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XM587E2/XM724 ELECTRONIC TIME FUZES SYSTEM VERIFICATION TEST PH--ETC(U)
JAN 78 J C RAVIS   DAAG39-75-C-0157

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Time Fuzes System Verification Test Phase, by

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Prepared by
HONEYWELL INC.
DEFENSE SYSTEMS DIVISION
600 SECOND STREET NE
HOPKINS, MINNESOTA 55343

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This report discusses the work performed during the System Verification Test (SVT) phase of engineering development of the XM587E2 and XM724 Electronic Time fuzes. A quantity of 600 fuzes was built and tested in a wide variety of environmental and ballistic conditions. Excellent results were obtained except for firings at zone 3 in the 175-mm gun. A failure analysis and corrective action effort was performed, including testing of fifty fuzes of a revised design. For completeness and continuity of this

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20. Abstract (Continued)

report, investigations, tests, analyses, and redesign activities performed by the Harry Diamond Laboratories are included.

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1. INTRODUCTION AND SUMMARY

This report documents the activities and accomplishments associated with the system verification test (SVT) phase of development of the XM587E2 and XM724 electronic time (ET) fuzes by the Defense Systems Division of Honeywell Inc. for Harry Diamond Laboratories (HDL) under contract DAAG39-75-C-0157. For completeness as a report on the SVT phase, some sections of this report were furnished by HDL to include work performed by that organization.

The XM587E2 fuze is designed for use on all high explosive artillery projectiles from 105mm through 8-inch, as well as for the 4.2-inch mortar. This fuze can be set for any time delay function between 0.3 and 199.9 seconds in 0.1 second increments by means of the XM36E1 fuze setter. This fuze can also be set for point detonating (PD) function and incorporates an independent mechanical backup mechanism for function on impact.

The XM724 is similar to the XM587E2 fuze except that it is modified for use on cargo-carrying projectiles. For this application, the following modifications were made to the basic XM587E2 fuze:

- Elimination of the PD setting mechanism.
- Elimination of the mechanical backup mechanism for impact function.
- Elimination of the booster pellet and booster cup.

The design of these fuzes maximizes piece part and subassembly commonality, and either fuze can be manufactured on a common assembly line. Two interchangeable piece parts, a printed wiring board and the bias spring, account for the internal differences between the two fuzes.

The XM587E2/XM724 fuzes consist of two assemblies crimped together to form a complete fuze assembly. These two assemblies are the electronics head (E-head) and rear fitting. The booster consists of a booster pellet placed in the booster cup which screws onto the back of the fuze.

The rear fitting contains the battery, safety and arming (S&A) module, and explosive train. An electrical interface is provided between the E-head and the rear fitting by means of three coil connectors in the E-head which mate with three posts on the top of the power supply in the rear fitting.

The E-head contains the timing functions, power conditioning circuits, interfacing circuits, and memory circuits which allow the time setting to be automatically selected by the XM36E1 fuze setter. The connection with XM36E1 fuze setter is provided by three concentric rings on the top of the E-head.

The following items were supplied by HDL as GFM under this contract:

Item	Part Number
Power Supply	11720216
MOS scaler/logic and overlead safety	11711256
MNOS counter	10990466
Booster pellet	117120213
Impact switch	11718418
M55 stab detonator	8798331
Electric detonator	11722405

The initial purpose of this development program was to build 2,000 fuzes for conducting DT/OT-II. These fuzes were to have been manufactured in accordance with the technical data package generated under the previous program (contract DAAG39-73-C-0176). However, the fabrication history and the test results from the previous program indicated three major design deficiencies. Development activities to correct these deficiencies were conducted, resulting in the following design changes:

- Redesign of the setting ring and plug assembly to ensure electrical continuity and to improve manufacturing yields.
- Repackaging and modularization of the power converter transformer to eliminate mechanical stress on the transformer core under low temperature conditions and to eliminate assembly problems due to miswiring.
- Change in the output lead explosive material from RDX to PBXN-5 in order to meet the Tri-Service fuze safety requirements of MIL-STD-1316A.

Initially, 600 XM587E2 fuzes were fabricated for system verification testing. System verification testing consisted of MIL-STD-331 and ballistic tests in all weapons and were completely acceptable except as noted in the following paragraph relative to ballistic tests in the 175mm gun. Proper airburst function at the set time exceeded 98 percent in the ballistic tests. Two deficiencies occurred during 175mm gun ballistic firing tests at zone 3:

- An early burst occurred (fuze functioned at approximately 5 seconds when set at 90 seconds) when fired at +145°F. This fuze had previously been subjected to a sequential 7-foot drop packaged tests.

- Proper airburst functional reliability was reduced when the fuze was exposed to temperatures ranging from -40°F to +145°F. At -40°F, a 40-percent dud rate was experienced. At ambient conditions and at +145°F, proper airburst functional reliability dropped to approximately 60 percent; however, essentially all these units functioned on impact.

These deficiencies were subject to a joint HDL/Honeywell series of investigations and diagnostic activities to determine the causes and to develop corrective measures. The early burst was determined to have been caused by leaking electrolyte, resulting in an intercomponent short circuit within the power supply. The dud conditions at -40°F were caused by a structurally weak gear in the S&A module.

The necessary design changes to correct these deficiencies were idientified and the appropriate design changes accomplished. The specific changes were as follows:

- Modification of the design of the power supply and fuze sleeve to preclude shorting between critical internal elements. The through-lead to the electric detonator was changed and rerouted around the power supply.

- Replacement of the structurally weak die-cast zinc gear-and-pinion assembly in the S&A module with a aluminum cut gear staked to a stainless steel pinion.

An additional lot of 50 fuzes incorporating the above design changes was fabricated to demonstrate the performance of the improved design. Ten units were shipped to the Yuma Proving Ground (YPG) and 20 units were shipped to Aberdeen Proving Ground (APG) for ballistic tests. Eight units were subjected to MIL-STD-331 tests at Honeywell and then shipped to YPG for ballistic tests. These units were tested in the top zones of the 155mm XM198 and 175mm guns with the following results:

- No early bursts occurred.

- The -40°F duds due to gear breakage were eliminated.

- Reliability of non-rough-handled fuzes at temperature extremes was 80 to 90 percent.

2. DESIGN CHANGES

HDL supplied a data package defining the baseline XM587E2/XM724 fuze design at the outset of the program. All drawing changes were accomplished by engineering change proposal (short form). During the course of the contract, 101 engineering change proposals were submitted on the XM587E2 and XM724 fuzes. Only the changes of major significance are discussed in this report.

2.1 Baseline Design

The baseline design at the start of the program is shown in figure 1. The following assemblies had major changes that were incorporated in all fuzes fabricated:

- Setting ring and plug assembly (part number 11711425).
- Power converter transformer assembly (part number 11811448).
- Lead charge (part number 11711258).

The changes are incorporated in the configuration shown in figure 2.

In addition to the changes incorporated in all fuzes fabricated, a proof lot of 50 fuzes was fabricated that had two additional changes. These changes were incorporated in the following assemblies:

- S&A module (part number 11720301).
- Power supply (PS127) (part number 1120216).

In the S&A module, the die-cast zinc gear-and-pinion assembly was replaced with an aluminum cut gear. The power supply was modified by moving it through the lead which connects the electronics output to the electric detonator outside of the power supply. This was done by using a laminated lead which went along the outside of the power supply assembly. These changes are discussed in detail in sections 2.2 and 2.3, respectively.

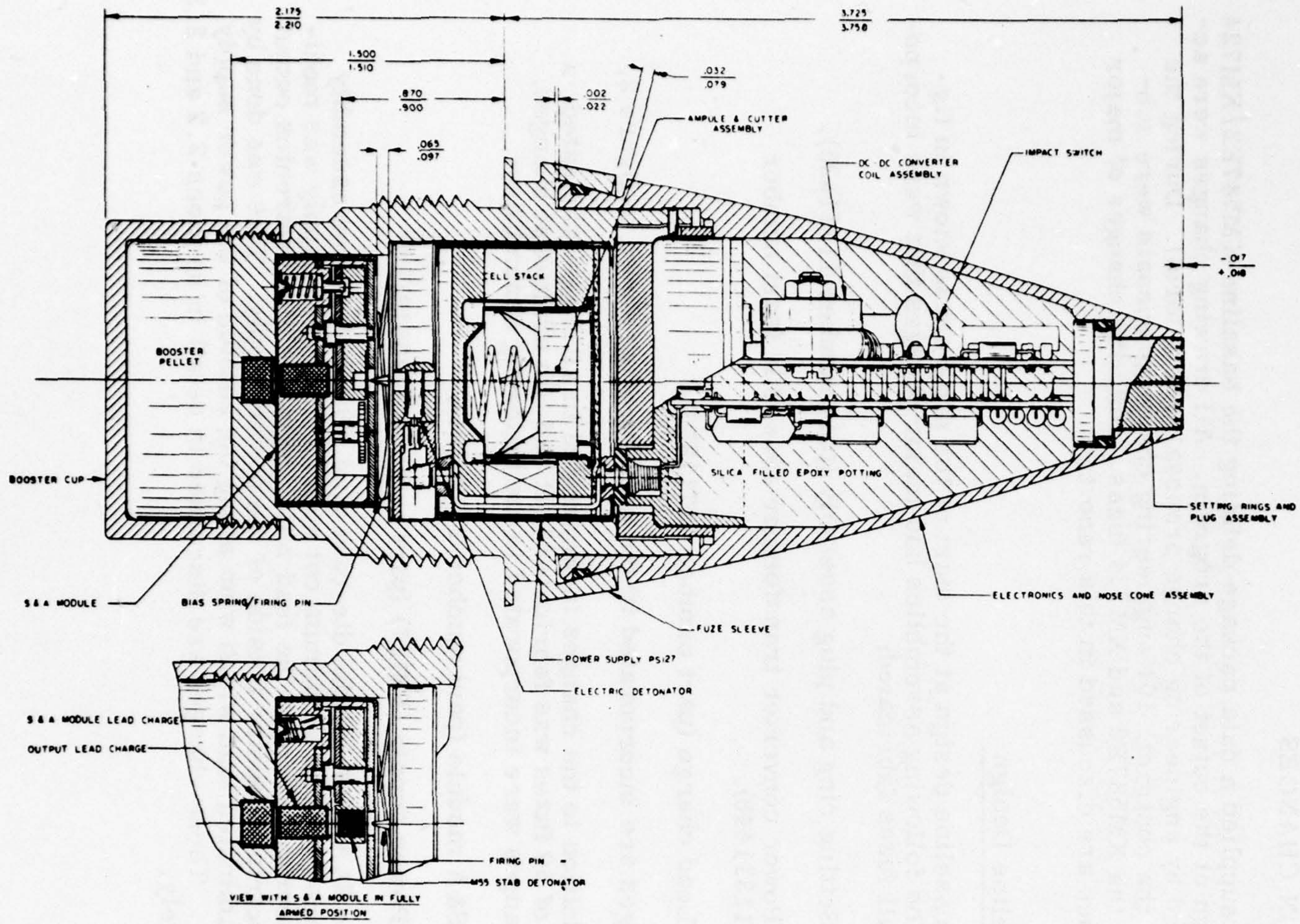


Figure 1. Baseline XM587E2 fuze configuration.

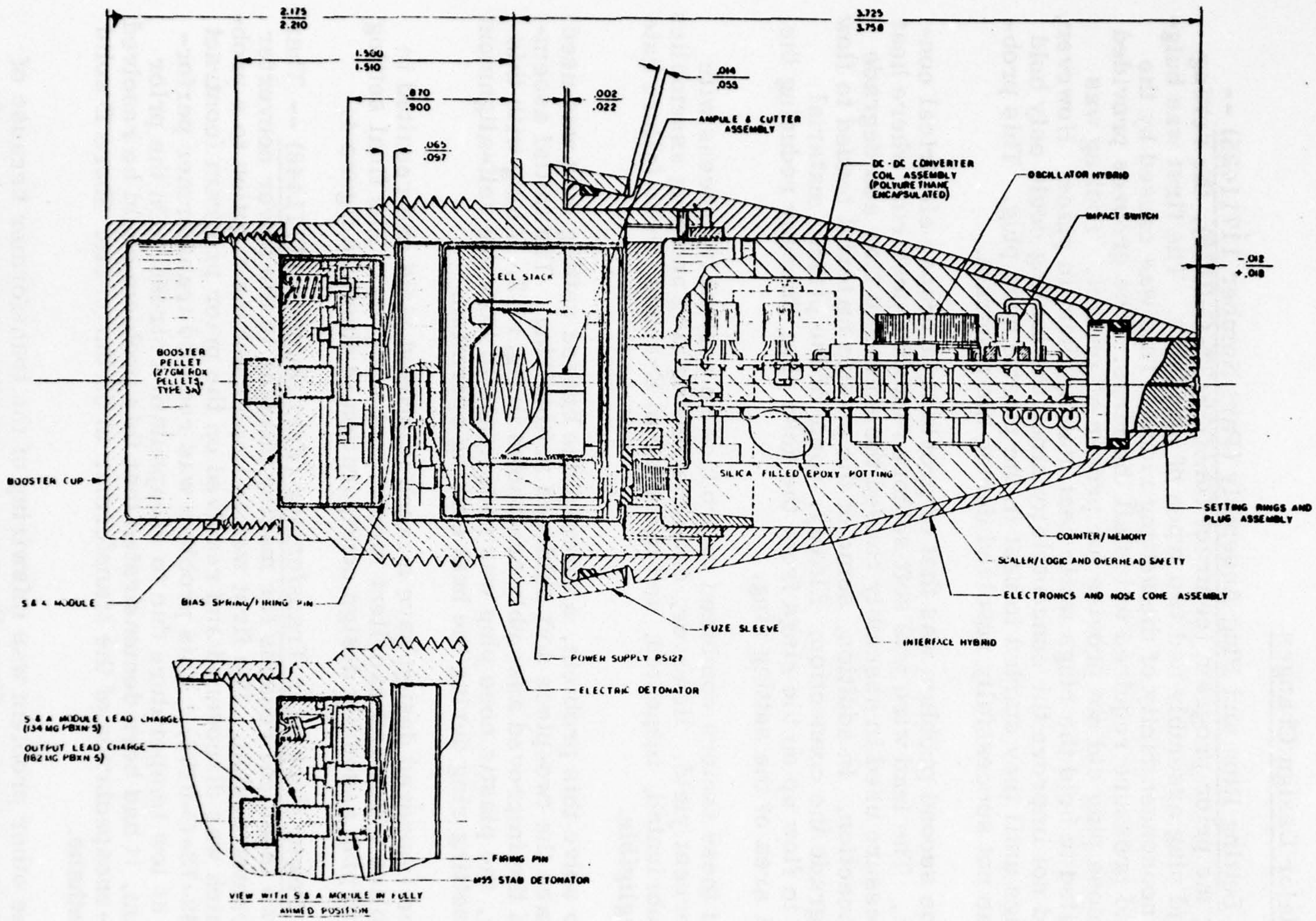


Figure 2. Revised XM587E2 fuze configuration.

2.2 Major Design Changes

2.2.1 Setting Ring and Plug Assembly (Part Number 11711425) -- During the prior program (contract DAAG39-73-C-0176), the setting ring and plug assembly had two types of problems. The first was bulging or nonconcentricity of the setting rings. This was caused by the heat and pressure required to install the rings. The grooves provided in the nose plug did not provide for proper alignment. Tooling was fabricated to hold the rings while heat staking them in place. However, this did not improve the concentricity since the tooling could only hold the rings until they started to seat in the plastic nose plug. This problem was not successfully resolved during the program.

The second problem was that of providing a proper electrical connection. The lead wire was soft soldered into the nose ring where heat and pressure used in assembly caused the solder to flow and degrade the connection. In addition, some of the plastic material tended to flow and degrade the connection. Finally, some of the plastic material tended to flow up on the rings from the nose plug, thereby reducing the contact area of the setting ring.

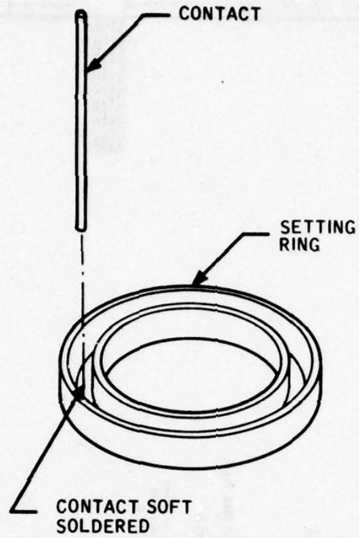
All these factors combined to produce an assembly process with a 70 percent yield. However, once the setting ring and plug assemblies were fabricated, inspected, and installed in E-heads, their failure rate was negligible.

To solve this problem, a three-piece brazed setting ring was used to replace the two-piece soft soldered setting ring. The initial assembly and the improved assembly are shown in figure 3. Along with this change, the plastic nose plug was redesigned to improve self-alignment of the setting ring during the heat staking operation.

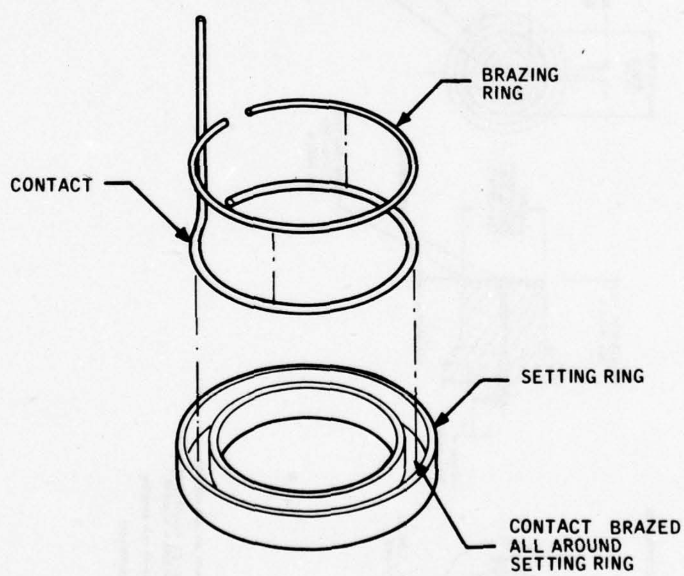
The improved design gave a much improved yield and resulted in assemblies which had excellent mechanical integrity. The final setting ring and plug assembly design configuration is shown in figure 4.

2.2.2 Power Converter Transformer (Part Number 11711448) -- There were two technical reasons for making changes in the power converter transformer design. The first was to implement the solution to a problem which was discovered and resolved on the prior program (contract DAAG39-73-C-0176). This problem was reduced transformer performance at low temperature due to encapsulation stress. On the prior program, it had been demonstrated that this problem could be resolved by pre-encapsulation of the transformer in 55 durometer Shore D solid polyurethane.

The other problem was miswiring of the transformer because of the numerous leads. Since the power converter operation depends on proper transformer phasing, miswiring caused nonoperation.



Initial Setting Ring



Improved Setting Ring

Figure 3. Comparison of initial and improved setting ring designs.

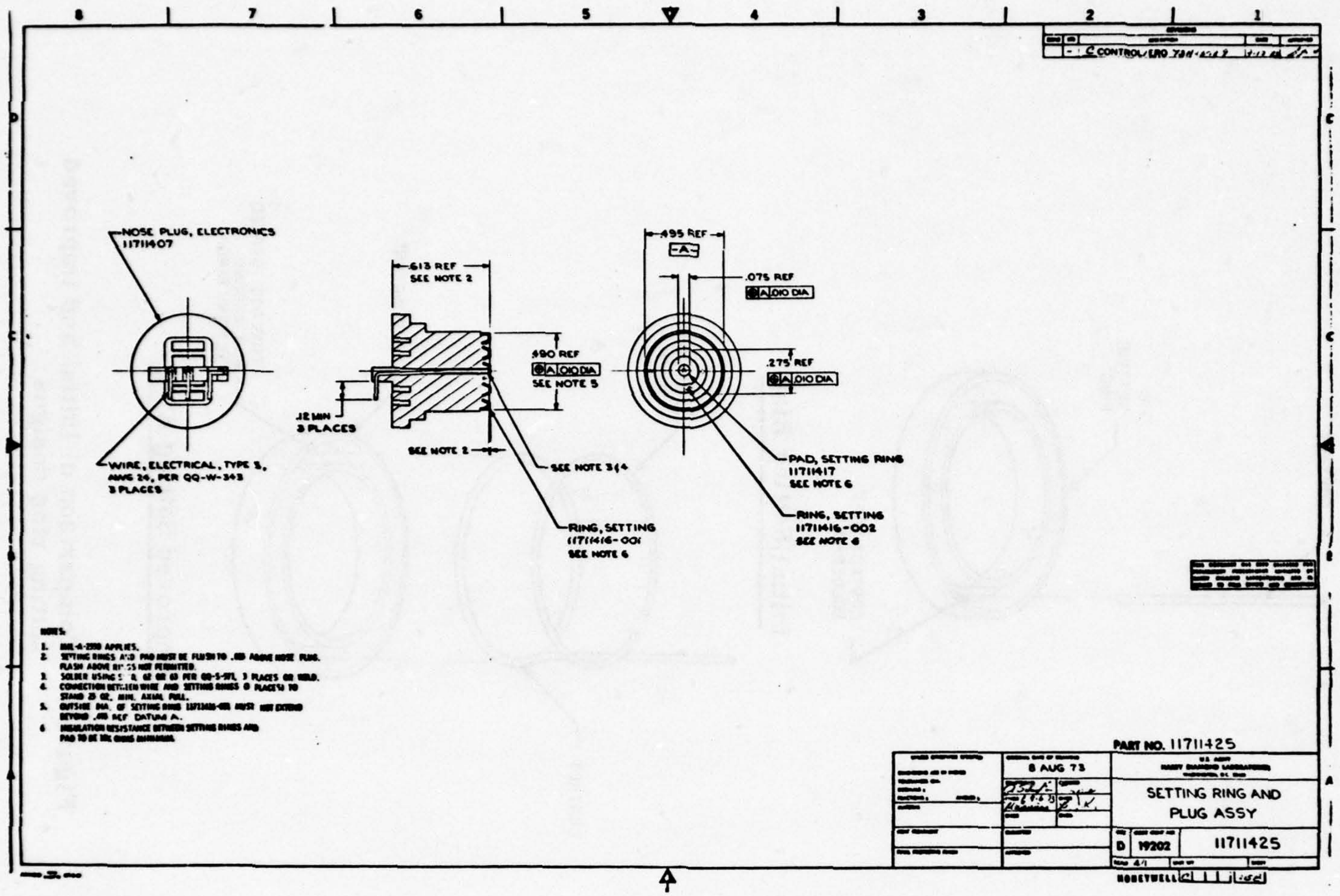


Figure 4. Setting ring and plug assembly.

The solution to both of these problems was to modularize the transformer with keyed output/input pins to preclude improper wiring and encapsulate the module in the proper encapsulant material. In addition, test requirements were developed to ensure that all transformers were tested for turns ratio and output phasing.

The new power converter transformer package is shown in figure 5. Fifteen units were fabricated to check out the assembly process. The units were tested per the test requirements, and 13 units were encapsulated and retested. One unit was tested for repeatability, with the results as shown in table I. In addition, two of the transformers that were encapsulated were subjected to shock per MIL-STD-883, method 2002.1, condition G. The shock level used is shown in figure 6. It will be noted that the shock level was approximately 1,000 g's less than the 30,000 g's required. This was due to setup and is not indicative of capability. Both transformers passed the test requirements after shock; the post-shock data are contained in table I.

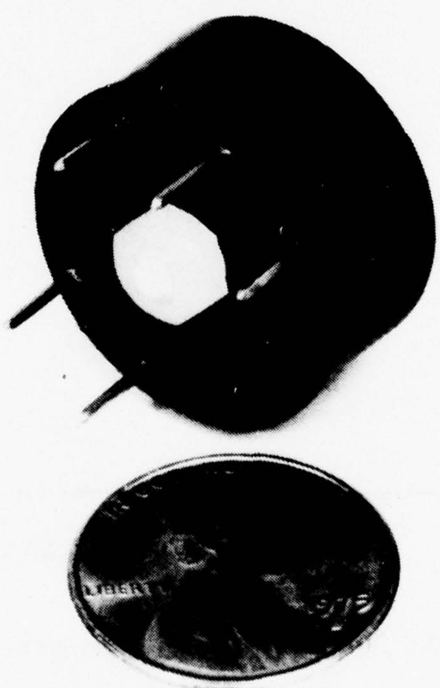


Figure 5. Power converter transformer.

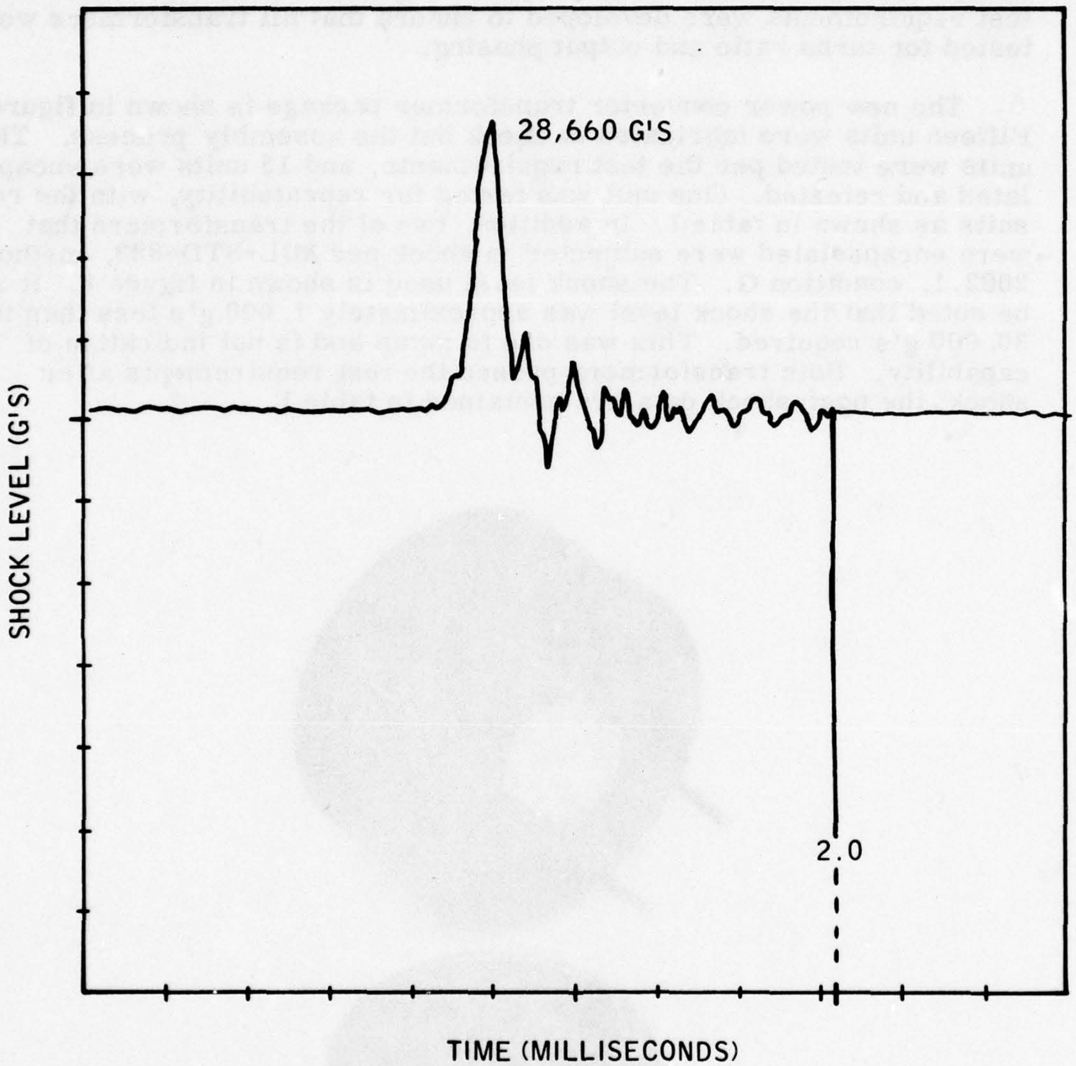


Figure 6. Shock pulse for transformer evaluation.

TABLE I. POWER CONVERTER TRANSFORMER POST SHOCK DATA

Transformer	Input Voltage	Output Voltage	Center Tap Input Voltage	Primary Coil 1 Resistance (Ohms)	Primary Coil 2 Resistance (Ohms)	Secondary Resistance (Ohms)	Output Phase (Degrees)
Pre-Encapsulation							
1	0.9967	14.572	0.4986	0.3356	0.3446	4.230	178.384
2	1.000	14.607	0.4998	0.3236	0.3386	4.258	178.424
3	1.006	14.709	0.5033	0.3196	0.2376	4.200	178.784
4	1.003	14.642	0.5000	0.2896	0.4416	4.184	178.514
5	0.9982	14.615	0.4992	0.2686	0.1996	4.168	179.154
6	1.001	14.660	0.5011	0.2686	0.1996	4.281	179.294
7	0.9964	14.619	0.4979	0.2076	0.1936	4.159	179.644
8	0.9981	14.643	0.4958	0.1976	0.2256	4.147	179.474
9	0.9989	14.640	0.4986	0.1796	0.2426	4.180	179.514
10	1.003	14.858	0.5019	0.1836	0.0856	4.212	179.354
11	1.003	14.685	0.5004	0.1196	0.5566	4.119	179.794
12	1.004	14.707	0.5010	0.1766	0.2136	4.137	179.594
13	1.001	14.707	0.5010	0.1806	0.2046	4.125	179.594
14	1.001	14.676	0.5001	0.1786	0.2076	4.126	179.684
15	1.002	14.675	0.5002	0.1846	0.2396	4.411	179.454
Post Encapsulation							
1	0.9975	14.586	0.4994	0.2356	0.1326	4.166	179.534
2	0.9950	14.505	0.4993	0.4946	0.1376	4.302	178.864
3	1.001	14.628	0.5031	0.4716	0.1356	4.201	178.624
4	1.003	14.661	0.5019	0.2396	0.1356	4.140	179.704
5	1.002	14.674	0.5016	0.2136	0.1366	4.211	179.534
6	1.002	14.644	0.5034	0.3846	0.1356	4.339	178.814
7	1.002	14.464	0.5029	0.4976	0.1406	4.203	179.124
8	1.004	14.656	0.5036	0.3466	0.1396	4.243	178.844
9	1.002	14.665	0.5024	0.2956	0.1396	4.284	179.324
11	0.9986	14.616	0.5000	0.2216	0.1356	4.113	179.644
13	1.005	14.698	0.5029	0.2396	0.1376	4.819	179.234
Repeatability							
4	1.003	14.642	0.5000	0.2896	0.4416	4.184	178.514
4	1.002	14.650	0.5004	0.2856	0.3716	4.2016	178.574
4	1.003	14.652	0.5008	0.2836	0.3606	4.189	178.574
4	1.001	14.620	0.4995	0.2856	0.3496	4.177	178.574
4	1.001	14.619	0.4997	0.2866	0.3516	4.182	178.594
4	1.001	14.623	0.4996	0.2826	0.3556	4.186	178.614
4	1.004	14.657	0.5008	0.2866	0.3576	4.201	178.604
Post Shock							
6	1.001	14.621	0.4999	0.0696	0.0616	4.601	181.074
13	1.000	14.621	0.4998	0.0726	0.0626	4.332	181.064

2.3 Proof Lot Fuzes

> NOTE: This section was furnished by and covers work performed by the Harry Diamond Laboratories

As a result of firings from the 175mm gun during system verification testing, two design deficiencies were noted. Correction of these deficiencies involved modifications of the gear-and-pinion assembly in the S&A module and modification of lead configuration and location in the power supply. These deficiencies and corrective modifications are discussed in detail in the following paragraphs.

2.3.1 S&A Module Gear-and-Pinion Assembly -- The rotor and gear train of the S&A module is shown in figure 7. An exploded view of the major S&A module piece parts is shown in figure 8. The rotor is eccentrically mounted and imbalanced such that the centrifugal forces resulting from spin about the fuze centerline cause it to rotate counterclockwise. The center of gravity of the rotor is shown in figure 7 close to the pivot at about the 1 o'clock position and is indicated by the symbol ⊕. The motion of the rotor is damped by a runaway escapement, resulting in an arming delay or safe separation distance. The torque produced by the rotor must therefore be transmitted through the gear train. If an impact such as from in-bore balloting forces occurs on the upper left hand portion of the S&A module, as viewed in figure 8, then the resulting impulse (or shock) will also tend to drive the rotor toward the armed position and will apply a shock loading to the gear train. In 175mm gun firings at zone 3, this impulsive side load may be several times as severe as the normal operating load of the gear train.

Die-cast zinc, of which the SVT vintage gear-and-pinion assemblies were made, is very sensitive to impact loads at temperatures below room temperature. In fact, due to the existence of a crystalline structure transition temperature, the impact energy required to break a die-cast zinc test specimen at -40°F may be as low as 5 percent of the room temperature value. This does not mean that die-cast zinc is not a suitable material for use in S&A device gear trains; it does mean that conservative designs must be used to allow for the cold temperature impact sensitivity.

The corrective action taken was to replace the die-cast zinc gear with one machined from wrought aluminum, which does not go through a crystalline transition. This aluminum gear is staked onto a one-piece machined pinion and shaft and, in construction, is similar to what is used in the M732 and M577 fuzes, the M125 booster, and the safety adapter for the M564/M565 fuzes. The functional form of this new assembly is identical to the die-cast zinc version. Laboratory tests were performed to confirm that the new machined gear set is

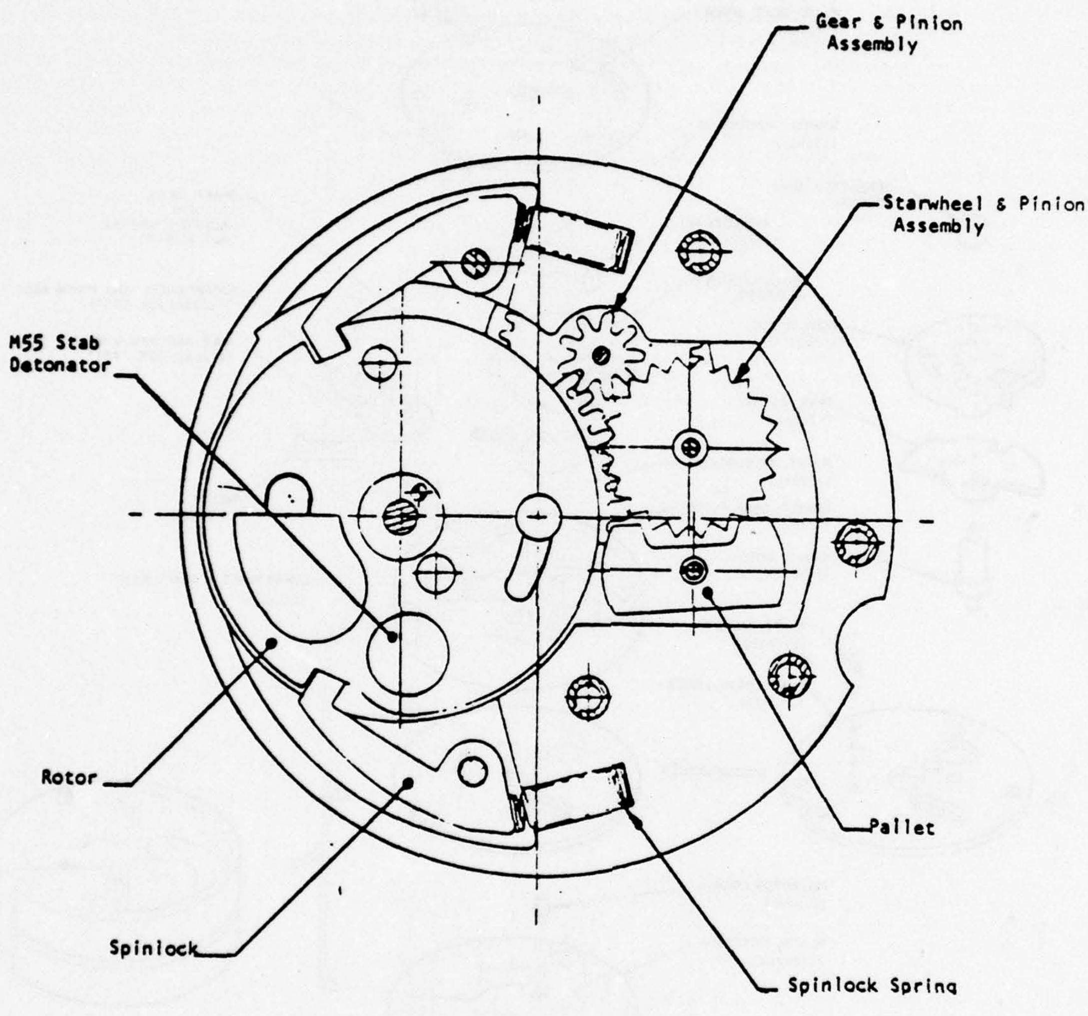


Figure 7. Rotor and gear train of the S&A module of the XM587E2/XM724 fuzes.

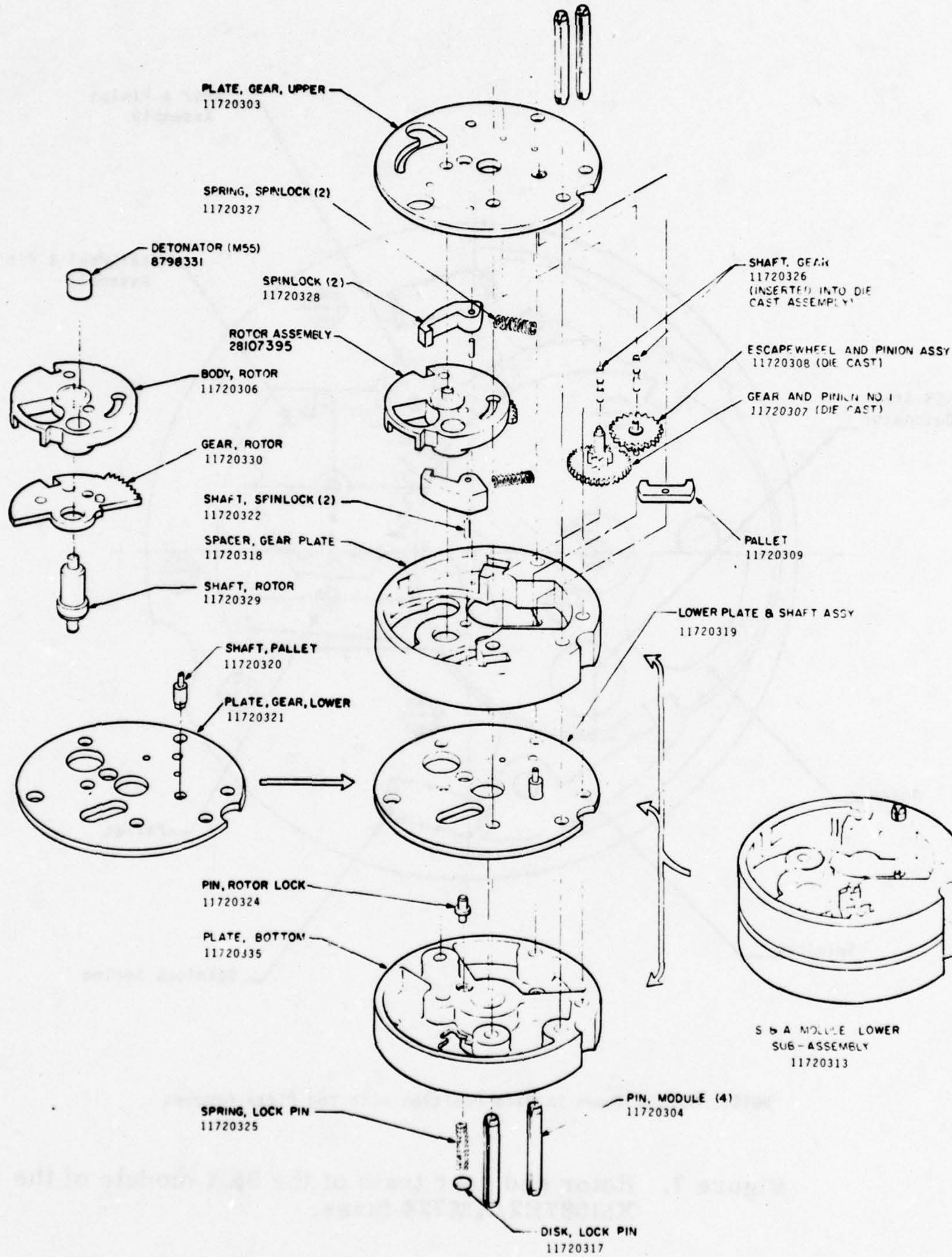


Figure 8. Exploded view of the XM587E2/XM724 fuze S&A module.

functionally interchangeable with the zinc gear and that it is considerably more resistant to damage from impact loading at -40°F.

2.3.2 Power Supply -- A partial section view through an SVT vintage fuze power supply is given in figure 9. The section is such that the detonator through-lead may be seen running from one terminal to the other through a scallop in the outer edge of the cell stack. The upper terminal is electrically connected to the fuze firing circuit. The lower terminal is electrically connected to the detonator bridgewire. Application of power supply power to this lead has been demonstrated to be adequate to reliability initiate the electric detonator.

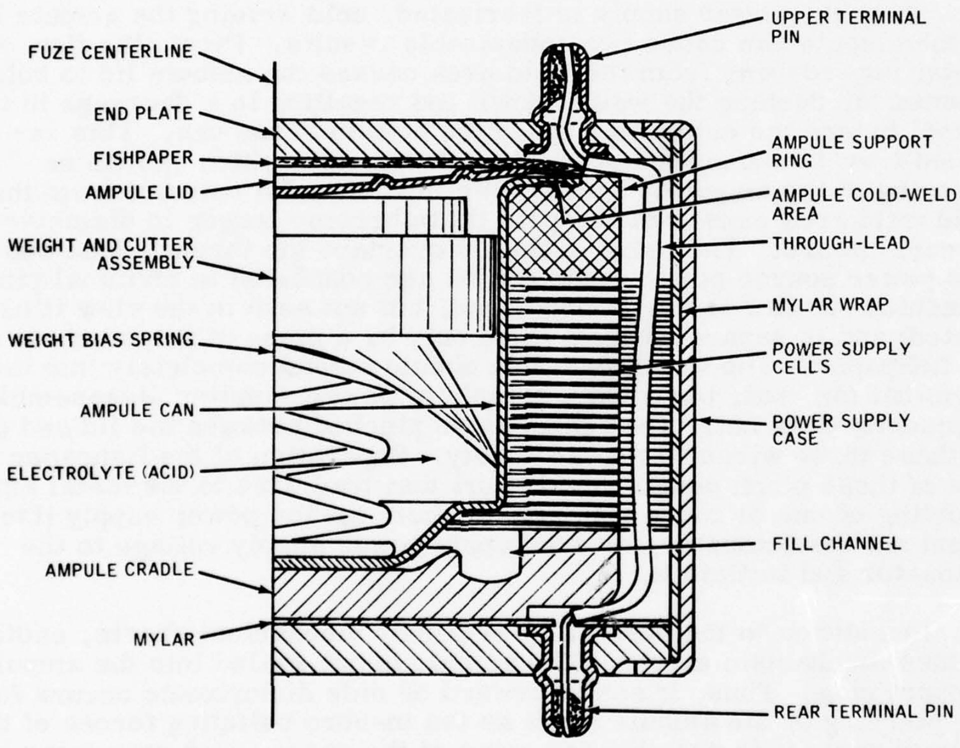


Figure 9. Cross-sectional view of the SVT vintage power supply.

Normal operation of the power supply is as follows. In-bore launch acceleration acts to drive the cutter and weight in the copper ampule containing an acid electrolyte down against the forces of the bias spring and the damping dashpot action of the weight moving through the acid. If the acceleration is of sufficient magnitude and duration, the cutter points pierce the thin section of the ampule can, allowing the acid to escape. Under centrifugal force due to the projectile spin about the fuze centerline, the acid flows back up along the outside of the ampule and into the power supply cells. The electrolytic action between the acid and the alternating lead- and lead-dioxide-covered power supply plates produces the electrical power for the fuze.

When the power supply is fabricated, cold welding the ampule lid to the ampule can cause two undesirable results. First, the flow of metal inward away from the weld area causes the ampule lid to bulge downward, pushing the weight down and resulting in a decrease in the travel before the cutter tips touch the bottom of the can. This reduced travel reduces the base-down drop height which can cause piercing of the ampule. Second, the flow of metal outward from the cold weld area causes the ampule lid to become larger in diameter and to curl upward. This edge of the lid overlaps the through-lead and the two power source power leads (which are connected to terminal pins in a fashion similar to the through-lead, but not seen in the view illustrated) and is separated from them only by a piece of polyethelyne coated fishpaper. The wire insulation should extend completely into the terminal pin, but, based on a sample of power supplies disassembled, frequently does not. The fishpaper is pinched between the lid and each of these three wires during assembly. Separation of the fishpaper and one of these pinch points would short that lead wire to the metal ampule. Shorting of one or more leads could short out the power supply itself, short out the detonator, or even apply power supply voltage to the detonator and initiate it.

In addition to the possibility of purely mechanical shorts, another failure mechanism exists. The ampule is not sealed into the ampule support ring. Thus, if some forward or side disturbance occurs following piercing of the ampule (such as the in-bore balloting forces of the 175mm gun), it is possible for some of the excess acid remaining in the fill channel to be splashed up between the ampule and the support ring and onto the fishpaper. The fishpaper absorbs the acid and becomes conductive, especially in thin sections. Depending on how much acid is splashed in this manner and where, it is possible to short any combination of terminal wires to the ampule lid. This electrolyte splashing and terminal shorting has been demonstrated using a jolt machine. It is also conceivable that the acid could be splashed onto the fishpaper at one point only and would, after a delay of a few seconds, spread through the fishpaper and cause two terminal leads to be shorted to the ampule lid. If the two leads thus shorted were the through-lead and a power source power lead, then a delayed functioning of the electric detonator would result. This is the only known single failure mechanism which could cause a 4-5 second function of a fuze set to 90 seconds, and it is believed to be the most likely cause of the early burst at YPG during 175mm gun testing.

In addition to the shorts discussed above, another shorting possibility exists at the rear terminal pin. The ampule cradle is a die-cast aluminum piece part. Due to the fact that it is immersed in the acid and adjacent to a power supply power (negative) plate, a potential approaching full power supply voltage is developed on the cradle. It has been demonstrated that shorting the through-lead to this cradle will initiate the electric detonator. The insulation on the through-lead is supposed to extend through the Mylar and into the terminal pin, but, again, disassembly of a sample of power supplies has shown that this is not always true. Power supplies have been found where the bare through-lead is separated from the cradle by only a few thousands of an inch of air. Any relative motion of these parts, such as in a gun firing, might result in an electrical short circuit. Also on the bottom of the power supply is a terminal for fuze (or power supply) grounding. Shorting of that lead to the cradle would short out the power supply cell stack.

For the shorting cases discussed, immediate shorting of the through-lead to the power supply power would result in firing the electric detonator into an out-of-line S&A module. Laboratory tests indicate that the S&A module would probably arm and, since the impact backup is the only remaining fuze functioning mode, an impact function could be expected. If the through-lead is shorted to the power supply ground lead, the electric detonator will not be initiated by the electronic timer, and an impact function will result. If the power source cell stack is shorted, the additional electrical load will result in a short power supply life and, again, impact functions can be expected. Some combination of these internal power supply shorts is believed to be responsible for the larger than expected number of impact functions in the 175mm gun firings at +145°F.

The design improvements made to remedy the power supply deficiencies are shown in figure 10. It will immediately be noticed that the through-lead is no longer present. It has been replaced by a one-piece strap which extends from the top to the bottom of the power supply and is formed around plastic posts on either end to become the male portions of the connectors. The metal terminal pins are replaced with plastic, and no part of the detonator firing lead conductor is exposed to the inside of the power supply. Between the posts, the strap is laminated between layers of high-strength, high-temperature plastic, and is bonded to the case for ease of handling. The nearest conductor to the strap is the power case, which is grounded, so any shorts to the strap could not be expected to result in functioning of the electric detonator.

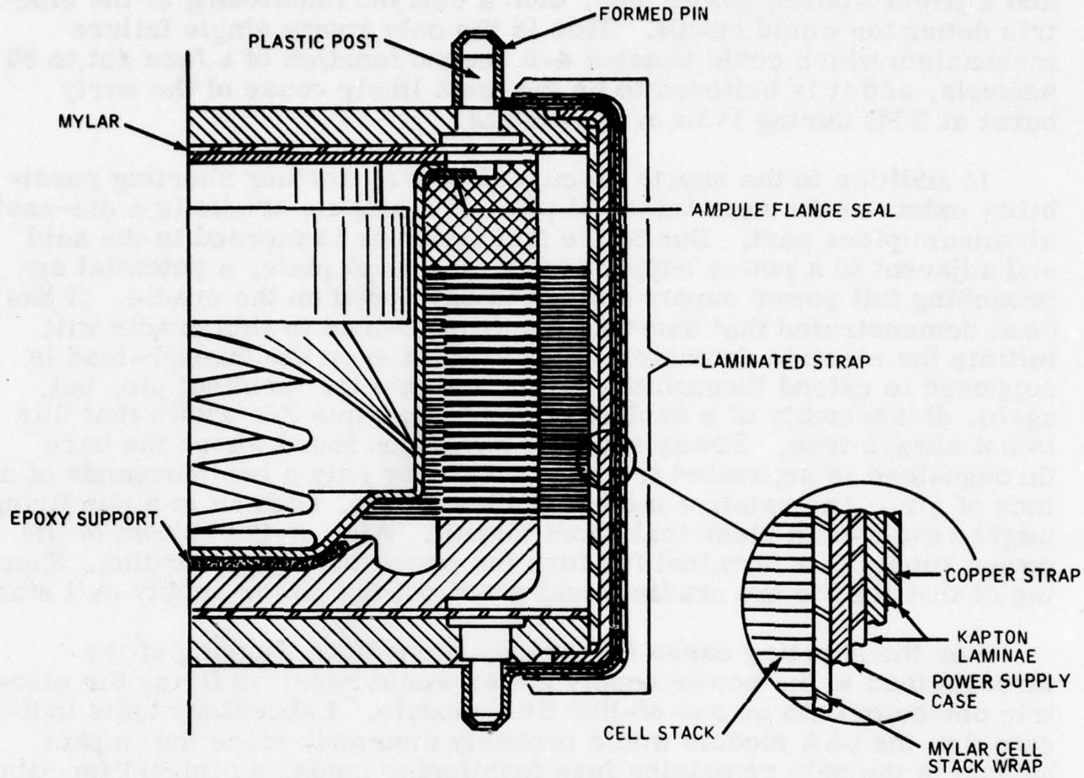


Figure 10. Improved power supply design.

The ampule cold weld has been replaced by a tungsten inert gas (TIG) weld, resulting in a flat ampule lid (increasing cutter travel and drop height) and eliminating the rolled up edge of the lid. The ampule is sealed into the support ring to prevent acid splashing and, should that seal fail, the fishpaper has been replaced by Mylar to prevent wicking and shorting through the insulator. Additional inspection and control procedures have been introduced to ensure that the insulation on the remaining internal power supply leads extends through the Mylar insulators and into the terminal pins.

In addition to sealing the ampule to the support ring, a cured-in-place epoxy support has been added at the bottom of the ampule. This accommodates the higher position of the ampule caused by the flange seal at the support ring and ensures that the ampule is supported both at the top and the bottom.

2.4 Design Studies

2.4.1 PBXN-5 Study -- PBXN-5 explosive is listed as Tri-Service acceptable output lead explosive in Change Notice 2 of MIL-STD-1316A. The use of this explosive in the lead charges of the XM587E2/XM724 fuzes will permit Tri-Service acceptance/use without special waivers. Tests conducted under contract DAAG39-73-C-0212 demonstrated that PBXN-5 meets the safety and the basic explosive propagation requirements. The tests which were conducted under this contract were aimed at demonstrating that the PBXN-5 output lead explosive meets the XM587E2/XM724 fuze output requirements.

Approximately 125 output leads fabricated with PBXN-5 were tested for various output characteristics. The results of these and previous tests are summarized in table II. The results with PBXN-5 are essentially the same as the results obtained with the originally specified RDX leads and with the M577 fuze lead charges used as controls.

The results of the tests conducted under this contract and tests conducted under the previous contract show that PBXN-5 leads satisfy the functional and safety requirements of the XM587E2/XM724 fuzes.

2.4.2 Rotor Shaft Investigation -- This investigation was to evaluate the performance characteristics of annealed rotor shafts with respect to forces encountered during horizontal 40-foot drop tests.

Breakage of the rotor shaft during 40-foot drop tests was first observed under a previous contract which prompted the investigation of a change from 303 stainless steel (condition B) to 416 stainless steel. Test results indicated that 416 stainless steel was an unacceptable choice.

In conjunction with this contract, a lot of 23 S&A modules with annealed 303 stainless steel rotor shafts was fabricated and subjected to horizontal 40-foot drop tests. Following the tests, examination revealed that the units were safe to handle and dispose of in accordance with MIL-STD-331. However, the top journal on two units had broken and the shafts of the remaining units had bent.

Based on the test results, it was determined that rotor shafts made from 303 stainless steel (condition B) are adequate from the standpoints of function and safety, and there would be no advantage in changing to annealed (Condition A) material.

2.4.3 S&A Module Piece Part Lubrication Study -- The lubricant used in the XM587E2/XM724 fuzes is Emralon 330, which consists of fluorocarbon particles dispersed in phenolic resin. The piece parts are essentially tumble coated and then baked to cure the lubricant. This

TABLE II. XM587E2/XM724 FUZE EXPLOSIVE TRAIN TEST RESULTS SUMMARY

Fuze Characteristics	PBXN-5 Leads		RDX Leads		M577 Fuze Leads	
	Function Rate	Output Dent (Inch)	Function Rate	Output Dent (Inch)	Function Rate	Output Dent (Inch)
Functional						
Electric Detonator to M55 Stab Detonator to S&A Module to Output Lead	Not tested		20/20	Not Recorded	Not applicable	
M55 Stab Detonator to S&A Module to Output Lead	113/113	0.017 Minimum	135/135	0.017 Minimum	Not applicable	
M55 Stab Detonator to S&A Module Lead, 0.056-Inch Gap	20/20	0.017 Minimum	Not tested		Not applicable	
M55 Stab Detonator to S&A Lead, 0.061-Inch Gap	20/20	0.017 Minimum	Not tested		Not applicable	
M55 Stab Detonator to S&A Module Lead (R. Stresau Laboratory conducted Varicomp tests)	99.99 percent at 95 percent		99.97 percent at 95 percent		Not applicable	
S&A Module to Output Lead (R. Stresau Laboratory conducted Varicomp tests)	99.99 percent at 95 percent		99.98 percent at 95 percent		Not applicable	
S&A Module to Output Lead to Booster	20/20	0.175	20/20	0.067	Not applicable	
S&A Module to Output Lead to M-5 Propellant, 0-Inch Air Gap	Not tested		5/5	0.039	Not tested	
S&A Module to Output Lead to M-5 Propellant, 2-Inch Air Gap	20/20	0.038	10/10	0.038	10/10	0.029
S&A Module to Output Lead to M-5 Propellant, 4-Inch Air Gap	Not tested		10/10	0.035	Not tested	
S&A Module to Output Lead to M-10 Propellant, 0-Inch Air Gap	20/20	0.0106	10/10	0.013	5/5	0.0015
S&A Module to Output Lead to M-10 Propellant, 4-Inch Air Gap	Bruceton	0 (1)	20/20	0 (1)	5/5	0 (1)
4.2-Inch M335A2 Mortar Cargo Ejection Test	Not tested		10/10, Same as HDL test		Not tested	
155mm XM629 Projectile Pressure/Time Test	5/5, Same as baseline		5/5, Same as baseline		Baseline	
Safety						
Electric Detonator Static Safety, Rotor in Last Tooth Position	Not tested		20/20	Safe	Not applicable	
Electric Detonator Static Safety, Rotor Removed (R. Stresau Laboratory Conducted Varicomp Test)	< 1 in 1×10^{14}		< 1 in 1×10^{14}		Not applicable	
M55 Stab Detonator Static Safety, Rotor in Last Tooth Position	Not tested		30/30 safe	---	Not applicable	
M55 Stab Detonator Static Safety (R. Stresau Laboratory Conducted Varicomp Test)	< 1 in 1×10^{53}		< 1 in 1×10^{53}			

(1) Burned slightly.

lubricant was selected based on considerable testing and scanning electron microscope analysis conducted under the previous contract, with emphasis on durability during vibration.

During this study task, 45 (Lot 6) 2-year-old S&A modules were divided into three equal groups and tested as follows:

- 15 units - Control group, no vibration.
- 15 units - Transportation vibration per MIL-STD-331, test 119, procedure I (4 hours per axis).
- 15 units - Transportation vibration per MIL-STD-331, test 104, procedure I (8 hours per axis).

Ten units of each group were then spin-armed on a production fixture and the arming delay was measured in terms of the revolutions to arm at 1700 rpm. Spin results compared favorably with those obtained during a 1973 lot acceptance testing. All units were then carefully disassembled (and explosives removed) and subjected to examination and photographic documentation, including scanning electron microscope enlargement of significant bearing surfaces and potential wear areas on selected units of each group.

In addition to the 45 units (lot 6), 22 units from a different lot (lot 5) were tested and examined in a similar manner (however, MIL-STD-331, test 119 was omitted and seven control units were used instead of 15) to provide some information on lot-to-lot variations in the lubricant applied to the piece parts. A summary of the spin test data is shown in table III.

Results of this analysis of the data in table III indicate the following:

- The standard deviations remained nearly constant or decreased (improved) in all groups except the lot 6 group subjected to the longer vibration test (MIL-STD-331, test 104). The standard deviation of this group increased significantly from a rather low 0.66 to 1.84, but is still lower than the lot 5 control group was in 1973 (1.90).
- The means increased in all groups, but the most change occurred in lot 6; the nonvibrated (control) group mean increased 1.62 (to 25.56) and the group that was vibrated per MIL-STD-331, test 104 increased 2.68 (to 26.97) from the 1973 spin-arm data. Both shifts are considered statistically significant.

TABLE III. SPIN TEST DATA ANALYSIS SUMMARY

		1973 Spin Test	1975 Spin Test	Change	Statistical Significance Level (Percent)
Lot 6	Control Group (No Vibration)	$\overline{X}$ = 23.94 σ = 1.16	$\overline{X}$ = 25.56 σ = 1.26	+1.62 +0.10	99 --
	MIL-STD-331, Test 119 (4 Hours Per Axis)	$\overline{X}$ = 24.78 σ = 0.77	$\overline{X}$ = 25.38 σ = 0.50	+0.60 -0.27	90 --
	MIL-STD-331, Test 104 (8 Hours Per Axis)	$\overline{X}$ = 24.29 σ = 0.66	$\overline{X}$ = 26.97 σ = 1.84	+2.68 +1.18	99.9 99
Lot 5	Control Group (No Vibration)	$\overline{X}$ = 24.29 σ = 1.90	$\overline{X}$ = 26.97 σ = 1.56	+2.68 -0.34	-- --
	MIL-STD-331, Test 104 (8 Hours Per Axis)	$\overline{X}$ = 23.73 σ = 1.01	$\overline{X}$ = 24.62 σ = 0.93	+0.89 -0.08	90 --

Note: Calculated means and standard deviations from the original lot acceptance data for the entire lots are as follows:

Lot 6	Lot 5
$\overline{X}$ = 24.66	$\overline{X}$ = 23.86
σ 1.66	σ = 1.21

Variations from these values may be expected with small sample sizes, such as the quantities of 5-10 used in the individual study groups above.

The statistical significance values were obtained from t tests for mean shifts and f tests for variance shifts. Levels below 90 percent are not considered significant and are omitted.

Not included in the mean and standard deviation calculations were two units that ran very slowly. Unit 841 from the lot 6 MIL-STD-331, test 119 group took 301 turns to arm and unit 882 from the lot 6 MIL-STD-331, test 104 group took 75.2 turns to arm.

Analysis of these two units indicates the following:

- Damage at the edge of the top bearing plate hole for the starwheel of unit 841 probably caused excessive arming delay.

- Damage at the edge of the pallet hole of unit 882 may have caused a temporary hangup (sound during the spin-arm test indicated a delay prior to escapement start rather than slow running--such a delay may also have occurred in unit 841).

- There is no evidence that the lubricant was inadequate or contributed in any way to the long delay times.

Analysis of scanning electron microscope photographs taken of bearing surfaces and potential wear areas on typical units from each of the study groups revealed the following:

- Considerable variation can be expected in the lubricant appearance when surfaces of piece parts are magnified.

- Variations in lubricant appearance observed in this study do not appear to affect function.

- More wear-in or burnishing of the lubricant is evident with increased vibration testing.

- White flakes or particles in some scanning electron microscope photographs of burnished areas are basically Teflon.

- The only significant metal deformation due to vibration in the gear train was on the small pinion gear teeth (where they were engaged during vibration); this was only evident after the longer vibration test and is not considered sufficient to affect function.

An attempt was also made to develop a series of color photographs depicting the range of color to be expected on properly lubricated piece parts. The lubricant changes color from blue to green during the curing process and becomes brown with over-cure. Inspection for proper color or shade is currently more subjective than is desirable for lot acceptance purposes.

It was soon discovered that the color and shade obtained in color photographs varied greatly with changes in lighting, orientation of piece parts, type of film, processing techniques and materials, aging of photographs, etc. A given piece part may be made to appear green or brown or blue or black in a photograph by changing one or more of the above variables. Some piece parts seem to change color or shade while being turned between one's fingers. A rather large range of color was observed between piece parts in the study units -- from brownish to slightly bluish, although predominately green, with no apparent effect on function.

The results of this study were documented in a report entitled XM724/XM587E2 S&A Module Piece Part Lubrication Study. The information contained in this report will provide a baseline for future reference whould questions arise regarding the lubricant coating or vibration effects on the lubricant, but the original goal of developing color standards for inspection of lubricant application was not met.

3. HARDWARE FABRICATION

Hardware fabrication on this contract involved the following major areas:

- Piece parts and components.
- Hybrid interface circuit.
- Hybrid precision oscillator circuit.
- S&A module.
- Rear fitting.
- E-head.
- XM587E2 fuze.
- XM724 fuze.

3.1 Piece Parts and Components

Only one of the electrical components had a significant problem during this contract--the impact switch (part number 11718418). Loose fibrous strands were found in this switch during receiving inspection analysis. Since no other switches were available for the fuze fabrication, these switches were used.

Near the end of this contract, switches from another vendor became available. These new switches were found to be electrically and mechanically acceptable. The comparison of the switches from the two vendors is contained in appendix A.

During a later fabrication stage, a solderability problem was found with the new impact switches. However, this problem was resolved by the use of a pretiming procedure as described in appendix B.

A summary of the mechanical receiving inspection rejects is shown in table IV. This shows that the major problem was initial tooling fabrication.

Although most of the dimensional problems were of a minor nature, one mechanical piece part was very troublesome. This was the rear fitting sleeve (part number 11722622). This part had numerous cosmetic and dimensional defects.

TABLE IV. MECHANICAL PIECE PARTS RECEIVING INSPECTION REJECTS

Cause of Reject	Type of Reject	Number of Part Numbers Rejected
Improper tooling	Dimensional	15
Tooling wear	Dimensional	2
Poor process control	Dimensional	3
Gold instead of tin finish	Plating	1
Print in error	Plating	1
Poor packaging	Damaged Parts	1

3.2 E-Head Test Sets

Two automatic test sets to test the XM587E2/XM724 fuze E-heads were designed and fabricated under this contract. The test set consists of (1) a data terminal, (2) the electronic console, and (3) the E-head holding fixture. The equipment is shown in figure 11. The fixture provides electrical connection to the test set by making electrical contact to the E-head contacts shown in figures 12 and 13.

The equipment is controlled by an integral microcomputer. The system program is stored in an erasable programmable read-only memory (EPROM), which ensures program security while at the same time making it possible to easily modify the system to incorporate test changes. In order to change the program, however, it is necessary to remove the EPROM (Intel 1702A), erase it with ultraviolet radiation, and subsequently reprogram it at a 1702A EPROM programming facility.

Figure 11. XM587E2/XM724 fuze automatic test system (part number 11711452).

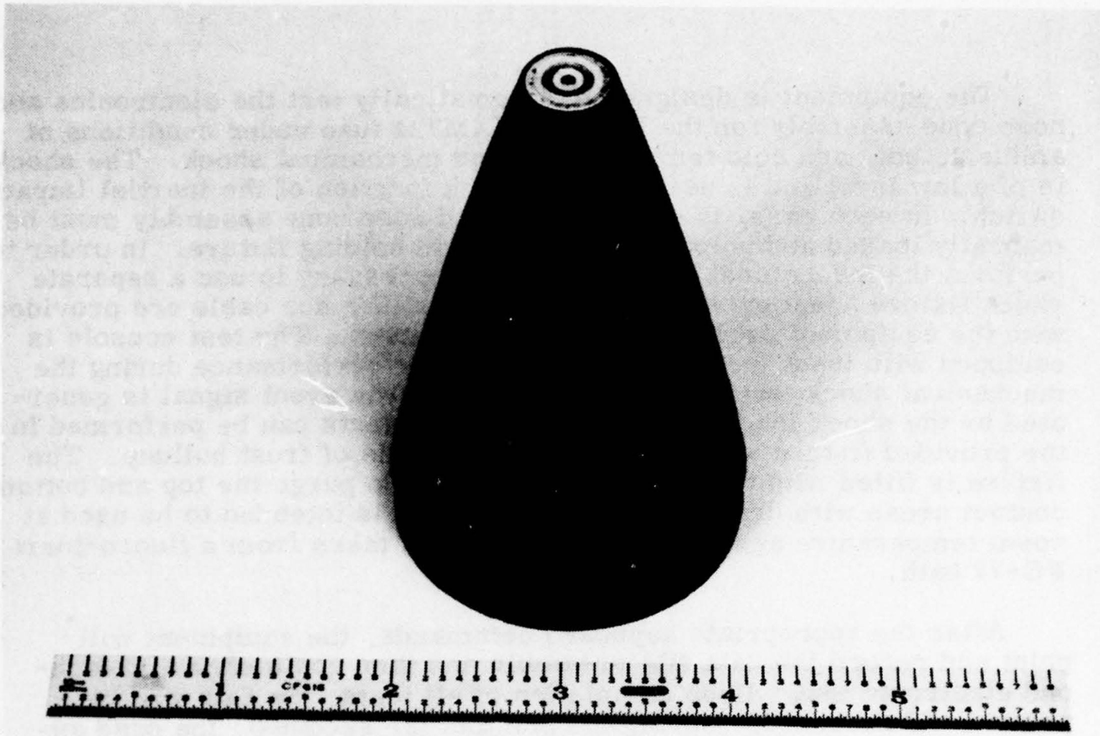


Figure 12. Electronics and nose cone assembly -- top view (part number 11411430).

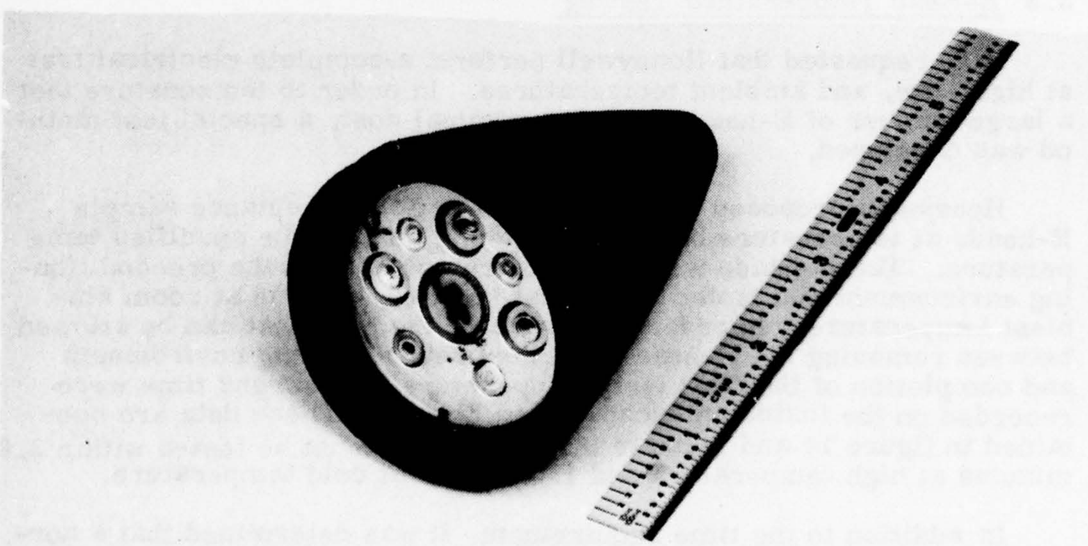


Figure 13. Electronics and nose cone assembly -- bottom view (part number 11711430).

The equipment is designed to automatically test the electronics and nose cone assembly for the XM587E2/XM724 fuze under conditions of ambient, hot, and cold temperatures and mechanical shock. The shock is of a low level and is used only to check function of the inertial impact switch. In each case, the electronics and nose cone assembly must be manually loaded and unloaded in the E-head holding fixture. In order to perform the mechanical shock test, it is necessary to use a separate shock fixture adapter cable. Neither the fixture nor cable are provided with the equipment or documented in this report. The test console is equipped with input jacks in order to monitor performance during the mechanical shock test to determine when a drop event signal is generated by the shock machine. Continuous cold tests can be performed in the provided fixture without the usual problems of frost buildup. The fixture is fitted with the necessary plumbing to purge the top and bottom contact areas with dry nitrogen. The fixture is intended to be used at room temperature and loaded with cold units taken from a fluoro-inert FC-77 bath.

After the appropriate keyboard commands, the equipment will print and record the data file preamble and then commence a 35-second electronic test. Upon completion of all tests, the data will be printed and recorded. During the printout (25 seconds), the nose assembly can be unloaded and a new assembly installed. A separate preliminary equipment manual was prepared which fully describes the testers.

3.3 E-Head Temperature Testing

HDL requested that Honeywell perform a complete electrical test at high, low, and ambient temperatures. In order to temperature test a large number of E-heads at an economical cost, a special test method was developed.

Honeywell proposed to test the first article acceptance sample E-heads at temperature by preconditioning them at the specified temperature. The E-heads would then be removed from the preconditioning environment and tested in the test fixture, which is at room ambient temperature. In order to determine the time that can be allowed between removing the E-head from the preconditioning environment and completion of the final test, temperature data versus time were recorded on the inside an encapsulated E-head. These data are contained in figure 14 and indicate that the device must be tested within 2.0 minutes at high temperature and 1.0 minute at cold temperature.

In addition to the time requirement, it was determined that a normal test fixture and method would allow frost buildup on the contacts and cause test problems. In order to solve this problem, a special

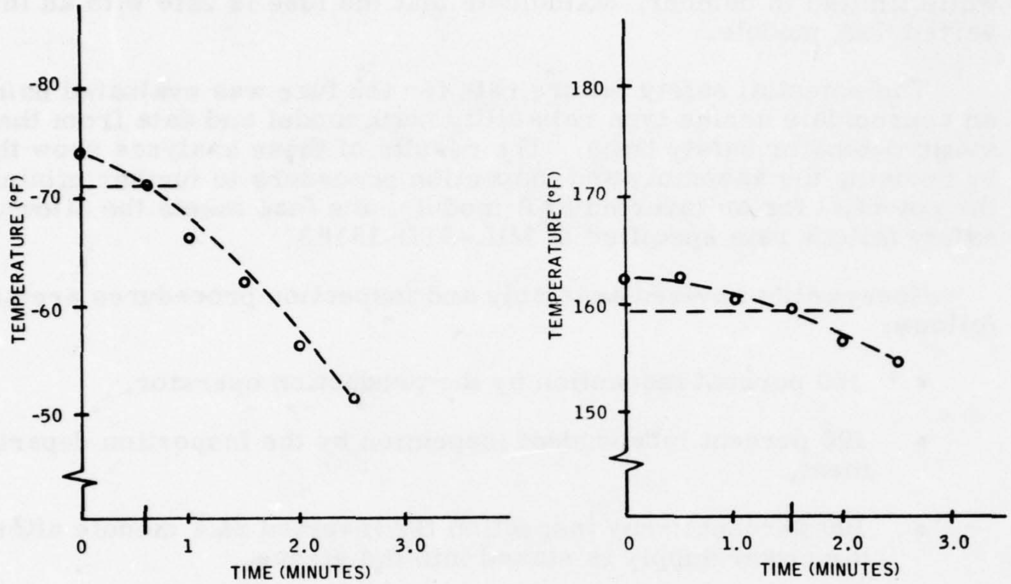


Figure 14. E-head interval temperature versus time after removal from preconditioning.

test fixture was developed. This fixture required a minimum of operator effort, but provided an enclosed space for the E-head during cold temperature testing. The fixture was designed so that the operator placed the E-head in the fixture and turned it until it dropped in place. The cover was then rotated over the E-head and latched with a slight hand pressure. The design provided for contact wiping on all contacts. To remove the moisture in the contact area, the design provided for a leakage of dry nitrogen under a slight pressure into the contact area. In addition to these provisions, the E-heads were placed in an inert fluid during the cold temperature preconditioning. This fluid wet the contact surfaces and also helped to retard frost buildup during the transition from the preconditioning chamber to the test fixture.

3.4 Inverted S&A Module

An XM587E2 fuze with an inverted S&A module was discovered at Honeywell during first article acceptance tests. Inverting the S&A module exposed the S&A module explosive lead to the output of the electrical detonator and suggested a potential safety failure mode which was omitted in previous evaluations.

Static detonator safety tests were conducted by Honeywell and HDL to evaluate the magnitude of this potential failure mode. These tests, while limited in number, do indicate that the fuze is safe with an inverted S&A module.

The potential safety failure rate for the fuze was evaluated using an appropriate series type reliability math model and data from the static detonator safety tests. The results of these analyses show that, by revising the assembly and inspection procedure to further minimize the potential for an inverted S&A module, the fuze meets the allowable safety failure rate specified in MIL-STD-1316A.

Honeywell's revised assembly and inspection procedures are as follows:

- 100 percent inspection by the production operator.
- 100 percent independent inspection by the Inspection department.
- 100 percent x-ray inspection for inverted S&A module after the power supply is staked into the sleeve.

The use of mechanized inspection in production would eliminate the need for triple inspection.

A comprehensive engineering report detailing the results of these tests and analysis was provided to HDL during March 1976.

3.5 Hybrid Circuits

The hybrid interface and hybrid precision oscillator circuit were fabricated by Honeywell's Aerospace (now Avionics) Division in St. Petersburg, FL. The problems encountered with the hybrid circuits fall into the following major areas:

- Component defects.
- Thin-film resistors.
- Training of production operators for gold ball bonding.
- Active laser trim of thin-film networks.

The component defects were mainly defects in components supplied by vendors. These component problems are summarized in table V.

TABLE V. SUMMARY OF COMPONENT PROBLEMS

Component Description	Component Defect
Zener Diode SCZ 142	Wrong component supplied by vendor
Thin-Film Networks	Two lots defective for resistor timing
Thick-Film Networks	Chips in glass, general quality

Two thin-film resistor lots were rejected because of poor stability caused by improper trimming. The final resolution of the thin-film resistor problem was to obtain acceptable units from another vendor.

The training of production operators for gold ball bonding posed major problems. The operators who were skilled in aluminum ultrasonic bonding were expected to make a rapid transistion to gold ball bonding. However, it turned out that nearly an equivalent time was required to train an unskilled operator as to retrain an operator skilled in aluminum ultrasonic bonding for gold ball ultrasonic bonding. In addition, a higher level of skill was required for bonding of 0.7-mil gold wire than bonding of 1.0-mil gold wire.

The problem of making a transition from a few (10 units per day) to 200 units per day caused considerable difficulty. This approach was forced by schedule considerations and would have been accomplished more gradually had a choice been available.

Active laser trimming caused a problem since the laser light caused circuit transistor characteristics to change. Two solutions were available, the first being the use of a cover with a trimming hole and the second being conformal coating of the transistors prior to laser trim. Since the approach of using a hole in the cover can still cause some problems depending on the laser used, the conformal coat prior to active laser trimming was used.

Twenty-seven preproduction interface hybrid circuits built by the Honeywell Aerospace Division were selected for environmental testing. These units were fabricated primarily with 0.7-mil gold bonding wire. The production units will use primarily 1.0-mil gold bonding wire. The results are as follows:

- Nine units were mechanically shocked in the Z1 and Z2 orientation. See table VI.
- Nine units were thermally shocked (-55°C to +71°C) - X11, X16, X20, X24, X25, X28, X31, and X40. All passed.
- Nine units were subjected to constant acceleration (20,000 g's in the Z1 orientation) -- X1, X15, X21, X22, X23, X26, X30, and X37 passed; X7 failed.

TABLE VI. SUMMARY OF INTERFACE HYBRID CIRCUIT ENVIRONMENTAL TESTING - NINE UNITS MECHANICALLY SHOCKED IN Z1 AND Z2 ORIENTATIONS

Orientation	Shock (G's)	Passed (Unit Serial Number)	Failed (Unit Serial Number)
Z1	36,000	X2, X4, X9	X12, X13
Z2	40,000		
Z1	30,000	X14, X18, X28	X29
Z2	34,000		

- The nine units that were thermally shocked were then subjected to mechanical shock. All nine units passed. Units X11, X16, X28, X35, and X40 were shocked in the Z2 orientation at 25,000 g's. Units X20, X24, X25, and X31 were shocked in the Z1 orientation at 27,000 g's.

Failure analysis indicated that units X12, X13, and X29 failed because of broken 0.7-mil gold bonding wires. From this and prior failure data, it appears that 30,000-g shock levels are the practical limit for the use of 0.7-mil gold bonding wire. This may not be true for packaging situations which are different than the existing hybrid interface circuit. Unit X7 failed because of improper bond placement on Q8, resulting in a collector-to-base short after centrifuging.

The failure analysis report covering these defects is contained in appendix C. The preproduction hybrid interface circuit results were reviewed, the proper corrective actions were taken, and product quality continually improved during the fabrication of lots 1 and 2. The receiving inspection results of the 5000 hybrid circuits are summarized in table VII.

3.6 First Article Acceptance Sample E-Head Fabrication

A flow diagram of the electronics assembly yields is shown in figure 15. This figure shows that a yield at each key assembly point is as follows:

- Printed Circuit Board Assemblies - 99.1 percent
- Electronics assemblies (unencapsulated) - 100 percent.
- Electronics assemblies (encapsulated) - 92.6 percent.

TABLE VII. RECEIVING INSPECTION RESULTS ON HYBRID CIRCUITS

Device	Lot Number	Quantity	Receiving Inspection Rejects
Hybrid Interface Circuit	1	815	5
Hybrid Precision Oscillator Circuit	1	830	0
Hybrid Interface Circuit	2	1701	7
Hybrid Precision Oscillator Circuit	2	1670	13
Total	-	5000	25

In order to achieve the results shown in figure 15, printed circuit board assemblies and electronics assemblies had to be repaired. A failure analysis report covering the components which failed is contained in appendix D.

In addition to the in-process failures, only about 80 percent of the electronics (encapsulated) passed the required point detonating lot sample test. The test was repeated on all units which failed, and some had been rerun up to six times before they functioned. The exact cause of this problem is unknown, but the impact switch was suspected since prior failure analysis on this device indicated foreign material inside the switch housing. A summary of point detonating switch testing is shown in figure 16.

Functional testing and failure analysis of switches supplied by the manufacturer of the first article acceptance sample impact switches (Kaupp) confirmed that the problem was one of problem with the Kaupp switches. The failure analysis report on the impact switches is contained in appendix A.

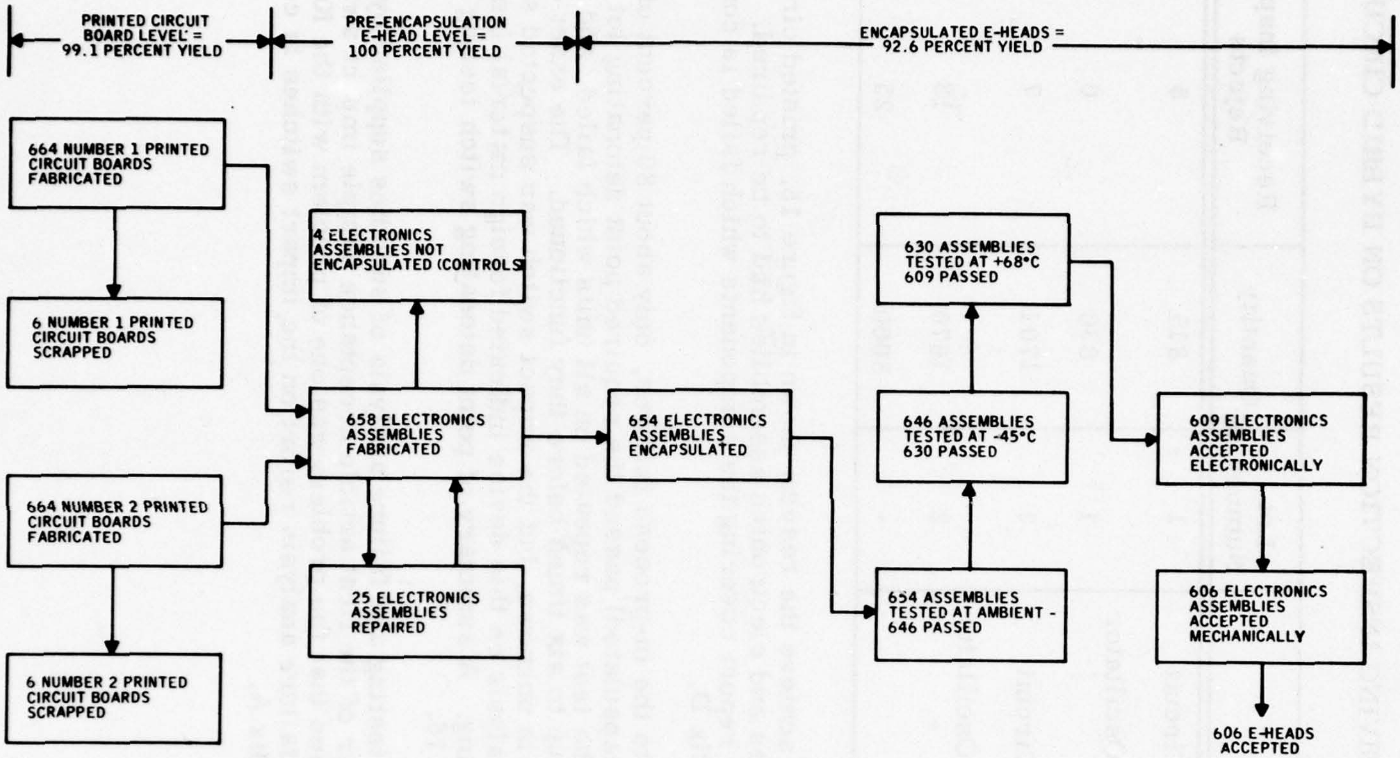


Figure 15. First article acceptance sample lot summary for electronics assembly (part number 11711430).

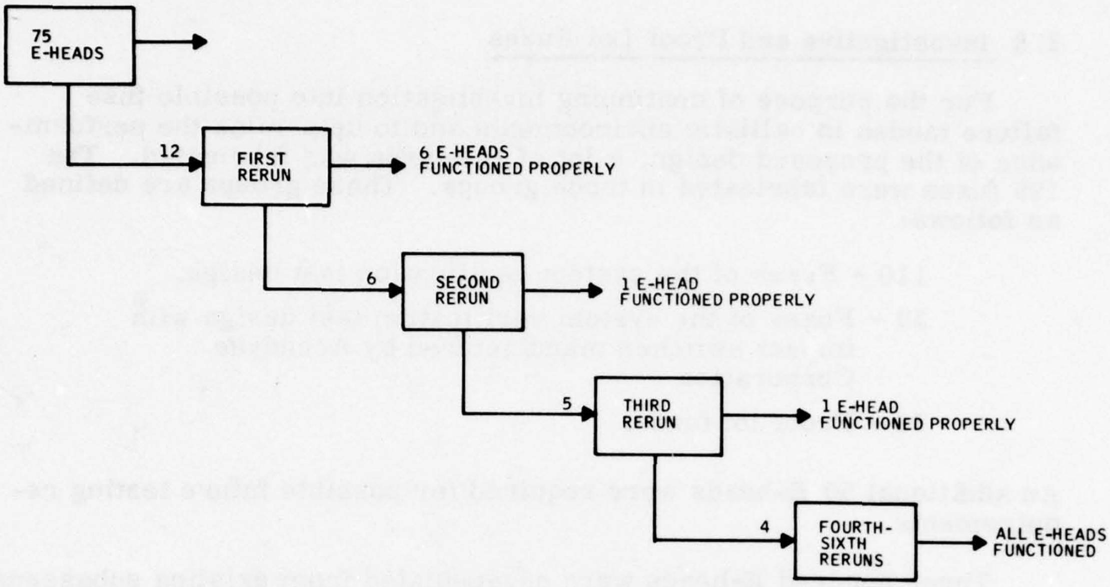


Figure 16. Impact switch test results

3.7 First Article Acceptance Sample Fuze Fabrication

A summary of the yield data for the XM587E2/XM724 fuze electronics assembly (part number 11711430) is shown in figure 15.

The yield data for the first article acceptance sample fuze fabrication are as follows:

594 - Fuzes crimped.
-1 - Fuze would not set after crimping.
-2 - Fuze with O-ring not seated properly.

591 - Fuze yield without repair.
+1 - Fuze with O-ring not seated properly had rear fitting removed and a new rear fitting installed.

592 - Total fuzes.

This gives a yield of 99.6 percent for the fuze assembly process.

3.8 Investigative and Proof Lot Fuzes

For the purpose of continuing investigation into possible fuze failure modes in ballistic environments and to determine the performance of the proposed design, a lot of 199 fuzes was fabricated. The 199 fuzes were fabricated in three groups. These groups are defined as follows:

110 - Fuzes of the system verification test design.

29 - Fuzes of the system verification test design with impact switches manufactured by Accudyne Corporation

60 - Proof lot fuzes.

An additional 50 E-heads were required for possible future testing requirements.

Three hundred E-heads were encapsulated from existing subassemblies to obtain a required 250 E-heads for Task 16 and for the 30 XM587E2 fuze training models. Two hundred and sixty-five of these contained existing (Kaupp) impact switches and 35 contained Accudyne impact switches. The yield data on the 300 E-heads are shown in table VIII.

TABLE VIII. E-HEAD YIELD DATA

Number Fabricated	Mechanical Rejects	Electrical Rejects (1)	Yield
265 with Existing Impact Switch	1	19	93 percent
35 with Accudyne Impact Switch	0	4	88.6 percent
Total	1	23	92 percent

(1) Does not include impact switch test failures.

Receiving inspection on the lot of Accudyne impact switches indicated that the switches did not meet the solderability requirements of specification 11718418. The cause of the solderability problem was the leads, which are made of an iron/nickel composition not normally considered easily solderable. A copy of the metallurgical analysis is contained in appendix B.

In order to render to leads solderable, the special procedure recommended in appendix B was used for the 35 special E-heads with Accudyne impact switches.

The system verification test and proof lot fuzes were fabricated with a yield at each inspection/test operation as shown in figure 17. The 29 fuzes with Accudyne impact switches were fabricated with a yield at each inspection/test operation as shown in figure 18.

3.9 Fuze Failure Analysis

Four of the fuzes which had been rejected during assembly were subjected to a failure examination. The results of this examination are shown in table IX.

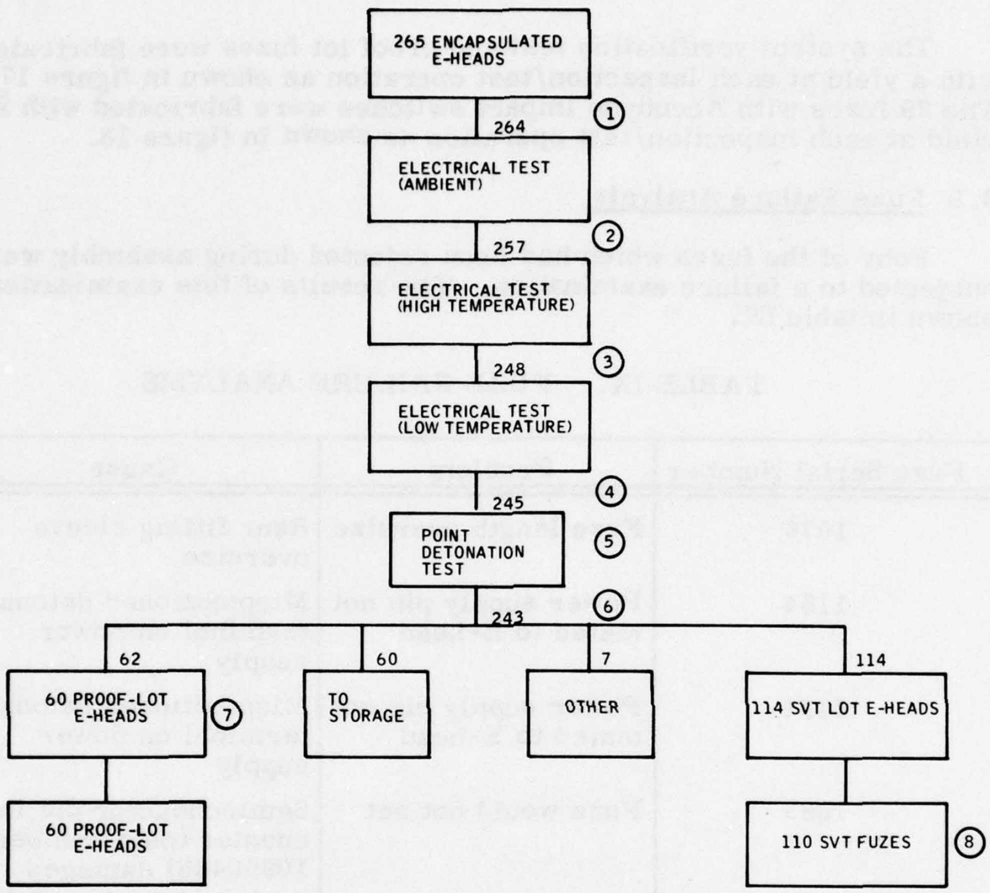
TABLE IX. FUZE FAILURE ANALYSIS

Fuze Serial Number	Problem	Cause
1076	Fuze length oversize	Rear fitting sleeve oversize
1184	Power supply pin not mated to E-head	Mispositioned detonator terminal on power supply
2121	Power supply pin not mated to E-head	Mispositioned detonator terminal on power supply
1063	Fuze would not set	Semiconductor die in counter (part number 10990466) damaged during impact switch testing

The power supply pin not mated to E-head problems was caused by reworked power supplies in proof lot fuzes. This was a modified design accomplished during a rework operation. However, it does indicate that an improved mechanical structure must be achieved when a new power supply is developed for the proposed changes.

Since the other failures were single occurrence problems and no other defects of this kind could be found, corrective action was not required.

At the conclusion of E-head fabrication, all electrical components which had failed during the factory build were submitted for failure analysis. A copy of the failure analysis report for these components is contained in appendix D.



(1) ONE E-HEAD WAS LOST DURING THE STAKING AND POTTING PROCESS

(2) SEVEN E-HEADS WERE REJECTED AT ROOM AMBIENT TEMPERATURE BY THE AUTOMATIC TESTER. HOWEVER, FOUR OF THEM MAY BE ACCEPTED ON A WAIVER FOR TEST 1-5 (B).

(3) NINE E-HEADS WERE REJECTED DURING HIGH TEMPERATURE TESTING.

(4) THREE E-HEADS WERE REJECTED DURING LOW TEMPERATURE TESTING.

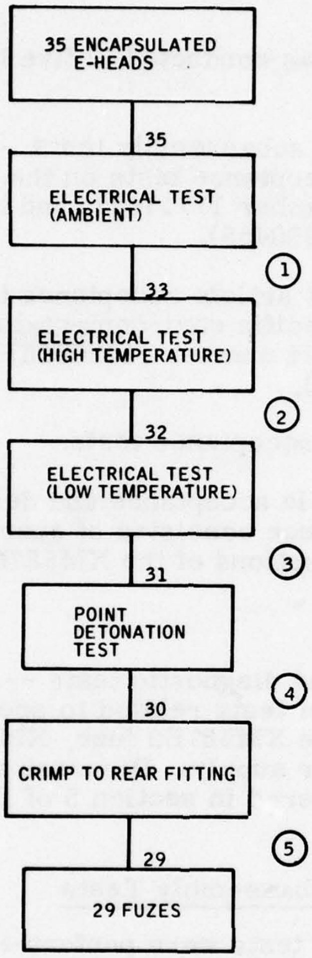
(5) 241 E-HEADS WERE SUBJECTED TO THE PD TESTING. 75 FAILED THE TEST. ONLY 10 OF THE 241 E-HEADS WERE REQUIRED TO PASS THE PD TEST.

(6) TWO E-HEADS WERE REJECTED DURING POST PD TEST INSPECTION, ONE WITH A LOOSE ORIENTATION CUP AND ONE WITH A LOOSE CENTER PAD IN THE NOSE PLUS ASSEMBLY.

(7) COIL CONTACTS WERE DAMAGED ON TWO E-HEADS DURING REWORK; i.e., MILLING OF A SLOT TO ACCOMODATE THE ADDED EXTERNAL POWER SUPPLY WIRE.

(8) FOUR FUZES WERE REJECTED AFTER CRIMPING; THREE WITH IMPROPERLY SEATED O-RINGS, AND THAT COULD NOT BE SET WITH THE FUZE SETTER.

Figure 17. Flow diagram, fuze yield data (Kaupp impact switches).



(1) TWO E-HEADS WERE REJECTED FOR PARAMETRIC FAILURES DURING ROOM AMBIENT TEMPERATURE ELECTRICAL TESTING.

(2) ONE E-HEAD FAILED HIGH TEMPERATURE ELECTRICAL TESTING.

(3) ONE E-HEAD FAILED LOW TEMPERATURE ELECTRICAL TESTING.

(4) ONE E-HEAD FAILED PD TESTING, BUT PASSED THE POST PD ELECTRICAL TEST.

(5) ONE FUZE WAS REJECTED AFTER THE CRIMPING OPERATION FOR EXCEEDING THE 3.76-INCH MAXIMUM DIMENSION.

Figure 18. Flow diagram, fuze yield data (Accudyne impact switches).

4. TEST PROGRAM

The test program was conducted in five basic areas as summarized below:

- Component and subassembly tests -- This test sequence consisted of lot acceptance tests on the hybrid precision oscillator: circuit (part number 11711427) and hybrid interface circuit (part number 1990455).

- Component first article acceptance tests -- This test sequence consisted of specific environmental and functional tests on the S&A module (part number 11720300) and rear fitting (part number 11720291-1).

- S&A module lot acceptance tests.

- Fuze first article acceptance and design evaluation tests -- This test sequence consisted of specific environmental tests and physical examinations of the XM587E2 fuze.

- Ballistic tests.

- Investigative and diagnostic tests -- This test sequence consisted of a series of tests related to specific areas of investigation conducted on the XM587E2 fuze, XM724 fuze, S&A module, E-head, and power supply. Discussions of these tests and the test results are covered in section 5 of this report.

4.1 Component and Subassembly Tests

Four lot acceptance tests were performed on the two hybrid circuits. From each shipment of units, some of the total quantity was randomly selected and segregated from the remainder of the lot. This was done prior to any inspection. The units selected were representative of all the date codes. The selected units were randomly numbered from 1 to XXX. The respective date codes and serial numbers were entered into a lot acceptance test log, and the units were marked accordingly. The test were performed on an "as-units-are-available" basis.

A summary of the lot acceptance results is contained in tables X through XIII.

Failure analysis of the 57mm gun fired units from Lot 1 of both hybrid circuits was completed. One of the 11 hybrid interface circuits which were recovered failed to operate after this shock environment. Failure analysis revealed a broken lead wire on the emitter of Q6. Four

TABLE X. LOT ACCEPTANCE TEST SUMMARY INTERFACE HYBRID CIRCUIT (PART NUMBER 11711610), LOT 1

Subgroup	Test	Lot Total Percent Defective	Acceptance Number	Quantity	AQL (Percent)	Number of Failures	Pass/ Fail
A1	External Visual	20	1	18	2.0	1	Pass
A2	Operating Parameters	5	4	158	1.3	2	Pass
A3	High Temperature Performance	15	1	25	1.4	0	Pass
A4	Low Temperature Performance	15	1	25	1.4	0	Pass
B1	Temperature Cycling	15	1	25	1.4	0	Pass
B2	Shock (Mechanical)	15	1	25	1.4	1	Pass
B3	Constant Acceleration	15	1	25	1.4	0	Pass
B4	High Temperature Storage	15	1	25	1.4	1	Pass
B5	Lead Integrity	30	0	8	0.64	0	Pass
B6	Solderability	30	0	8	0.64	0	Pass
C1	57mm Gun Firing	20	0	11	0.46	1	Fail

TABLE XI. LOT ACCEPTANCE TEST SUMMARY, INTERFACE HYBRID CIRCUIT (PART NUMBER 11711610), LOT 2

Subgroup	Test	Lot Total Percent Defective	Acceptance Number	Quantity	Number of Failures	Pass/Fail
A1	External Visual	20	1	18	0	Pass
A2	Operating Parameters	5	4	158	0	Pass
A3	High Temperature Performance	15	1	25	0	Pass
A4	Low Temperature Performance	15	1	25	0	Pass
B1	Temperature Cycling	15	1	25	0	Pass
B2	Shock (Mechanical)	15	1	25	0	Pass
B3	Constant Acceleration	15	1	25	0	Pass
B4	High Temperature Storage	15	1	25	0	Pass
B5	Lead Integrity	30	0	8	0	Pass
B6	Solderability	30	0	8	0	Pass
C1	57mm Gun Firing	20	0	11	0	Pass

TABLE XII. LOT ACCEPTANCE TEST SUMMARY, HYBRID PRECISION OSCILLATOR CIRCUIT (PART NUMBER 11711625), LOT 1

Subgroup	Test	Lot Total Percent Defective	Acceptance Number	Quantity	AQL (Percent)	Number of Failures	Pass/ Fail
A1	Oscillator Characteristics	5	3	132	1.0	2	Pass
A2	Current	15	1	25	1.4	0	Pass
A3	Electrostatic Shield and Visual	20	1	18	2.0	0	Pass
B1	Temperature Cycling	15	1	25	1.4	0	Pass
B2	Constant Acceleration	15	1	25	1.4	0	Pass
B3	High Temperature Storage	15	1	25	1.4	0	Pass
B4	Shock	15	1	25	1.4	6 ①	Pass
B5	Solderability	30	0	8	0.64	0	Pass
B6	Lead Integrity	30	0	8	0.64	0	Pass
C1	57mm Gun Firing	20	0	11	0.46	4	Fail

① Waiver W-0157-11 was approved by HDL. This waiver was for a testing error which caused the test failures.

TABLE XIII. LOT ACCEPTANCE TEST SUMMARY, HYBRID PRECISION OSCILLATOR CIRCUIT (PART NUMBER 11711625), LOT 2

Subgroup	Test	Lot Total Percent Defective	Acceptance Number	Quantity	Number of Failures	Pass/Fail
A1	Oscillator Characteristics	5	3	132	1	Pass
A2	Current	15	1	25	0	Pass
A3	Electrostatic Shield and Visual	20	1	18	0	Pass
B1	Temperature Cycling	15	1	25	0	Pass
B2	Constant Acceleration	15	1	25	0	Pass
B3	High Temperature Storage	15	1	25	0	Pass
B4	Shock	15	1	25	1 ①	Pass
B5	Solderability	30	0	8	0	Pass
B6	Lead Integrity	30	0	8	0	Pass
C1	57mm Gun Firing	20	0	11	0	Pass

① Waiver W-0157-11 was approved by HDL. This waiver was for a testing error which caused the test failures.

of the 11 hybrid precision oscillator circuits which were recovered failed to operate after this shock environment. Failure analysis showed that the R-16 resistor of one unit was fractured and that the other failures were due to broken lead wires. In one unit, two 1-mil wires were broken; in the other units, single 1-mil and 0.7-mil wires were broken. Failure analysis results on these units are contained in appendix E.

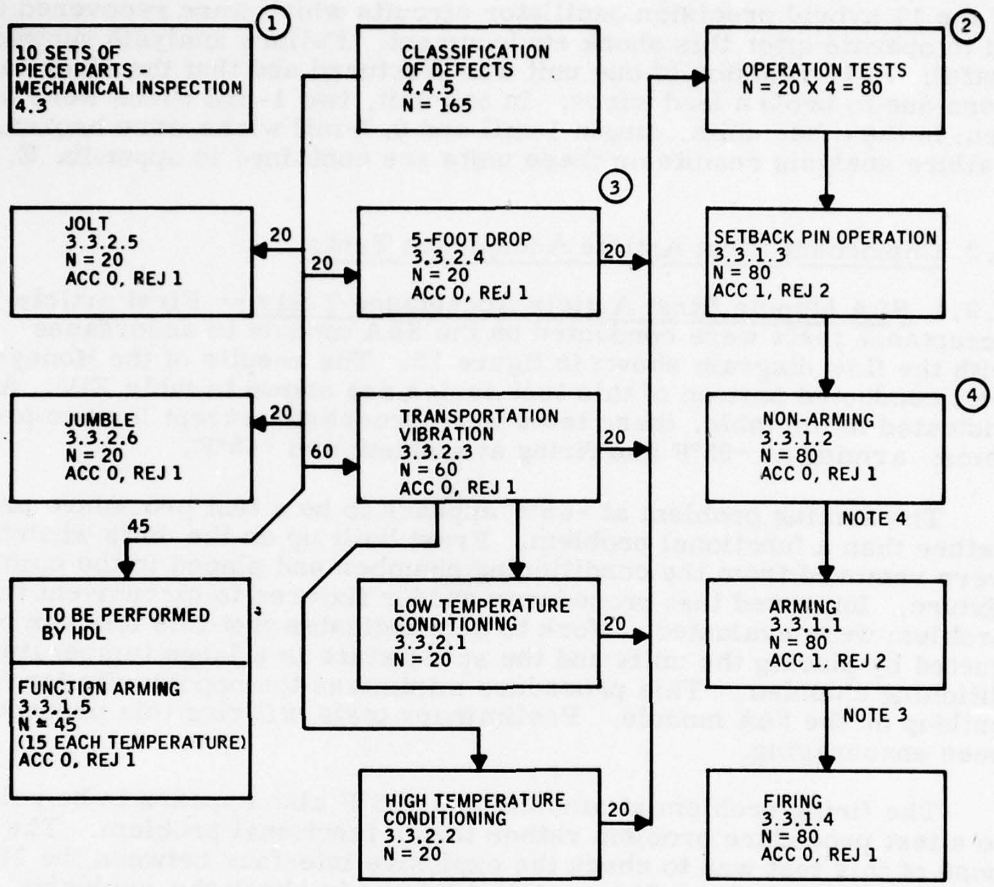
4.2 Component First Article Acceptance Tests

4.2.1 S&A Module First Article Acceptance Tests -- First article acceptance tests were conducted on the S&A module in accordance with the flow diagram shown in figure 19. The results of the Honeywell conducted portion of this test series are shown in table XIV. As indicated in the table, these tests were successful except for two problems: arming at -65°F and firing at ambient and -65°F.

The arming problem at -65°F appears to be a test procedure problem rather than a functional problem. Frost built up on the units when they were removed from the conditioning chamber and placed in the spin fixture. Improved test procedures and/or fixtures to circumvent this problem were evaluated. Work to date indicates that this test can be conducted by placing the units and the spin fixture in a large temperature conditioning chamber. This procedure minimizes the opportunity for frost buildup on the S&A module. Preliminary tests utilizing this procedure have been encouraging.

The firing problem at ambient and -65°F also appears to be related to a test procedure problem rather than a functional problem. The purpose of this test was to check the explosive interface between the M55 stab detonator and the S&A module lead and to check the explosive output of the S&A module lead. All of the S&A module leads were initiated by the M55 stab detonator and all produced the required dent in the aluminum witness block.

The only problem which was encountered was initiation of the M55 stab detonators at the specified energy level of 3/4 inch-ounce. Examination of the first units which did not initiate when tested at ambient conditions revealed that the firing pin only dented and did not rupture the case of the M55 stab detonator. This condition is indicative of low energy input: i.e., energy being absorbed by the test fixture. Examination of the test setup showed that the free (unguided) fall of the drop height onto the firing pin was probably excessive. This could permit the weight to cock in flight and strike the firing pin at an angle. This examination also revealed that there was interference of the firing pins in the firing pin guides.



(1) NUMBERS IN BOXES REFER TO REQUIREMENT PARAGRAPH, NUMBER OF UNITS TO BE TESTED (N), AND ACCEPT (ACC) AND REJECT (REJ) LEVELS.

(2) EACH SAMPLE OF 20 UNITS FROM THE 5-FOOT DROP, VIBRATION, AND VIBRATION PLUS TEMPERATURE CONDITIONINGS WERE TO BE SUBJECTED TO ALL SPECIFIED OPERATION TESTS. TEMPERATURE CONDITIONED UNITS WERE TO BE TEMPERATURE CONDITIONED BEFORE EACH TEST.

(3) THE SETBACK PINS OF THE UNITS FROM THE 5 FOOT DROP TEST WERE TO BE EXAMINED AND RESAFED AS REQUIRED PRIOR TO PERFORMING THE SETBACK PIN OPERATION TEST.

(4) THE NON-ARMING TEST WAS TO BE PERFORMED ON THE ENTIRE SAMPLE AT AMBIENT TEMPERATURE; HIGH AND LOW TEMPERATURE PRECONDITIONING WAS NOT REQUIRED FOR THIS TEST.

Figure 19. S&A Module first article acceptance test flow diagram.

TABLE XIV. S&A MODULE FIRST ARTICLE ACCEPTANCE TEST RESULTS

Test	Requirement Paragraph	Acceptance Criteria	Number Tested	Number Accepted	Comments
Jolt	3.3.2.5	S&A module safe	20	20	Rotor safe, held by both spin locks and the setback pin.
Jumble	3.3.2.6	S&A module safe	20	20	Rotor safe, held by both spin locks and the setback pin.
5-Foot Drop	3.3.4.2	S&A module safe	20	20	Rotor safe, held by both spin locks
Transportation Vibration	3.2.2.3	S&A module safe	60	60	Rotor safe, held by both spin locks and the setback pin.
Setback Pin Operation	3.3.1.3	Engaged aft at 800 g's	80	80	All tested at ambient temperature.
		Disengaged aft at 1100 g's	80	80	All tested at ambient temperature.
Non-arming	3.3.1.2	S&A module safe	80	80	1100 rpm non-arm without setback pin.
Arming					
Ambient	3.3.1.1	S&A module arms in 23 to 32 turns	40	40	All armed within specification.
+160°F	3.3.1.1	S&A module arms in 23 to 32 turns	20	20	All armed within specification.
-65°F	3.3.1.1	S&A module arms in 23 to 32 turns			Test not completed at this time.
Firing					
Ambient	3.3.1.4	0.040-inch dent	20	20	Some units initiated on second try.
+160°F	3.3.1.4	0.040-inch dent	20	20	All units fired 3/4 inch-ounce.
-65°F	3.3.1.4	0.040-inch dent	20	20	Some units fired 1-1/2 inch-ounce.

At this point, the test setup was revised. A new drop fixture which reduced the free fall to approximately 1 inch was introduced and all of the firing pin guides were drilled out and tested for freedom of the firing pin.

The units which failed to initiate on the first test were retested, and all functioned properly.

The same problem reappeared during the -65°F portion of the test. Again, examination of the units which did not initiate revealed that the firing pin only dented and did not rupture the case of the M55 stab detonator. At this point, it was concluded that the structure of the S&A module could be absorbing some of the input energy; i.e., an M55 stab detonator mounted in the S&A module is not rigidly supported. Therefore, the all-fire energy level for M55 stab detonator mounted in the S&A module could be higher than the all-fire level for a rigidly mounted M55 stab detonator.

It was decided to complete the test with an energy level of 1-1/2 inch-ounces. The remaining units were tested at this level, and all initiated and functioned properly.

The S&A module specification control drawing (11720300) is currently being reviewed and updated in light of the conponent first article acceptance test results. Present plans call for repeating the testing, excluding the function-on-arming test, in lieu of the lot acceptance test for lot 1.

Ballistic tests of 37 function-on-arming test rounds were completed at Aberdeen Proving Ground (APG). Thirty-six of the 37 units tested functioned properly between 23 and 32 turns of the projectile. One unit functioned on impact, apparently because of malfunction of the function-on-arming test round rather than the S&A module. An S&A module arming failure would not be likely to have resulted in a function on impact. None of the 37 units functioned before the minimum arming distance of 400 projectile calibers.

4.2.2 Rear Fitting First Article Acceptance Tests -- First article acceptance tests consisting of environmental and function tests were conducted on sample rear fittings. The results of these tests are shown in table XV.

TABLE XV. REAR FITTING FIRST ARTICLE ACCEPTANCE TEST RESULTS

Test	Requirements	Results
Waterproofness	Remain impervious to water penetration	32/32
Detonator Resistance After 5-Foot Drop	2 to 11 ohms	32/32
Power Supply Resistance After 5-Foot Drop	Greater than 100, 000 ohms	32/32
Power Supply Torque After 5-Foot Drop	10 inch-pounds minimum ①	24/32
Firing	.040 deep dent	64/64

① The power supply torque requirement after 5-foot drop is specified as an advisory requirement in drawing 11720291.

The only problem which was encountered during these tests was meeting the advisory power supply torque requirement of 10 inch-pounds after the 5-foot drop test. Twenty-four of the 32 units tested met the requirement; however, eight units failed at 2.5 inch-pounds. Present plans call for improving the sleeve/power supply stake prior to the assembly of subsequent lots of rear fittings.

4.3 S&A Module Lot Acceptance Tests

The 1594 S&A modules required for lot 1, consisting of 1400 fuzes, were completed through lot acceptance testing. The results of the lot acceptance tests, which were performed in accordance with the plan specified in modification P00006 to the contract, are summarized in table XVI. The results of these tests show that this lot of S&A modules meets the requirements of the specified test plan. An engineering test report detailing the test procedures and results was mailed to HDL during the first week of March 1976.

TABLE XVI. S&A MODULE LOT ACCEPTANCE TEST RESULTS

Test	Number of Units Within Specification		
	Ambient	-40°F	+160°F
Transportation Vibration	96/96		
Setback Pin Operation	32/32	32/32	32/32
Non-Arming	32/32	32/32	32/32
Arming	32/32	19/32 ①	32/32
Firing	32/32	32/32	32/32

① High limit is advisory (all of the units not within specification were over the high limit). Failures due to difficulty in controlling frost formation.

4.4 Fuze First Article Acceptance and Design Evaluation Tests

A summary of the first article acceptance and design evaluation test results is contained in table XVII. The only failures occurred during fungus, waterproofness, and potting porosity tests.

The fungus test failure was caused by power supply initiation. A reason for this failure could not be determined; however, the failure was probably not caused by the fungus environment.

Each of the two fuzes that failed waterproofness testing had a small amount of moisture in the booster cup. The moisture was only visible with ultraviolet light. There was no evidence of leakage into the rear fitting. The units were considered safe and operable following the test.

Fourteen fuzes had porosity in excess of the requirement immediately below the electronics cover. The depth of the porosity was not deep enough to expose any electronic component.

Three of the 14 fuzes tested also had porous areas in other locations of the nose cone. Two units had a porous area approximately 0.300 x 0.175 x 0.150 inch immediately above the top of the hybrid precision oscillator circuit flat surface, and one unit had a porous area approximately 0.250 x -.120 x 0.075 inch adjacent to the hybrid interface circuit.

TABLE XVII. SUMMARY OF FIRST ARTICLE ACCEPTANCE AND DESIGN EVALUATION TEST ON FUZES

Test	Number Tested	Number of Failures
First Article Acceptance Tests		
Salt Fog	5	0
Waterproofness ①	5	2
Jolt and Jumble	12	0
Temperature and Humidity	20	0
5-Foot Drop	10	0
Thermal Shock	20	0
40-Foot Drop	10	0
Transportation Vibration	59	0
Crimp Joint Strength	20	0
Potting Porosity ②	15	14
Design Evaluation Tests		
Jolt and Jumble	9	0
Jumble and Jolt	9	0
Temperature and Humidity	10	0
Fungus ③	5	1
Dust	5	0
Rough Handling	24	0
5-Foot Drop	5	0

① Two units had some leakage in the booster cup, but did not leak in the rear fitting.

② All 14 units had porosity in excess of the requirement immediately below the electronics cover; three of the 14 units had porosity in excess of the requirement in the area of electronic components.

③ The power supply intiated in one unit during testing.

Corrective action for these failures consisted of removal of ribs in the back of the electronics cover and use of mechanical vibrators on the evacuation chambers that remove trapped air during the encapsulation process.

4.5 Ballistic Testing

NOTE: This section was furnished by and covers work performed by the Harry Diamond Laboratories.

4.5.1 Fabrication and Conditioning of Fuzes--Six hundred fuzes were fabricated as a first article acceptance sample. These fuzes, completed at the end of November 1975, were divided into three groups -- those fuzes shipped immediately to Aberdeen Proving Ground (APG), those shipped immediately to Yuma Proving Ground (YPG), contractor-conducted environmental tests and quantities appear in table XVIII.

TABLE XVIII. BALLISTIC TEST QUANTITIES

	Shipped Immediately	Transportation Vibration, Procedure II	Relative Humidity	Temperature Shock	Temperature and Humidity	Other	Totals
Aberdeen Proving Ground (APG)	275	35	24	20	20		374
Yuma Proving Ground (YPG)	88 ①	24			10		122
Honeywell	29					75	104
							600

① 48 of these fuzes were subjected to TECOM sequential rough handling at YPG prior to firing.

Ten fuzes not assigned to particular guns for firing were included in the quantities shipped to each proving ground as spares. Honeywell retained a control quantity of 29 unconditioned fuzes. The 75 conditioned fuzes shown as retained by Honeywell represent those fuzes subjected to environmental testing which called for disassembly and inspection. The specific tests conducted are discussed in section 4.4.

4.5.2 Reliability Phase--The system verification testing comprised several phases for which different accept/reject criteria were formulated. Two hundred and seventy-one of the nonconditioned fuzes were fired in the reliability phase. An overall minimum score of 92-percent proper airburst functions was required together with the more exacting requirement of no worse than 80 percent in aby subset. As can be seen from table XIX, 260 of the 271 fuzes (96 percent) exhibited proper airburst function, while 11 fuzes either dudded or functioned on ground impact. Twenty-four of the 25 subsets met or exceeded the 80-percent criterion. The only failing subset was for the 175mm gun (firing zone 3) at -40°F. Exclusive of all rounds fired from the 175mm gun, airburst function was achieved on over 98 percent of the rounds (237/241).

TABLE XIX. SYSTEM VERIFICATION TEST RESULTS, RELIABILITY PHASE

Gun	Projectile	Firing Zone	-40°F	70°F	145°F	Total
4.2-inch M30	M329	10 increments	10/10			10/10
105mm M108	M1	7	10/10	19/21	10/10	
105mm XM204	M1	8			9/10	48/51
155mm M109A1	M107	2	10/10	10/10	10/10	
	M107	4		10/10		
	M107	5	10/10	10/10	10/10	
	M107	6		10/10		
	M107	8	10/10	19/20	10/10	
	M483	8	10/10	10/10	10/10	
	M549	8		10/10		159/160
8-inch M2	M106	1	10/10	10/10		20/20
175mm M2A2	M437	3	6/10	9/10	8/10	23/30
Total						260/271

The 105mm M108 gun firings at +70°F numbered 21 rather than 20 because the first non-airbursting round was reported by an APG observer as having fallen short and was initially classified as a non-test unit; a spare round was fired. Subsequent examination of the pressure gage from the gun showed no abnormality, and, therefore, the malfunctioned fuze was reentered in the scoring as a dud.

A slight modification was made in the originally conceived system verification test plan to include firings from the 105mm XM204 gun and the 155mm XM198 gun. While firings from the XM204 gun were achieved, the XM198 gun was never made available to the program.

4.5.3 Environmental Phase -- Ninety-three fuzes were fired in the environmental phase of the testing following exposure to selected MIL-STD-331 environments of rough handling (test 114), thermal shock (test 113), temperature and humidity (test 105), and transportation vibration (test 119, procedure II). As can be seen in table XX, 85 of the fuzes exhibited proper airburst function (85/95 = 91 percent), while eight fuzes either dudded or functioned on ground impact. Thus, the criterion of 85 percent overall airburst function and no less than 75 percent in any subset was successfully met.

TABLE XX. SYSTEM VERIFICATION TEST RESULTS, ENVIRONMENTAL PHASE

Test Conditions	-40°F	70°F	145°F	Total
105mm M137E1 Gun, M1 Projectile, Firing Zone 7				
Rough Handling	7/8	8/8	6/8	
Thermal Shock		8/9		
105mm XM204 Gun, M1 Projectile, Firing Zone 8				
Thermal Shock		10/10		39/43
155mm M109A1 Gun, M107 Projectile, Firing Zone 8				
Temperature and Humidity		19/20		
Transportation Vibration, Procedure II		19/20		38/40
175 mm M2A2 Gun, M437 Projectile, Firing Zone 3				
Temperature and Humidity		8/10		8/10
Total				85/93

4.5.4 Plywood Target Phase -- The plywood target phase of the system verification testing was intended to ensure that the S&A module provides safe separation for the gun crew out to 400 calibers and also that the S&A module be fully armed so as to permit fuze function no later that 800 calibers from the muzzle of the gun. The results of this testing are summarized in table XXI.

TABLE XXI. SYSTEM VERIFICATION TEST RESULTS, PD SET FUZES

Test Conditions	Results
155mm M1A1 Gun, M107 Projectile, Firing Zone 1 Function at 800 Calibers	13/15 (1)
105mm M137E1 Gun, M1 Projectile, Firing Zone 7 Non-Functionat 400 Calibers, Transportation Vibration, Procedure II	15/15

(1) Two fuzes which did not function against 5-inch-thick plywood target did function on ground impact.

Fifteen fuzes previously conditioned by transportation vibration, procedure II, and set for point detonation (PD) were fired from a 105mm M137E1 gun at firing zone 7. None of the fuzes functioned upon impacting 5-inch-thick plywood located at 400 calibers from the muzzle of the gun.

Fifteen fuzes set for PD were fired from a 155mm M1A1 gun at firing zone 1. Thirteen of the fuzes functioned upon impacting 5-inch-thick plywood located at 800 calibers from the muzzle of the gun. The other two rounds penetrated the plywood without functioning and subsequently functioned on ground impact. It was concluded that the velocity change resulting from impact with 5-inch-thick plywood at the velocity resulting from firing at zone 1 from the indicated gun was too close to the limit of the fuze's required impact sensitivity. It is recommended that, in conducting the 800-caliber test in the future, 8-inch-thick plywood be used in place of 5-inch-thick plywood.

In a separate fire-on-mechanical-arming test conducted as part of the first article acceptance sample testing of the S&A module, actual arming distances were obtained for 36 fuzes fired at zone 7 from the 105mm gun. Special test rounds were constructed so that, when the S&A

module snapped fully in line, an electric detonator was fired, detonating the projectile. Video and photographic cameras recorded the detonations and permitted measurement of distance from the gun muzzle. Although the test was conducted on 12 S&A modules at each of three temperatures (-40°F, +145°F, and ambient), no trend with temperature was noted, and the results are lumped for presentation in figure 20. It can be seen that the mean distance was 53.9 meters (513 calibers), with a standard deviation of 1.6 meters (15 calibers). There was one deviation from the primary distribution, but, at 48 meters, it was well beyond the minimum acceptable arming distance of 42 meters.

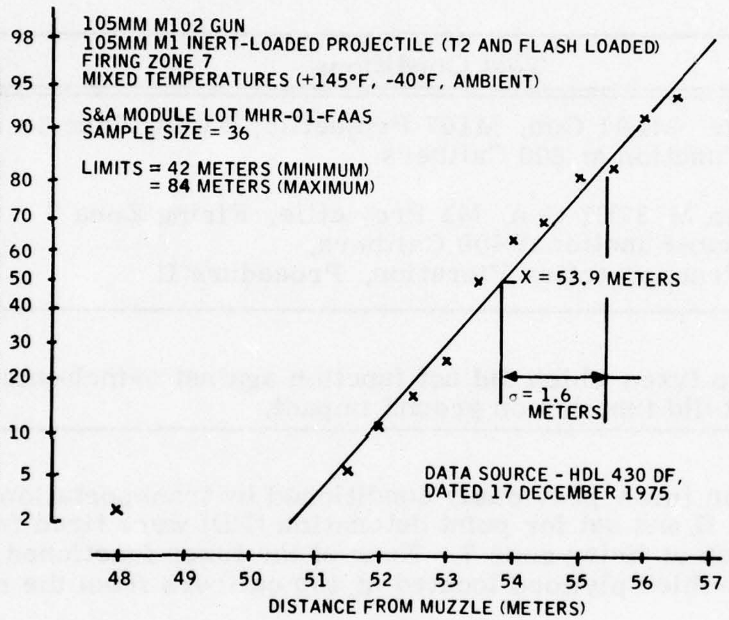


Figure 20. Results from fire on mechanical arming test.

4.5.5 <u>Safety Phase</u> -- The purpose of the safety phase of the test was to demonstrate that, even after being subjected to stringent environments, fuzes could be fired without endangering the gun crew. All safety phase testing was performed using the 175mm gun at firing zone 3.

Forty-eight fuzes were subjected to sequential rough handling at YPG as specified in "MTP" 4-2-602. Twenty-four fuzes were conditioned at -50°F, while a second quantity of 24 fuzes was conditioned at +145°F. All fuzes were subjected to 7-foot sequential drops at their conditioned temperatures. Two-thirds of the fuzes subsequently were subjected to either vertical or horizontal loose cargo conditioning, with three-fourths of those also being subjected to one or more bare fuze 5-foot drops. All 48 fuzes were examined by x ray following conditioning.

An additional 24 fuzes were subjected to transportation vibration (MIL-STD-331, test 119, procedure II), 12 each at -50°F and +145°F.

Only 51 of the 72 fuzes scheduled for firing in the safety phase were actually fired. Fifty of the projectiles functioned properly in the airburst mode, dudded, or functioned on ground impact, while one projectile functioned early with a projectile burst time estimated at 4 to 6 seconds after firing, although the fuze was set to 90.0 seconds. Only one additional fuze was fired after the early burst was recorded; the remaining fuzes were retained for analysis. Table XXII shows the results in terms of whether or not the projectile attained safe separation.

TABLE XXII. SYSTEM VERIFICATION TEST RESULTS, SAFETY PHASE

Test Conditions	Results -50°F	Results +145°F
175mm M2A2 Gun, M437 Projectile, Firing Zone 3		
Transportation Vibration, Procedure II at -50°F	12/12 safe	—
Transportation Vibration, Procedure II at +145°F	—	10/10 safe
Sequential Rough Handling at -50°F	8/8 safe	—
Sequential Rough Handling at +145 °F	16/16 safe	5/5 safe ①

① One projectile detonated approximately 5 seconds after firing.

About 25 percent of the sequentially rough handled fuzes were determined from the x rays to have prefunctioned power supplies, thus precluding a normal air burst function. Most of these fuzes, however, were still fired for evaluation of safety.

4.5.6 Disassembly of Environmentally Conditioned Fuzes--Of the 75 fuzes disassembled, rather than fired, after environmental conditioning, all 75 S&A mechanisms were found to be unarmed and with both spin detents engaged. Table XXIII summarizes the results from the inspection.

TABLE XXIII. DISASSEMBLED ENVIRONMENTALLY CONDITIONED FUZES

	Number Tested	S&A Safe	E-Head OK	Battery Not Activated	Remarks
Jolt Then Jumble	21	21	19 (1)	21	Mechanical failures in C/M IC's.
Jumble Then Jolt	9	9	9	9	
5-Foot Drop	15	15	15	10 (1)	3/3 Bd, 2/3 45° Bd Activated
40-Foot Drop	10	10	5 (1)	3 (1)	1/2 Bd, 2/245° Bd Non-activated
Fungus	5	5	5	4 (1)	Weld of ampule failed
Salt Fog	5	5	5	5	
Sand and Dust	5	5	5	5	
Waterproofness	5	5	5	5	

(1) Less Than Perfect Result

Seven of the 75 E-heads became defective as a result of the environments. Two E-heads suffered internal damage after being subjected to the double environment of jolt followed by jumble. The remaining five E-heads were physically smashed or broken in 40-foot drop. All E-head faults would either have been detected by the fuze setter prior to firing or would have so deformed the nose cone as to preclude any attempt at setting.

Thirteen of the 75 power supplies activated; seven of these activated in 40-foot drop testing, five in 5-foot drop testing, and one during the fungus testing. The latter fault proved to be a defective cold weld in the ampule of the power supply not traceable in any way to the fungus environment. The power supplies activated during 40-foot drop testing were to be expected since 40-foot drop forces are too similar to the high-g signature of gun fire. The power supplies which activated on 5-foot drop testing were not expected since the fuzes are normally expected to operate properly after receiving a 5-foot drop and, in prior tests, had indeed done so. The problem was traced to ampule covers "dished in" during fabrication at the cold welding operation. This fault reduced travel of the internal dashpot of the ampule, thus precluding activation resulting from small drops. The dashpot travel had not been an independently specified parameter in the acceptance of power supplies.

4.5.7 8-Inch XM736 Binary Projectile Testing -- The XM736 binary projectile is one of the M509 family of special-purpose 8-inch projectiles. The XM736 projectile is under development by Edgewood Arsenal and was being test fired from the 8-inch M110E3 gun at Dugway Proving Ground (DPG) during the same time frame as the XM587E2 fuze system verification testing. HDL was invited to submit a quantity of fuzes for testing, and six were fired on 12 March 1976.

Test results, as shown in table XXIV, were 100-percent successful. Burst heights were measured using video tapes. Time to burst was recorded only by observer-held stop watches, and all readings equalled 23 seconds within operator precision. The test did, however, uncover an incompatibility between the fuze and the M509 family of projectiles. An interference exists between the propellant cup of the projectile and the intrusion end of the fuze. In order to perform the testing, about 0.039 inch was machined from the inside diameter of the propellant cups of the projectiles used.

TABLE XXIV. SPECIAL COMPATIBILITY TEST WITH XM736 BINARY PROJECTILE

	XM736 Projectile Serial Number	XM587E2 Fuze (Without Booster) Fuze Serial Number	Height of Burst (Meters)
Without Muzzle Break	380	364	376
	381	297	380
	374	236	373
With Muzzle Break	382	377	371
	379	399	387
	375	382	375
Results -- All Proper (6/6)			

4.5.8 Proof Lot Ballistic Testing -- Fifty proof lot fuzes were fabricated for evaluation of the power supply and S&A module modifications. These fuzes were tested in the 155mm XM198 and 175mm guns. The test results are shown in table XXV.

TABLE XXV. PROOF LOT TEST RESULTS

Test Description	Proof Lot Tests		System Verification Tests	
	Proper Function	Duds	Proper Function	Duds
Aberdeen Proving Ground				
• 155mm XM198 Gun, Firing Zone 8, +145°F	8/10	0/10	10/11	0/11
• 155mm XM198 Gun, Firing Zone 8, -40°F	9/10	0/10	8/10	0/10
Yuma Proving Ground				
• 175mm Gun, Firing Zone 3, -40°F	7/10	1/10	9/10	1/10
• 175mm Gun, Firing Zone 3, +145°F After 7-Foot Drop	6/8	0/8	1/8	0/8

If the results after sequential 7-foot drop test are excluded, then the proof lot fuzes had an 80 percent correct function rate and the system verification test fuzes had a 90 percent correct function.

Compared in the test results after sequential 7-foot drop testing, the proof lot fuzes had a 75-percent rate and the system verification test fuzes had a 12.5-percent correct function rate. However, it was known that the SVT lot fuzes had power supplies which would activate during the sequential 7-foot drop test.

Comparing the test results of proof lot fuzes before and after sequential 7-foot drop testing (80 percent and 75 percent, respectively), it appears that the sequential 7-foot drop test had little effect on the modified power supplied. A grouping of the test results by testing with and without 7-foot drops is contained in table XXVI.

TABLE XXVI. RESULTS COMPARISON, PROOF LOT TESTING BEFORE AND AFTER SEQUENTIAL 7-FOOT DROP

Type of Test	Results (Percent)	
	Proof Lot	System Verification Test Lot
Without 7-Foot Drop	80	90
With 7-Foot Drop	75	12.5

5. INVESTIGATIVE AND DIAGNOSTIC ACTIVITIES

5.1 Performance Reliability at -40°F

> NOTE: This section was furnished by and covers work performed by the Harry Diamond Laboratories.

In March 1976, 10 reliability-phase fuzes were mounted on M437A2 175mm projectiles and conditioned at -40°F prior to firing. Five of the projectiles were high explosive loaded, while the other five projectiles were inert loaded with wax and contained flash charges. All fuzes were set at 90.0 seconds and projectiles fired with zone 3 charges. The test conditions were somewhat complicated by the fact that undersized booster pellets were erroneously installed on all fuzes and a faulty control on the temperature chamber resulted in a runaway cold temperature chamber. The exact lowest temperature and exposure time conditions were not known. However, all units were stabilized at -40°F before firing.

Recovery of the units indicated proper fuze function on all five units on the inert-loaded projectiles. However, four of the five units loaded with high explosive malfunctioned. These four units were initially identified as duds.

After some delays, the four dud units were recovered, examined at YPG, and shipped to HDL for analysis. All four units had unfired output lead charges and all four S&A module rotors were only slightly beyond the fully unarmed position. All four electric detonators had fired into unarmed S&A modules. Based on the smoke patterns, it was concluded that all electric detonators functioned after the spin detents had retracted.

In June 1976, the test was repeated, again using both high explosive and inert-loaded projectiles, but adding a control set of projectiles with M582 mechanical time superguide fuzes. Proper sized booster pellets were used and a proper temperature conditioning environment was maintained. The results of these tests, in terms of proper function for each group of units tested, are summarized below:

Fuze	Inert-Loaded Projectiles	High Explosive-Loaded Projectiles
XM587E2	1/5	3/5
M582	4/5	4/5

Since impact functions frequently occur when using flash-loaded inert projectiles, whether the fuzes are armed or not, it was not possible to conclude whether or not the malfunctions of the inert-loaded rounds were true functions on ground impact or actual duds. The results of this test eliminated the undersized booster as contributing to the malfunction, and the failures did not appear to be associated with inert loading. However, the problem of overall low performance reliability at -40°F was again evident.

Again in July 1976, 24 test projectiles were assembled and fired from the same 175mm gun at zone 3 and conditioned at -40°F as in the previous tests. Half of the test projectiles had firing pins and half did not. All projectiles were fully inert.

One unit was completely lost and, in four units, ground impact drove the S&A module into the inert wax filter of the projectile. Only one of these four units was available for post-flight analysis. This unit, along with the 19 other units were analyzed. Only one of the twenty failed to arm. It had a broken tooth on gear-and-pinion 1 as was the case with one of the fully armed units. It was significant that the same gear tooth was broken on both units. This particular gear tooth is load bearing only in the unarmed condition and is not load bearing on ground impact. It was thus concluded that tooth breakage occurred because of in-bore balloting forces rather than ground impact.

A summary of the possible causes of the duds in 175mm gun firings at zone 3 and -40°F is contained in table XXVII.

TABLE XXVII. ANALYSIS OF DUD FUZES RESULTING FROM 175MM GUN FIRINGS AT ZONE 3 AND -40°F

Possible Causes	Relevant Data and/or Diagnostic Test Considered	Conclusion
1. Undersized booster pellets.	1. Examination of recovered duds showed that the output lead charge had not fired.	1. No.
2. Runaway temperature chamber.	2. A retest at -40°F repeated the low reliability score.	2. No.
3. Poor reliability following HE projectiles rather than inert projectiles.	3. A retest at -40°F showed improper functions more evenly divided between inert- and high explosive-loaded projectiles.	3. No.
4. S&A module did not arm at -40°F when fired from a 175mm gun at firing zone 3.	4. Non-armed S&A modules were verified in recovered duds. A broken tooth in the gear of die-cast gear-and-pinion 1 was found in all four recovered duds, the single non-armed S&A module from vertical recovery diagnostic testing, and the lone failure from an S&A module test vehicle.	4. Most likely.

5.2 Early Burst Analysis

NOTE: This section was furnished by and covers work performed by the Harry Diamond Laboratories.

This activity involved an analysis of an early burst that occurred with a fuze assembled on a high explosive-loaded 175mm M437A2 projectile. The test unit was conditioned at +145°F and fired with firing zone 3 propellant. The fuze had previously been subjected to a 7-foot sequential packaged drop test at +145°F. The fuze was set at 90.0 seconds with the XM36E1 fuze setter and was interrogated as 90.03 seconds just prior to firing. The early burst was not observed directly, but was crudely calculated as between 4 and 6 seconds.

The analysis was initiated by preparing a list of probable causes along with a judgment relative to the potential for each to cause the problem (see table XXVIII). Each of the probable causes was analyzed in detail and, as indicated in the table, all were eliminated except for a possible power supply malfunction which was investigated. The analysis included disassembled fuzes which had been previously subjected to sequential rough handling or transportation vibration. None indicated evidence of failures.

In addition, fuzes were subjected to forces deemed equivalent to the balloting forces encountered in the bore of the 175mm gun. As above, no failures in the E-head were detected. Bonds in the silicon monolithic integrated circuits used in the E-head were subjected to forces up to 40,000 g's without any wire bond damage. Based on these examinations, the E-head was eliminated as a source of the early burst problem.

The power supply was then subjected to an analysis. Special test projectiles were subjected to the ramming forces. None exhibited failures which could have caused an early burst.

An examination of the internal structure of the power supply, however, revealed configuration features which could result in certain critical intercomponent shorts, some of which would permit power supply potential to appear on the detonator through-lead. For example, shorting of two leads through a piece of already deformed 0.012-inch fishpaper would cause an early burst.

The most likely cause of the early burst was determined to be the splashing of a small amount of electrolyte, released at gun fire, onto the fishpaper. The electrolyte would then wick under the two critical leads, which would provide a current path to the electric detonator, thus causing early detonation of the projectile.

TABLE XXVIII. EARLY BURST ANALYSIS

Possible Causes	Relevant Data and/or Diagnostic Test Considered	Conclusion
1. Defective projectile.	1. X-ray of projectile normal.	1. Very unlikely.
2. Impact with airborne object.	2. No birds noted in area.	2. Very unlikely.
3. Spontaneous ignition of some in-line explosive.	3. After first 24 hours of manufacture, virtually unheard of.	3. Very unlikely.
4. S&A module moving forward on firing pin.	4. Requires in excess of 30 g's, which would entail a yaw of 27 degrees at expected precession frequency of 8 hertz.	4. Very unlikely.
5. Mis-set fuze.	5. Sequence of erroneous actions required deemed highly improbable. Fuzes set to 9.0 seconds (most likely mis-set for 90.0 seconds) did not replicate early burst.	5. Very unlikely.
6. Electronic fault.	6. Disassembly of 10 of the fuzes subjected to sequential rough handling and two subjected to transportation vibration, procedure II revealed no E-head faults. Two independent *fault tree* analyses and forced faults on laboratory breadboards could not replicate 4- to 6-second time-out. Eight fuzes were balloted, and no E-head's failed. 15 fuzes fired vertically were recovered and analyzed. 40 silicon monolithic ICs were subjected to repeated shocks up to 40,000 g's without bond failure.	6. Unlikely.
7. Battery preactivated in gun tube.	7. No voltage could be generated from any power supply during ramming or subsequent gun elevation.	7. Unlikely.
8. Critical intercomponent short in battery.	8. Detailed inspection of internal construction of power supply revealed several possible mechanisms which could initiate the electric detonator at an improper time.	8. Most likely.

5.3 S&A Module Investigations

The S&A module investigations were conducted to determine the corrective action required on the broken gear teeth which were experienced during 175mm gun firings at zone 3 and -40°F. The use of an aluminum cut gear assembled to a stainless steel pinion in place of the die-cast zinc gear-and-pinion assembly was previously identified as a potential fix.

One hundred and twenty-two S&A modules were fabricated with an aluminum cut gear. The results of the spin tests, which are performed as part of the normal assembly operations, are shown in tables XXVII and XXVIII. One hundred and twenty-one of the 122 units tested armed in the 1700 rpm arming test, and seven units exceeded the 32.0 turns-to-arm maximum arming delay limit. This 7-percent reject rate previously experienced with the die-cast zinc gear-and-pinion assembly is not considered significant. Mean and standard deviation data from this test, which are shown at the bottom of tables XXIX and XXX, compare favorably with previous builds. These test results show that the use of the new aluminum cut gear does not degrade the low spin rate performance of the S&A module.

These S&A modules were then assembled into test vehicles and/or fuzes as follows, and control samples consisting of S&A modules with the die-cast zinc gear and pinion assemblies were also provided as indicated:

Description	Test S&A Module	Control S&A Module
S&A Module Test Vehicle	24	--
Special S&A Module Test Vehicle	48	48
Fuzes	60	60+

Drawings of the special S&A module test vehicle were submitted to HDL under separate cover.

The 24 units which were assembled into the standard S&A module test vehicles were subjected to transportation vibration cycling (MIL-STD-331, test 119, procedure 1 at +145°F). All of the units were then subjected to a 2500-rpm spin test for arming. The results of this spin arming test are shown in table XXXI. All of the units armed. However, six of the 24 units tested exceeded the 32.0 turns-to-arm maximum arming delay requirement.

TABLE XXIX. S&A MODULE ALUMINUM CUT GEAR SPIN TEST RESULTS, FIRST ITERATION

1700 RPM Turns to Arm	1100 RPM No Arm	1700 RPM Turns to Arm	1100 RPM No Arm
28.6	OK	27.0	OK
26.2		27.0	
25.3		27.1	
25.7		27.1	
28.3		26.7	
27.7		24.8	
27.3		28.8	
26.0		26.2	
25.9		34.2	
32.8		27.0	
25.6		28.0	
27.4		28.8	
33.8		43.0	
26.4		38.7	
26.7		26.2	
27.6		24.7	
26.3		28.0	
28.6			
28.6		$\bar{X}$	26.90
45.1			1.50
27.5		$+3\sigma$	30.35
25.9		-3σ	23.45
25.7			

TABLE XXX. S&A MODULE ALUMINUM CUT GEAR SPIN TEST RESULTS, SECOND ITERATION

1700 RPM Turns to Arm	1100 RPM No Arm	1700 RPM Turns to Arm	1100 RPM No Arm	1700 RPM Turns to Arm	1100 RPM No Arm
25.4	OK	25.6	OK	25.8	OK
26.1		28.5		26.8	
25.0		25.5		26.3	
25.1		25.3		27.4	
27.3		26.1		25.9	
26.3		44.1		25.1	
26.4		26.3		24.9	
26.9		26.3		29.0	
25.8		27.2		26.4	
25.8		27.2		26.2	
26.1		25.6		26.9	
26.5		27.6		27.2	
25.8		N/A		27.5	
26.2		26.8		25.7	
27.5		26.2		24.2	
29.0		27.0		27.5	
25.9		25.9		26.4	
25.5		26.3		28.1	
27.2		26.3		25.1	
26.7		24.7		26.2	
25.8		26.0		27.3	
26.2		26.9		26.4	
25.5		25.9		27.5	
26.3		26.5		26.7	
26.5		27.6			
30.1		25.2		$\bar{X}$ 26.43	
26.2		27.0		1.01	
25.7		25.6		$+3\sigma$ 29.45	
27.6		26.5		-3σ 23.41	

TABLE XXXI. S&A MODULE ALUMINUM GEAR SPIN TEST RESULTS AFTER TRANSPORTATION VIBRATION

Turns to Arm at 2500 RPM
27.5
29.2
43.2
45.3
39.7
25.5
27.8
27.6
27.7
30.8
118.7
26.8
28.3
28.1
28.5
28.8
26.1
27.3
27.3
27.4
28.0
27.1
53.9
98.8

Forty-eight of the special S&A module test vehicles, 24 containing test S&A modules and 24 containing the control S&A modules, were also tested at Honeywell. Twenty-four units, 12 containing test S&A modules and 12 containing the control S&A modules, were subjected to transportation vibration cycling (MIL-STD-331, test 119, procedure 1 at +145°F). All of the units were then subjected to 155mm, zone 1 ballistic firings at -40°F. These units were fired at a range of 500 meters for arming and function. The results of these tests and the subsequent disassembly and analysis show that the aluminum cut gear is equivalent to the die-cast zinc gear and pinion assembly.

The remaining 48 special S&A module test vehicles were shipped to YPG for 175mm, zone 3 ballistic firings at -40°F. These units were to be fired for recovery. HDL reported that this test was somewhat less than successful in that a large percentage of the test vehicles separated from the projectiles upon impact and that the majority of the function/ no function data were lost.

5.4 Power Supply Investigations

An investigation to determine the effects of the 7-foot drop packaged test on the system verification test lot of power supplies and a new lot fabricated by HDL was begun. A quantity of 32 units was fabricated, of which 16 were from the SVT lot and 16 were new power supplies manufactured by HDL. These units contained no electronics, only power supplies, S&A modules, and nose cones filled with potting material, with three wires connected to the power source +, -, and T terminals and brought out through holes in modified nose plugs.

Electrical checks and x rays were made as shown in figure 21.

The 32 units were packaged in four ammunition boxes, eight to a box. The four ammunition boxes were packaged in two wire-wrapped wooden boxes, two ammunition boxes to a wooden box. The old and new power supplies were evenly distributed between the two boxes. One box was conditioned at -55°F and one box was conditioned at +140°F, both for 16 hours minimum.

After temperature conditioning, they were dropped six times each from 7 feet.

After the drop, the units were unpacked and electrically checked for power supply voltage. Those units with activated power supplies were connected to a monitor circuit with an electronic assembly load, and power supply voltage, scaler period, arm, and fire signals were monitored on a chart recorder.

A summary of the results is as follows:

- Of the eight SVT lot power supplies conditioned cold, eight were observed to have activated when checked after 7-foot drop-testing.
- Of the eight new power supplies conditioned cold, none were observed to have activated when checked immediately after 7-foot drop testing. However, when checked 24 hours later, three units showed a short circuit between the + and - terminals, which is an indication of activation.

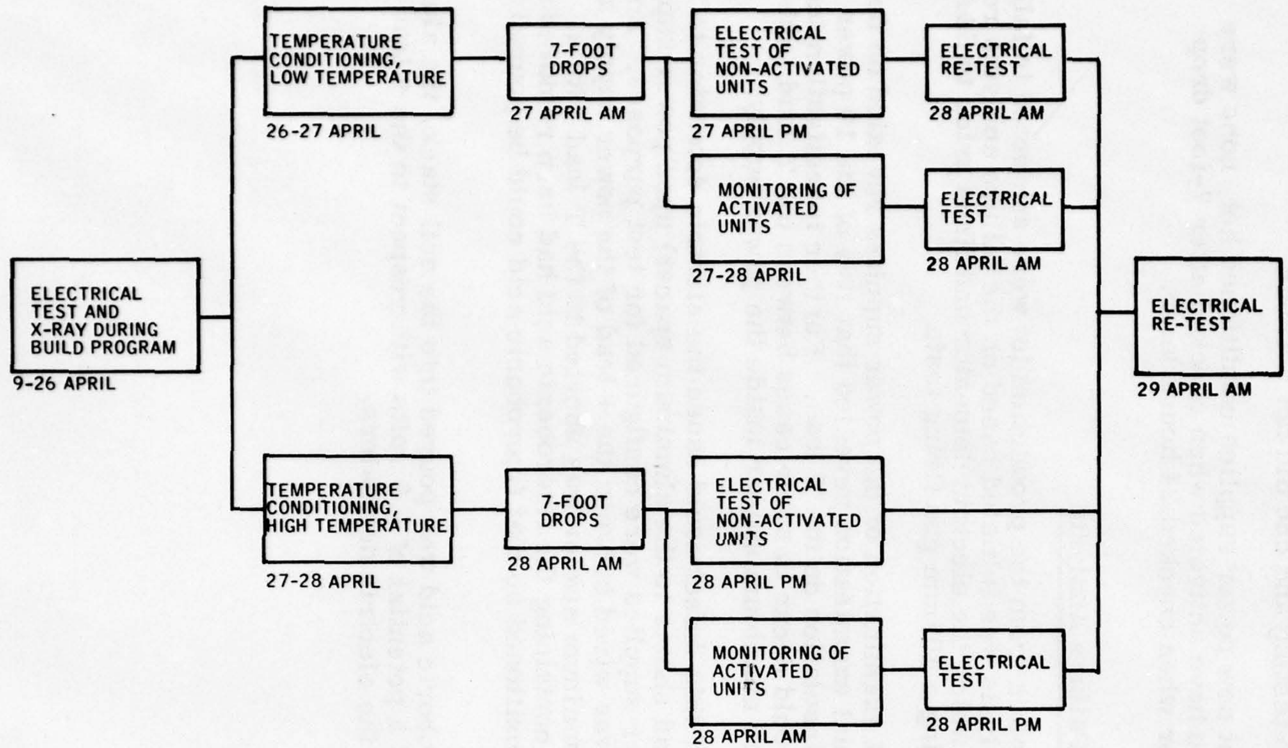


Figure 21. Power supply investigation chronological block diagram.

- Of the eight SVT lot power supplies conditioned hot, seven were observed to have activated when checked after the 7-foot drop testing and one did not activate.
- Of the eight new power supplies conditioned hot, none were observed to have activated when checked after 7-foot drop testing, nor when checked 24 hours later.

5.5 Power Supply Failure Analysis

Ten power supplies from the production lot were subjected to failure analysis. This analysis was initiated based on the failure analysis results of the fuze in which the electric detonator had fired prior to S&A module arming during a 105mm gun firing test.

External visual examination of the power supplies revealed no defects. Internal visual examination revealed that five of the 10 power supplies had short insulation on the T lead. Further investigation indicated that a short could occur in some cases between the T lead in the power supply and the aluminum spacer inside the power supply.

To determine if this defect could cause the electric detonator to fire (assuming the T lead shorts to the aluminum spacer) upon power supply initiation, two power supplies were configured for test purposes. An electric detonator was wired between the + lead of the power supply and the T lead. The aluminum spacer was shorted to the T lead with a wire. The ampule containing the fluoroboric acid had been removed and the power source positioned so that fluoroboric acid could be poured into the cell stack.

When the fluoroboric acid was poured into the cell stack, the aluminum plate indicated a potential of 1.5 volts with respect to the + lead and in both cases fired the electric detonators.

6. SPIN SWITCH DEVELOPMENT

6.1 Summary

A suitable spin switch design was formulated to act as a launch timing initialization switch. Breadboard models were fabricated and tested. Testing of two switch models included simulated setback and balloting shocks, extreme temperature operation, transportation vibration, and current carrying capability. The testing demonstrated the capability of the design to meet all use requirements.

Minor problems encountered were the breaking loose of the nonfunctional weld between the leaf and terminal pin, and the working loose of one terminal pin from its press fit in the cover during transportation vibration. These problems are readily correctable.

Requirements for the spin switch were established as shown in table XXXII.

6.2 Spin Switch Design

Tradeoff calculations were made considering various mass and spring combinations. From these, a 3/32-inch diameter steel ball working against a 0.050-inch wide by 0.004-inch thick beryllium copper leaf spring was selected as the optimum configuration. An initial design layout was prepared as shown in figure 22. This layout shows the fit of the spin switch into the fuze electronics cover as well as the construction of the switch.

One breadboard model was fabricated to the initial layout. The base and cover were machined from unfilled ABS plastic. (For eventual molded parts, 20 percent glass-filled ABS is planned - giving an option to mold the switch base as part of the fuze electronics cover.) For the first model, the switch base was left attached to the parent stock to facilitate mounting on a spin test fixture. Terminals were L-shaped pieces of 0.031-inch-thick brass.

The beryllium copper leaf was resistance welded to one terminal. The end of the leaf had a spherical dimple for electrical contact with the flat terminal and a shoe to ride against the inside surface of the switch base to support the leaf during setback acceleration.

Performance of the first model was as expected except that the 20,000-g balloting shock deformed the V-shaped offset of the leaf where it contacted the ball, permanently closing the contacts. (The offset, which was included to accommodate possible use of a cylindrical mass instead of a ball, serves no function in the design.)

TABLE XXXII. REQUIREMENTS FOR SPIN SWITCH

Area	Requirement
• Closed on Firing	Open at or shortly after muzzle exit
• No Open (Momentary Chatter OK)	1100 rpm
• All Open (No Chatter Permissible)	2500 rpm - 1700 rpm desired
• Setback	30,000 g's
• Balloting	20,000 g's
• Interface	Compatible with installation in or as part of the fuze electronics cover
• Electrical	Less than 5 ohm - 1 ohm desired (after worst-case storage at fuze level)
	40-volts maximum circuit voltage
	10-milliampere test current
	500-milliampere maximum operational current (must remain closed 300 seconds)
• Sealing	Compatible with potting in silica-filled epoxy
• Temperature	
Operating	-58°F to +160°F
Storage	-65°F to +160°F

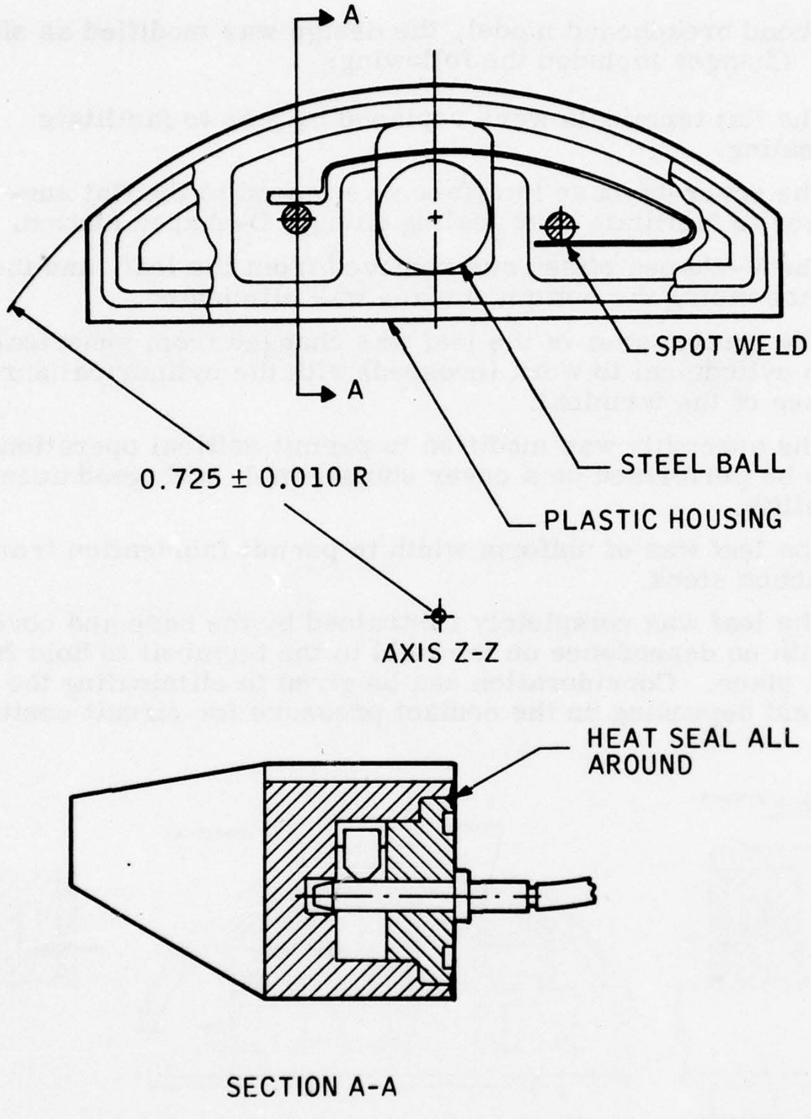


Figure 22. Spin switch initial design layout.

For the second breadboard model, the design was modified as shown in figure 23. Changes included the following:

- The flat terminals were replaced by pins to facilitate sealing.
- The cover-to-base interface was moved to the flat surface to facilitate heat sealing using a D-shaped platten.
- The V-shaped offset was removed from the leaf, and the shoe riding the bottom surface was eliminated.
- The contact area of the leaf was changed from spherical to cylindrical to work (crossed) with the cylindrical surface of the terminal.
- The assembly was modified to permit critical operations to be performed on a cover subassembly with good accessibility.
- The leaf was of uniform width to permit fabrication from ribbon stock.
- The leaf was completely restrained by the base and cover with no dependence on the weld to the terminal to hold it in place. Consideration can be given to eliminating the weld depending on the contact pressure for circuit continuity.

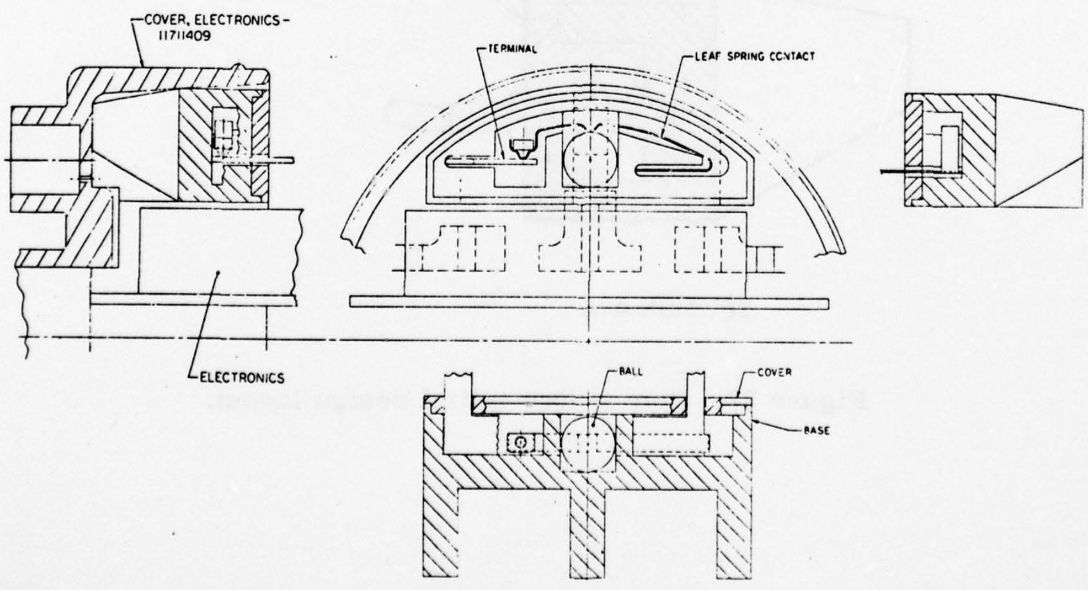


Figure 23. Spin switch configuration.

6.3 Breadboard Model Test Results

Three units were fabricated to the second model configuration. One with a Lucite cover was intended for display and was tested for function only. The other two units were subjected to a limited environmental test program. On one of these units, the leaf was welded to the terminal. On the other, an imperfect weld came loose prior to testing, and the unit was left unwelded to provide a comparison between the welded and unwelded configurations. Test results are summarized in table XXXIII.

TABLE XXXIII. SUMMARY OF SECOND ITERATION SPIN SWITCH BREADBOARD MODEL TESTING

	RPM at Function			
	Unit 1 (1)		Unit 3 (1)	
	Open	Close	Open	Close
Initial Functional Test	1400	1390	1300	1290
At Low Temperature (2)	1410	1400	1280	1270
At High Temperature (2)	1420	1410	1290	1280
At Ambient Temperature	1420	1410	1280	1270
After Setback Shocks (30,000 G's 0.15 Millisecond)				
First Shock	1380	1370	1210	1200
Second Shock	1360	1350	1220	1210
Third Shock	1420	1410	1160	1150
After Balloting Shock(s) (20,000 G's for 0.15 Millisecond)				
One Shock (Directed to Open Contacts)	1210	1200	1110	1100
Two Shocks (Transverse to Sensitive Axis)	1330	1320	900	890
After Transportation Vibration	1370	1360	1050 (3)	1040
During Current Test (4) (500 Milliamperes for 300 Seconds)	Closed		Closed	
After Current Test (4)	1480	1500	Over 3000	

(1) Unit 3 had the leaf welded to the terminal.
Unit 1 had the leaf free (weld failed prior to test).

(2) Temperature runs were made with the spin fixture at ambient and the conditioned switch (-65°F or +160°F) mounted and functioned within 1 minute after removal from the temperature chamber.

(3) The terminal pin worked loose and weld to blade failed. Reading is after repair (left unwelded).

(4) The switch must remain closed. Function after testing is not required.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 System Verification Test Conclusions

Excellent overall results were obtained in all weapons other than the 175mm gun.

The low reliability of the fuze in 175mm gun firings at -45°F was caused by a structural failure of the die-cast zinc gear-and-pinion assembly in the S&A module.

The most probable cause of the observed early burst was a power supply malfunction.

The plywood target thickness should be increased from 5 inches to 8 inches or more for 155mm gun firing tests.

7.2 Investigative and Diagnostic Conclusions

The low reliability of the fuze in 175mm gun firings at -45°F can be corrected by changing from a die-cast zinc gear-and-pinion assembly to an aluminum cut gear.

The power supply failure mode (intercomponent shorts) can be eliminated by moving the power supply through lead.

7.3 Recommendations

The following design changes incorporated into the proof lot fuzes should become a permanent part of the fuze design:

- Replacement of the die-cast zinc gear-and-pinion assembly in the S&A module with an aluminum cut gear.
- Movement of the power supply through-lead outside the power supply.

APPENDIX A

FAILURE ANALYSIS REPORT --
XM587E2 FUZE IMPACT SWITCH (PART NUMBER 11718418),
KAUPP AND ACCUDYNE

Honeywell

Reliability

PREFAILURE ANALYSIS REPORT - 1

1. REPORT NO.			
			66803
2. PART NO. 11718418	3. PART NAME Impact Switch	4. F & A NO.	5. DATE 7/14/76
6. SERIAL NO.	7. MFR. Accudyne/Kaupp	8. PROJECT XM587	

1. Background

Impact switches from two vendors were submitted to the Failure Analysis Lab for evaluation. The vendors, Kaupp and Accudyne, were to be compared on the basis of part quality.

2. Analysis

Sixteen impact switches, eight from each vendor were electrically tested per specification 11718418. All sixteen devices passed the switch non-function test at 40g acceleration. The switch function test was then performed. The impact switches were submitted to an acceleration varying from 340 to 505 g's (see Table 1). Testing indicated 5 of the 16 units functioned only intermittently. Table 1 shows the "g" levels where the switches malfunctioned and the percentage of malfunction. All five of the intermittent switches were manufactured by Kaupp. The Accudyne switches were functional for 100% of the testing.

External visual examination showed a noticable difference in the appearance of the lead welds on the Accudyne switches. (See Photo 1). The Accudyne welds were quite sloppy and irregular in appearance. By contrast the Kaupp welds were homogeneous and compact. Lead pull tests on both switch types indicated no weld strength differences. Both types of welds sustained 5 lbs of weight.

The impact switch construction is shown in Photo 2. The switch consists of a contact cone, a support spring, and dielectrically insulated terminals. The external leads are welded as previously discussed. The construction of the switches of both vendors are essentially identical.

Internal visual examination revealed organic contamination to some degree in all the Kaupp switches. The contamination was white in appearance and located in and on the contact cone. Contamination was also found on the spring and inside the switch housing. Those Kaupp switches which were intermittent during electrical testing revealed the largest amounts of contamination, specifically on the contact cone tip where the electrical connection is made (See Photo 3). The presence of the contamination prevented consistent switch closure. Attempts to remove the contamination by ultra-sonic cleaning with Freon were unsuccessful. Accudyne switches were free of contamination.

Conclusion

Sixteen impact switches from two separate vendors, Accudyne and Kaupp, were analyzed. The eight Accudyne switches exhibited welds which were poor in appearance but satisfactorily strong. Switches manufactured by Accudyne were found to be free of contamination and passed all electrical tests.

HP-270

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PREFAILURE ANALYSIS REPORT - 2

Reliability

1. REPORT NO.
66803

Eight impact switches manufactured by Kaupp showed welds which were neat in appearance. Internal visual, however, revealed large amounts of contamination inside the switches. The amount of contamination correlated directly to the electrical failure of 5 of the 8 Kaupp switches. The contamination prevented consistent switch contact.

Prepared by: J.C. Timmerman
J.C. Timmerman
Failure Analyst

Approved by: D.A. Tabor
D.A. Tabor
Reliability Engineer

HP-272

Table
Impact Switch Functional Testing

Device Number	Vendor	Switch State @ 40G	Switch State @ 340G	Switch State @ 350G	Switch State @ 360G	Switch State @ 375G	Switch State @ 400G	Switch State @ 415G	Switch State @ 455G	Switch State @ 495G	Switch State @ 505G
1	AccuDyne	Off	On	On	On	On	On	On	On	On	On
2	AccuDyne	Off	On	On	On	On	On	On	On	On	On
3	Kaupp	Off	On	On	On	On	On	On	On	On	On
4	Kaupp	Off	On	On	Off	Off	Off	On	Off	On	On
5	Kaupp	Off	On	On	On	On	On	On	On	On	On
6	Kaupp	Off	Off	On	On	On	On	On	On	On	Off
7	Kaupp	Off	Off	Off	Off	Off	Off	Off	Off	On	Off
8	Kaupp	Off	Off	Off	Off	Off	Off	Off	Off	Off	On
9	Kaupp	Off	Off	On	On	Off	Off	Off	Off	Off	Off
10	Kaupp	Off	On	On	On	On	On	On	On	On	On
11	AccuDyne	Off	On	On	On	On	On	On	On	On	On
12	AccuDyne	Off	On	On	On	On	On	On	On	On	On
13	AccuDyne	Off	On	On	On	On	On	On	On	On	On
14	AccuDyne	Off	On	On	On	On	On	On	On	On	On
15	AccuDyne	Off	On	On	On	On	On	On	On	On	On
16	AccuDyne	Off	On	On	On	On	On	On	On	On	On

Number	Vendor	% Failure During Above Testing
1	AccuDyne	0%
2	AccuDyne	0%
3	Kaupp	0%
4	Kaupp	33.3%
5	Kaupp	0%
6	Kaupp	22.2%
7	Kaupp	88.8%
8	Kaupp	88.8%
9	Kaupp	77.7%
10	Kaupp	0%
11	AccuDyne	0%
12	AccuDyne	0%
13	AccuDyne	0%
14	AccuDyne	0%
15	AccuDyne	0%
16	AccuDyne	0%

Honeywell

PREFAILURE ANALYSIS REPORT - 2

Reliability

1. REPORT NO.
66803

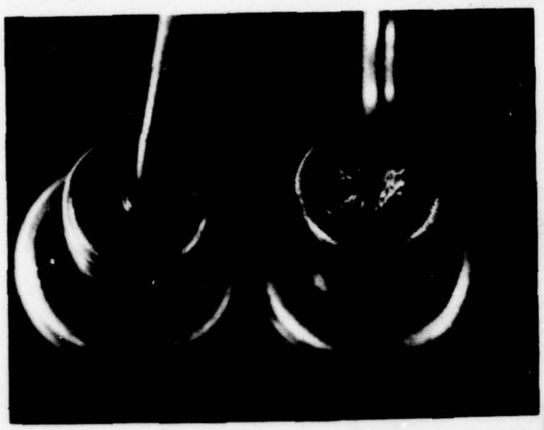

Photo 1 - MAG10X

The Kaupp switch is on the left. The Accudyne switch is on the right. Note the difference in weld appearance.

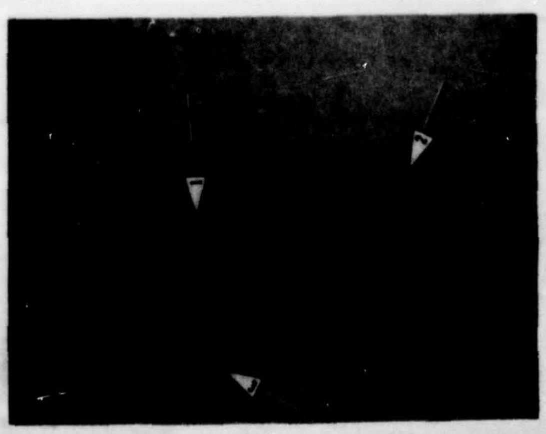

Photo 2 - MAG10X

Typical switch construction.

1. Contact cone
2. Spring
3. Dielectric spacer

HP-272

PREFAILURE ANALYSIS REPORT - 2

1. REPORT NO. 66803

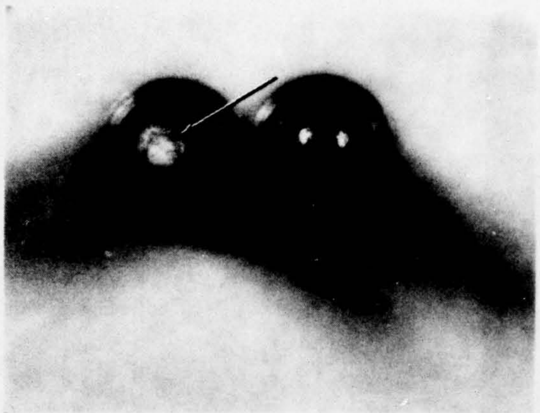

Photo 3 - 12X

The contact cones from two Kaupp switches. The arrow indicates contamination on the tip of the cone for device #8. This switch malfunctioned 88.8% of the time. The remained cone is clean and did not malfunction.

HP-272

APPENDIX B

METALLURGICAL LABORATORY REPORT SOLDERABILITY OF XM587E2 FUZE IMPACT SWITCH LEADS

COPY LIST:

J.M. Hoegfeldt

J.R. Pitcher

KEYWORDS:

Solderability

ATTACHMENTS:

Lab Sample No. 40413

Honeywell

GOVERNMENT AND AERONAUTICAL PRODUCTS DIVISION

REPORT NO. 7931

DEV. NO. W3987-PB-3000-400M

ENGINEERING TEST REPORT

DATE September 1, 1976

ISSUED BY: G&APD METALLURGICAL LABORATORY

SUBJECT: Impact switch leads, solderability of (XM-587)

BACKGROUND: The latest lot of the above parts exhibited unacceptable coverage when solderability tested in receiving inspection. (RI)

MATERIAL SUBMITTED:

Thirteen (13) P/N 11718418 impact switches, lot designation 8554 government furnished.

PURPOSE OF REQUEST:

1) Determine cause of poor solderability

2) Recommend salvage procedure for approximately 50 parts needed for production.

CONCLUSIONS:

1) Poor solderability is due to the iron/nickel alloy leads being uncoated. This material is not readily solderable unless coated or plated; most commonly with gold, tin, or tin-lead solder.

2) The leads can be made solderable by using the method in the Procedure and Results section below.

PROCEDURE AND RESULTS:

Three parts were examined in the Scanning Electron Microscope - Microprobe for indications of surface conditions or chemistry that would deleteriously affect solder wetting. Rather than any surface condition effecting solderability, the leads were found to be uncoated iron/nickel, not normally considered easily solderable. This accounts for the poor coverage when the parts were tested in RI as the flux used would not remove oxides of iron and (especially) nickel preventing wetting.

DATA BOOK NO.	PAGE	
REQUESTED BY Ken Lai	DATE 8/27/76	WRITTEN BY T.D. Schleisman
DEPARTMENT APE&A		APPROVED J.R. Pitcher & JMH

HE-44 (DITTO MASTER)
HE-44A (DUPLICATOR)
REV 4/75

AD-A053 125 HONEYWELL INC HOPKINS MN DEFENSE SYSTEMS DIV F/G 19/1
XM587E2/XM724 ELECTRONIC TIME FUZES SYSTEM VERIFICATION TEST PH--ETC(U)
JAN 78 J C RAVIS DAAG39-75-C-0157
UNCLASSIFIED HDL-CR-78-157-1 NL

2 OF 2
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A053125

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DATE
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DDC

In order to render the leads solderable tests were run on parts using different fluxes and cleaners. The simplest most efficent method found is as follows:

1) Dip the leads in 25% Nitric acid for 3-5 seconds with slight agitation.

2) Water rinse

3) Isopropyl alcohol rinse

4) Dip in alpha 611 flux - a liquid mildly activated organic flux.

5) Solder dip for 5 seconds - 63/37 solder at 450°F

6) Isopropyl alcohol rinse.

This procedure caused the leads to have a smooth continuous coating of the solder. No evidence of de-wetting was seen with subsequent dips using either the 611 or a non-activated flux.

APPENDIX C

FAILURE ANALYSIS LABORATORY REPORT
XM587E2 FUZE HYBRID INTERFACE CIRCUIT FAILURES
(PART NUMBER 11711610)

GOVERNMENT
and AERONAUTICAL
PRODUCTS DIVISION

FAILURE ANALYSIS REPORT

Honeywell

FAILURE ANALYSIS LAB

HF-119

DATE	PROJECT	MALFUNCTION OR F&A REPORT #	REPORT #
25 September 1975	XM587		65660
PART NAME Hybrid Interface Circuit	DWG/PART # 11711610		GENERIC P/N
S/N X12, X13, X29	MANUFACTURER Honeywell		DATE CODE 7533 (X12, X13) 7527 (X29)

1. BACKGROUND 2. ANALYSIS PROCEDURE 3. EQUIPMENT USED 4. CONCLUSIONS 5. RECOMMENDATIONS (OPTIONAL)

1. Background

Three Hybrid Interface Circuits were submitted to the Failure Analysis Lab after failing shock testing at Hopkins, Minnesota. Serial numbers X12 and X13 were subjected to shocks of 36KG and 40KG each. Serial number X29 was shocked at 30KG and 34KG.

2. Analysis Procedure

• SN X12

The hybrid microcircuit failed parameter +Vp of the Positive Polarizing Voltage Circuit, V1AD of the Monitor Line Drive Circuits, and T5A of the Initializing Circuit. Decapsulation revealed a broken 0.7 mil internal lead wire on the Q12 base (see Figure 1). This open lead resulted in Q12 failing to turn on. When Q12 remains off T5A is increased since Q9 is not driven hard enough to discharge capacitor C1 within 0 to 200 usec.

The Q10 emitter region exhibited a chipout and microfracture (see Figure 2). The damage was apparently done during the placement of the emitter ball bond. The microfractures propagated enough during shock testing to result in a Q10 collector to emitter short. This defect resulted in the failure of parameter V1AD.

The third defect noted on this unit was an electrically overstressed transistor, Q8. The overstress condition melted the emitter metalization, isolating the bond area from the contact window area (see Figure 3). The overstress probably occurred prior to shock testing with any link between the two areas of emitter metalization destroyed during the shock test. This resulted in a 0.00 voltage measurement for +Vp.

• SN X13

The hybrid microcircuit failed parameter +Vp of the Positive Polarizing Voltage Circuit. The failure of this parameter is indicative of an open circuit associated with transistor, Q8. Decapsulation revealed a broken 0.7 mil lead wire on the Q8 base (see Figure 4). The probable cause of the break being a slight degradation of the wire during bonding coupled with the severity of the shock test.

• SN X29

The hybrid microcircuit failed various parameters of the Monitor Line Drive Circuit, Fuze Power Circuit, Initializing Circuit, and the Firing Circuit. Decapsulation revealed broken 0.7 mil leads on the transistor Q6 emitter, Q9 emitter, and the Q10 base (see Figure 5). The leads were broken as a result of the severe stresses of the shock test on areas where the wires were slightly degraded. The degradation could be attributed to irregularities in the wire as it was purchased and/or bonding related degradation.

4. Conclusions

The failure analysis results are as follows:

• SN X12

Transistor Q12 base lead broken due to test severity and lead degradation. Transistor Q10 emitter region exhibits a chipout apparently from the bonding capillary. The chipout created microfractures which propagated to the Q10 collector during the shock test.

Transistor Q8 shows an open circuit in the emitter metalization as a result of an electrical overstress.

• SN X13

Transistor Q8 exhibited a broken base lead due to shock test stresses and lead degradation.

• SN X29

Transistor Q6 emitter, Q9 emitter, and Q10 base leads are broken due to shock test stressing coupled with minor lead degradation.

Prepared by J.C. Timmerman
J. C. Timmerman
Failure Analyst

Approved by B.E. Goblish
B. E. Goblish
Reliability Engineer

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GOVERNMENT
and AERONAUTICAL
PRODUCTS DIVISION

FAILURE ANALYSIS REPORT

Honeywell

REPORT # 65660

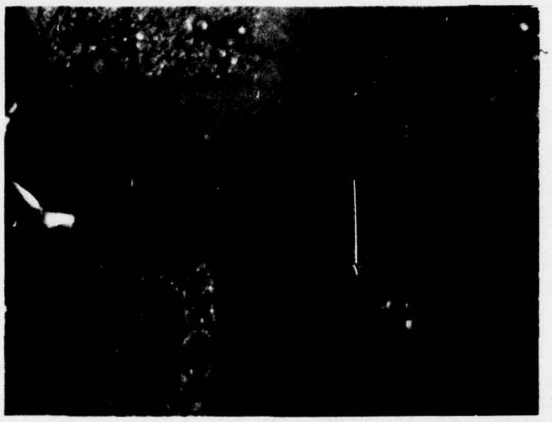

Figure 1 - Mag. 30X

Transistor Q12 base lead open.

Figure 2 - Mag. 400X

Transistor Q10 exhibits a chipout in the emitter region which causes a collector to emitter short.

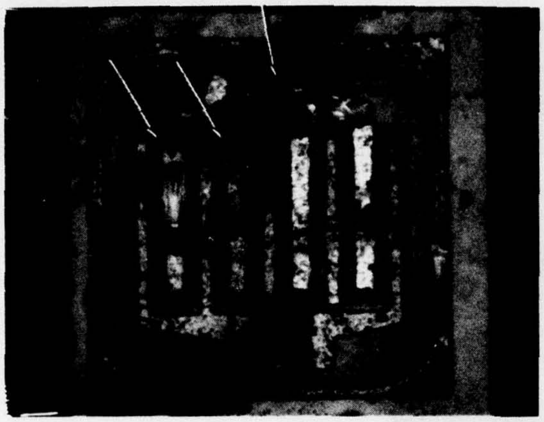

Figure 3 - Mag. 165X

Transistor Q8 emitter metalization shows signs of overstress. The arrows indicate the open circuit.

Figure 4 - Mag. 30X

Transistor Q8 base lead is broken open.

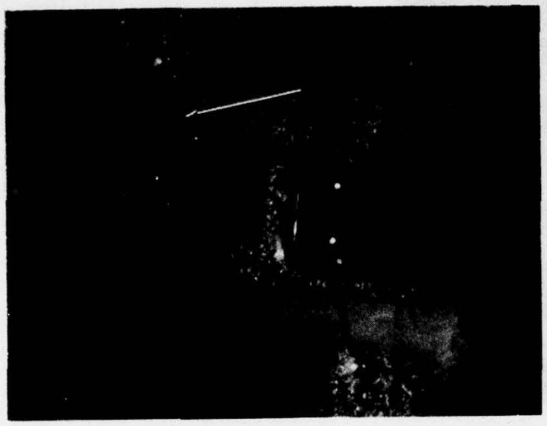

Figure 5 - Mag. 30X

Transistor Q6 emitter lead is shown broken as were the Q10 base and the Q9 emitter leads.

APPENDIX D

FAILURE ANALYSIS LABORATORY REPORT
XM587E2 FUZE FIRST ARTICLE ACCEPTANCE SAMPLE, XM587E2 FUZE LOT 1, AND XM724 FUZE LOT 1 FAILURES

GOVERNMENT and AERONAUTICAL PRODUCTS DIVISION

FAILURE ANALYSIS REPORT

Honeywell

FAILURE ANALYSIS LAB

HF-119

DATE	PROJECT	MALFUNCTION OR F&A REPORT #	REPORT #
1 July 1976	XM587E2 XM724		66623
PART NAME	DWG/PART #		GENERIC P/N
See Below	Various		
S/N	MANUFACTURER		DATE CODE
See Below	Various		Various

1. BACKGROUND 2. ANALYSIS PROCEDURE 3. EQUIPMENT USED 4. CONCLUSIONS 5. RECOMMENDATIONS (OPTIONAL)

1. Background

Four Hybrid Interface Circuits, three Hybrid Precision Oscillators, two 2N6010 transistors, and six solid tantalum capacitors were submitted for failure analysis. The units comprised most of the discrete part fallout from XM587E2 First Article Acceptance Sample (FAAS), XM587E2 Lot 1, and XM724 Lot 1. Table 1 provides a complete listing of the discrete part fallout from the above lots. Those not submitted to the Failure Analysis Lab were returned to HDL.

2. Analysis Procedure

The analyses of the failed devices proceeded as follows:

- Hybrid Precision Oscillator, SN 1236 - Assembly 1673

Electrical tests indicated a start-up voltage of -8.8Vdc (S/B -7.50Vdc max.). The device would not oscillate but tracked the D.C. input voltage from -8.8Vdc to -30Vdc. External visual examination showed no defects. Decapsulation and internal visual examination revealed conductive epoxy present on the large resistor array. The epoxy essentially short circuited 2N3799 transistor, Q1, emitter to collector (see Photo 1). The epoxy provided a conductive path from resistor R6 to resistor R4.

- Hybrid Precision Oscillator, SN 1283 - Assembly 1695

Electrical tests showed a start-up voltage of -8.8Vdc (S/B -7.50Vdc max.). The device would not oscillate but tracked the D.C. input voltage. External visual examination showed no defects. Decapsulation and internal visual examination revealed dendrites on the substrate surface (see Photos 2 and 3). The dendrites grew toward the transistor Q3 collector from the base and emitter. Further examination revealed more dendrites on the surface of the Q3 die. The dendrites appeared to short circuit the Q3 base - emitter and grew from both the base and emitter toward the die collector metallization ring (see Photos 4 and 5). It was noted that the ball bonds on the die and the stitch bond on the thick film were covered with a silver-grey residue (see Photos 6 and 7). Similar residue in smaller quantities was found on the bonds of transistor Q2. In order to determine the material composing the dendrites and the residue contamination on the bonds the device was submitted to the Metallurgical Laboratory. It was found that the dendritic formations are silver and that the residue present on the transistor bonds contains silver (see attached Metallurgical Lab Report 7821). On the basis of the above information it is concluded that some silver residue (probably silver epoxy used for die attachment) was present on the bonder collet during the bonding process. This silver material in the presence of moisture resulted in the dendrites on the substrate and on the die. A contaminated bonder collet also explains the presence of silver material on the transistor bonds.

- Hybrid Precision Oscillator, SN 680 - Assembly 1738

Electrical tests indicated a start-up voltage of -4.0Vdc (S/B -6.50Vdc min). The device would not oscillate but tracked the D.C. input voltage. External visual examination revealed no failure related defects. Internal visual examination showed the cause of failure to be a lifted ball bond on the transistor Q4 emitter (see Photo 8).

- Hybrid Interface Circuit #1116

Electrical testing verified the device failure at parameter T5B of the initializing circuit. No delay time measurement could be made. External visual examination showed no defects. Decapsulation and internal visual examination showed one lead of capacitor C1 to be open. The lead dress showed evidence of deformation due to handling (see Photo 9).

- Hybrid Interface Circuit #1349

Electrical testing showed all parameters to be within specification. Failure not verified.

- Hybrid Interface Circuit #1433

Electrical testing verified the circuit failure at parameter T5B of the initializing circuit. No delay time measurement could be made. External visual examination showed no defects. Decapsulation revealed a lifted lead bond on capacitor C1 (see Photo 10).

- Hybrid Interface Circuit #5215

Electrical measurements showed IR3 to be slightly out of specification limits at 1.12 mAdc (S/B 0.77 to 1.03 mAdc). The parameter appeared unstable. In addition, parameter V8B = -28.32 Vdc (S/B -22.6 to -26.0Vdc). No external defects were noted. Decapsulation and internal visual examination revealed no component defects relating to the failure. Microprobing showed diode CR23 and resistor R3 to be within specification limits. All bonds and lead wires in the associated circuitry were intact. The cause of the failure may have been surface contamination in the area of resistor R3 which was removed during decapsulation.

- G.E. Transistor 2N6010

Two small signal silicon NPN transistors were submitted. One of the two was known to be functional. The functional device was electrically tested and found to operate normally with h_{FE}=196. The second device was open circuited base to emitter and functional base to collector. External visual revealed the emitter lead to be loose in the epoxy encapsulation. A crack was evident in the epoxy near the emitter lead (see Photo 11). Decapsulation verified the emitter lead to be open (see Photos 12 and 13). The cracked epoxy encasement allowed sufficient movement of the external emitter lead to break the internal lead wire at the post bond heel.

- Solid Tantalum Capacitors - C4 of Assemblies 1186, 1423, 5313, 5325 and C1 of Assembly 1428 Short Circuited

Six solid tantalum capacitors (orange drop type) were submitted after failing electrically. Five of six exhibited nominal dissipation factor (D.F.) and capacitance values on first testing. However, during the leakage tests at rated voltage (50Vdc) all five units exhibited leakage currents of 1.0mAdc. Retesting showed the units to be essentially short circuited. Short circuiting was the initial failure mode observed before submittal to failure analysis. Decapsulation revealed an MnO_2 layer of irregular thickness. Because of the thin areas of MnO_2 the tantalum capacitors would not heal normally after an initial dielectric breakdown. Photo 14 illustrates the appearance of the MnO_2 in the breakdown area. Insufficient dielectric strength for the rated voltage combined with poor healing due to an irregular MnO_2 layer resulted in the capacitor failures.

One of six solid tantalum capacitors, C4, showed an intermittent open circuit during electrical testing. External visual examination revealed one external lead was loose (see Photo 15). Partial decapsulation showed the break to occur in the area of a void in the orange epoxy (see Photo 16). Handling combined with the weakened lead support caused by the epoxy void resulted in the open circuit.

4. Conclusions

Failure analysis was conducted on four hybrid interface circuits, three hybrid precision oscillators, two 2N6010 transistors and six tantalum slug capacitors. A summary of the results follows:

Hybrid Precision Oscillator

- SN 1236

  Failure Mode: High start-up voltage, no oscillations.
  Failure Mechanism: Q1 shorted emitter to collector due to conductive epoxy on resistor array.

- SN 1283

  Failure Mode: High start-up voltage, no oscillation.
  Failure Mechanism: Silver dendritic growth short circuiting transistor Q3 base to emitter.

- SN 680

  Failure Mode: Low start-up voltage, no oscillation.
  Failure Mechanism: Lifted ball bond on transistor Q4 emitter.

Hybrid Interface Circuits

- SN 1116

  Failure Mode: T5B failure in initializing circuit.
  Failure Mechanism: Open lead on capacitor C1.

- SN 1349

  Failure Mode: Failure not verified.

- SN 1433

  Failure Mode: T5B failure in initializing circuit.
  Failure Mechanism: Open lead on capacitor C1.

- SN 5215

Failure Mode: IR3 and V8B failures of current check and firing circuit.
Failure Mechanism: Undetermined, probably surface contamination near resistor R3.

Transistor 2N6010 - One unit was known to be functional and was not analyzed.

- G.E. 2N6010

Failure Mode: Open circuit emitter to base.
Failure Mechanism: Cracking of encasement epoxy near the emitter lead resulted in an open internal lead wire.

Solid Tantalum Capacitors

- 5 of 6

Failure Mode: Capacitors were short circuited.
Failure Mechanism: Dielectric strength insufficient for rated voltage and irregular MnO_2 layer.

- 1 of 6

Failure Mode: Capacitor intermittent open circuit.
Failure Mechanism: Broken lead aggravated by epoxy void.

Prepared by J. Timmerman Approved by D. Tabor

J. Timmerman
Failure Analyst

D. Tabor
Reliability Engineer

TABLE I

Origin	Part Type	Part Code	# Failures	Disposition
First Article Acceptance Sample	Transformer	T1	1	FA Lab
(FAAS)	Transformer	T1	1	FA Lab
XM587E2	Hybrid Interface Circuit	A1	1	
Quantity - 658	Hybrid Precision Oscillator	A5	1	FA Lab Report 66623
	Counter/Memory	A3	3	Returned to H.D.L.
Lot I	Hybrid Interface Circuit	A1	3	FA Lab Report 66623
XM587E2	Counter/Memory	A3	10	Returned to H.D.L.
Quantity - 1140	Solid Tantalum Capacitors	C4	3	FA Lab Report 66623
	Scaler Logic Overhead Safety Circuit	A2	1	Returned to H.D.L.
	Solid Tantalum Capacitors	C1	1	FA Lab Report 66623
	Hybrid Precision Oscillator	A5	11	FA Lab Report 66623
Lot I	Hybrid Interface Circuit	A1	1	FA Lab Report 66623
XM724	Solid Tantalum Capacitors	C4	2	FA Lab Report 66623
Quantity - 460	Counter/Memory	A3	1	Returned to H.D.L.

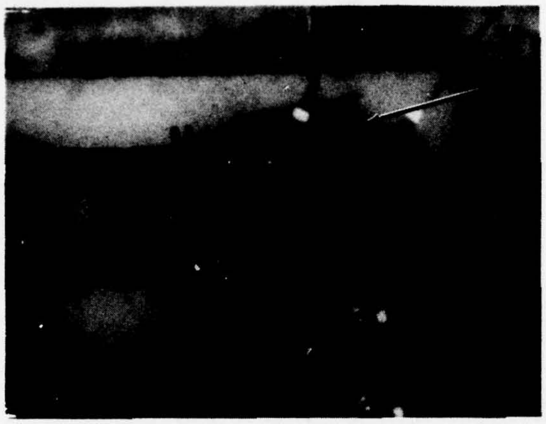

Photo 1 - Mag. 80X

Conductive epoxy short circuiting transistor Q1 collector to emitter on oscillator SN 1236.

Photo 2 - Mag. 80X

Dendritic growth near transistor Q3 on oscillator SN 1283. The thick film pads are electrically Q3 base and Q3 emitter.

Photo 3 - Mag. 110X

Close-up of the dendrites shown in Photo 2.

Photo 4 - Mag. 400X

The left side of the Q3 die surface. The arrows indicate areas of dendritic growth.

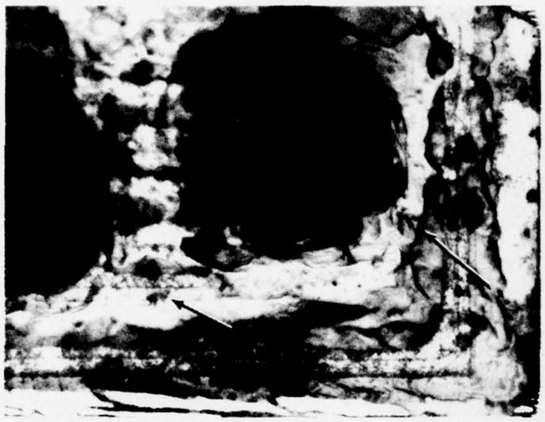

Photo 5 - Mag. 400X

The right side of the Q3 die shown in Photo 4. Arrows indicate dendrites.

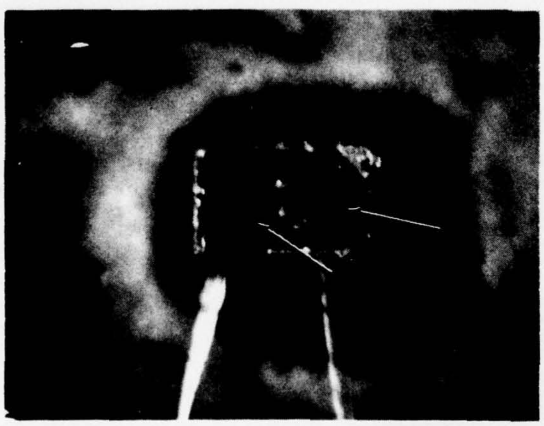

Photo 6 - Mag. 110X

Overall view of the Q3 die on oscillator SN 1283. Note the contaminated bonds.

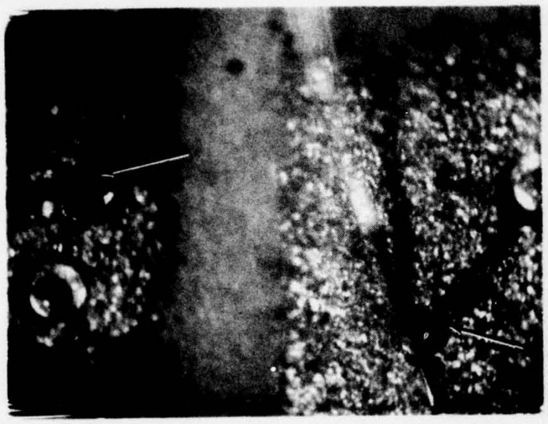

Photo 7 - Mag. 110X

The stitch and safety bonds on the Q3 emitter and base leads. Note the discoloration.

Photo 8 - Mag. 80X

The transistor Q4 emitter bond is lifted on oscillator SN 680.

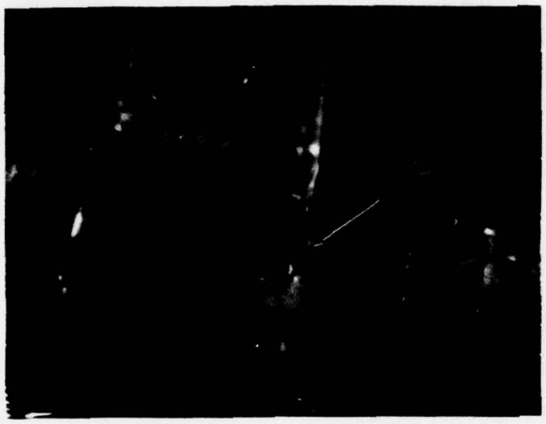

Photo 9 - Mag. 25X

Interface circuit capacitor C1 with an open lead wire.

Photo 10 - Mag. 25X

Capacitor C1 with a lifted ball bond.

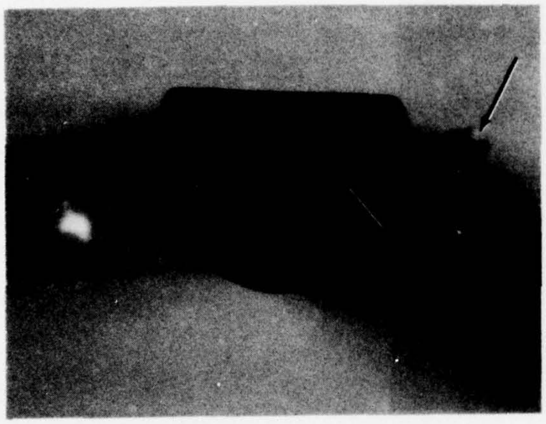

Photo 11 - Mag. 10X

External view of the bottom of transistor 2N6010. Note the crack in the epoxy encasement near the emitter lead. The top arrow identifies the emitter lead.

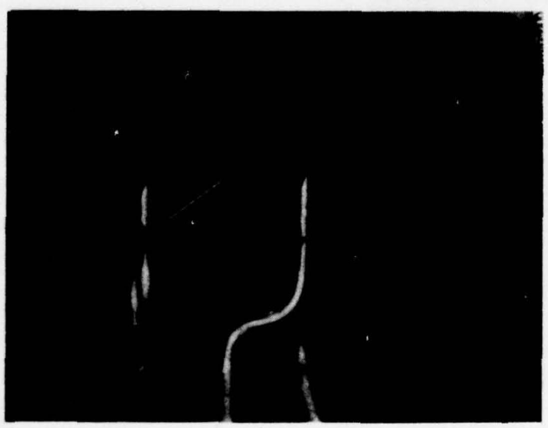

Photo 12 - Mag. 10X

Transistor 2N6010 after decapsulation. The arrow shows the area of the emitter lead break.

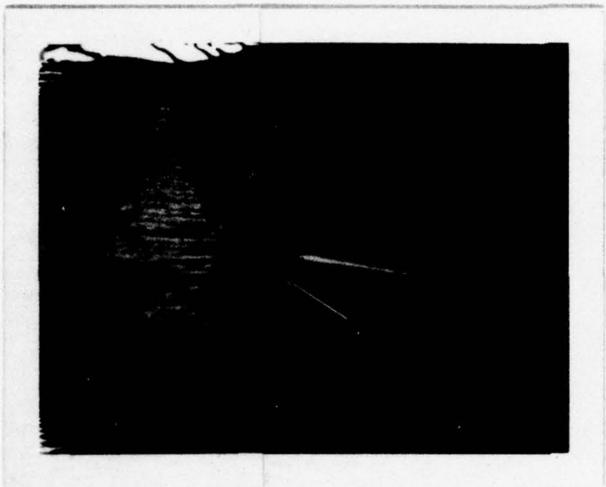

Photo 13 - Mag. 110X

Close up of the emitter lead shown in Photo 12. The break in the internal lead is apparent.

Photo 14 - Mag. 25X

Typical evidence of dielectric breakdown in a solid tantalum capacitor's MnO_2.

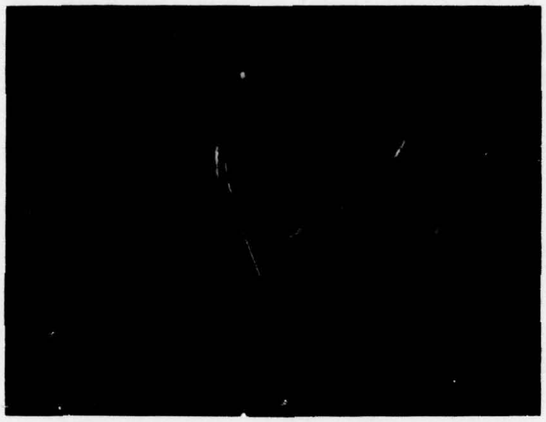

Photo 15 - Mag. 10X

External appearance of the intermittently open lead on 1 of 6 solid tantalum capacitors.

Photo 16 - Mag. 15X

Partial decapsulation revealed a void in the epoxy surrounding the break in the capacitor lead.

COPY LIST:

J. Timmerman
H1030

Honeywell

GOVERNMENT AND AERONAUTICAL
PRODUCTS DIVISION

REPORT NO. 7821

DEV. NO. W3987-EE-0030-111L

ENGINEERING TEST REPORT

DATE June 15, 1976

PAGE 1 OF 2

ISSUED BY:
G&APD METALLURGICAL LABORATORY

SUBJECT: Dendrite Formation on XM-587 Hybrid.

BACKGROUND:

During Production Electrical testing, a hybrid was found which tracked D-C but which did not oscillate. The hybrid was opened and stripped of most of the silicone potting on the hybrid and visually examined. This visual examination showed a dendrite formation which looked similar to that studied in August of 1975. The hybrid was then submitted to the Metallurgical Laboratory for analysis and documentation of the dendritic material.

PURPOSE OF REQUEST:

Analyze and document the dendritic material and determine the cause of discoloration on some ball bonds.

CONCLUSION:

The dendrites are silver, as was the case in August 1975. The discolored ball bonds show the presence of silver and some silicone which had not been completely removed. The silver most likely has a thin sulfide layer on its surface as a result of the stripping operation, making it dark.

DISCUSSION:

The hybrid was carbon coated to prevent charging during SEM analysis. Figures 1 through 4 show areas of dendrite formation which can be seen more readily by a light microscope than on the SEM. The x-ray map of Figure 3 clearly shows the silver dendrite shape. Figure 2 (secondary mode) shows the same area, but the photo must be studied carefully to see the dendrites as they are largely obscured by a residue film on the substrate. The sulfur distribution, Figure 4, shows a slight sulfur enhancement in the dendrite area, so that the dark visual appearance of the silver dendrites could be due to a sulfide layer.

X-ray analysis of area A of Figure 5 shows major sulfur, trace aluminum, silicon, silver and nickel. Area B of Figure 5, a discolored ball bond, shows major sulfur and gold; minor silver and aluminum; trace nickel.

KEYWORDS:

XM-587
Dendrite

ATTACHMENTS:

11 Figures

DATA BOOK NO.	PAGE		
REQUESTED BY: B. Goblish H1030	DATE: 5/24/76	WRITTEN BY: D.J. Hajicek H1840	
DEPARTMENT: Failure Analysis Laboratory		APPROVED	

40145
6/11/76 lks

HE-44 (DITTO MASTER)
HE-44A (DUPLICATOR)
REV 4/75

DISCUSSION: (continued)

X-ray analysis of the dendrite material shows major aluminum (from Al_2O_3 substrate), silver and sulfur. Trace amounts of silicon, nickel, lead and chlorine are present.

X-ray analysis of the discolored ball bond on Q_2 (Figure 7), shows major gold (and possibly sulfur), minor silver and trace aluminum.

Figures 5 and 6 give some idea of the silver distribution on transistor Q_3. The discoloration of the ball bond could be due to sulfided silver since both these elements are present on the ball bond. The same seems to be true for the discolored bonds on Q_2, but the high gold peak obscures the sulfur peak so that it is not possible to tell how much sulfur is present, if any.

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SCANNING ELECTRON MICROSCOPE-MICROPROBE RECORD

Figure 1.

160 X

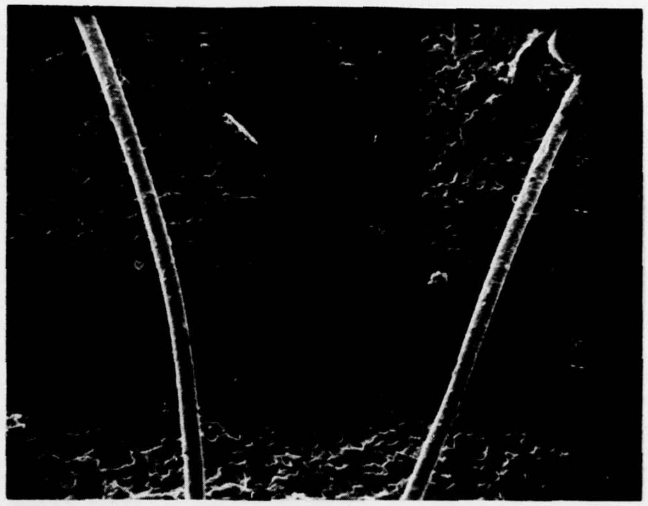
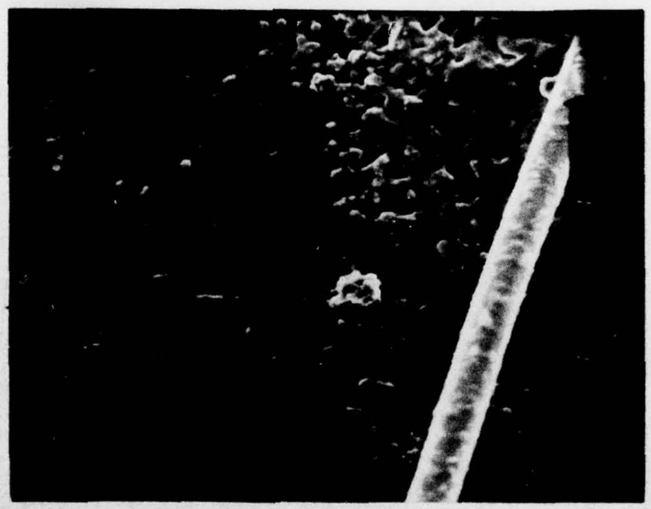


Figure 2.

400 X



DEVICE/PART NO. XM-587 Hybrid   CUSTOMER B. Goblish

ENGINEER D.J. Hajicek   MODE Secondary and X-ray

FIGURE 1. Q3, area of dendrite formation between connector pads, dendrites are roughly under where the wires cross over the ceramics. 2. Q3. Detail of dendrites.

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Figure 3.

400 X

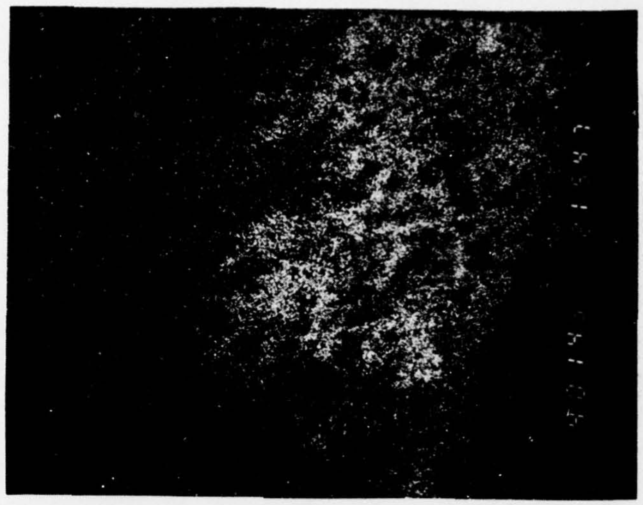

Figure 4.

400 X

DEVICE/PART NO. XM-587 Hybrid CUSTOMER B. Goblish

ENGINEER D.J. Hajicek MODE Secondary and x-ray

FIGURE 3. Q_3, x-ray map for silver on the area of Figure 3. 4. Q_3, map for sulfur as above.

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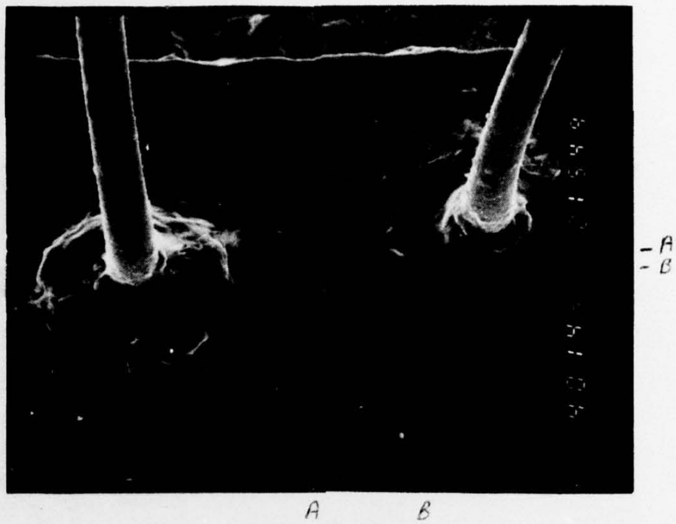

Figure 5.

400 X

Figure 6.

400 X

DEVICE/PART NO. XM-587 Hybrid

CUSTOMER B. Goblish

ENGINEER D.J. Hajicek

MODE Secondary and x-ray

FIGURE 5. Q3, transistor with ball bonds. Some silicone coating still present, obscuring active area. 6. Q3, Map for silver on the area of Figure 5. There is some silver on the ball bonds and on the transistor in the center region.

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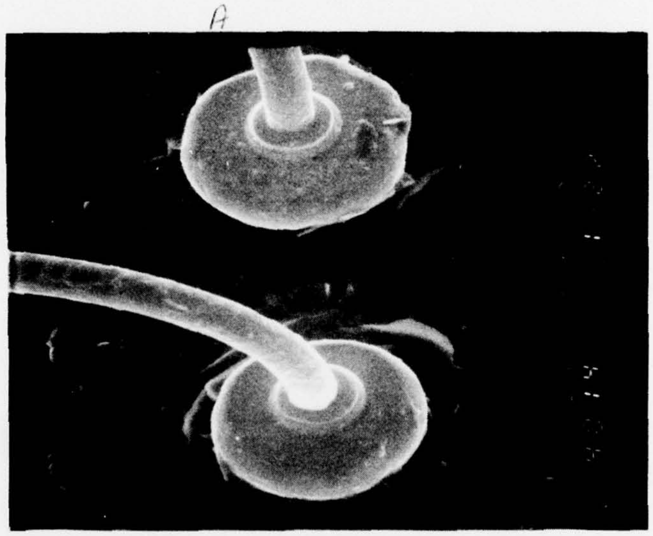

Figure 7.

400 X

DEVICE/PART NO. XM-587 Hybrid CUSTOMER B. Goblish

ENGINEER D.J. Hajicek MODE Secondary and X-ray

FIGURE 7. Q2, ball bonds which were discolored.

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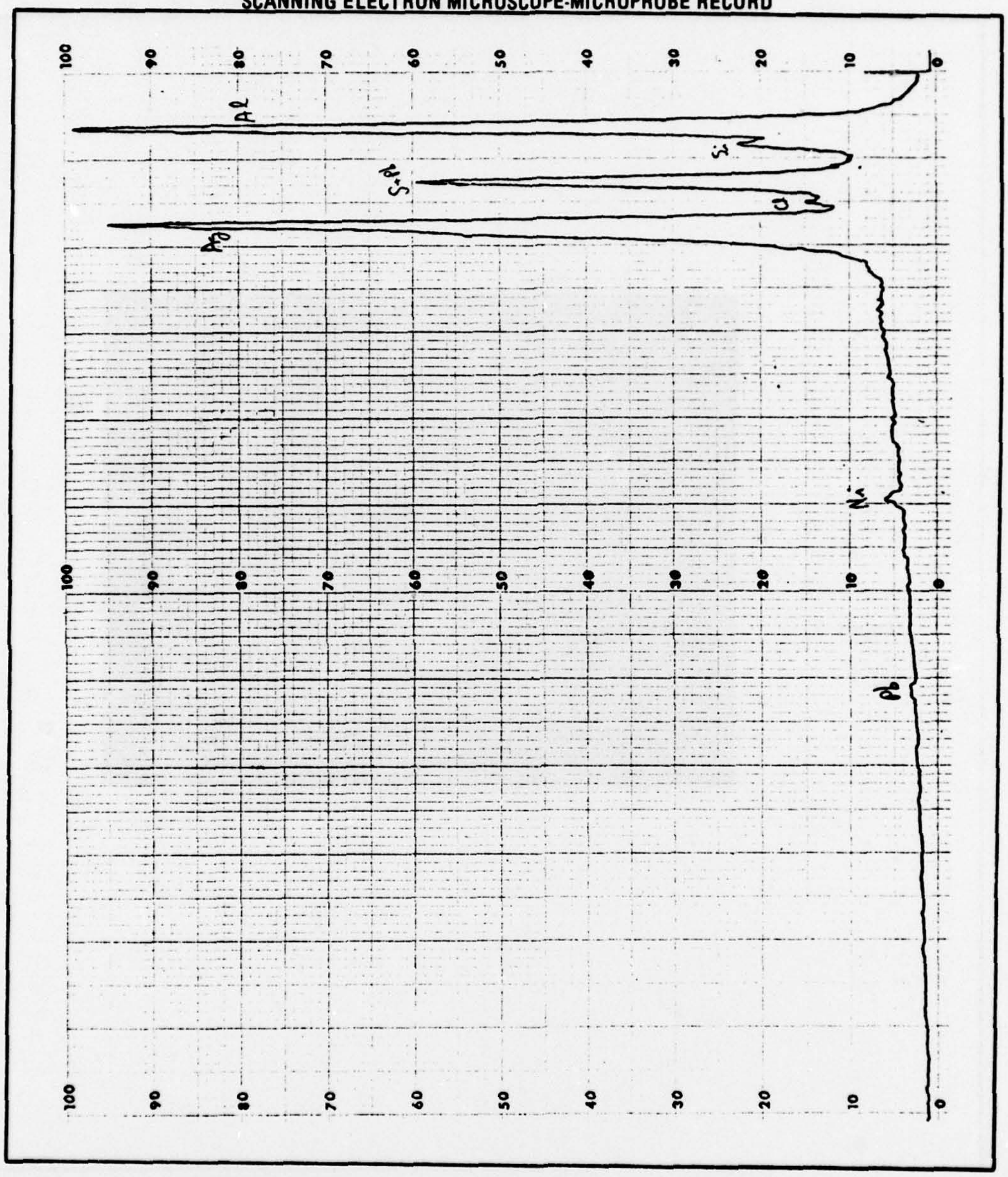

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FIGURE 8. Analysis of dendrite of Figure 2. 21KV.

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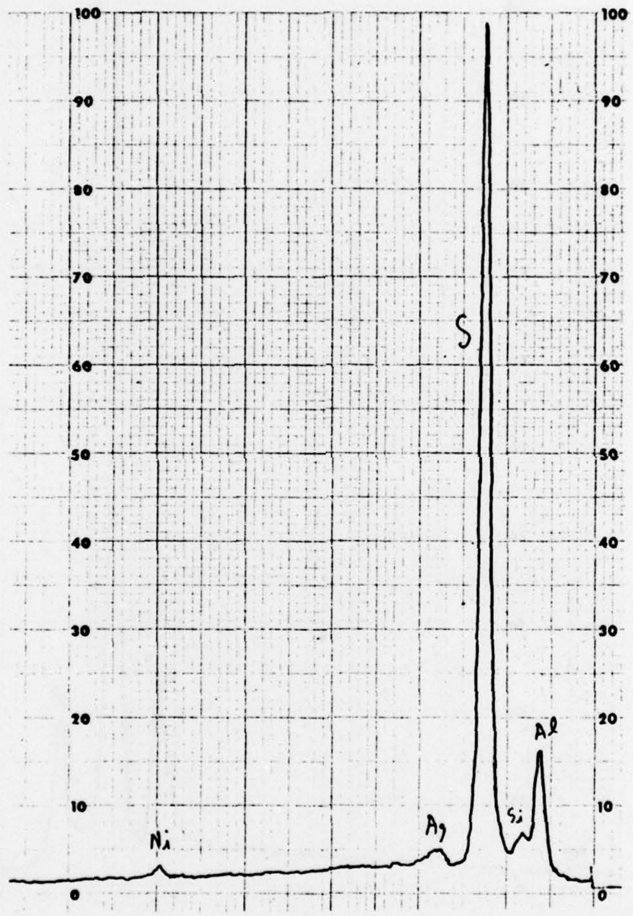

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FIGURE 9. Analysis of area A on Figure 5.

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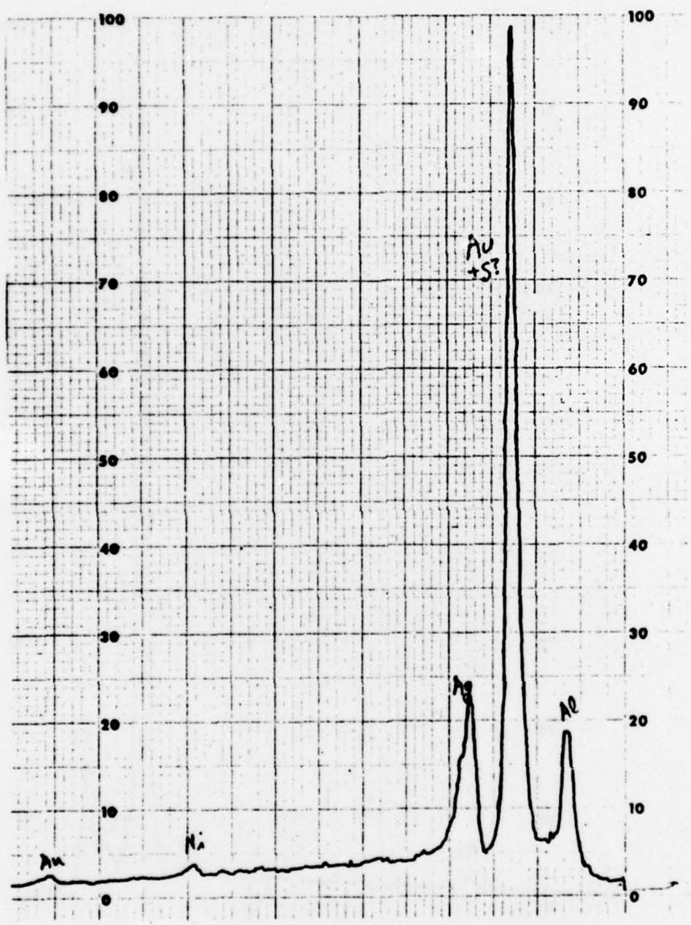

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FIGURE 10. Analysis of area B of Figure 5.

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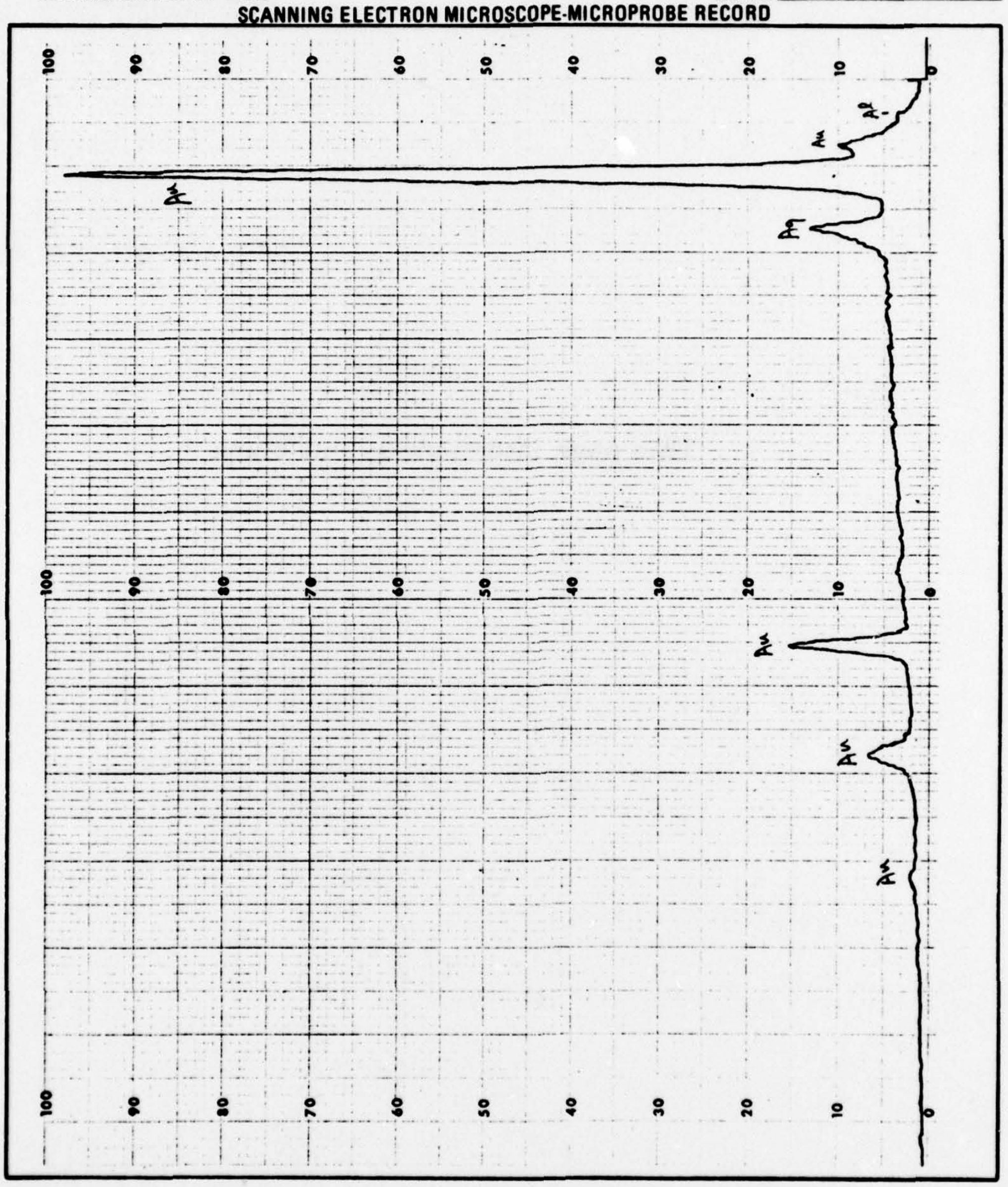

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FIGURE 11. Analysis of ball bond.

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APPENDIX E

FAILURE ANALYSIS LABORATORY REPORT
XM587E2 FUZE HYBRID INTERFACE CIRCUIT AND PRECISION OSCILLATOR CIRCUIT
(PART NUMBERS 11711610 AND 11711625)

GOVERNMENT and AERONAUTICAL PRODUCTS DIVISION

FAILURE ANALYSIS REPORT

Honeywell

FAILURE ANALYSIS LAB

HF-119

DATE	PROJECT	MALFUNCTION OR F&A REPORT #	REPORT #
9 February 1976	XM587		66194 and 66195
PART NAME: Hybrid Interface Circuit Precision Hybrid Osc.	DWG/PART #: 11711610 and 11711625		GENERIC P/N
S/N: 42, 59, 110 14 & 91	MANUFACTURER: Honeywell		DATE CODE: 7537

1. BACKGROUND 2. ANALYSIS PROCEDURE 3. EQUIPMENT USED 4. CONCLUSIONS 5. RECOMMENDATIONS (OPTIONAL)

1. Background

Three Hybrid Interface Circuits and two Precision Hybrid Oscillators were submitted to the Failure Analysis Lab for failure determination. The hybrid microcircuits had failed Lot 1 Acceptance Testing.

2. Analysis Procedure

- SN 59 - Hybrid Interface Circuit

The hybrid microcircuit failure was not verified electrically. Analysis was discontinued.

- SN 110 - Hybrid Interface Circuit

The hybrid microcircuit failure was not verified electrically. Analysis was discontinued.

- SN 42 - Hybrid Interface Circuit

Electrical testing per the HDL specification drawing 10990455, subgroup A2, operating parameters indicated failures at the following test points; IR3, IR8, VIIA and V5D. Test measurements at IR3, VIIA and V5D implied an open circuit or high impedance at diode CR23. Chemical decapsulation revealed the anode lead bond had lifted from the CR23 diode die (see Figure 1). Transistor Q6 also revealed a metallization smear shorting the Q6 emitter and base (see Figure 2). The failure of parameter IR8 resulted from the transistor Q6 short circuit. The smear on the Q6 die resulted from a misplaced ball bond.

- SN 14 - Hybrid Precision Oscillator

Electrical testing per HDL-0002-071, Group A, confirmed the oscillator output tracked the DC input level intermittently at high temperature. The failure mode implied an intermittent open circuit in the twin-T network or the initial stages of the amplifier. Chemical decapsulation revealed the emitter lead of transistor Q1 to be broken (see Figure 3). The lead was apparently degraded during the bonding process.

- SN 91 - Hybrid Precision Oscillator

  Electrical tests per HDL-0002-071, Group A, revealed a low (-9 Vdc minimum) start up voltage with elevated temperature. Decapsulation did not reveal any obvious surface defects. Microprobing revealed the source of the failure to be a high impedance contact at capacitor C3. Placement of the ball bond on the capacitor termination metallization created a microfracture around the bond (see Figure 4).

4. Conclusions

Failure Analysis results are as follows:

- SN 59 - Failure not verified.

- SN 110 - Failure not verified.

- SN 42 - Failure Mode - Failed operating parameters IR3, IR8, VIIA, V5D.

  Failure Mechanism - Lifted ball bond on diode CR23.

  Smeared metallization across the transistor Q6 base-emitter metallization due to a misplaced ball bond.

  Mechanism Cause - Oxides or other foreign material on the die metallization.

- SN 14 - Failure Mode - Intermittent oscillation at elevated temperature.

  Failure Mechanism - Transistor Q1 emitter lead broken.

  Mechanism Cause - Lead wire handling.

- SN 91 - Failure Mode - Low start-up voltage at high temperature.

  Failure Mechanism - Microfracture of the termination metallization around the ball bond on capacitor C3.

  Mechanism Cause - Poor capacitor termination metallization adherence.

Prepared by J. C. Timmerman — Approved by B. E. Goblish

J. C. Timmerman
Failure Analyst

B. E. Goblish
Reliability Engineer

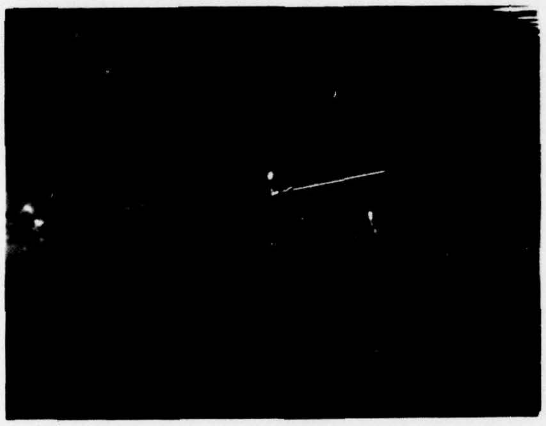

Figure 1 - Mag. 25X

Ball bond lifted off the CR23 die.

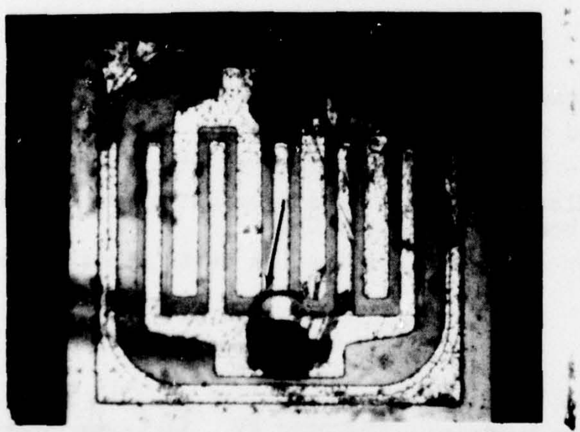

Figure 2 - Mag. 165X

Transistor Q6 die with a metallization smear across the B-E metallization. The smear resulted from a misplaced ball bond.

Figure 3 - Mag. 30X

Transistor Q1 emitter lead broken.

Figure 4 - Mag. 22X

Capacitor C3 showing the location of the intermittent bond which caused the oscillator failure. Note the metallization still attached to the gold ball bond.

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