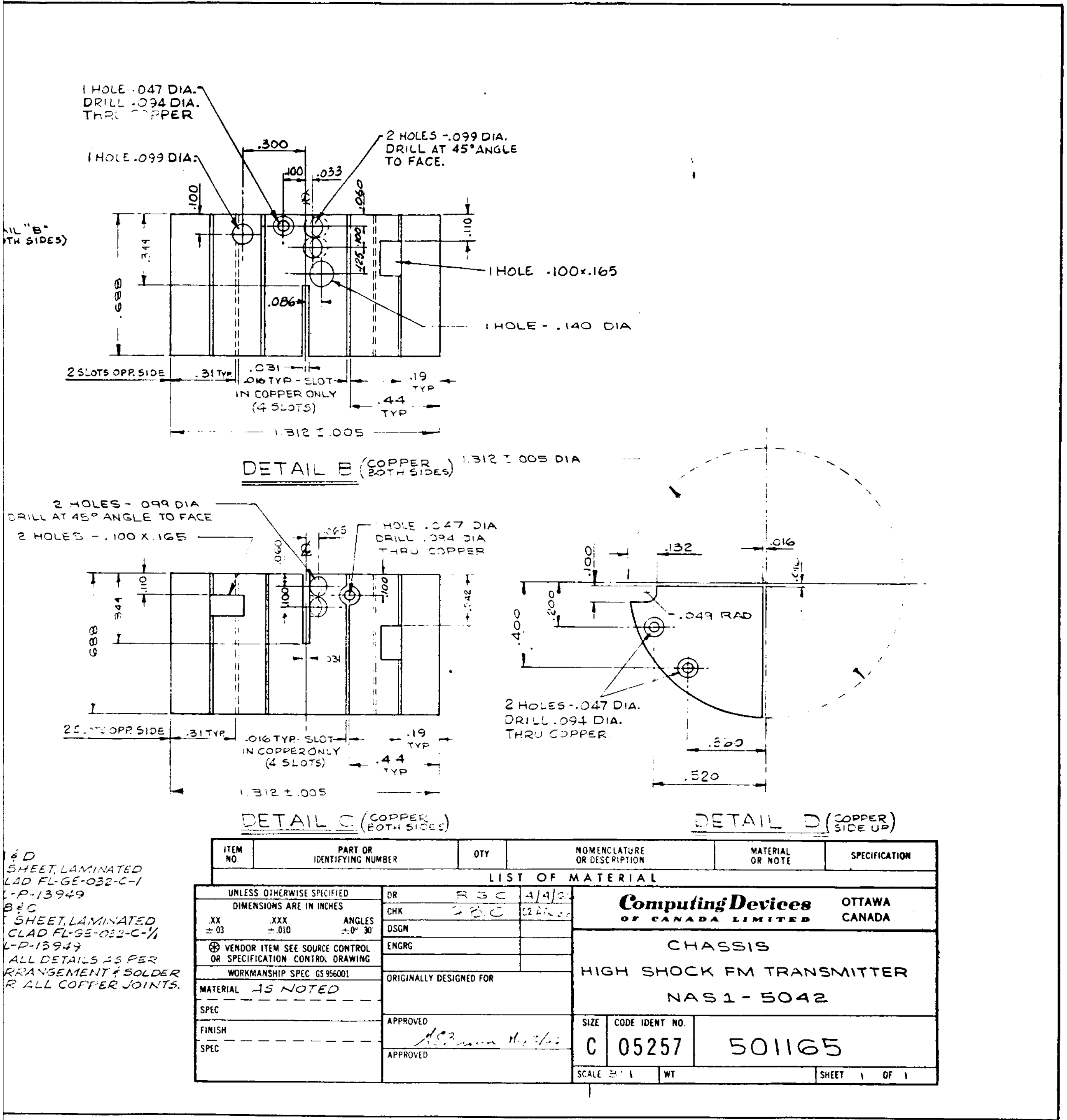


Figure 11. Chassis, Computing Devices Drawing No. 501165

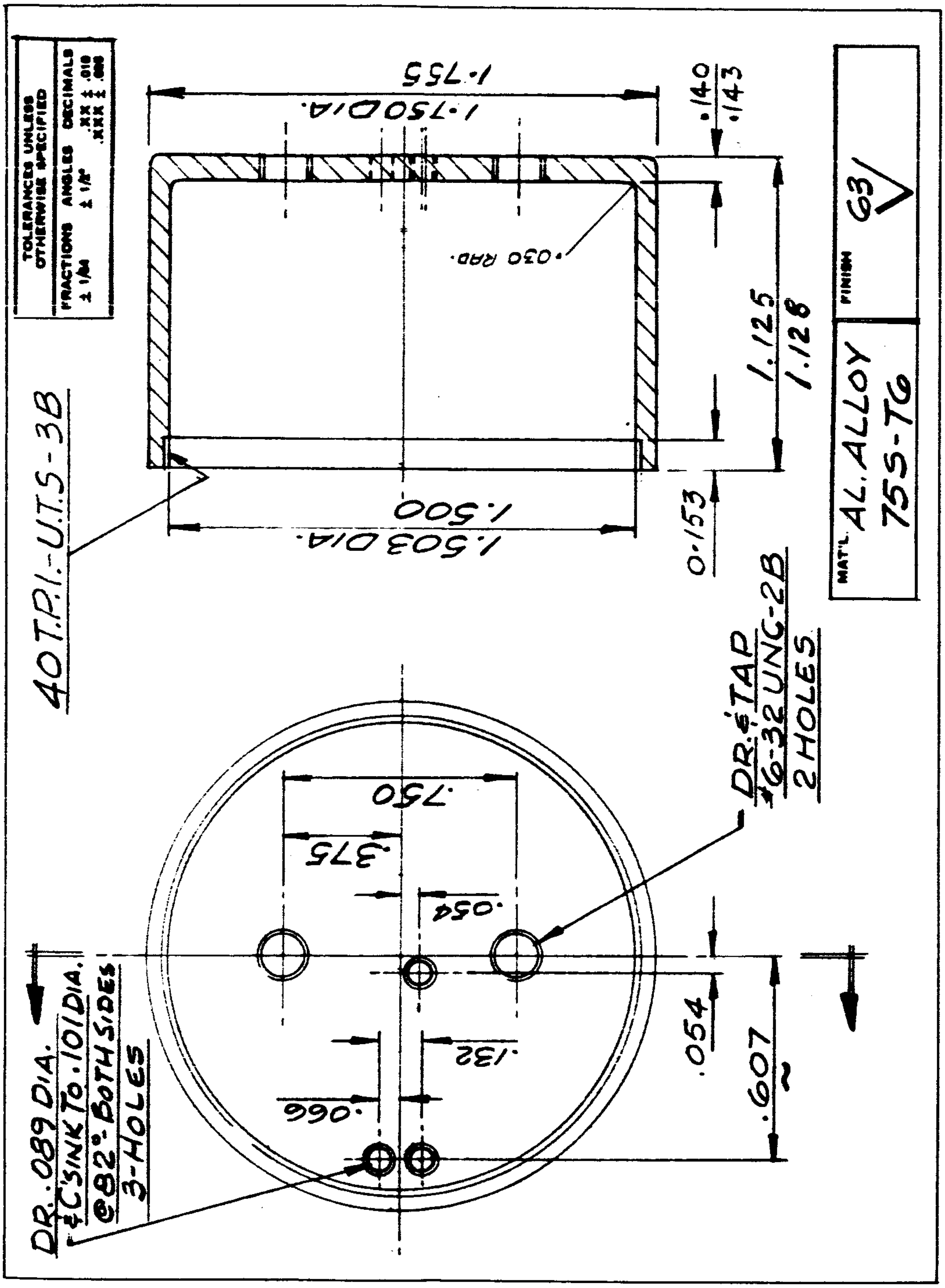


Figure 12. Case, Computing Devices Drawing No. 501166

Figure 12.

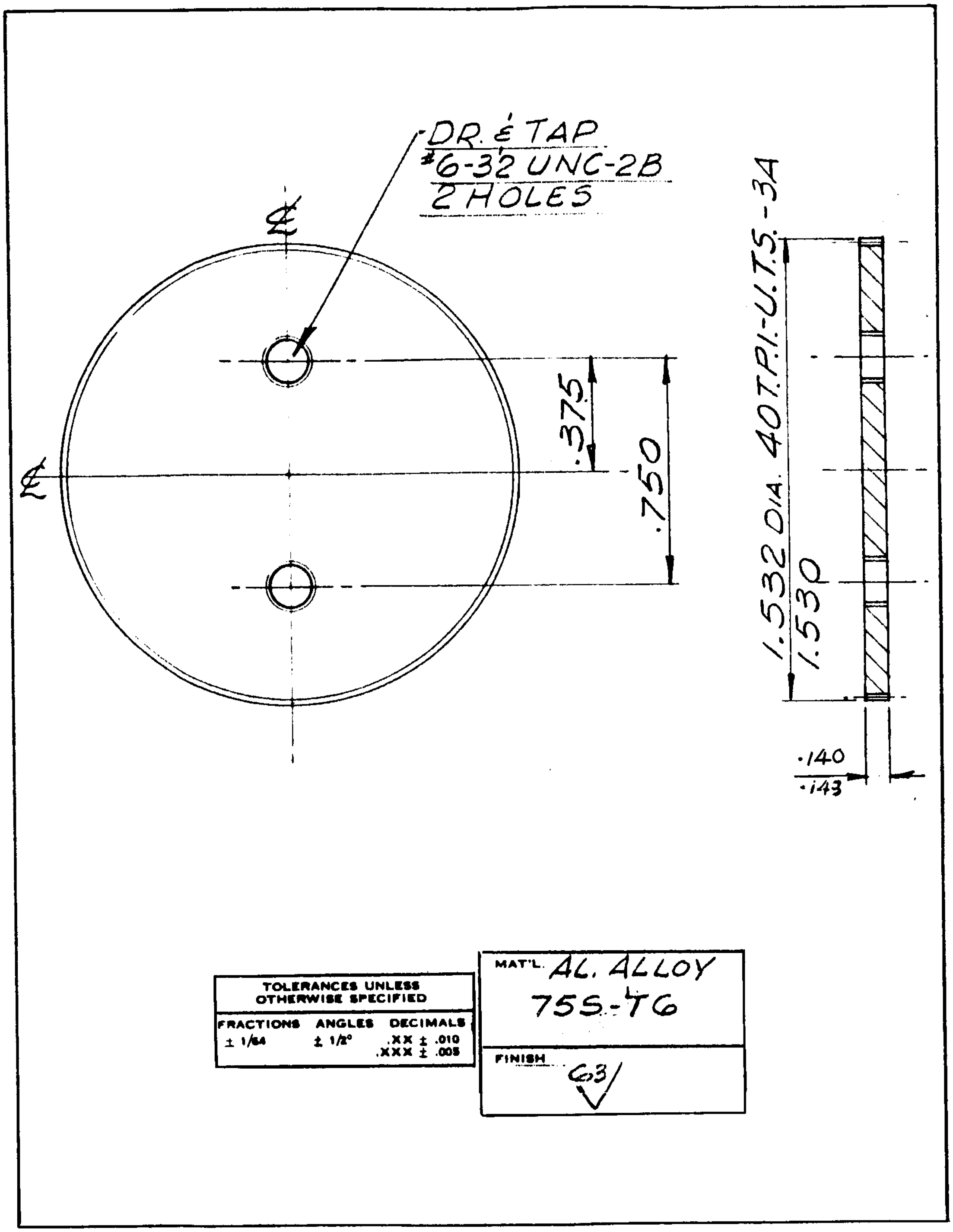


Figure 13. Cover, Computing Devices Drawing No. 501167

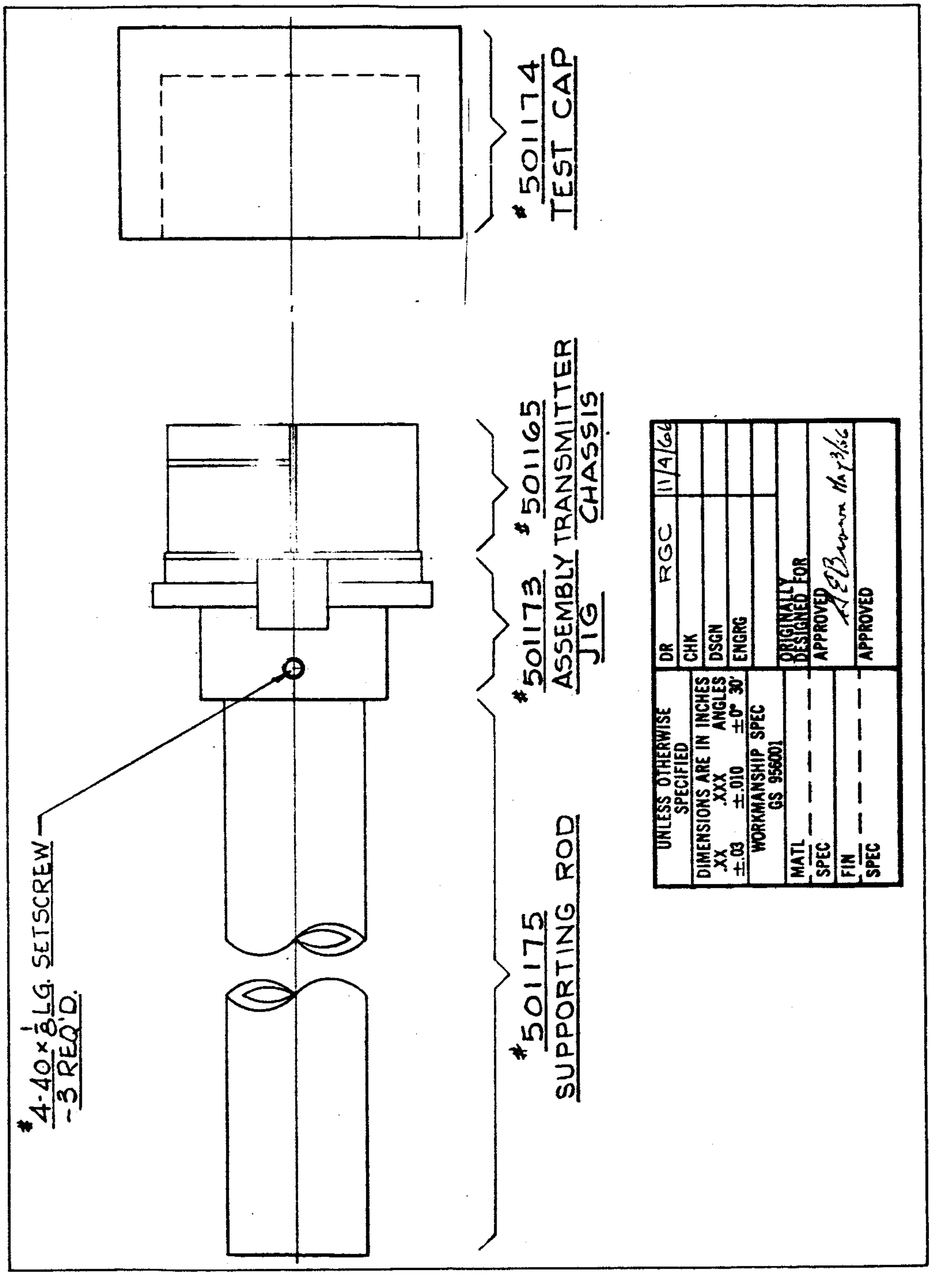


Figure 14. Chassis and Jig Assembly, Computing Devices Drawing No. 501168

Figure 14.

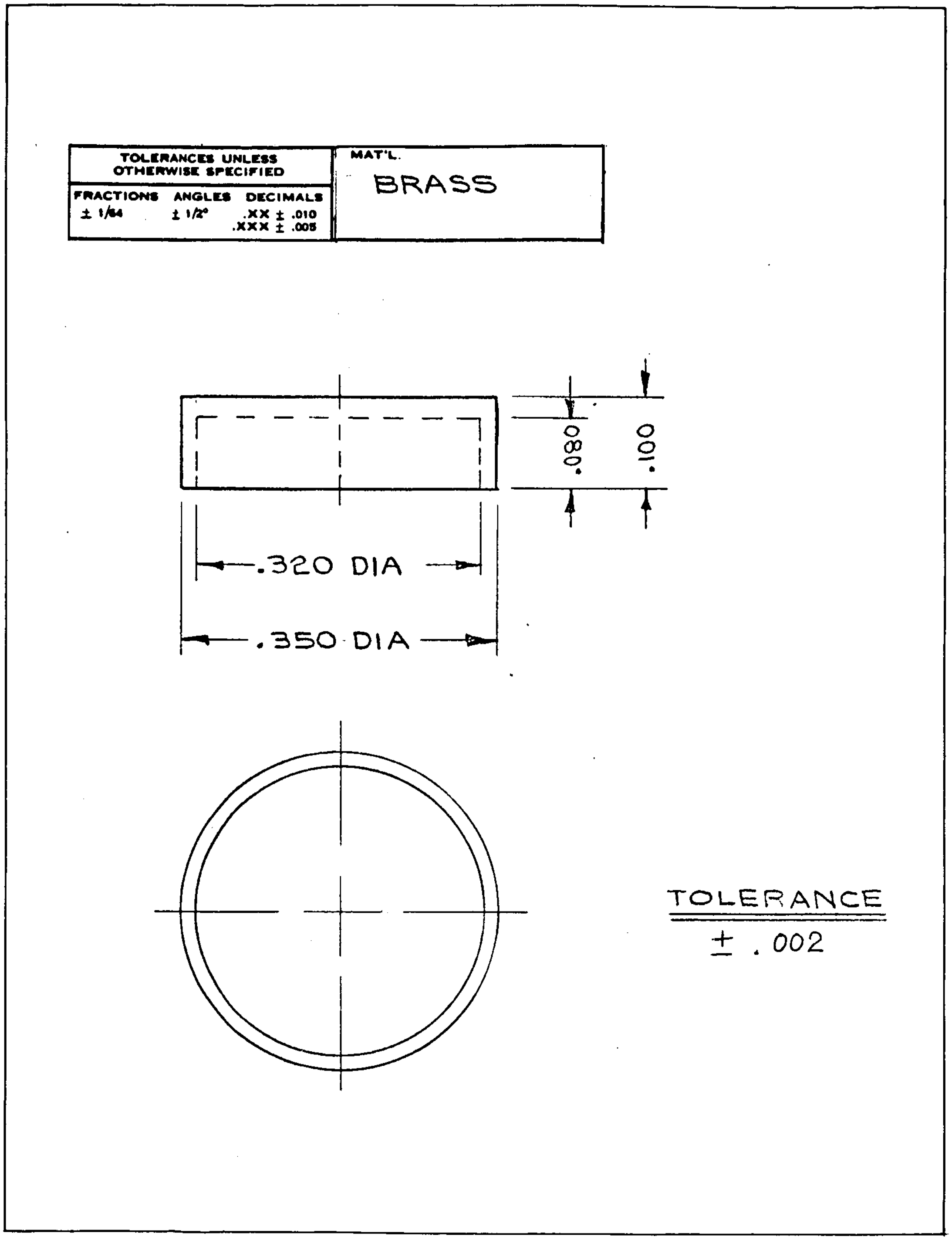


Figure 15. TO-39 Transistor Case,
Computing Devices Drawing No. 501169

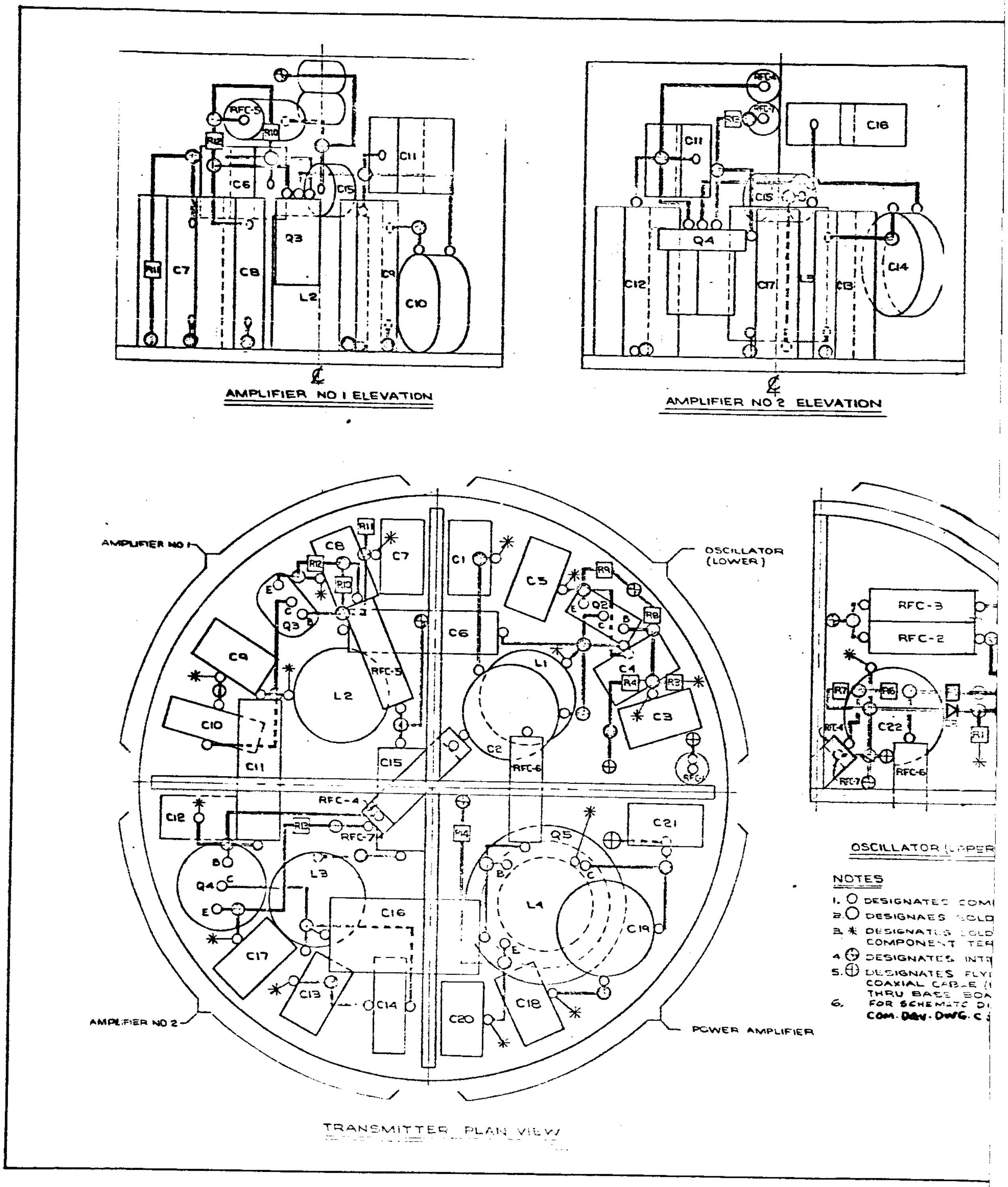

AMPLIFIER NO 1 ELEVATION
AMPLIFIER NO 2 ELEVATION
AMPLIFIER NO 1
OSCILLATOR (LOWER)
AMPLIFIER NO 2
POWER AMPLIFIER
TRANSMITTER PLAN VIEW
NOTES

Figure 16.

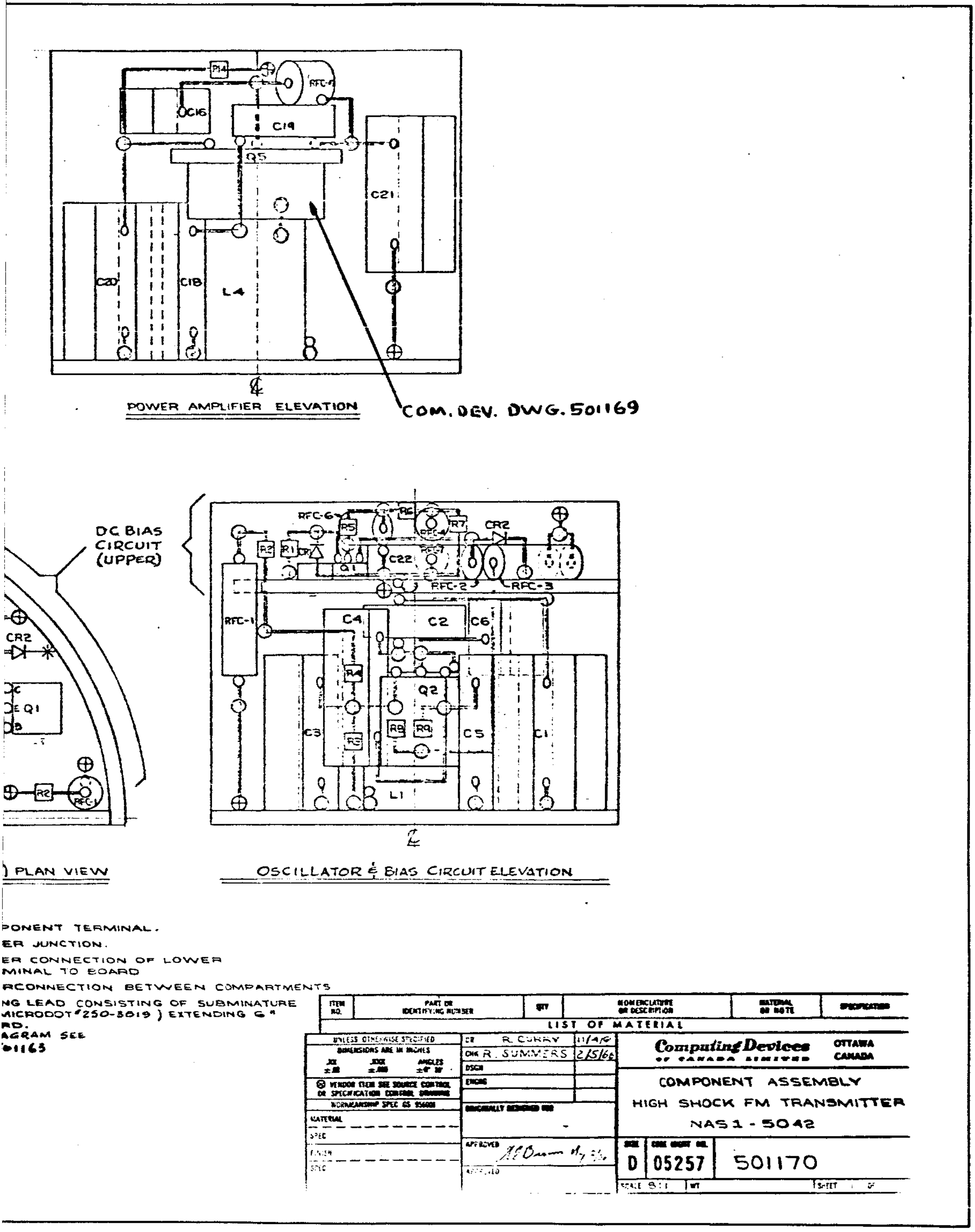


Figure 16. Component Assembly, Computing Devices Drawing No. 501170

ITEM		PART NO.	PART NO.	QTY.	NAME & MATERIAL	SPECIFICATION	
30							
29							
28		VY04C220K		1	CAPACITOR C20	47 pf	VITRAMON
27		DD-501		1	CAPACITOR C22	500 pf	ERIE
26		CYFM10C4R7C		1	CAPACITOR C16	4.7 pf	CORNING
25		EF5		1	CAPACITOR C15	1500 pf FEED THRU	AEROVOX
24		CYFM10C2R7C		1	CAPACITOR C11	2.7 pf	CORNING
23		VY04C6R8K		2	CAPACITOR C7,* C12*	6.8 pf	VITRAMON
22		VY04C0R5K		1	CAPACITOR C6	0.5 pf	"
21		VY04C3R9K		2	CAPACITOR C4, C21	3.9 pf	"
20		VY04C150K		4	CAPACITOR C3, C5, C8, C17	15 pf	VITRAMON
19		N750-301		4	CAPACITOR C2, C10, C14, C19	10 pf	ERIE **
18		VY04C220K		4	CAPACITOR C1*, C9*, C13, C18*	22 pf	VITRAMON
17		PD6008A		2	DIODES CR1, CR2		TRW **
16		100 A10L		3	RESISTOR R12, R13, R14	100	CTS OF CANADA CERADOT
15							
14		220 A10L		1	RESISTOR R9	220	"
13		2200 A10L		2	RESISTOR R8, R10	2.2 K	"
12		470 A10L		2	RESISTOR R6*, R7	470	"
11		390 A10L		1	RESISTOR R5*	470	"
10		200000 C10L		1	RESISTOR R4	100K	"
9				1	RESISTOR R3	10K	"
8		3300 A10L		1	RESISTOR R2*	33 K	"
7		6800 A10L		1	RESISTOR R1, R11	6.8K	"
6		4426-3K		7	CHOKE RFC-1,2,3,4,5,6,7	.56 μH	JEFFERS
5			501172-2	1	COIL L4	2 1/2 TURNS	Com Dev **
4			501172-1	3	COIL L1, L2, L3	3 TURNS	Com Dev **
3		2N3866		1	TRANSISTOR Q5		RCA OR VECTOR **
2		2N3663		3	TRANSISTOR Q2, Q3, Q4		GE
1		T1522		1	TRANSISTOR Q1		TEXAS INST

MATERIAL LIST

NOTES
* NOMINAL VALUE AS SHOWN, FINAL TO BE DETERMINED ON ASSEMBLY.
** REFER TO ENGINEERING REPORT.

Figure 17. Component Parts List, Computing Devices Drawing No. 501170

Figure 17.

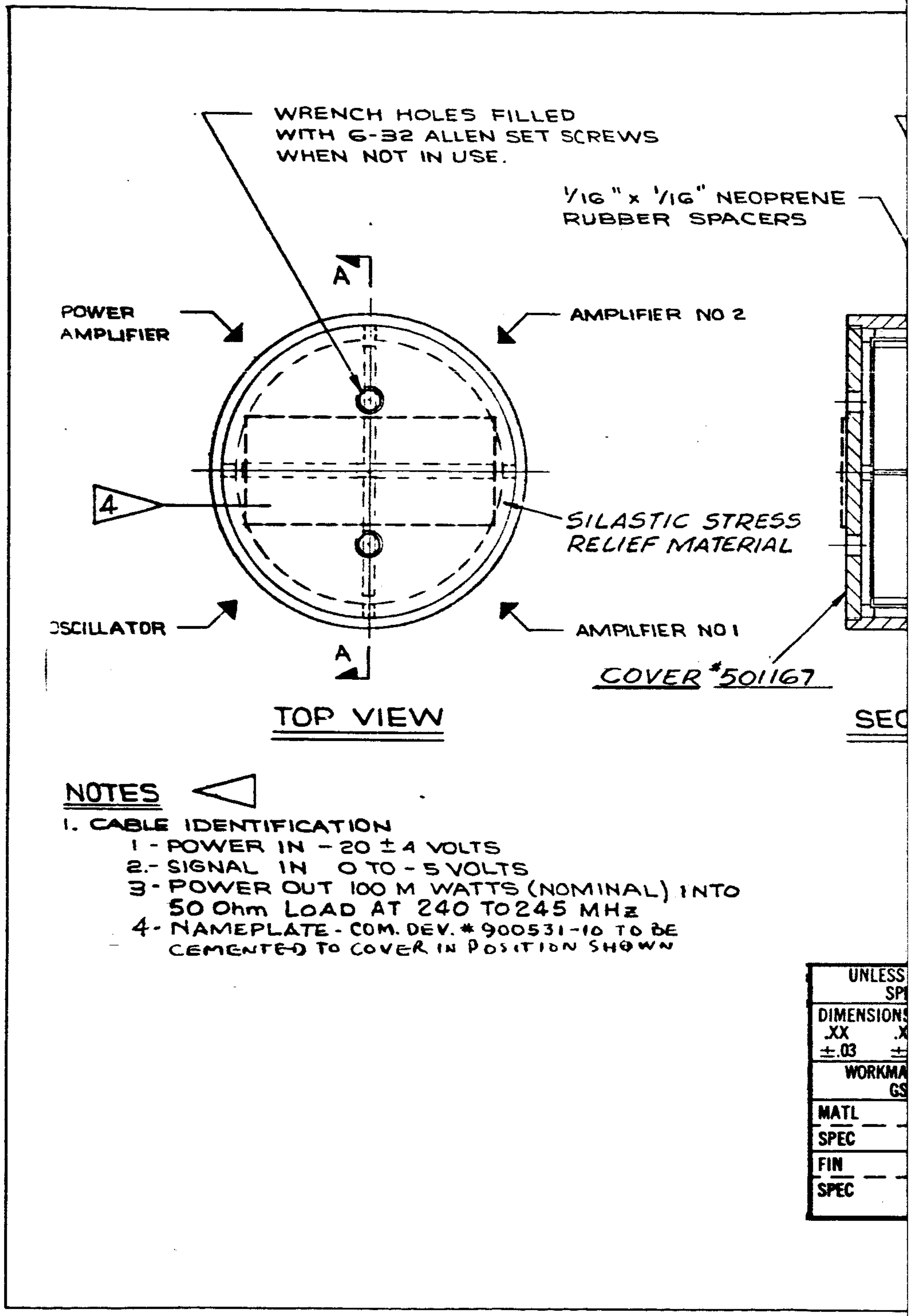
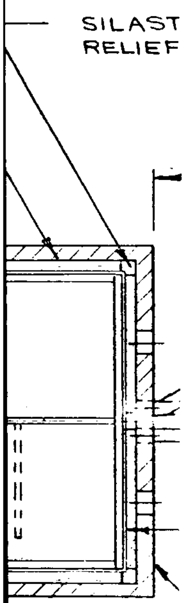

WRENCH HOLES FILLED
WITH 6-32 ALLEN SET SCREWS
WHEN NOT IN USE.
1/16" x 1/16" NEOPRENE
RUBBER SPACERS
A
POWER
AMPLIFIER
AMPLIFIER NO 2
4
SILASTIC STRESS
RELIEF MATERIAL
OSCILLATOR
AMPILFIER NO 1
A
COVER #501167
TOP VIEW
SEC
NOTES
1. CABLE IDENTIFICATION
1 - POWER IN - 20 ± 4 VOLTS
2.- SIGNAL IN 0 TO - 5 VOLTS
3 - POWER OUT 100 M WATTS (NOMINAL) INTO
50 Ohm LOAD AT 240 TO 245 MHz
4 - NAMEPLATE - COM. DEV. # 900531-10 TO BE
CEMENTED TO COVER IN POSITION SHOWN
UNLESS
SP
DIMENSIONS
.XX .X
±.03 ±
WORKMA
GS
MATL
SPEC
FIN
SPEC

Figure 18.



TION A-A

OTHERWISE CIFIED	DI
	CI
ARE IN INCHES	DS
XX ANGLES	
010 ±0° 30′	EI
NSHIP SPEC 956001	
	OI DI
	A
	A

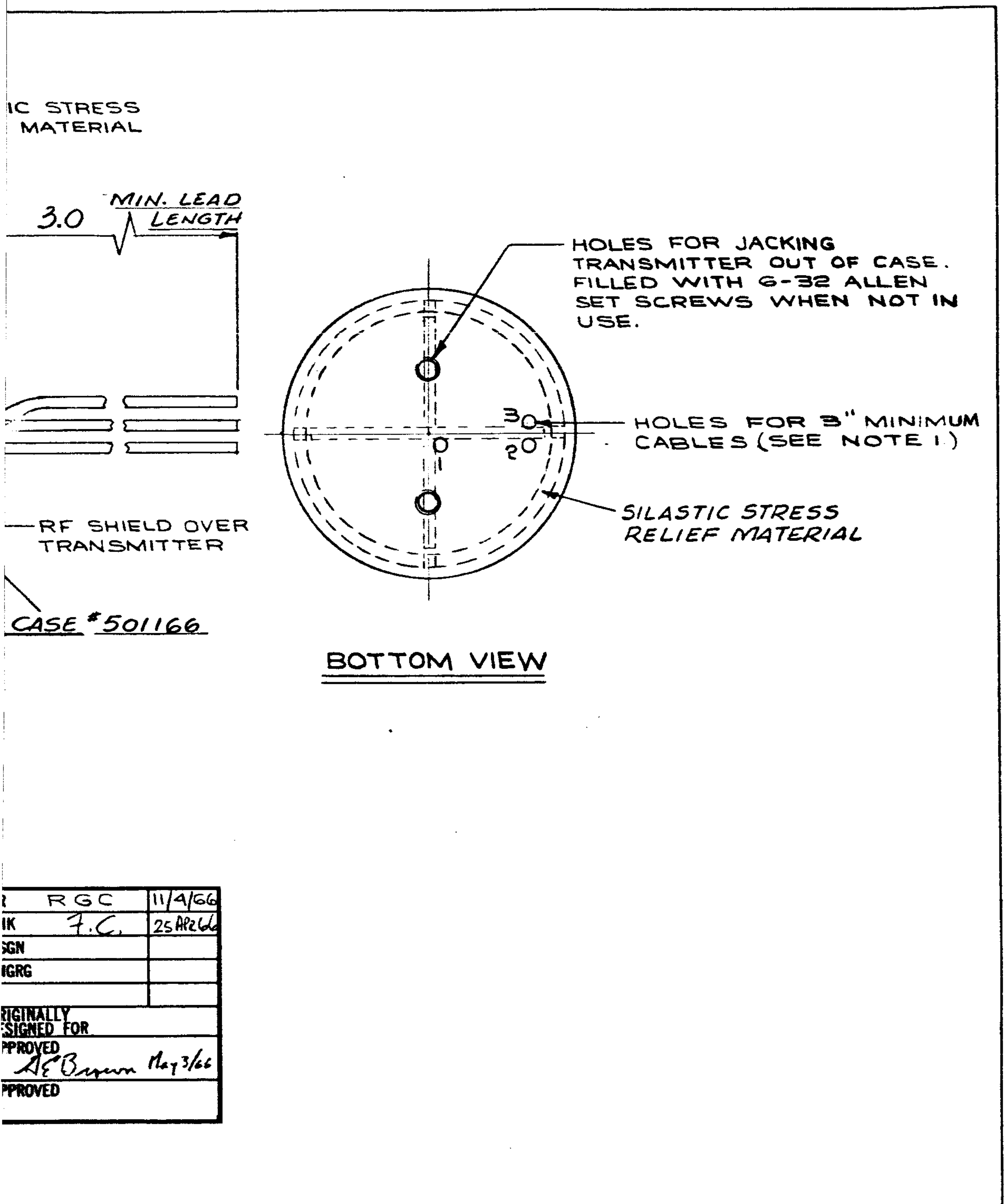
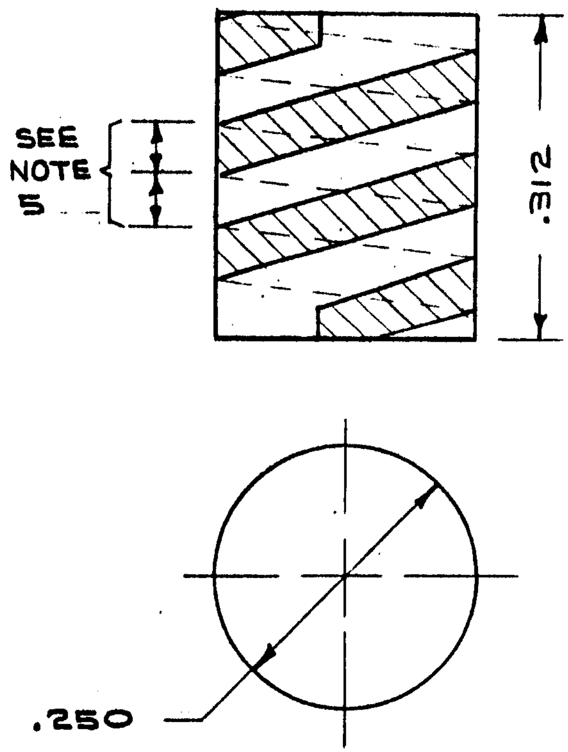


Figure 18. Transmitter Assembly,
Computing Devices Drawing No. 501171



Notes

1. Substrate - Lucalox, General Electric
   Lamp Glass Department
   Cleveland, Ohio
   Polycrystalline Alumina
   99.9% Al_2O_3

2. Coil - Hanovia Liquid Silver #467
   Engelhard Industries Inc.
   East Newark, N.J.
   - Thickness - 6 layers baked individually at 1600°F.
   Thickness 0.001 to 0.0015 inches.

3. Q - Minimum 140 at a frequency greater than 200 MHz.

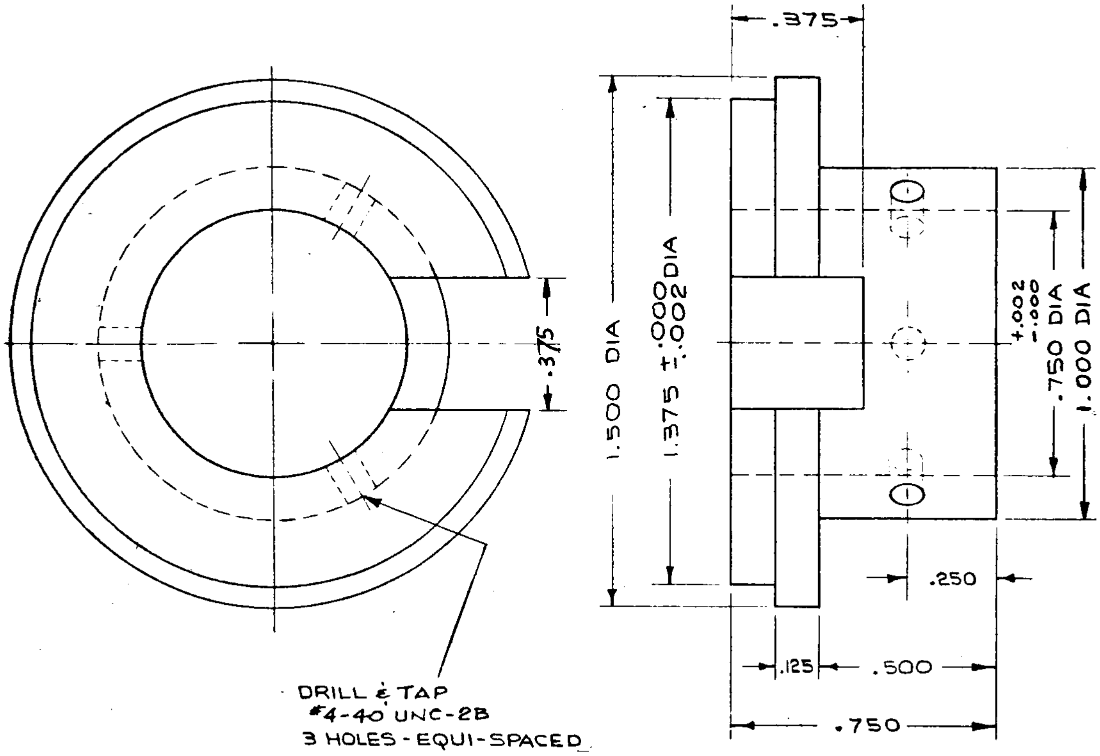
4. Number of Turns
   - Refer to Drawing No. 501170 Sh.2

5. Coil Spacing should maintain approx. equal widths of coil and insulation.

Tolerance - Substrate 0.005" or 1% whichever is greater.

Figure 19. R.F. Coil Assembly, Computing Devices Drawing No. 501172

Figure 19.



UNLESS OTHERWISE SPECIFIED	DR RGC	5APR66
DIMENSIONS ARE IN INCHES .XX ±.03 .XXX ±.010 ANGLES ±0° 30'	CHK	
	DSGN	
	ENGRG	
WORKMANSHIP SPEC GS 956001		
MATL AL. ALLOY	ORIGINALLY DESIGNED FOR	
SPEC 24S-T4	APPROVED	
FIN		
SPEC	APPROVED	

Figure 20. Assembly Jig, Computing Devices Drawing No. 501173

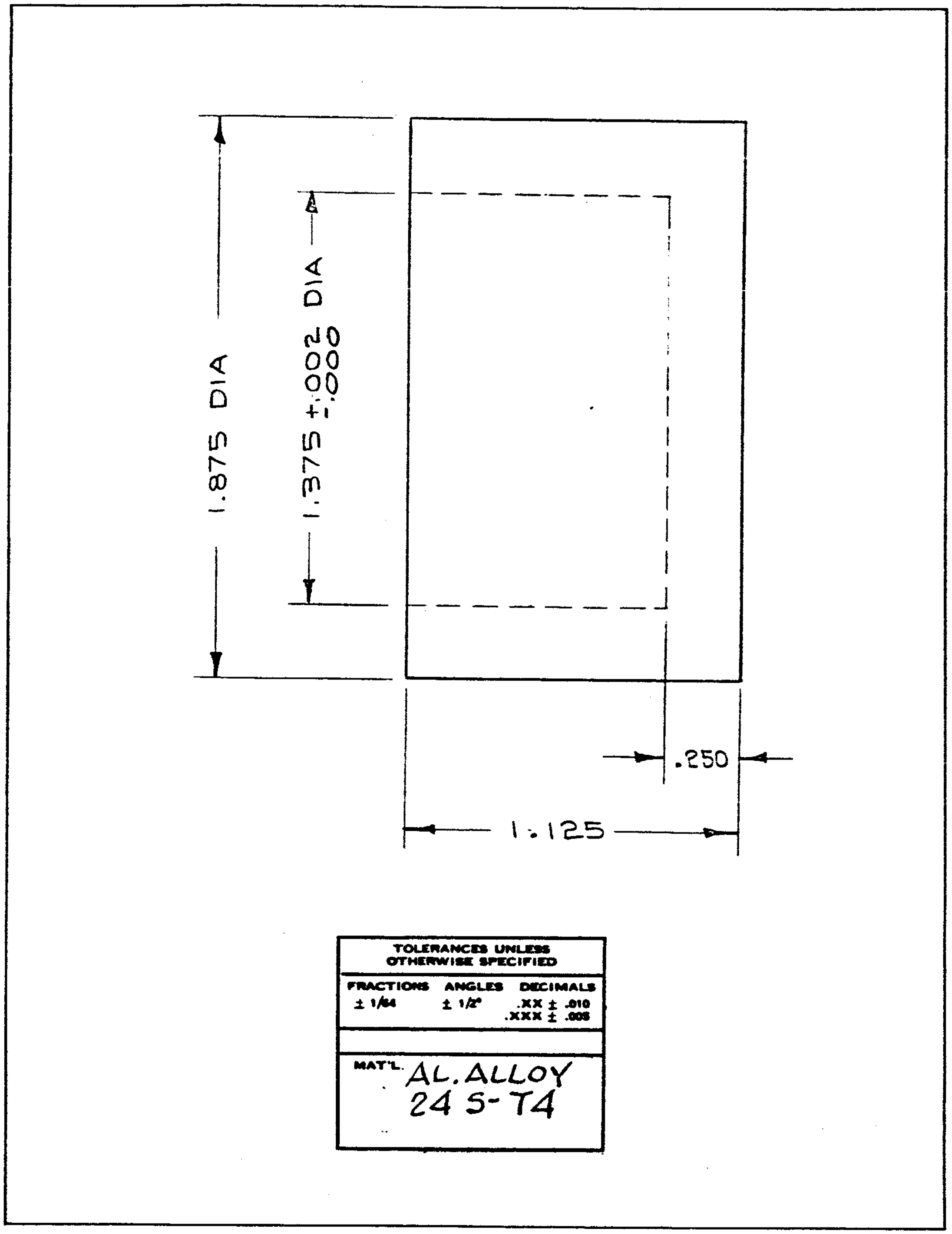
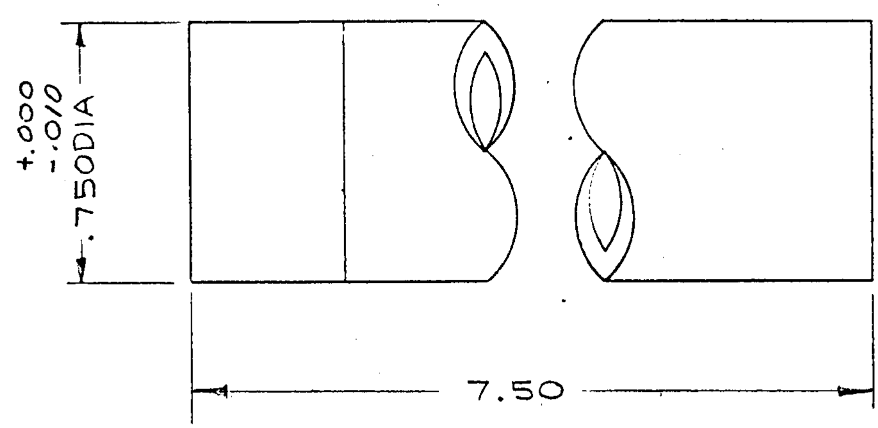


Figure 21. Test Cap, Computing Devices Drawing No. 501174



TOLERANCES UNLESS OTHERWISE SPECIFIED		
FRACTIONS	ANGLES	DECIMALS
± 1/64	± 1/2°	.XX ± .010 .XXX ± .005
MAT'L. ACRYLIC TUBE		

Figure 22. Support Rod, Computing Devices Drawing No. 501175

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