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SECOND QUARTERLY PROGRESS REPORT

PRODUCTION ENGINEERING MEASURE (PEM)

MANUFACTURING METHODS AND TECHNIQUES FOR PIEZOELECTRIC TRANSFORMERS

CONTRACT DAAB07-76-C-0008

October 14, 1975 to January 14, 1976

PLACED BY:

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The second Quarterly Report for Contract DAAB07-76-C-0008 describes the progress and status of this program to establish a cost-effective production capability for 18mm and 25mm piezoelectric ceramic transformers. Progress toward building the first engineering samples is reviewed and the interconnection techniques for the 18mm package are discussed.

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SECOND QUARTERLY REPORT

CONTRACT NO. DAAB07-76-C-0008
Manufacturing Methods and Techniques for Piezoelectric Transformers

PERIOD COVERED: October 14, 1975 to January 14, 1976

PREPARED BY:

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T. Rudy

OBJECT OF STUDY:

The objective of this contract is to establish a production capability for 18mm and 25mm piezoelectric ceramic transformers with all required manufacturing methods, test procedures and production tooling for high production rates. These transformers are to be used in conjunction with a power supply for operating night vision image intensifier tubes.

DISTRIBUTION STATEMENT

ABSTRACT

The second Quarterly Report for Contract DAAB07-76-C-0008 describes the progress and status of this program to establish a cost-effective production capability for 18mm and 25mm piezoelectric ceramic transformers. Progress toward building the first engineering samples is reviewed and the interconnection techniques for the 18mm package are discussed.

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PURPOSE

This Production Engineering Measure (PEM) contract covers all of the tooling, test methods, package designs, mounting techniques, interconnection techniques and other manufacturing methods and techniques required for eventual production of 18mm and 25mm piezoelectric transformers. These units are to be used with a power supply to improve the performance and reduce cost for image intensifier tubes used in various night vision devices.

SECTION I
APPROACH

Our approach to both the 18mm and 25mm PET designs, its advantages and the analytical method used to determine performance of these transformers was discussed in the first quarterly report[1].

(1) First Quarterly Progress Report, Production Engineering Measure (PEM), Manufacturing Methods and Techniques for Piezoelectric Transformers, Contract Number DAAB07-76-C-0008, July 14, 1975 to October 14, 1975.

SECTION II
PROCESS REVIEW

This section updates the status of each process step planned for manufacturing both the 18mm and 25mm PETs. Since there are only minor differences between the 18mm and 25mm process, one process outline will suffice. The new materials and special tooling, which have been purchased, designed or built and not discussed last quarter, are discussed below.

A. RAW MATERIALS

The standard operating procedure for processing raw materials, calculating batch compositions and compounding each batch was fully described in the first quarterly report.

B. COMPLETED PROCESSES

This section will describe manufacturing procedures completed in the first two quarters of this program. Each operation is identified with a number, description and a list of the materials, tools, fixtures and procedures required to complete the operation. The various manufacturing and inspection operations are indicated in the flow diagram, Figure 1.

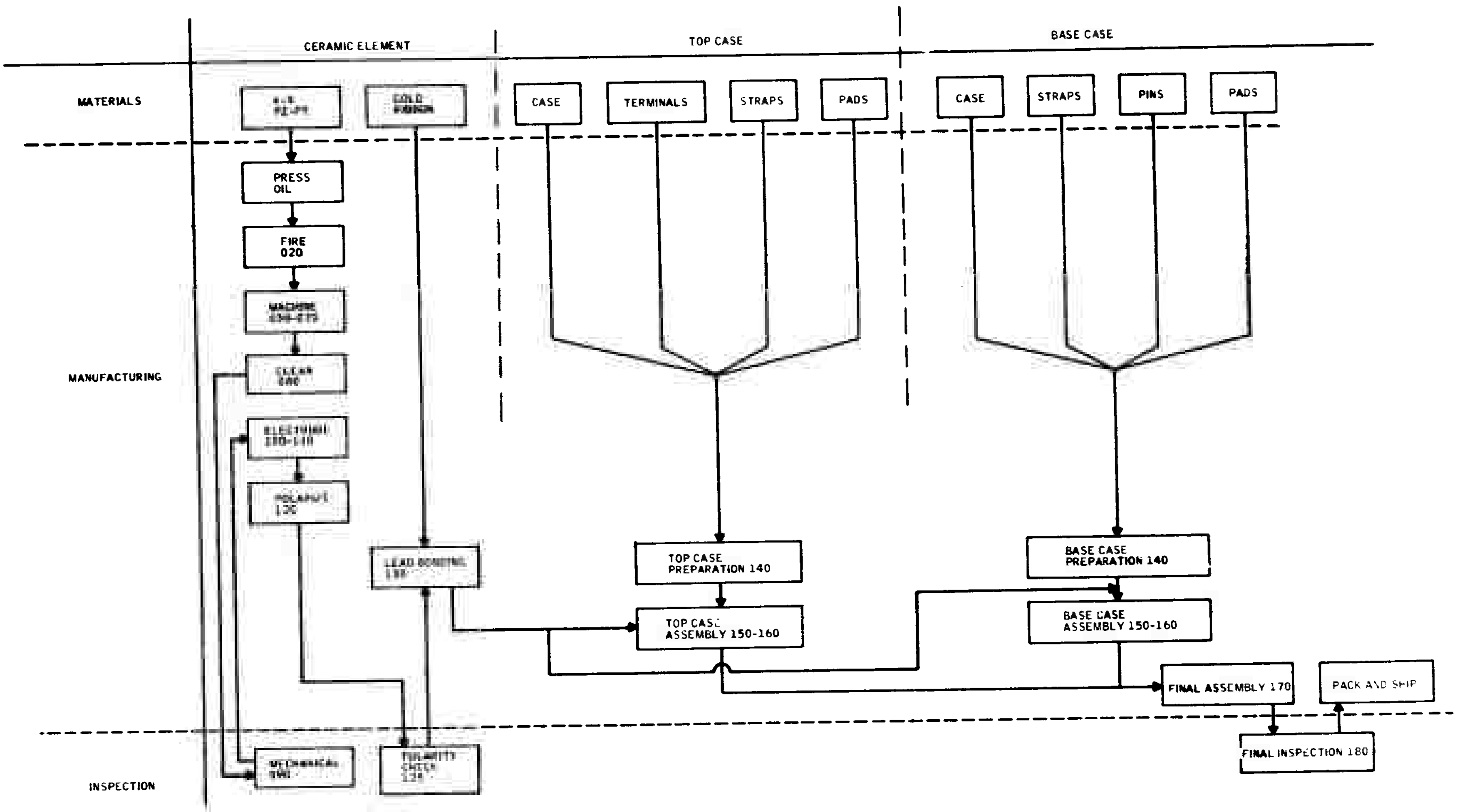


Figure 1. 18mm and 25mm Packaged PET Flow Diagram

MANUFACTURING PROCEDURE FOR
18MM AND 25MM PACKAGED PETS

OP 010 Slug Processing

A. Materials Required

1. 1800 grams K-9 type PZ-PT Material

B. Tools and Fixtures

1. Hand Die 2-1/2-inch I. D. x 10-inch long
2. Knockout Punch
3. Denison Press (50 ton)
4. Vernier Calipers
5. 1800 gram volumetric gage

C. Procedure

1. Load material (1800 grams) into die. Place upper punch in sleeve and press to 15 tons pressure.
2. Eject slug from die and identify.
3. Check length - 4.8 ± 0.1 inches.

OP 020 Hot Press Slugs

A. Materials Required

1. MgO Sand

B. Tools and Fixtures

1. 4-inch O. D. x 2-1/2-inch I. D. x 7-inch long Alumina Die
2. Alumina Bottom Plate 4-inch diameter x 3/4-inch
3. Two Alumina Push Rods 2-1/4-inch diameter x 1-1/4-inch
4. Hot Press
5. 1240°C Temperature Cam

C. Procedure

1. Tape alumina plug in outer die. Pour a small amount MgO in bottom of die.
2. Place slug in mold and cover with additional MgO.
3. Center top spacer over slug.
4. Center three die sets in hot press and close press.
5. Heat to a temperature of 1240°C and pressure of 300 psig.
6. After hot press cycle is completed, open furnace, remove die sets, remove slugs, clean off excess sand and place slug in envelope with identification.

OP 030 Blanchard Grind Slugs (Top and Bottom)

A. Materials

1. 3M Tape, double sided

B. Tools and Fixtures

1. Steel Bars
2. No. 11 Blanchard Surface Grinder

C. Procedure

1. Tape face of Blanchard chuck.
2. Place slugs on the chuck and block in with steel bars.
3. Start grinder and remove 0.050 inch of material after a smooth surface has been obtained.
4. Remove slugs and repeat steps 1-3 for side two.

OP 040 Core Drill Slugs

A. Tools and Fixtures

1. Three Core Drills
   Sizes: 1-inch O. D.
   1-5/8-inch O. D.
   2-1/4-inch I. D.
2. Three Jaw Chuck
3. Gorton Vertical Mill

B. Procedure

1. Center slug in the three jaw chuck under the vertical spindle.
2. Start mill with 1-inch core drill and water coolant and core drill out of the smallest slug.
3. Repeat using 1-5/8-inch core drill.
4. Repeat using 2-1/4-inch core drill.
5. Save second slug for 18mm elements and third slug for 25mm elements. First slug and outer shell are scrap material.

OP 050 Hone I. D. of Slugs

A. Tools and Fixtures

1. Sunnen Hone
2. Mandrel 2GP28-1000 VA for 18mm
3. Mandrel 2GP28-1625 WD for 25mm
4. Truing Sleeves
5. Diamond Stones P28787
6. 1.040-inch and 1.700-inch Plug Gages

B. Procedure

1. Carefully true up hones on the machine with the truing sleeves.
2. Size inside diameters of slugs using very little pressure so as not to crack the slug.

   1.040 inch = 18mm   1.700 inch = 25mm

OP 060 Grind O. D. of Slugs

A. Tools and Fixtures

1. Grinding Arbors
   18mm
   25mm
2. Brown and Sharp No. 1 Universal Grinder

B. Procedure

1. Place one to two 18mm or 25mm I. D. ground slugs on arbor and back up with spacers.
2. Place the arbor between centers of grinder.
3. Grind the O. D. diameter to 1.476 ± 0.001 inch for 18mm slugs or 2.100 ± 0.001 inch for 25mm slugs.
4. Remove and store for next operation.

OP 065 Slice 25mm Half Torroids

A. Materials

1. Do-All Mounting Wax
2. Mounting Blocks
3. Methyl Alcohol

B. Tools and Fixtures

1. Do-All Diamond Band Saw
2. 300°C Oven

C. Procedure

1. Heat 2.1-inch O. D. x 1.7-inch I. D. 25mm slug with a mounting block until mounting wax melts.
2. Mount base of slug to block and cool.
3. Mount block in band saw.
4. Slice slug to produce two (2) 1.000 ± 0.001-inch high toroids.
5. Reheat to melt wax and demount.
6. Cool and clean off excess wax in methyl alcohol.

OP 070 Mount and Slice Slugs*

A. Materials

1. P. C. Slurry mix with No. 600 boron carbide
2. Mounting Pad

---

* Subcontract operation at Varian Vacuum Division, Lexington, Mass.

B. Tools and Fixtures

1. Varian 686 Slicing Machine
2. Blade Package 0.008 x 1/4-inch blades with 0.013-inch thick spacers

C. Procedure (Subcontract*)

1. Mount slugs on submount base with wax.
2. Place slurry mix in the wafering machine.
3. Mound sub-base on machine.
4. Properly tension blade package.
5. Slice slugs into 0.010 ± 0.0005-inch thick elements.
6. Demount in alcohol.
7. Pack and ship.

OP 080 Clean Elements

A. Materials

1. Detergent
2. Chlorethene
3. Alcohol
4. Plastic tray

B. Tool and Fixtures

1. Ultrasonic Cleaner

C. Procedure

1. Unpack parts and place in a plastic tray.
2. Ultrasonic clean in chlorethene.
3. Ultrasonic clean in detergent solution.
4. Rinse in water.
5. Rinse in alcohol.

---

* Subcontract operation at Varian Vacuum Division, Lexington, Mass.

OP 090 Inspection of Unelectroded 18mm and 25mm Elements

Mechanical size is now measured. Inside diameter, outside diameter, flatness and parallelism, thickness and surface finish.

OP 100 Apply Silver Electrodes

A. Materials

1. Silver Electrode Paste
2. Ethyl Acetate cleaning solvent

B. Tools and Fixtures

1. Screen Printer
2. Silk screen frame; 18mm, 25mm
3. Nests; 18mm, 25mm
4. 300°C oven

C. Procedure

1. Mount silk screen frame in printer and center pattern.
2. Condition screen with silver paste.
3. Place clean parts, 5-18mm or 6-25mm in nest.
4. Mount nest in printer.
5. "Squeegy" silver paste on side one.
6. Remove nest and place parts in drier for curing.
7. Cool parts, reverse and do side two as in steps 3-6, above.

OP 110 Silver Fire

A. Tools and Fixtures

1. Belt Furnace (2000°F)
2. Setter plates 6 inches x 4 inches x 1/2 inch

B. Procedure

1. Place parts on setter plates.
2. Place plates on belt of furnace - temperature set at 1640°F.
3. Remove cooled parts and store.

OP 120* Polarization

A. Materials

1. Peanut Oil

B. Tools and Fixtures

1. 50 kV polarization station
2. Poling Fixture (see Figure 2)
3. Chlorethane degreaser

C. Procedure

1. Place 18mm or 25mm elements in poling fixture with positive and negative leads of primary electrodes connected to external leads.
2. Place fixture in 165°C oil bath.
3. Apply 1500 volts to elements for 60 seconds.
4. Short external leads of primary and connect to negative terminal of poler.
5. Connect secondary electrode to positive terminal of poler.
6. Apply 16.5 kV to part and hold for 60 seconds 18mm; 27 kV for 25mm.
7. Remove from hot oil.
8. Degrease part in chlorethane.
9. Mark polarity.
10. Store parts for next stage.

OP 125 Check Polarity

A. Tools and Fixtures

1. d_{33} checker
2. Sample Holder
3. Frequency Bridge

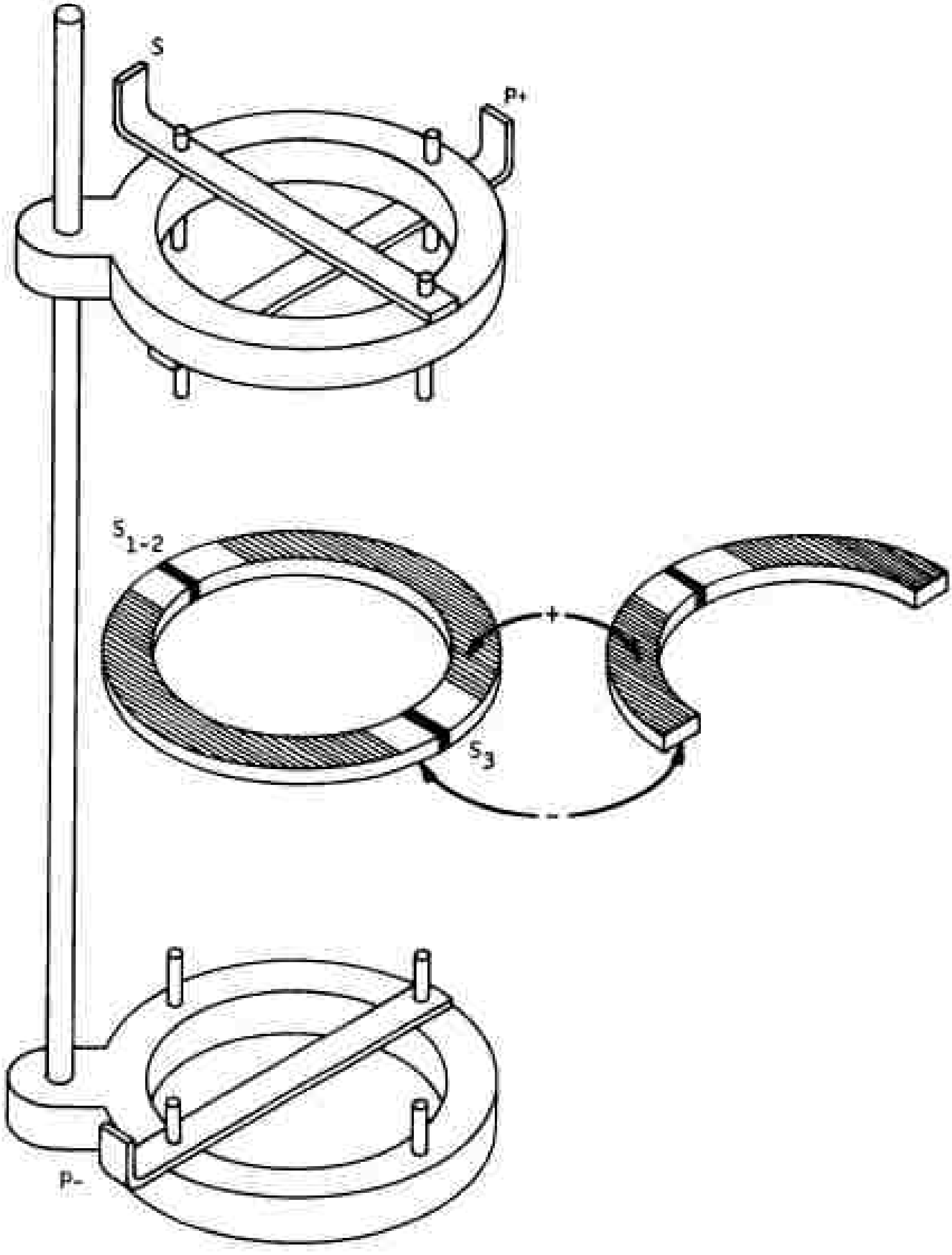


Figure 2. Poling Fixture, First Engineering Samples

B. Procedure

1. Place part in sample holder.
2. Scan resonant and antiresonant frequency for fa, fr and fa/fr between primary electrodes.
3. Repeat for secondary segments of element.
4. Insert part in d_{33} checker and check polarity.

OP 130* Lead Attachment, 18mm

A. Materials

1. Gold Ribbon 0.003-inch x 0.010 inch x 0.5 inch.

B. Tools and Fixtures

1. 18mm element welding fixture (Figure 3).
2. Hughes HPB-360 Pulse Bonder

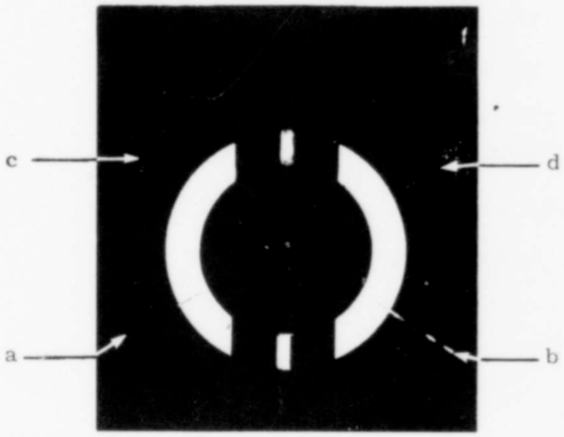
C. Procedure

1. Place element in welding fixture with negative side up.
2. Place gold ribbon in slots a and b (Figure 3A) and bond each ribbon with four to five welds with welder.
3. Turn element over so that ribbon from slot "a" is in slot "c" and ribbon from slot "b" is in slot "d."
4. Set ribbon leads in slots "b", "f", "g" and "e" and bond as in Step 2. (See Figure 3B).
5. Remove from bonding fixture and store in such a way as to maintain the ribbons flat.

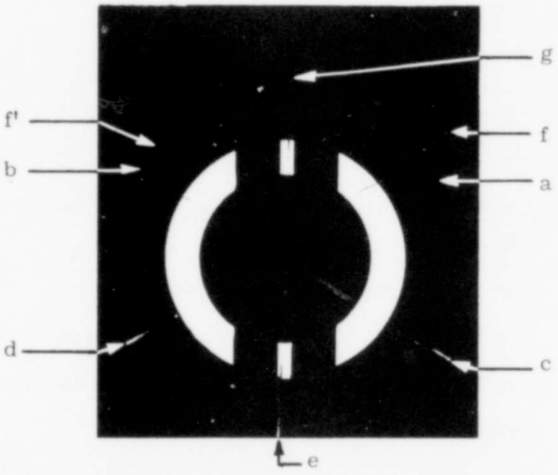
OP 140 PET Package Preparation 18mm

A. Materials

1. Package Case - Top
2. Package Case - Base
3. Terminals
4. Silicone Pads
5. 18mm Shorting Straps - Base



A. Step One Negative Leads



B. Step Two Positive Leads

Figure 3. Welding Fixtures and Gold Ribbon Bond Sequence for 18mm Elements

6. 18mm Shorting Straps - Top

7. 18mm Shorting Pins

8. TF Freon

9. Marking Ink P-12
Automated Packaging System

B. Tools and Fixtures

1. Staking Tool, 18mm

2. Arbor Press, 18mm

3. Staking Fixture

4. Pliers

5. Knife

6. No. 76 Carbide Drill

7. High Speed Drill Press

8. Ultrasonic Cleaner

9. Rubber stamps

10. Punch

C. Procedure

1. Place terminal pin in fixture.

2. Place top shorting strap over pin and then put top case over pin and strap.

3. Stake pin firmly to case (Figure 4A).

4. Repeat Steps 1 to 3 for each hole in case.

5. Drill 0.020-inch diameter holes as shown in Figure 4A.

6. Ultrasonic clean in freon.

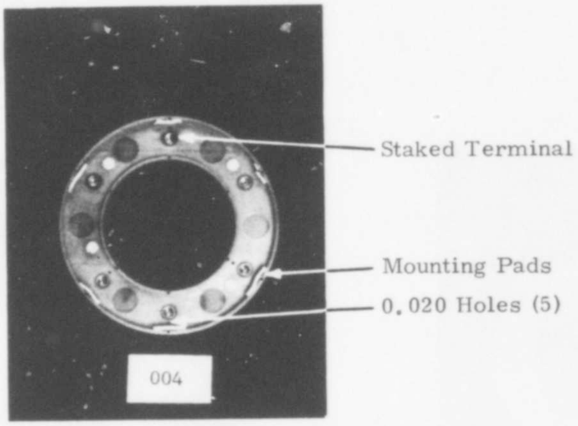
7. Cut and place mounting pads in locations shown in Figure 4A.

8. Using inked pad and rubber stamps, stamp terminal identification, date code, part number and serial number as shown in Figure 4B.

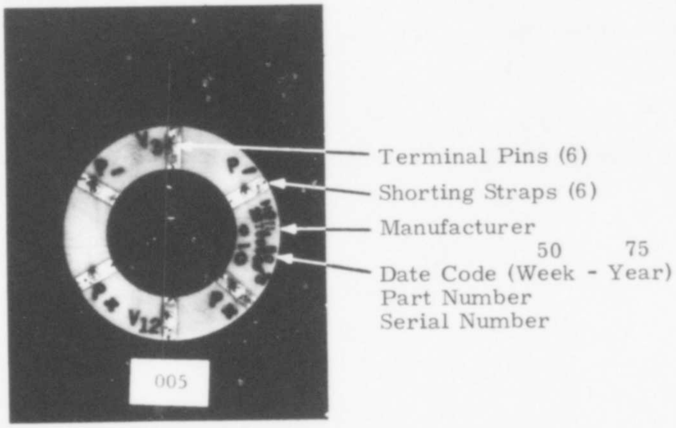
9. Ultrasonic clean package case-base in freon, cut and mount pads as shown in Figure 4C.

10. Locate base shorting straps on base and insert shorting pins through straps and case as in Figure 4D.

11. Drill 0.020-inch holes (4) as shown in Figure 4C.

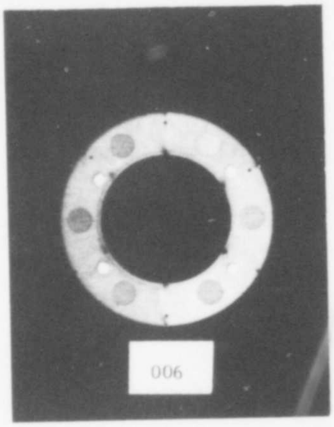


A. Inside Detail Terminal
Side of Case

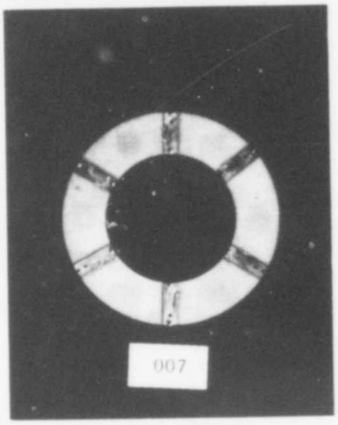


B. Outside Detail Terminal
Side of Case

Figure 4. 18mm PET Package Preparation



C. Inside Detail Base of Case



D. Outside Detail Base of Case

Figure 4. 18mm PET Package Preparation (Concluded)

OP 150 Half Package Assembly 18mm

A. Tools and Fixtures

1. Pliers

2. Hughes HPB-360 Pulse Bonder

3. Hughes Stored Energy Welder VTW-28C + VTA-60 Head

4. Tweezers

B. Procedure

1. Form ribbon leads by bending 90°

2. Insert each ribbon lead through 0.020-inch hole and then gradually pull leads through and guide PET element between mounting pads.

3. Pull leads taut and then thermal compression bond to shorting strap as shown in Figure 5A and B for base and top cases.

OP 160 Half Package Electrical Check

A. Tools and Fixtures

1. Automatic Test Console

2. Terminal Box

B. Procedure

1. Insert top PET case into terminal box (Figure 7).

2. From test console (Figure 6) record resonant frequency, input current, input voltage and output voltage on data sheet.

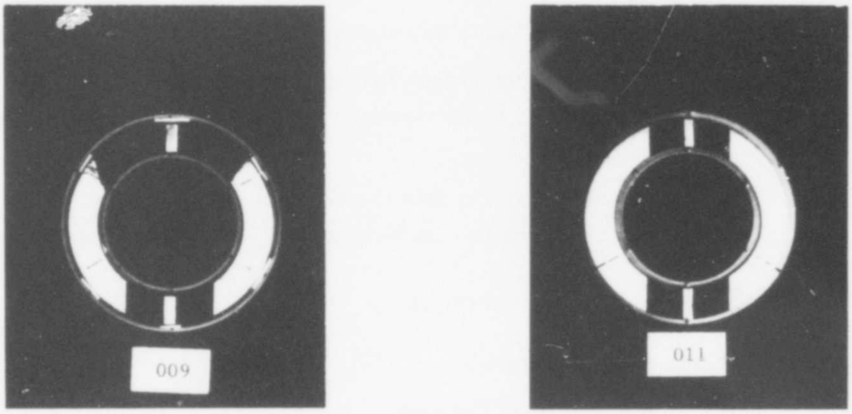
OP 170 Final Package Assembly

A. Tools and Fixtures

1. Pliers

2. Stored Energy Welder

3. Snips



A. Terminal Half B. Base Half

Figure 5. 18mm Assembled Half Packages

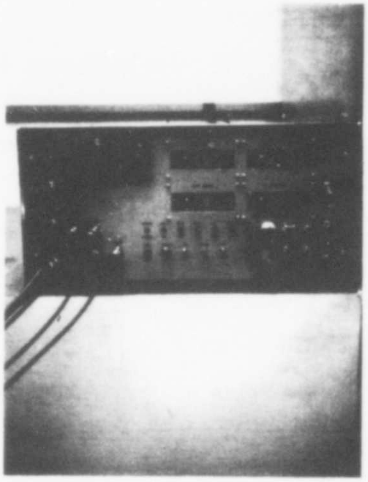


Figure 6. Automatic Test Console

Figure 7. 18 and 25mm Test Terminals

B. Procedure

1. Select half packages to be assembled based on the resonant frequency, Fr, of half-packaged elements. Fr to be within 200 cycles of each other.

2. Align shorting pins from base case with holes in terminal side of case.

3. Gradually force each of the 12 pins through holes in package and shorting strap with pliers.

4. After package is completely assembled, upset head of pin on terminal side with stored energy welder. Setting is 4 pounds and 8 watt-second discharge.

5. Repeat step 4 for each pin.

6. Snip off head of pin on base side of package.

7. Check electrical properties on test console and record data on data sheet.

OP 180 Final inspection per Test Procedures for Packaged 18mm and 25mm Piezoelectric Transformers. See Appendix A.

OP 140 PET Package Preparation 25mm

A. Materials

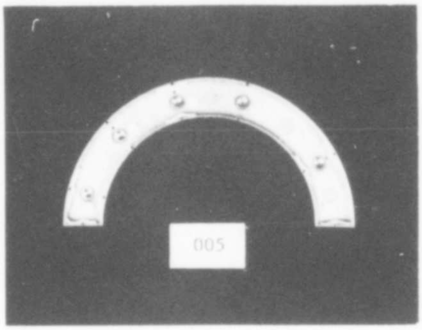
1. Package Case - Top
2. Package Case - Base
3. Terminals
4. Silicone Pads
5. 25mm Shorting Straps - Base
6. 26mm Shorting Straps - Top
7. 25mm Shorting Pins
8. TF Freon
9. Marking Ink P-12
   Automated Packaging System

B. Tools and Fixtures

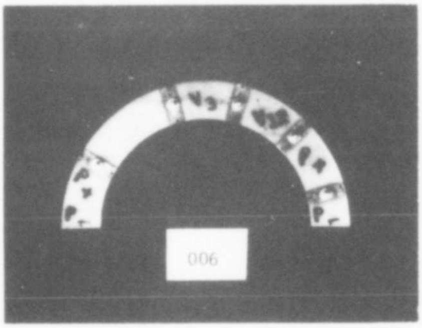
1. Staking Tool, 25mm
2. Arbor Press, 25mm
3. Staking Fixture
4. Pliers
5. Knife
6. No. 76 Carbide Drill
7. High Speed Drill Press
8. Ultrasonic Cleaner
9. Rubber Stamps
10. Punch

C. Procedure

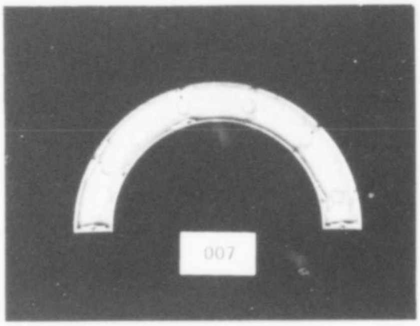
1. Place terminal pin in fixture.
2. Place top shorting strap over pin and then put top case over pin and strap.
3. Stake pin firmly to case (Figure 8A).
4. Repeat steps 1 to 3 for each hole in case.
5. Drill 0.020-inch diameter holes as shown in Figure 8A.
6. Ultrasonic clean in freon.
7. Cut and place mounting pads in locations shown, Figure 8A.
8. Using inked pad and rubber stamps, stamp terminal identification, date code, part number and serial number as shown in Figure 8B.
9. Ultrasonic clean package case-base in freon, cut and mount pads as shown in Figure 8C.
10. Locate base shorting straps on case and insert shorting pins through straps and case as in Figure 8D.
11. Drill 0.020-inch holes (4) as shown in Figure 8C.



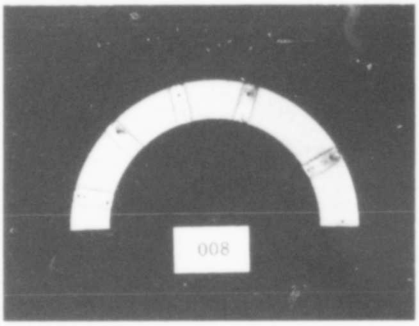
A. Inside Detail Terminal Side of Case



B. Outside Detail Terminal Side of Case



C. Inside Detail Base of Case



D. Outside Detail Base of Case

Figure 8. 25mm PET Package Preparation

SECTION III
STATUS AND FUTURE WORK

This section describes the status of work against the various tasks outlined in Figure 9 which were active during this second quarter effort.

A. TASK 1, 2 AND 3

(Work completed first quarter).

B. TASK 4. SLICING COST REDUCTION

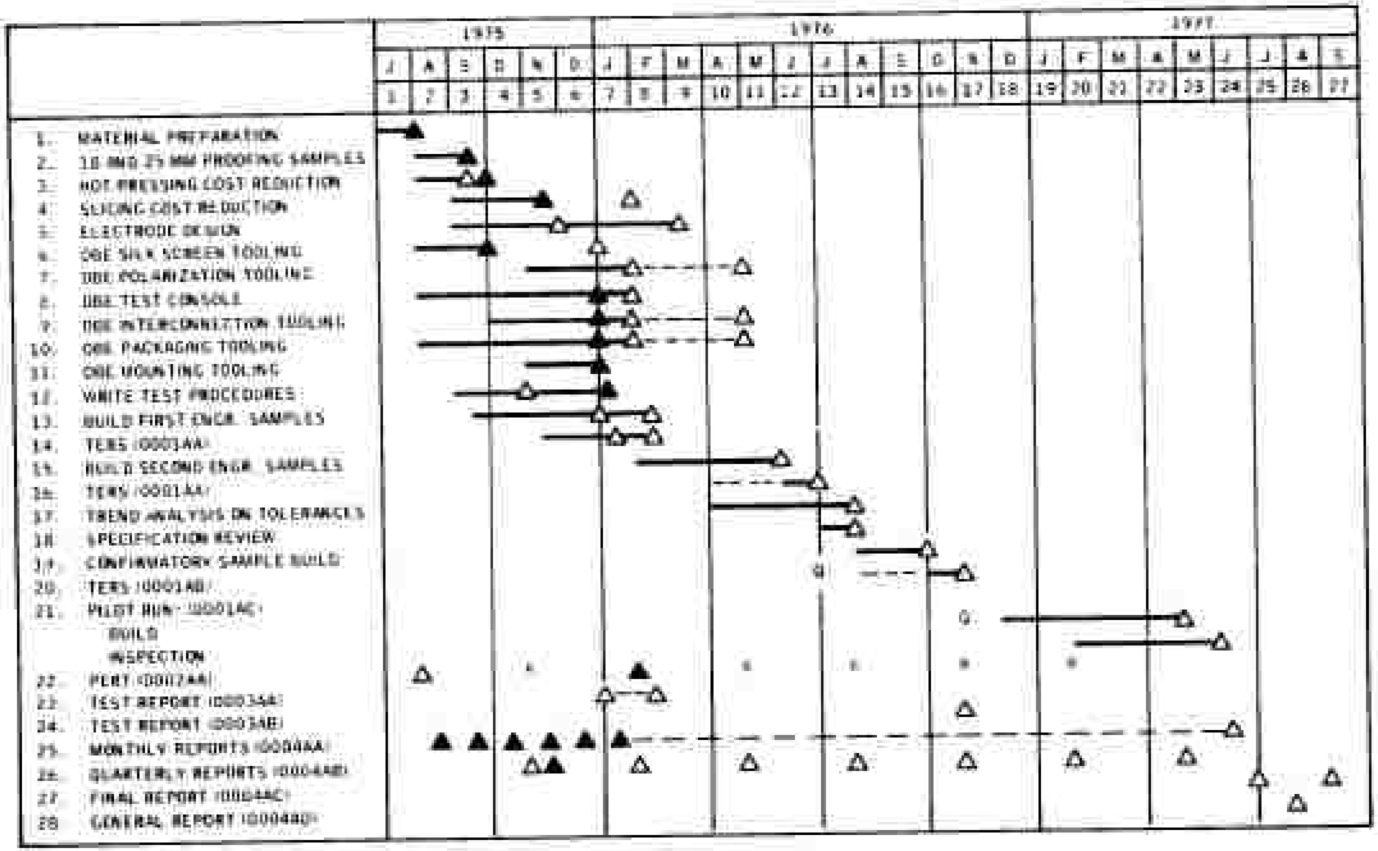
A third set of 18mm and 25mm PET elements have been sliced with the Varian wafering machine approach described last quarter. This represented a proofing run using 600 mesh silicon carbide grit slurry. About 400 18mm and 800 25mm elements were produced, which should approach the total quantity required for this contract.

The procedure used is described in OP 070 given in Section II. This equipment costs about $18,000 and has been forecasted for procurement in 1977, which will make the equipment available for production quantities of 18mm and 25mm PETs. Any additional slicing required during the duration of this contract will be continued to be handled on a purchase order basis. This task has, therefore, been completed.

C. TASK 5. ELECTRODE DESIGN

As indicated last quarter, additional electrode configurations are being considered for the second engineering sample build. Additional effort on the use of a single primary electrode and either a single or double secondary electrode, such as shown in Figure 10, is being considered. The primary electrode area is being varied and the location of the V_{1-2} and V_3 secondary electrode is being varied to optimize the efficiency and voltage step-up ratio of this unit.

Similarly, a single primary dual secondary electrode design is being considered to simplify the 25mm element construction and interconnection approach. The use of this approach and an integrated stack of four elements will reduce the number of leads from 10 to four.



DBE DESIGN BUILD AND EVALUATE
TERS TEST AND EVALUATION REVIEW AND SUBMIT
R REVISE QUARTERLY AS REQUIRED
Q REQUEST FOR APPROVAL TO START
Δ ORIGINAL OR REVISED COMPLETION DATES
▲ ACTUAL COMPLETION DATES

Figure 9. Program Status against Schedule

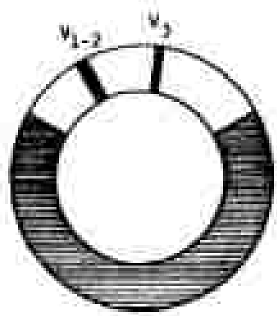


Figure 10. Single Primary-Double Secondary Electrode Design for 18mm PET's

D. TASK 6. SILK SCREEN TOOLING

Completed First Quarter

E. TASK 7. POLARIZATION TOOLING

The soft tooling that has been built and will be used for the first and second engineering sample build is shown in Figure 2. This fixture allows great flexibility in the poling of both the 18mm and 25mm elements. A production tank for heating oil and low and high voltage power supplies is available for the production polarization unit.

A turntable arrangement is also being designed to perform multiple poling of the 18mm and 25mm elements. This tooling will be completed as soon as the electrode design for production units is fixed.

F. TASK 8. TEST CONSOLE

The test console has been completed and the final test boxes built to contain the rated 10^7 ohm and 10 pf resistance and capacitance loads. These are shown in Figures 6 and 7, respectively. Details of the test console circuitry with the latest modifications to improve the power handling capability of the amplifiers is shown in Figure 11. This equipment works quite satisfactorily for both the 18mm and 25mm PETs.

G. TASK 9. INTERCONNECTION TOOLING

Use of thermal compression bonding of the gold ribbon to fired silver electrodes has worked quite satisfactorily; however, the pressure required to produce bonds requires flat ceramic elements and fixtures. Several elements have been broken during the assembly approach described in OP 013 of Section II. Thus, while the gold ribbon leads will continue to be used, we will examine other ways of making the bonds during the second engineering sample build.

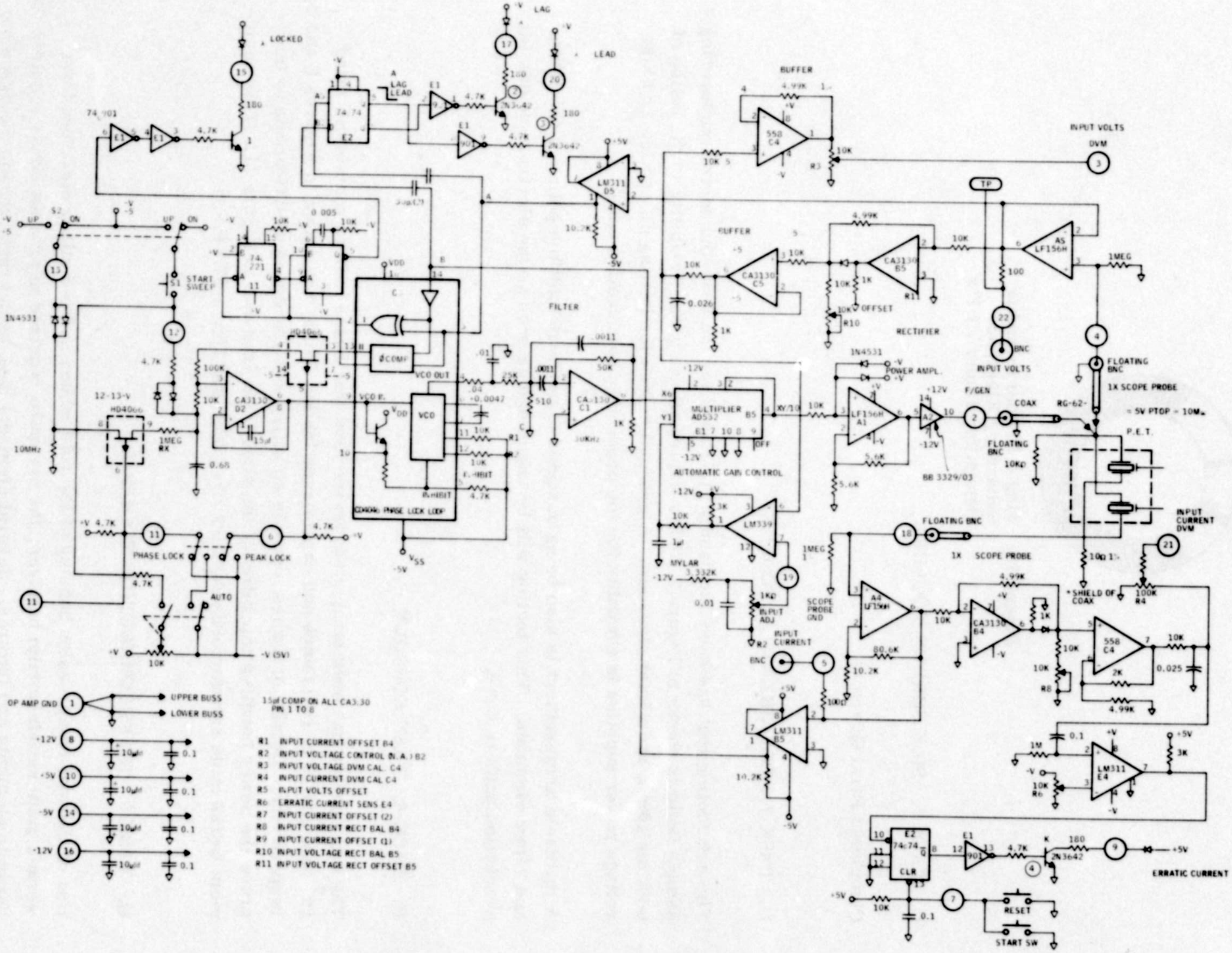


Figure 11a. Test Console Input Card

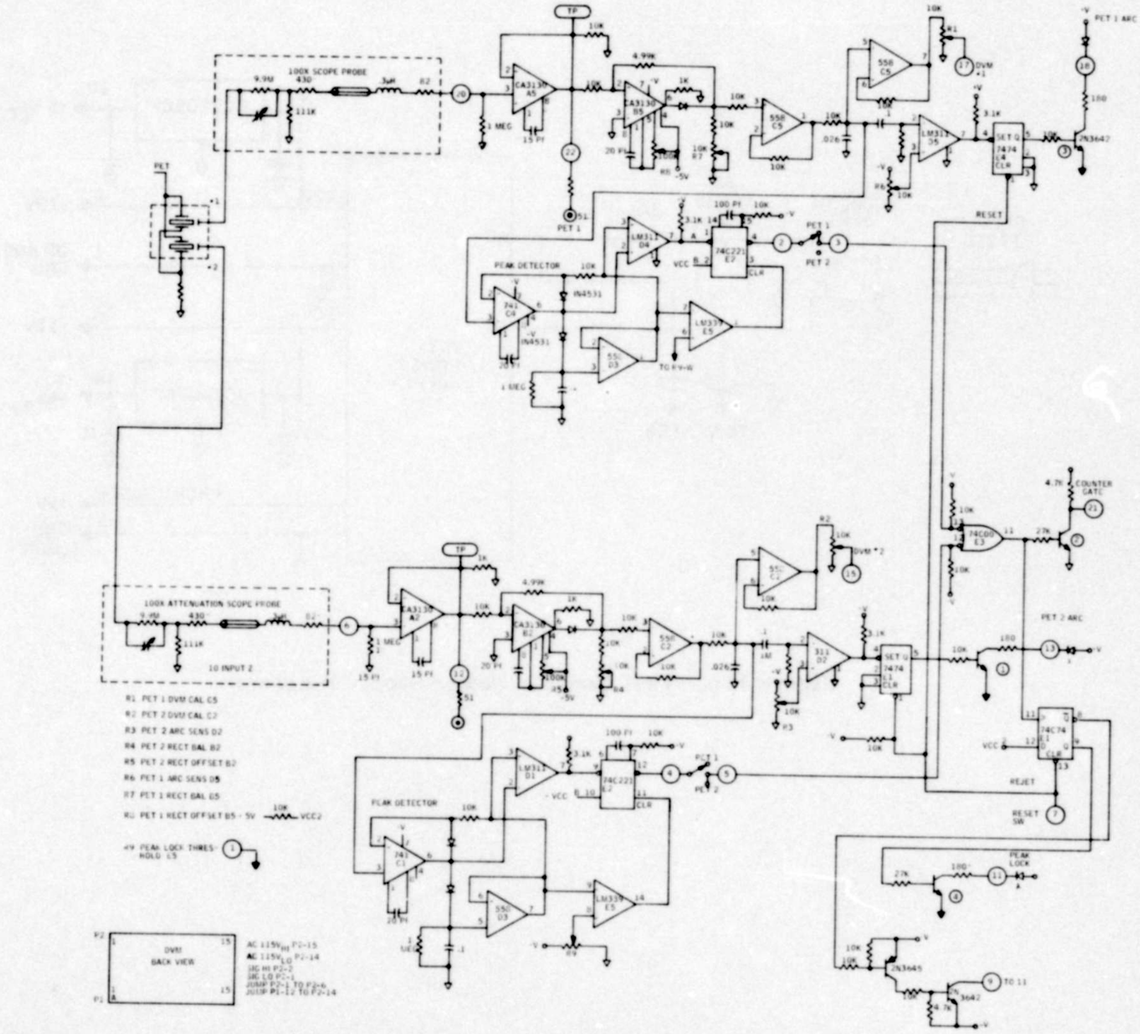


Figure 11b. Test Console Output Card

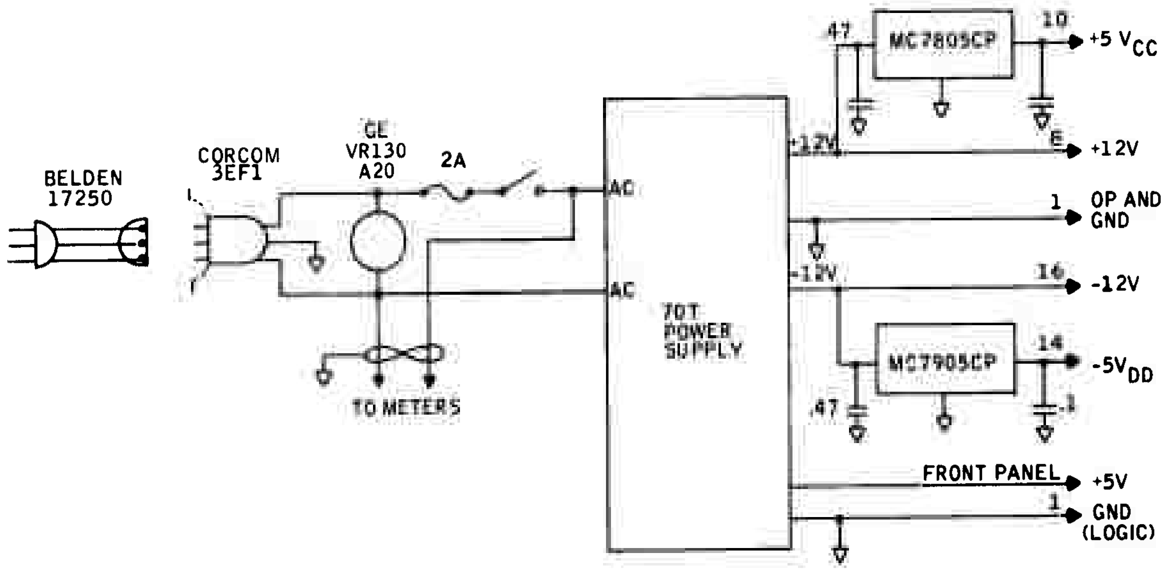


Figure 11c. Test Console Power Supply Diagram

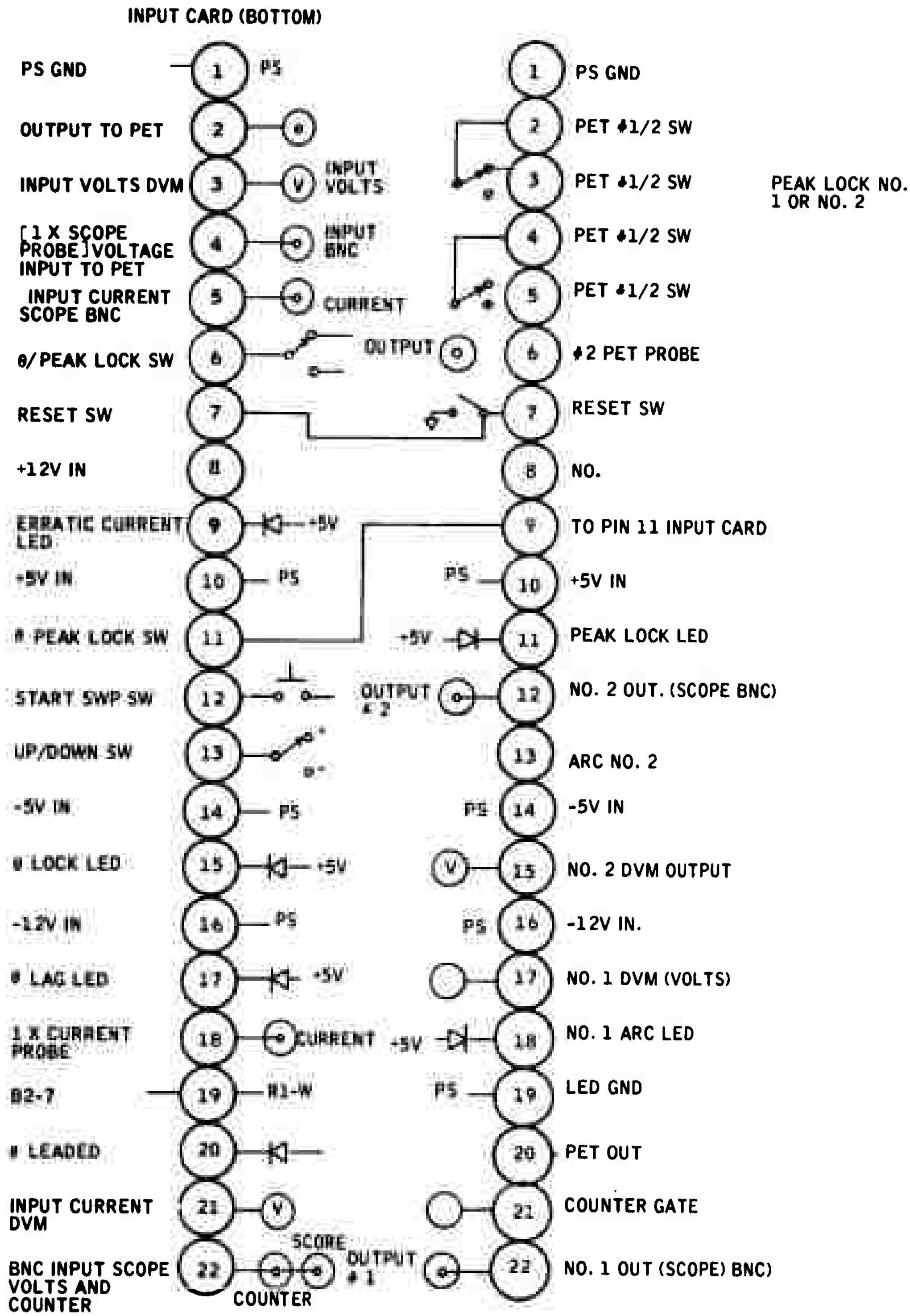


Figure 11d. Test Console Schematic for Main Frame Interconnect Wiring

H. TASK 10. PACKAGING TOOLING

The design of the injection molding tooling for the 25mm cases was completed as shown in Figure 12. Both the 18mm and 25mm tooling were built and about 50 halves (terminal and base sections) for each of the 18mm and 25mm cases were fabricated. The 18mm package design contained a tapered joint with a small butt seat which did not seat firmly. Thus, when the inside shorting pins were staked down the inside wall collapsed about 0.015 inch. The design of this portion of the die will be revised to that used in the 25mm seal. The revised case will be ready for the second engineering samples.

I. TASK 11. MOUNTING TOOLING

The mounting pads described in the First Quarterly Report have been punched into discs or cut into rectangular pads. This approach works quite satisfactorily; thus this task is complete.

J. TASK 12. TEST PROCEDURE

The test procedure that will be used to evaluate the various samples and pilot production 18mm and 25mm PET units is contained in Appendix A and will be used in conjunction with SCS-480 published in the First Quarterly Report.

K. TASK 13. BUILD FIRST ENGINEERING SAMPLES

Fifteen terminal half cases and 15 base half cases have been assembled as described in Section II. This work was delayed about two weeks to obtain the complete cases which were originally not expected to be complete for the first engineering samples. The 25mm terminals, mounting pads, shorting pins and shorting straps have been assembled as shown in Figure 8 and Section II. All 25mm elements have been poled, checked and are being bound together. The assembly of the 25mm packages and testing of all units will be completed according to the revised date noted in Figure 9.

L. PERT

A revised PERT Chart to reflect the delay in the first engineering samples was submitted in the sixth Monthly Report. This shows the program will be back on schedule by 3/20/76.

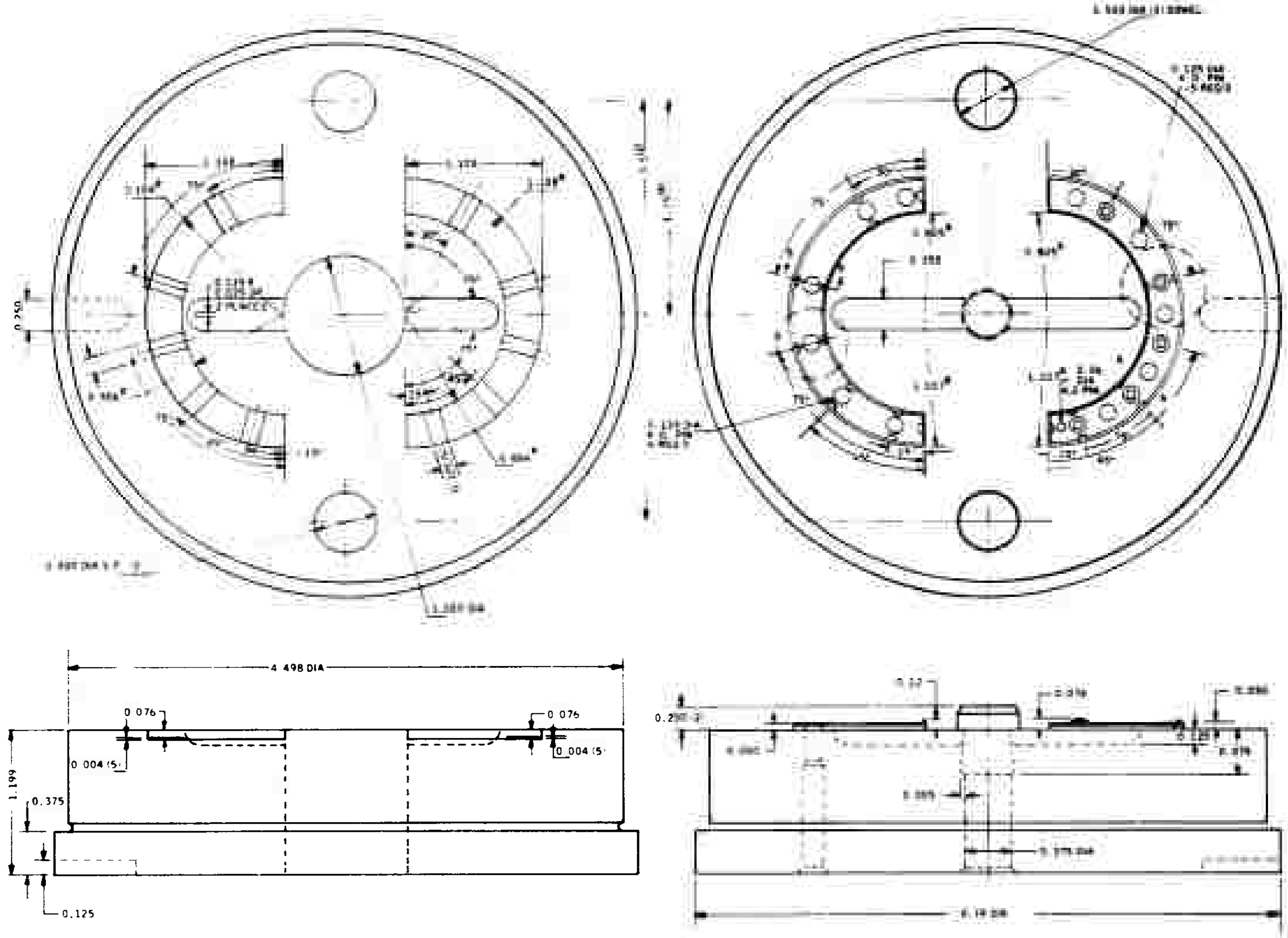


Figure 12. 25mm Injection Molding Die

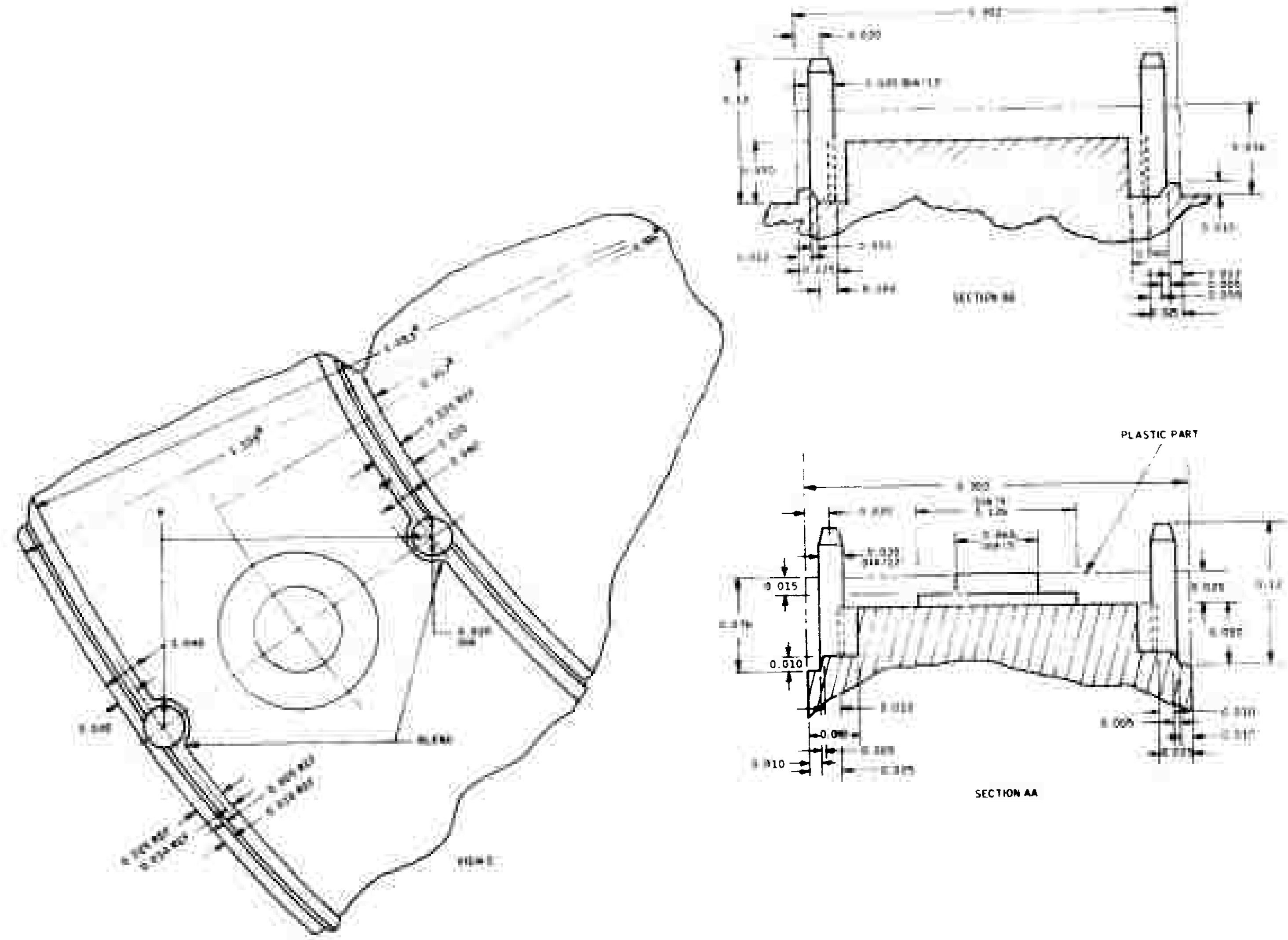


Figure 12. 25mm Injection Molding Die (Continued)

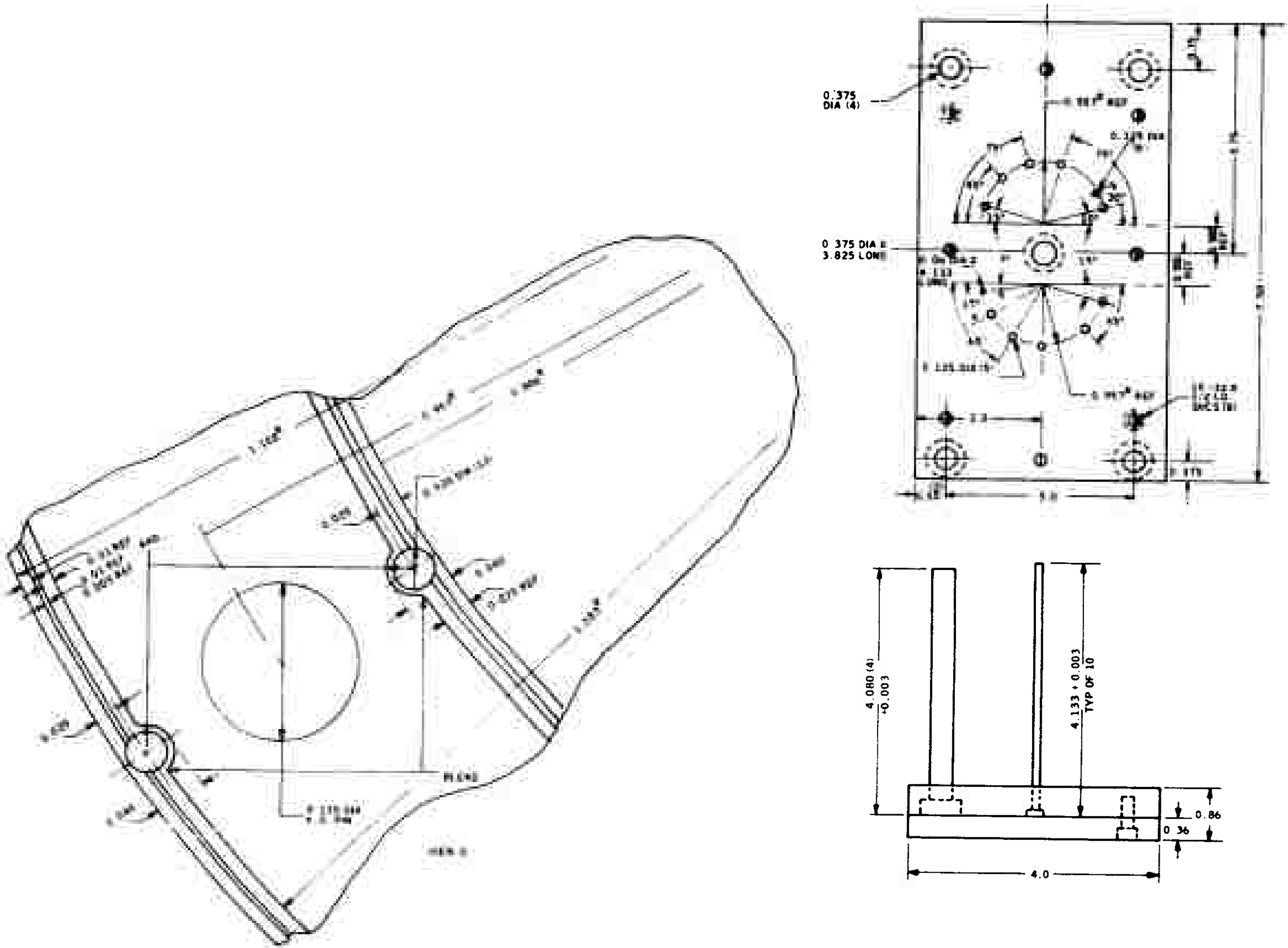


Figure 12. 25mm Injection Molding Die (Concluded)

SECTION IV
CONCLUSIONS

Work during the second quarter has produced the first assembled 18mm PET half packages. Work on both the 18mm and 25mm cases has produced a production-ready 25mm case, and with only minor modifications, an 18mm case. The electrode design and number of interconnections required to build these packages needs additional work which will be pursued next quarter. The test on the first engineering samples will be completed next quarter.

SECTION V
PROGRAM FOR NEXT INTERVAL

During the next quarter, the first engineering samples of 18mm and 25mm packaged PETs will be completed, tested and delivered. Modification in the 18mm package, electrode pattern on both the 18mm and 25mm elements will be reviewed and interconnection simplification will be studied. The second engineering sample build will be initiated.

SECTION VI
PUBLICATIONS AND REPORTS

The first quarterly report was submitted and approved January 12, 1976. This report was published and distributed in February. No other reports, talks or publications were made on the work associated with this program during the current quarter.

SECTION VII
IDENTIFICATION OF PERSONNEL

During the second quarter of this program, the following personnel worked the indicated hours in their area of responsibility. More detailed backgrounds of each professional person not given previously follow:

Individual	Responsibility	Hours
W. B. Harrison*	Program Manager	186
W. H. Kammeyer*	Production Engineer, Ceramic Manufacture and PET Assembly	69
G. O. Hendrickson	Metallurgical Engineer Interconnections	30
R. Keil*	Electronics Engineer PET Test Console Design	38
T. Rudy*	Plastic Engineer PET Package Design	162
L. F. Hiltner*	Quality Engineer	42
M. P. Murphy	Ceramic Technician Ceramic Manufacturing	250
M. R. Sandberg	Ceramic Technician Package Assembly	217
R. Bohlken	Electronic Technician Test Console Build	190
R. Larson	Plastic Technician	119
Miscellaneous	Production and Tooling	91
T. Lepsche	Development Engineer Interconnection	51

* Backgrounds given in First Quarterly Report.

T. G. LEPSCHE, Development Engineer

Program Responsibility: Gold Bonding of Interconnections

Current Assignment

Mr. Lepsche is a lead engineer in the Plating and Printed Circuit Laboratories, Thick Film Laboratories and the Hybrid Assembly Laboratory. Responsibility has included efforts on major programs such as C5A networks, BARC sensors, SSEC automative sensor hybrids, PAFM, SRC hybrids, TID-Denver Print-On-Paper, MC2138 and XM-587, as well as his current effort on PET for the Honeywell Ceramics Center

Professional Background

BSEE, Materials and Devices, University of Minnesota, 1973.

G. O. HENDRICKSON, Senior Materials Engineer

Program Responsibility: Interconnections and Package Assembly

Current Assignment

Mr. Hendrickson is responsible for establishing the interconnection techniques and final package assembly. He transferred to the Ceramics Department from the Honeywell Aerospace Division, where for the past 12 years in the Materials and Process (M&P) Engineering Section he applied ceramic-to-metal, glass-to-metal and anodic bonding to aerospace hardware. During this time, he was assigned to a consulting specialty in both nondestructive testing and experimental stress analysis.

Included in Mr. Hendrickson's prior assignments as a materials and process applications engineer were: (1) design and production engineering support on numerous aerospace programs, (2) specialization in module interconnect welding fabrication, (3) establishment of a Failure Analysis Laboratory and direction of mechanical and metallurgical analysis, (4) specialization in experimental stress analysis-and electronic module welding process development.

Before joining Honeywell, Mr. Hendrickson worked for Marquette Manufacturing Co. as a laboratory development metallurgist with primary responsibility for developing flux coatings for welding electrodes. He assisted in training sales personnel and resolving customer technical problems.

Professional Background

BS, Metallurgical Engineering, Michigan Technological University, 1957.

APPENDIX A

TEST PROCEDURES FOR PACKAGED 18MM AND 25MM PIEZOELECTRIC TRANSFORMERS

This document presents the details of the inspection and test program to be followed during contract DAAB07-76-C-0008. This test program falls within the framework of SCS-480.

Inspection and tests will be conducted in each of the three contract phases:

(a) Engineering sample phase

(b) Confirmatory sample phase

(c) Quality Conformance (Pilot Lot)

Table I summarizes the tests and the order of testing to which each group of units will be subjected. Table I also indicates the number of units to be subjected to each test. Where sampling inspection is indicated, it shall be in accordance with MIL-STD-105 or approved equivalent sampling procedures.

No failures will be allowed during the confirmatory tests; no more than one failure will be allowed for each subgroup of Quality Conformance testing. Wherever possible, Group B tests will be conducted on units which have already passed Group A testing.

All measurement equipment will be calibrated by the Instrumentation department and will be traceable to the Bureau of Standards. No equipment will be used in this test program on which the calibration period has expired.

The following paragraphs discuss the details of each of the tests. Not all assemblies will be subjected to each test. To determine the number of units to be subjected to each test, refer to Table I.

<u>Visual & Mechanical Examination (external)</u> - The physical characteristics of the piece parts, elements, subassemblies and PET assemblies will be determined using appropriate measurement techniques. Subassemblies and assemblies will be examined visually for proper assembly and workmanship. The weight of the assembly will also be determined as part of this inspection category.

<u>Visual & Mechanical Examination (internal)</u> - The internal workmanship of selected PETs will be examined by disassembling finished assemblies. The units will be examined visually for proper assembly and workmanship.

Table I. Tests to be Performed and Order of Testing

	PieceParts	Subassembly	Engineering Samples		Confirmatory Samples I	II	III	IV	Quality Conformance (Pilot Lot) A	B1	B2	B3	B4	B5
Sample Size	AQL 1.0	AQL 0.65	All	3	All	3	20	7	AQL 0.65	10	20	10	5	5
Visual & mechanical examination (external)	1	1	2	x	2	7			2			3		
Visual & mechanical examination (internal)				x		8								1
Resonant frequency +52°C			4		4				4					
+22°C		2	3		3				5					
-54°C			5		5				6					
Efficiency at resonance +52°C			4		4				4					
+22°C		3	3		3				5					
-54°C			5		5				6					
Voltage step-up at resonance +52°C			4		4				4					
+22°C		4	3		3				5					
-54°C			5		5				6					
Input capacitance & dissipation factor		5	6		6				7					
Secondary capacitance & dissipation factor		6	7		7				8					
Resistance to soldering heat				x	8						1			
Induced voltage				x	9	6		3	3		6	2		
Terminal strength				x	10						2			
Solderability				x		1							1	
Reduced barometric pressure				x		2								
High temperature storage				x		3				1				
Low temperature storage				x		4				2				
Humidity				x		5					3			
Life				x			1					1		
Mechanical vibration				x				1			4			
Mechanical shock				x				2			5			
Thermal shock			1		1				1					

Resonant Frequency - The resonant frequencies of assemblies and subassemblies will be determined using the automatic test console (see Appendix A). The element will be driven at 5 volts peak to peak sine wave. The load conditions during the test will be 10 pf and 10 megohm. The test will be conducted at +22°C ± 2°C and at +52°C ± 2°C and -54°C ± 2°C if so indicated in Table I. The elements will be stored at temperature a minimum of one (1) hour prior to testing.

Efficiency at Resonance - The efficiency at resonance of assemblies and subassemblies will be determined using the automatic test console. The test will be conducted under the same drive and load conditions and at the same temperatures as in the resonant frequency test. The efficiency at resonance will be calculated as follows:

$$\frac{P \text{ output (secondary)} \times 100 \text{ percent}}{P \text{ input (primary)}}$$

Voltage Step-up at Resonance - The voltage step-up at resonance of assemblies and subassemblies will be determined using the automatic test console. The test will be conducted under the same drive and load conditions and at the same temperatures as in the resonant frequency test. The step-up will be calculated as follows:

$$\frac{E_{pp} \text{ (secondary)}}{E_{pp} \text{ (primary)}}$$

Input Capacitance and Dissipation Factor - The input capacitance and dissipation factor of assemblies and subassemblies will be measured on a capacitance bridge at 1 volt peak to peak at 1KHz between the primary and ground. The test will be conducted at room temperature (+22°C ± 2°C).

Secondary Capacitance and Dissipation Factor - The capacitance and dissipation factor of the secondary of assemblies and subassemblies will be measured on a capacitance bridge at 1 volt peak to peak at 1KHz between the secondary and ground. The test will be conducted at room temperature (+22°C ± 2°C).

Resistance to Soldering Heat - The terminals of selected PET assemblies will be immersed to within 1/64 inch of the case in molten solder at 280°C ± 5°C for 30 ± 2 seconds.

After exposure to soldering heat, the PET will be allowed to cool and stabilize at room temperature. The PET will then be examined for physical damage and will be retested for resonant frequency, efficiency at resonance and voltage step-up at resonance at room temperature.

Induced Voltage - The induced voltage will be determined on selected PET assemblies. The PET will be driven for 5.0 ± 1/2 seconds at an input voltage sufficient to cause 150 percent of the rated output. The load on the secondary will be 10 pf and 10 megohms. During the test, the PET will be examined for evidence of continuous arcing, breakdown and abrupt changes in input current. The test will be conducted at room temperature (+22°C ± 2°C) on the automatic test console.

Terminal Strength - The secureness of the terminals of selected PET assemblies will be tested by applying 1/2 pound to each terminal in the direction of the terminal's axis. The load will be applied slowly to the terminal and then held for a period of 5 to 10 seconds. After the test, the terminals will be examined for looseness or other detrimental mechanical damage.

Solderability - The solderability of PET terminals will be determined by immersing them into molten solder to within 1/64 inch from the nearest insulating material. Prior to the test, the terminals will be prepared and aged per MIL-STD-202E, method 208C.

Barometric Pressure (reduced) - The PET will be rigidly mounted and subjected to a reduced pressure equivalent to an attitude of 50,000 feet (3.44 in. Hg) for one (1) hour. After exposure to this reduced pressure, the PET will be returned to ambient pressure and will be driven at resonance for 5.0 ± 1/2 seconds at an input voltage sufficient to cause 125 percent of the rated output. The load on the secondary will be 10 pf and 10 megohms. During this time, the PET will be examined for evidence of continuous arcing, breakdown and abrupt changes in input current. The PET will also be examined for physical damage.

Life - The PETs will be rigidly mounted with a minimum of 2 inches between units and within 2 inches of the temperature sensors.

During the test, the PETs will be driven at 125 percent of their rated voltage, i.e. 6.25 volts peak to peak at a temperature of 52°C ± 2°C. The load on the secondary will be 10 pf and 10 megohms. Any premature failure will be detected by the test circuitry and the time of failure will be automatically recorded.

During and after the test, the PETs will be tested for voltage step-up at resonance at 96, 240, 480, 960 and 2000 hours.

The PETs will then be returned to room temperature and tested for induced voltage, resonant frequency, efficiency at resonance, input capacitance, input dissipation, output capacitance and output dissipation. The units will also be examined for physical damage.

Mechanical Vibration (Longitudinal and Transverse) - The PET will be regidly mounted to the vibration table and will be vibrated with its radial axis parallel to the motion of vibration. Vibration will consist of two (2) thirty (30) minute sweeps over the frequency range of ten (10) hertz to 3500 hertz and back to ten (10) hertz while maintaining a constant 2.5g ± 0.2g. The PET will then be subjected to 10g vibration for five (5) minutes at each of the frequencies, 1020Hz ± 100Hz and 2080Hz ± 100Hz.

The direction of vibration will then be changed such that the radial axis is perpendicular to the motion of vibration. Vibration schedule will be as previously described except that after the 2080Hz exposure, the PET will be subjected to 10g vibration for five (5) minutes at 3140Hz ± 100Hz.

While under vibration, the primary will be driven at resonance with 5.0 volts peak to peak sine wave input and with a load on the output of 10 pf and 10 megohms and the PET will be continuously monitored for evidence of arcing, breakdown or abrupt changes in input current.

Mechanical Shock - Longitudinal Saw Tooth - The PET will be rigidly mounted with its radial axis in the vertical plane. The PET will be subjected to five shock pulses of nine millisecond duration saw tooth wave form whose peak force is 140g ± 14g measured with an oscilloscope.

The direction of shock will then be reversed so that the shock is still parallel to the radial axis. The shock schedule will be repeated.

During shock testing, the primary will be driven at resonance with 5.0 volts peak to peak sine wave input and with a load on the output of 10 pf and 10 megohms and the PET will be continuously monitored for evidence of arcing, breakdown or abrupt changes in input current. The test will also be monitored with an accelerometer mounted near the PET. The pulse shape and amplitude will be recorded.

Mechanical Shock - Transverse Saw Tooth - The PET will be rigidly mounted with its radial axis in the horizontal plane. The PET will be subjected to ten shock pulses of the amplitude, duration and form described in the previous paragraph.

The test will be monitored as described in the previous paragraph.

Mechanical Shock - Longitudinal Impulse - The PET will be rigidly mounted with it radial axis in the horizontal plane. The PET will be subjected to ten pulses of nominal half sine wave shape having a peak amplitude of 910g ± 45g and a duration of 0.10 ± 0.05 milliseconds. After oscillations will not exceed 90g at twelve milliseconds after the initial pulse.

The test will be monitored as described in the previous paragraph.

Thermal Shock - The PET will be subjected to ten thermal shock cycles. The temperature and duration of each cycle are as follows: 30 minutes minimum at $-65^{\circ}C + 0^{\circ}C - 5^{\circ}C$; 5 minutes maximum at $25^{\circ}C + 10^{\circ}C - 5^{\circ}C$; 30 minutes minimum at $+125^{\circ}C + 3^{\circ}C - 0^{\circ}C$; 5 minutes maximum at $25^{\circ}C + 10^{\circ}C - 5^{\circ}C$.

Thermal Shock (cont'd)

Separate temperature chambers will be used for the hot and the cold environments.

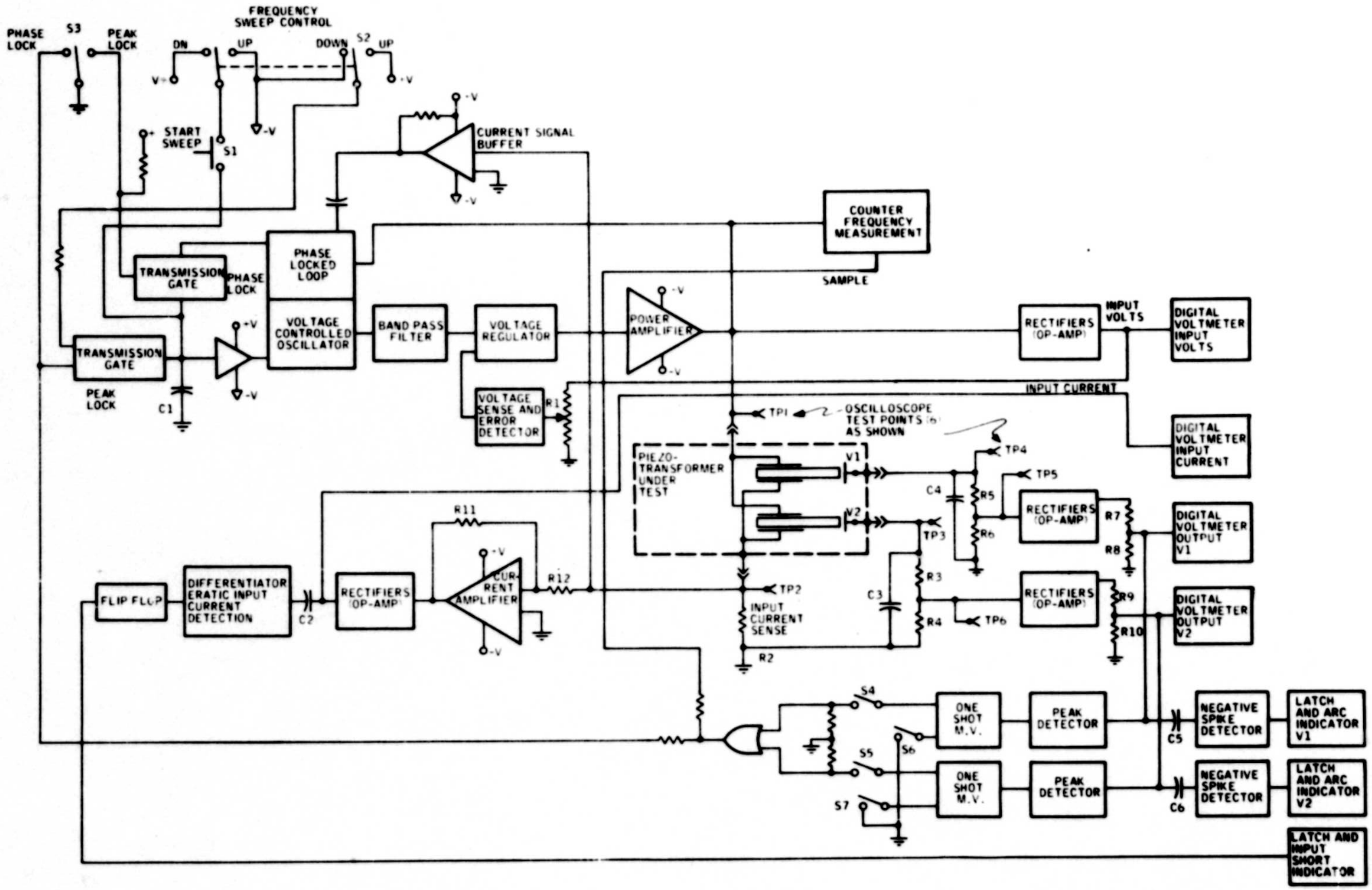
After the tests, the PET will be examined visually for mechanical damage and tested for resonant frequency, efficiency at resonance, input capacitance, input dissipation, output capacitance and output dissipation.

High Temperature Storage - The PET will be stored at +71°C for 8 hours minimum. The temperature will then be lowered slowly to +52°C and while at +52°C, the PET will be tested for resonant frequency, efficiency at resonance and voltage step-up ratio.

Low Temperature Storage - The PET will be stored at -65°C for 2 hours minimum. The temperature will then be raised slowly to -54°C and while at -54°C, the PET will be tested for resonant frequency, efficiency at resonance and voltage step-up ratio.

Humidity - The PET will be submersed in water at a temperature of +52°C for six hours. With one (1) hour after removal from the water, a voltage 112 percent of the rated voltage will be applied to the primary and the PET will be driven at resonance for either 48 hours during first article inspection or for 8 hours during quality conformance inspection. After this time, the PET will be tested for resonant frequency, efficiency at resonance and voltage step-up ratio.

The PET will also be examined for physical damage.



Piezotransformer Test Console Circuit

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