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FLEXIBLE EXPLOSIVE LEAD, EX 22 MOD 0 DESIGN EVALUATION

by

M. R. Osburn
Fuze Department

ABSTRACT. A description of the design evaluation tests performed on the Ex 22 Mod 0 Flexible Explosive Lead is presented, together with the test results.

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M. R. Etheridge, Capt., USN .... (ɴder
Thomas S. Amlie, Ph.D. .... Technic. ector

FOREWORD

This report presents a description of the design evaluation tests performed to determine the adequacy of the design of the Ex 22 Mod 0 Flexible Explosive Lead. This lead is used in the Phoenix AIM-54A guided missile.

The work covered in this report was performed under AIRTASK A05-510-233/216-1/W16-08-000.

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2 March 1970

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THOMAS S. AMLIE
Technical Director

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INTRODUCTION

The Ex 22 Mod 0 Flexible Explosive Lead is a component of the Ex 334 Mod 0 Fuze. The lead transfers (explosively) the explosive output of the Ex 334 Mod 0 Fuze to the Ex 60 Mod 0 Fuze Booster, whose purpose is to detonate the Ex 55 Mod 0 warhead. Figure 1 shows the configuration of these components.

This report gives a physical description of the Ex 22 Flexible Expl)sive Lead followed by a description of the tests used to evaluate its performance.

PHYSICAL DESCRIPTION

The Ex 22 Flexible Explosive Lead is, as the name implies, a flexible explosive component, as illustrated in Fig. 2 and 3. The detonating cord (the flexible part) consists of 30 grains per foot of RDX composition CH-6 explosive encased in a lead sheath. The lead sheath is covered with an extruded polyethelene coating over which go two layers of woven fiberglass yarn (see Fig. 4). The detonating cord is manufactured in continuous lengths up to a few hundred feet long.

At each end, ferrules are swaged onto the detonating cord. Figures 5 and 6 show a cutaway view of the donor and acceptor ferrules. The end ferrules are threaded to provide teeth which bite into the cord, the larger diameter threads bite into the fiberglass and the smaller diameter threads bite into the lead. The accepter charge (see Fig. 6) is 446 mg of RDX composition CH-6. The donor charge is 492 mg of the same explosive material. The overall length of the assembly is 12.5 in.

The assembled lead is covered with a transparent heat-shrinkable tubing to protect the label. This tubing was also found to significantly reduce the amplitude of lead movement when the lead was vibrated at its resonant frequency.

FIG. 1. Phoenix Explosive Components.

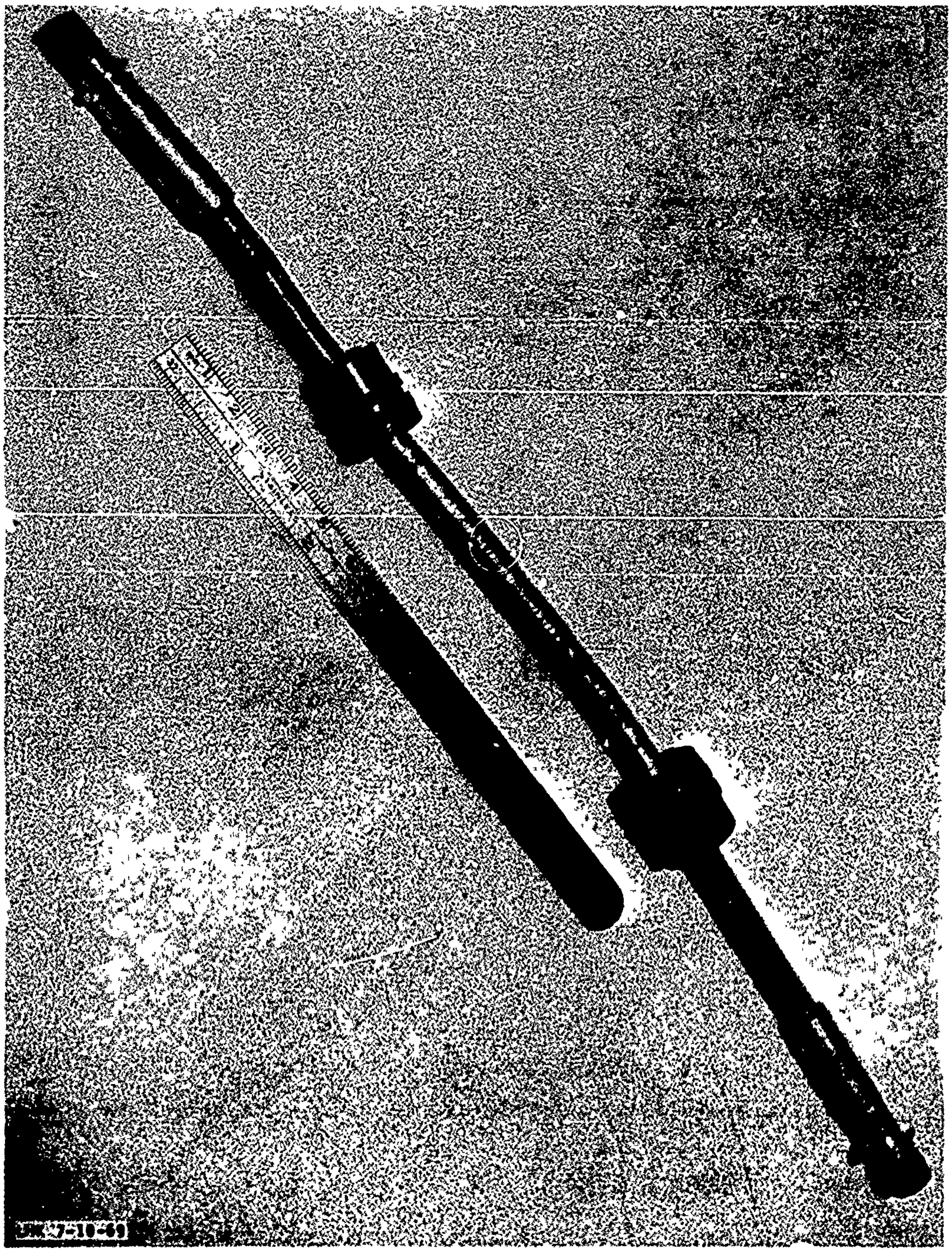

FIG. 2. Flexible Explosive Lead.

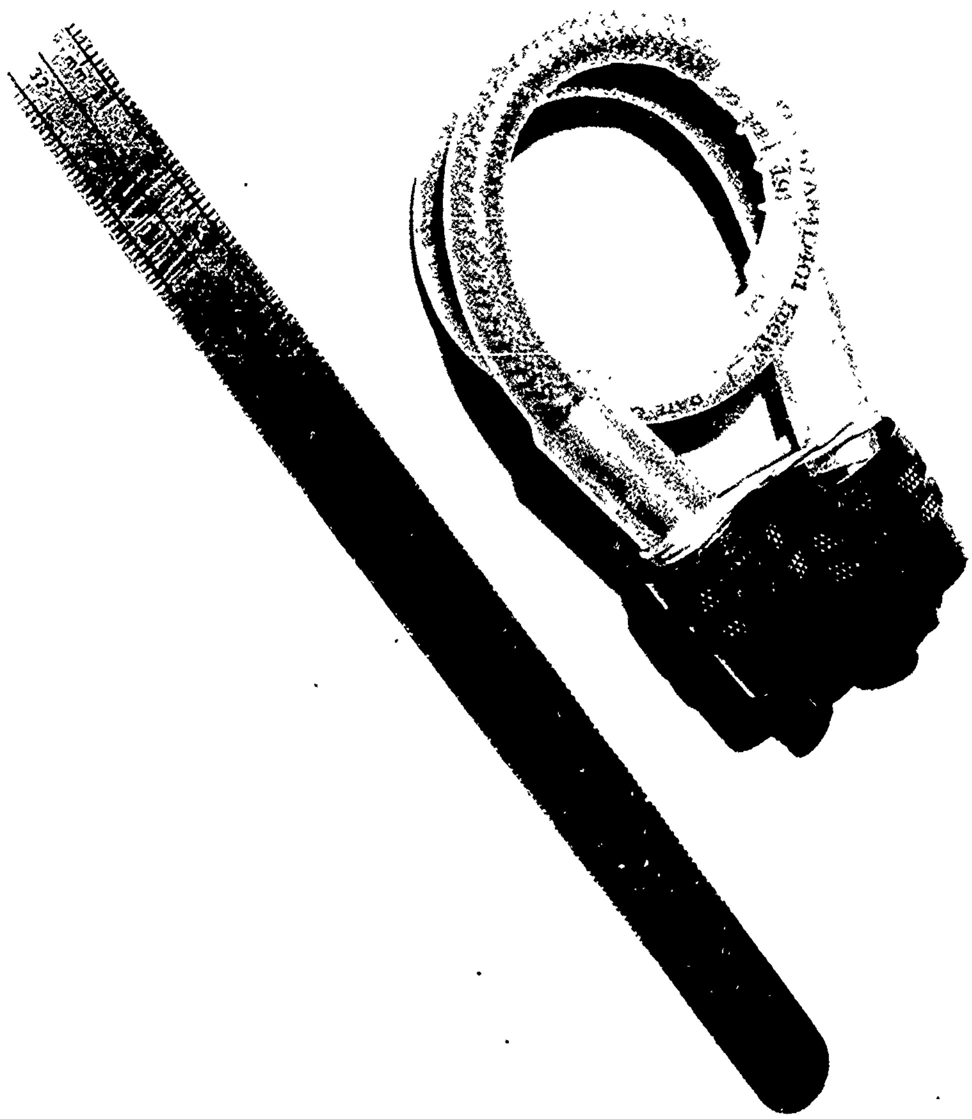

FIG. 3. Demonstration of Lead Flexibility.

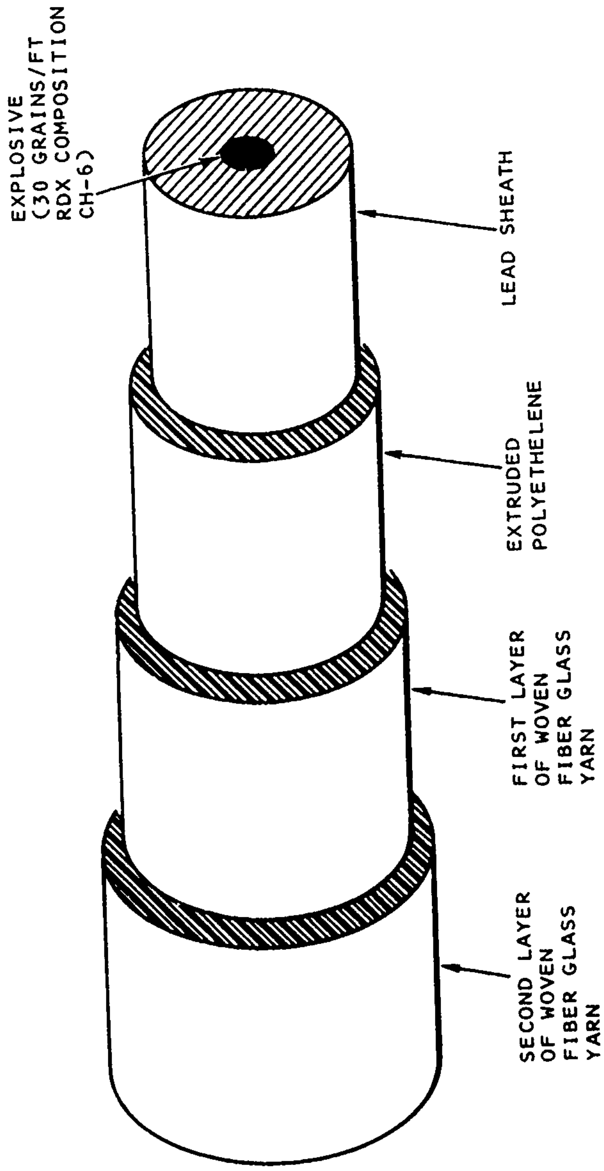

FIG. 4. Detonating Cord.

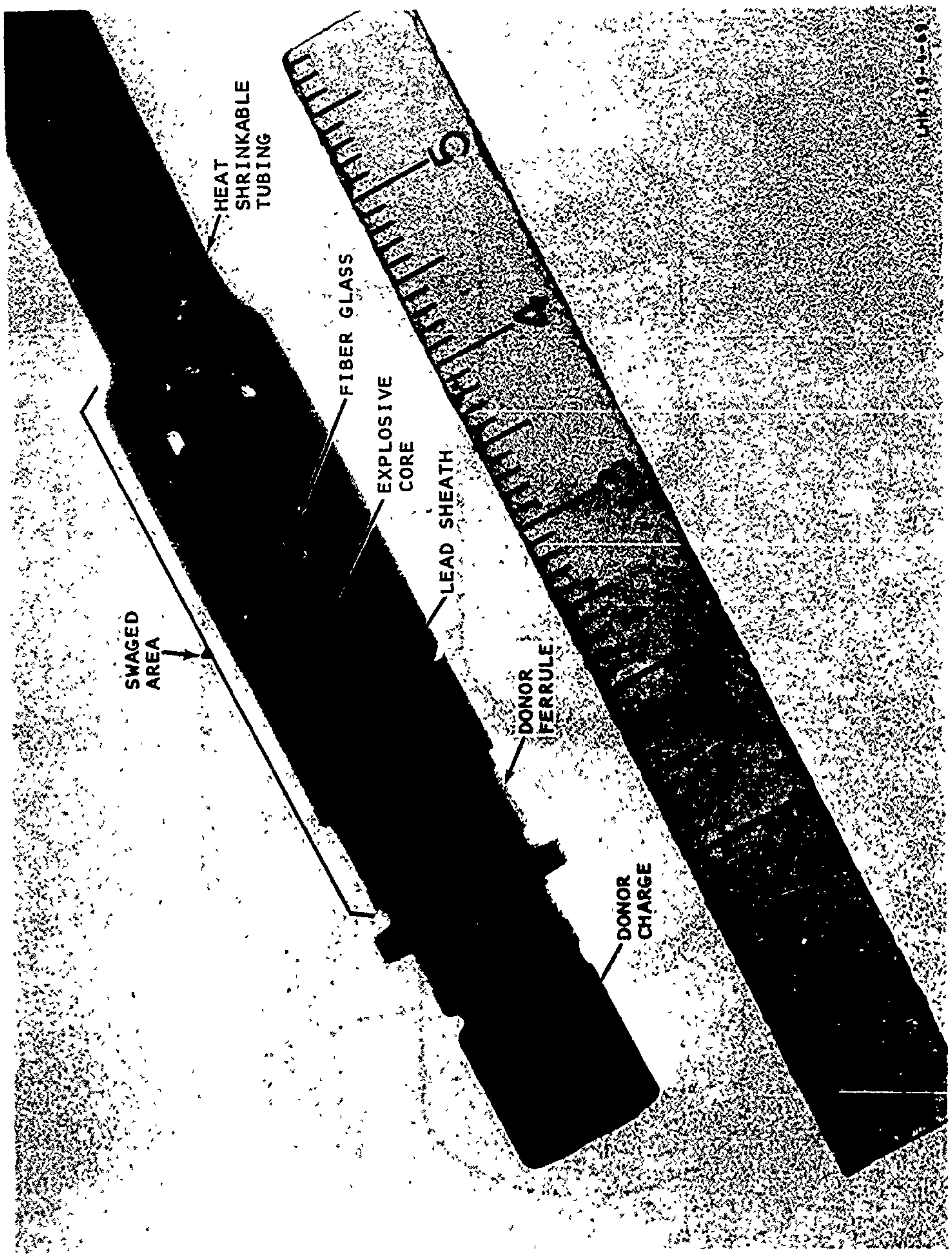

FIG. 5. Donor End of Lead.

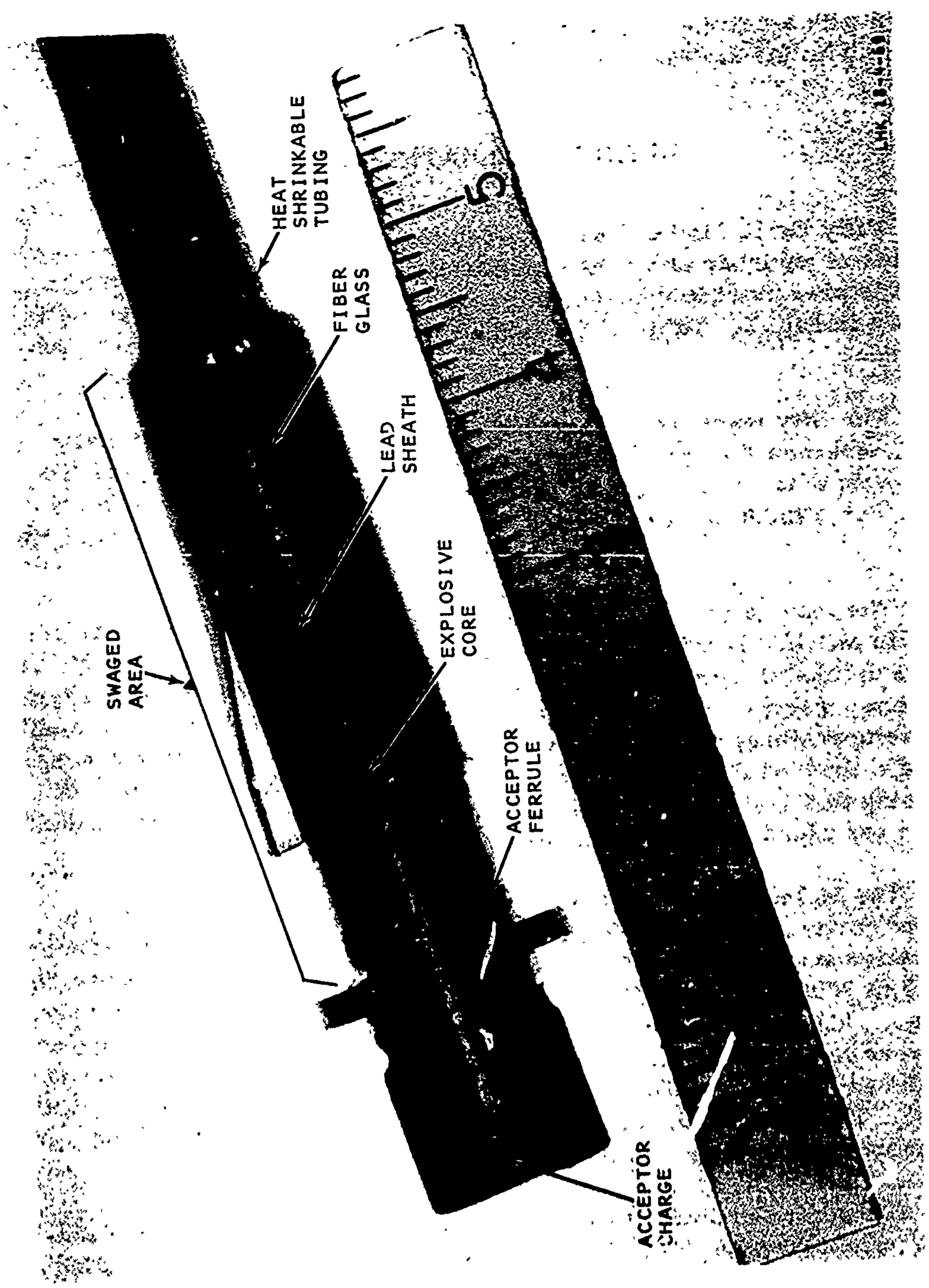

FIG. 6. Acceptor End of Lead.

The acceptor end of the lead fits into the explosive output coupling of the Ex 334 Mod 0 Fuze and is held in place by a coupling nut which locks with a bayonet type connection. The donor end fits into the booster with a similar arrangement.

DESIGN EVALUATION TESTS

Fifty Ex 22 Mod 0 Flexible Explosive Leads were subjected to a series of environmental tests to evaluate the lead design. The test plan is presented in the Appendix. A diagram of the test sequence is shown in Fig. 7. Table 1 shows the tests to which each lead was subjected.

The fifty leads were X-rayed, then subjected to a 20-lb tensile test, and then X-rayed again. Comparison of the X-rays before the test with those after the test showed that all leads had come through this test without being deformed, as was required for them to pass the test.

The leads were next subjected to Transportation Vibration as specified in MIL-STD-331, Test 104, Procedure I. For this test the 50 leads were divided into three groups, and each group was tested at a different temperature. Seventeen leads were vibrated at 160°F, 16 at ambient temperature, and 17 at -65°F. Since there was no performance requirement at this point in the test program, the only criterion for passing this test was that the leads show no deformation or irregularity when examined visually. All leads passed this test.

The 50 leads were then separated into different groups and subjected to various tests. Twenty-seven leads were subjected to random vibration at a power spectral density of 0.02 g^2/Hz over the bandwidth of 20 to 2000 Hz for two hours in each of three mutually perpendicular axes. This test was conducted at ambient temperature. After the test, 17 were fired to check their outputs as measured by the depth of dent produced in a 5/8-in. by 1 1/4-in. by 1 1/4-in. block of 1018 or 1020 steel. The depth of the dents showed that all 17 had withstood the environments of these tests.

The other ten units of the 27 were subjected to a destructive tensile test. The test plan in the Appendix called for applying an increasing tensile load to a lead while monitoring its electrical continuity from one

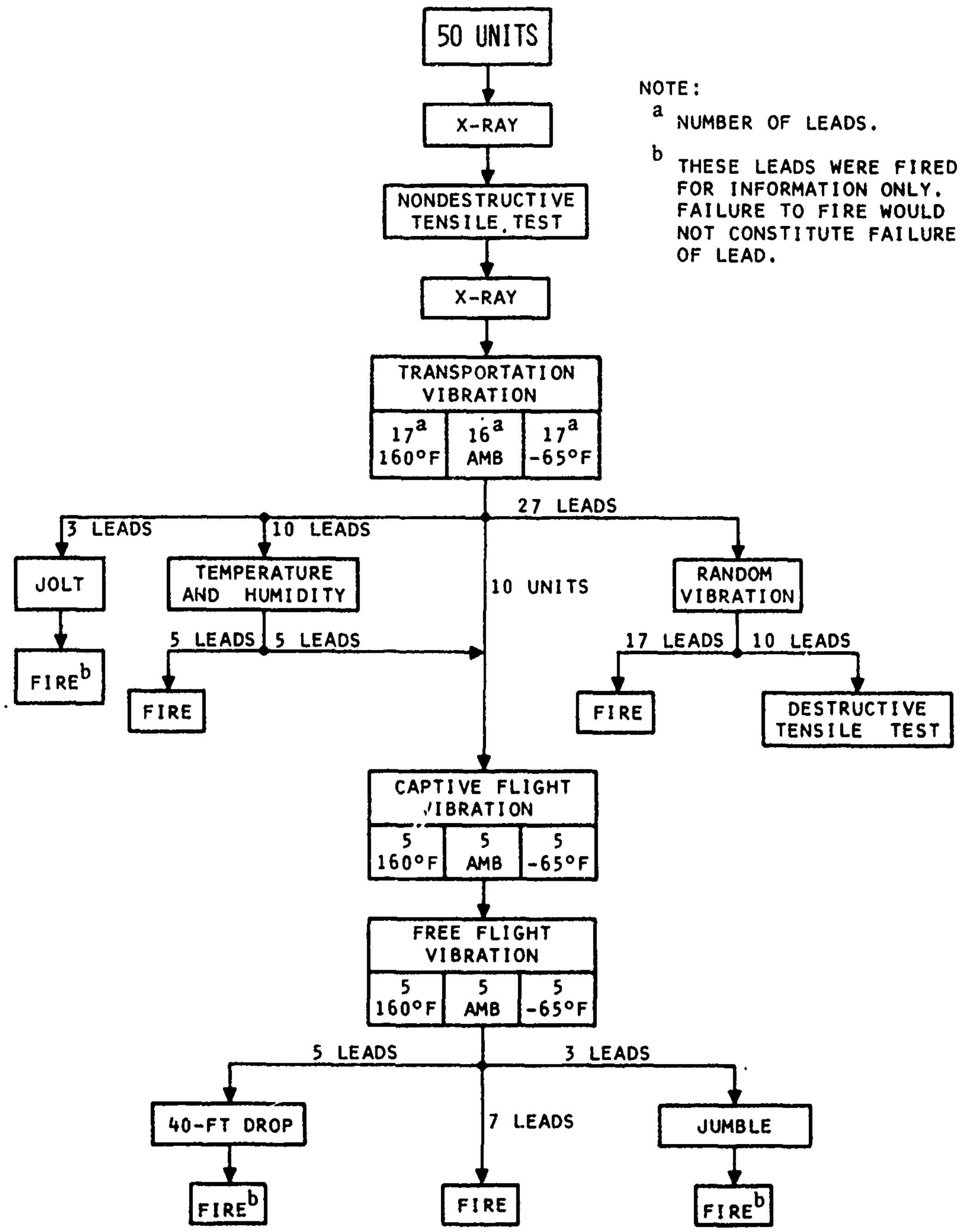

FIG. 7. Design Evaluation Test Sequence.

TABLE 1. Test Data for Individual Leads.

An entry marked with a dash indicates the lead did not undergo that test.

Test unit no.	Vibration tests (denoted by test temperature)				Destructive tensile load, lb	Other tests	Dent value, in.
	Transportation	Captive flight	Free flight	Random			
1	160°F	---	---	Ambient	280	---	---
2		---	---		266	---	---
3		---	---		276	---	---
4		---	---		---	---	.028
5		---	---		---	---	.028
6		---	---		---	---	.027
7		---	---		---	---	.029
8		---	---		---	---	.029
9		---	---		---	---	.025
10		160°F	160°F	---	---	Jumble	---
11				---	---	40-ft drop	---
12				---	---	40-ft drop	---
13				---	---	Temp. & hum.	.027
14				---	---	Temp. & hum.	.027
15		---	---	---	---	Temp. & hum.	.029
16		---	---	---	---	Temp. & hum.	.026
17		---	---	---	---	Jolt	---
18	Ambient	---	---	Ambient	280	---	---
19		---	---		252	---	---
20		---	---		260	---	---
21		---	---		---	---	.028
22		---	---		---	---	.032
23		---	---		---	---	.029
24		---	---		---	---	.027
25		---	---		---	---	.028

TABLE 1. (contd.)

Test unit no.	Vibration tests (denoted by test temperature)				Destructive tensile load, lb	Other tests	Dent value, in.
	Transportation	Captive flight	Free flight	Random			
26	Ambient	---	---	Ambient	---	---	.028
27	↓	Ambient	Ambient	---	---	---	.027
28	↓	↓	↓	---	---	---	.028
29	↓	↓	↓	---	---	---	.027
30	↓	↓	↓	---	---	[Temp. & hum. Jumble]	---
31	↓	↓	↓	---	---	[Temp. & hum. 40-ft drop]	---
32	↓	---	---	---	---	Temp. & hum.	.032
33	↓	---	---	---	---	Jolt	---
34	-65°F	---	---	Ambient	---	---	.028
35	↓	---	---	↓	---	---	.028
36	↓	---	---	↓	---	---	.025
37	↓	---	---	↓	---	---	.028
38	↓	---	---	↓	---	---	.027
39	↓	---	---	↓	276	---	---
40	↓	---	---	↓	238	---	---
41	↓	---	---	↓	276	---	---
42	↓	---	---	↓	280	---	---
43	↓	---	---	---	---	Temp. & hum.	.027
44	↓	---	---	---	---	Temp. & hum.	.029
45	↓	-65°F	-65°F	---	---	[Temp. & hum. Jumble]	---
46	↓	↓	↓	---	---	40-ft drop	---
47	↓	↓	↓	---	---	40-ft drop	---
48	↓	↓	↓	---	---	---	.029
49	↓	↓	↓	---	---	---	.029
50	↓	---	---	---	---	Jolt	---
							$\bar{x}$ = .028
							σ = .0016

ferrule to the other. The point of failure would be considered the point at which continuity was broken. It turned out, however, that this test plan would not work. It was found that in six units continuity was not broken until long after the maximum tensile load had been achieved, but in one unit continuity was broken long before the maximum load had been reached. The other three had no electrical continuity to begin with. X-rays of these three revealed no discrepancies in their construction. The ferrules were insulated from the lead sheath, possibly by the epoxy used in the assembly of the leads. Because of these inconsistencies it was decided to note only the maximum load achieved before the leads ruptured. The average maximum load was 268 lb, and the minimum was 238 lb. The original design goal had been for the leads to withstand a 150-lb tensile load without severing. These ten leads exceeded that goal by a large margin.

Three leads were subjected to the Jolt Test after the Transportation Vibration Test. The Jolt Test was performed according to MIL-STD-331, Test 101. Following this test visual examination revealed no discrepancies in the leads; however, when they were fired, they showed a significantly reduced output, indicating they had sustained internal damage to the explosive structure. The criterion for passing this test was that the leads must not have detonated or burned during this test. It was not required that they be functional following this test; therefore, the leads passed this test.

Ten leads underwent Temperature and Humidity, Test 105 of MIL-STD-331 following Transportation Vibration. Five leads were fired, upon completion of this test, to check their ability to function after being subjected to this environment; the dent values obtained were sufficient to meet the test requirement.

The other five units from the Temperature and Humidity Test were combined with the ten units remaining from the Transportation Vibration Test, and together they were subjected to Captive Flight Vibration (see specification 7 in the Appendix). Visual examination following this test revealed no discrepancies in the leads.

These 15 units were then subjected to the Free Flight Vibration Test as specified in specification 8 in the Appendix.

Seven units were fired following this test. The dents obtained were of an acceptable depth. The success of these units in firing also demonstrated the ability of the leads to pass all preceding tests.

Three units from the group that had been given the Free Flight Test were subjected to the Jumble Test, as prescribed by MIL-STD-331, Test 102. These units sustained slight deformation of the acceptor booster cup during this test (see Fig. 8). These units were fired, and the dents obtained were of acceptable depth. Since the only criterion for passing this test was that the leads must not detonate or burn during the test, the leads exceeded this requirement by proving to be functional within acceptable limits as well.

The other five units were subjected to the Forty-Foot Drop Test, Test 103, MIL-STD-331. This test was performed in conjunction with the design evaluation test of the Ex 334 Mod 0 Fuze. The test vehicle used is shown in Fig. 9; it is approximately 5 ft long and weighs 650 lb. The mounting configuration of the fuze and lead is shown in Fig. 10. The tests were performed with the vehicle in the five attitudes prescribed in MIL-STD-331. Extensive damage to the leads was sustained in these tests. In the 45°-from-vertical, tail-down drop, the lead was broken into three separate pieces (see Fig. 11). Again in the nose-down drop, the lead was broken in two, as shown in Fig. 12 and 13. However, since the explosive did not burn or detonate, these leads successfully passed this test.

DEVELOPMENTAL TESTS

Two significant tests that were conducted during the development of this lead will be included in this report.

One test was conducted by subjecting the leads to extensive vibration at their resonant frequency. The mounting of the lead in the missile leaves the entire length of explosive cord unsupported and therefore susceptible to vibration. The first two leads, S/N 1 and 2, were attached to a vibration fixture (the same one as used for the design evaluation tests) to which the leads are mounted in the same configuration as in the missile.

Photographic means were used to determine the resonant frequency of the leads; the frequency was revealed to be between 90 and 100 Hz. The greatest excursions occurred when the leads were vibrated along the axis corresponding to the missile longitudinal axis. The heat-shrinkable tubing used to protect the identification plate had been removed on S/N 1. The film showed much greater excursions at the

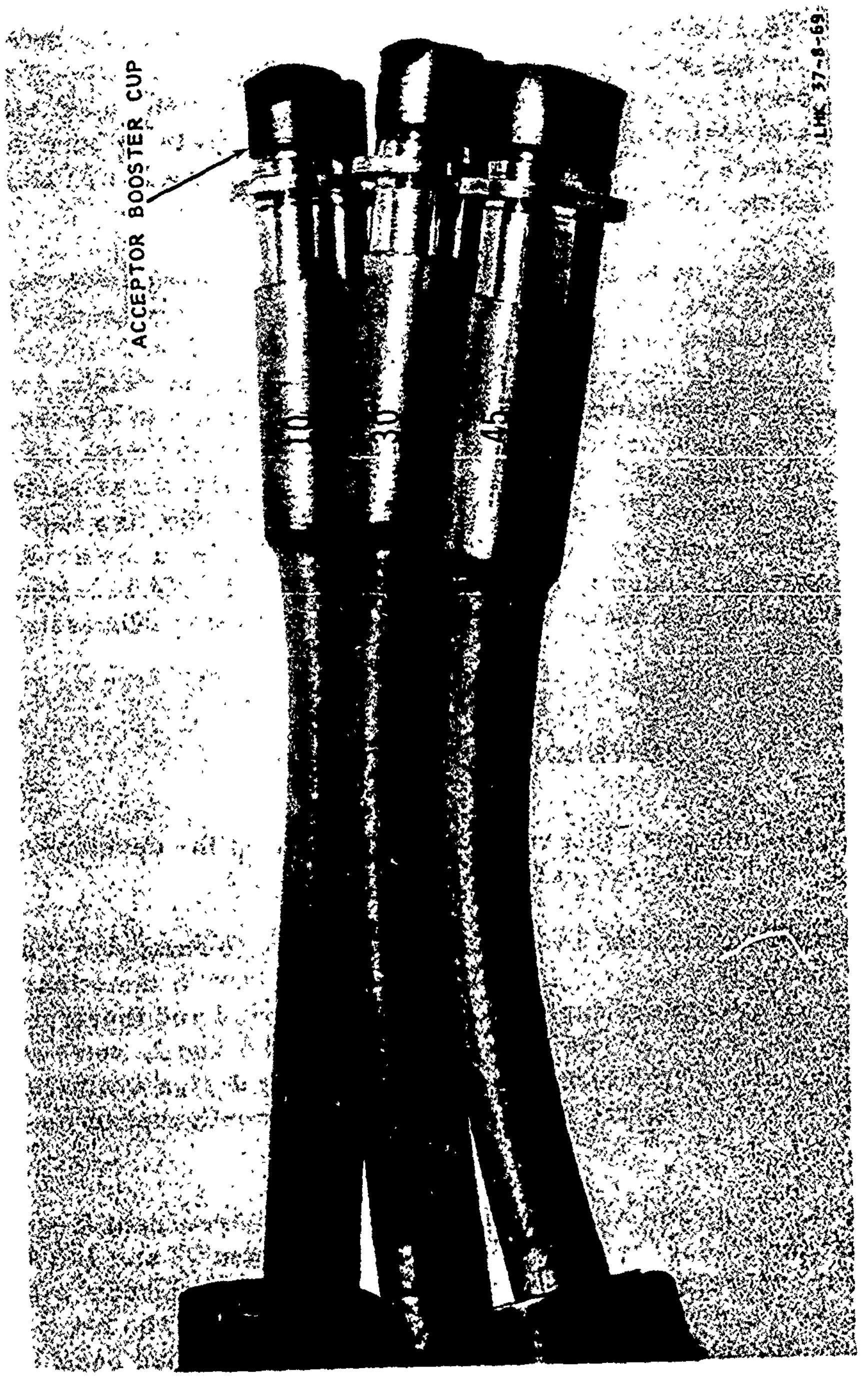

FIG. 8. Leads Following Jumble Test.

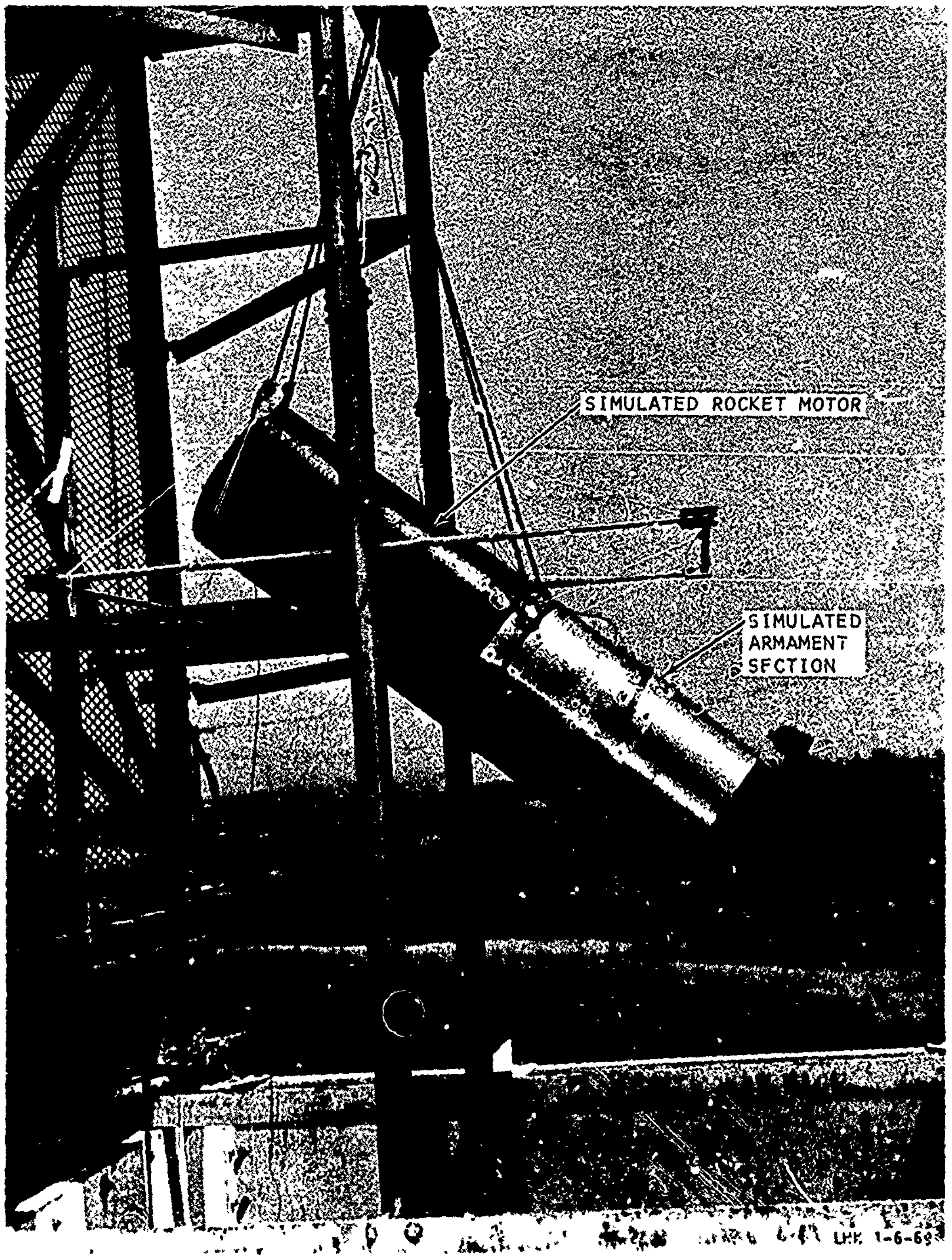

FIG. 9. Test Vehicle for 40-ft Drop Test.

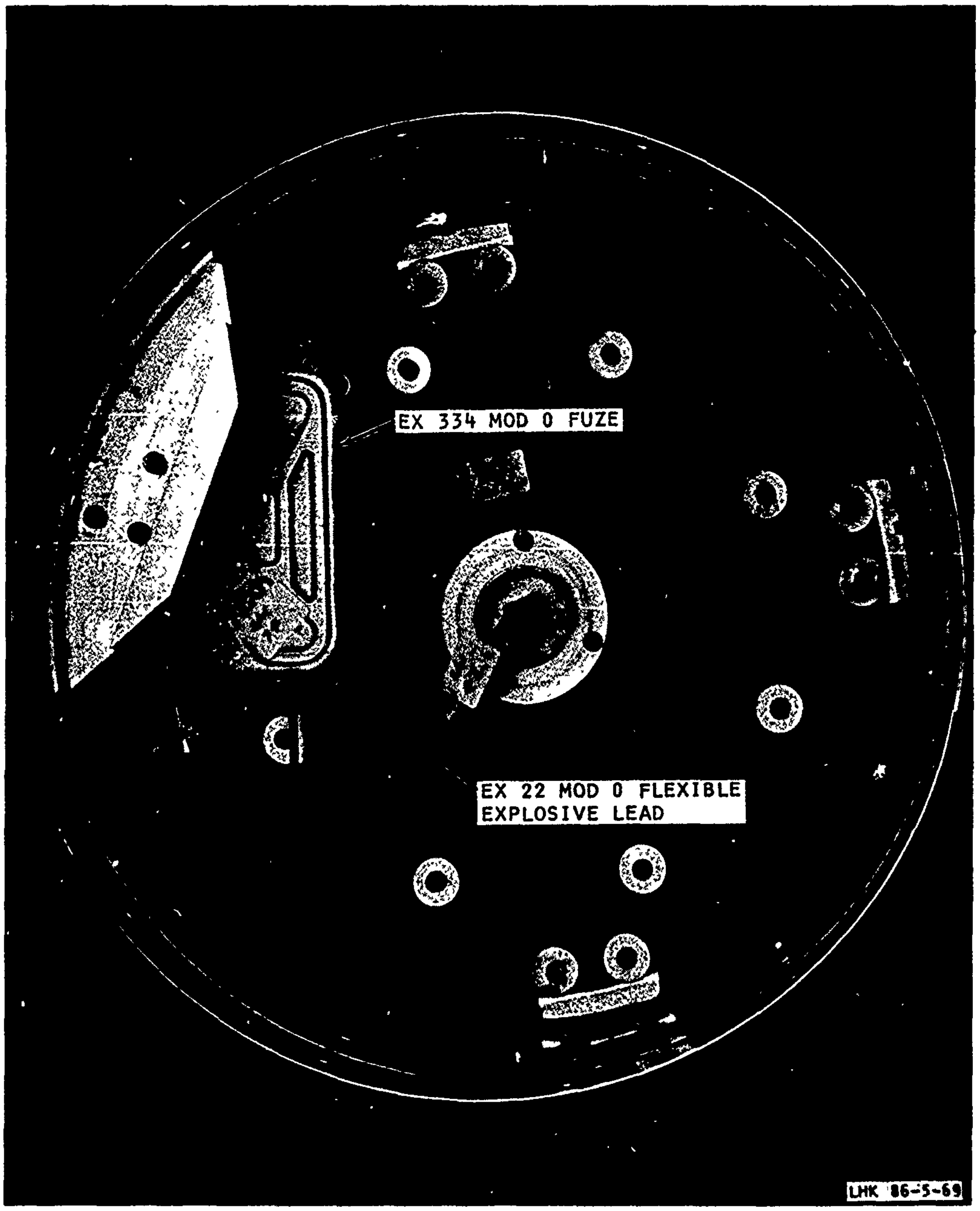

FIG. 10. Armament Section (looking forward).

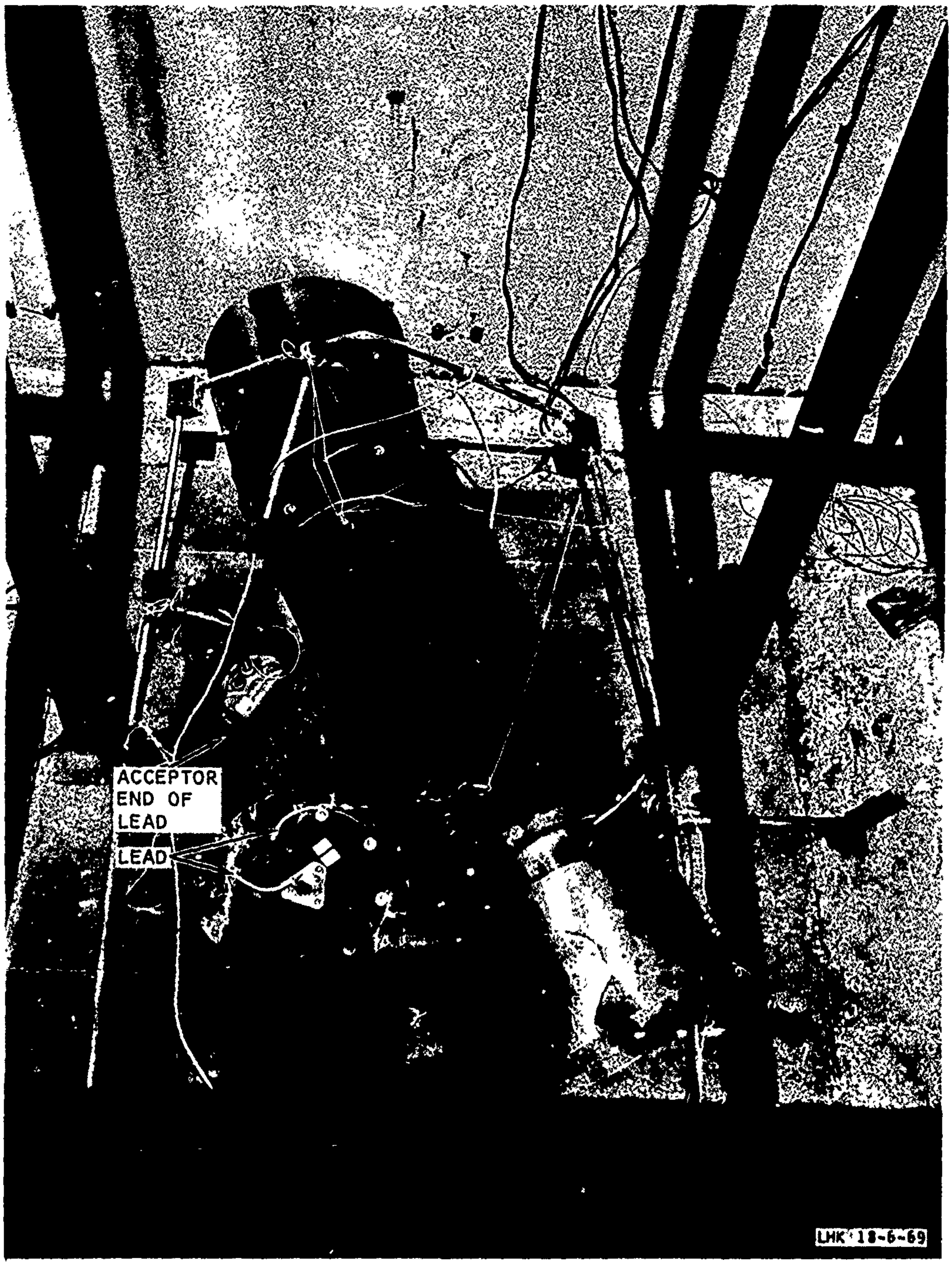

FIG. 11. Forty-Five-Degree-from-Vertical Drop.

FIG. 12. Nose-Down Drop.

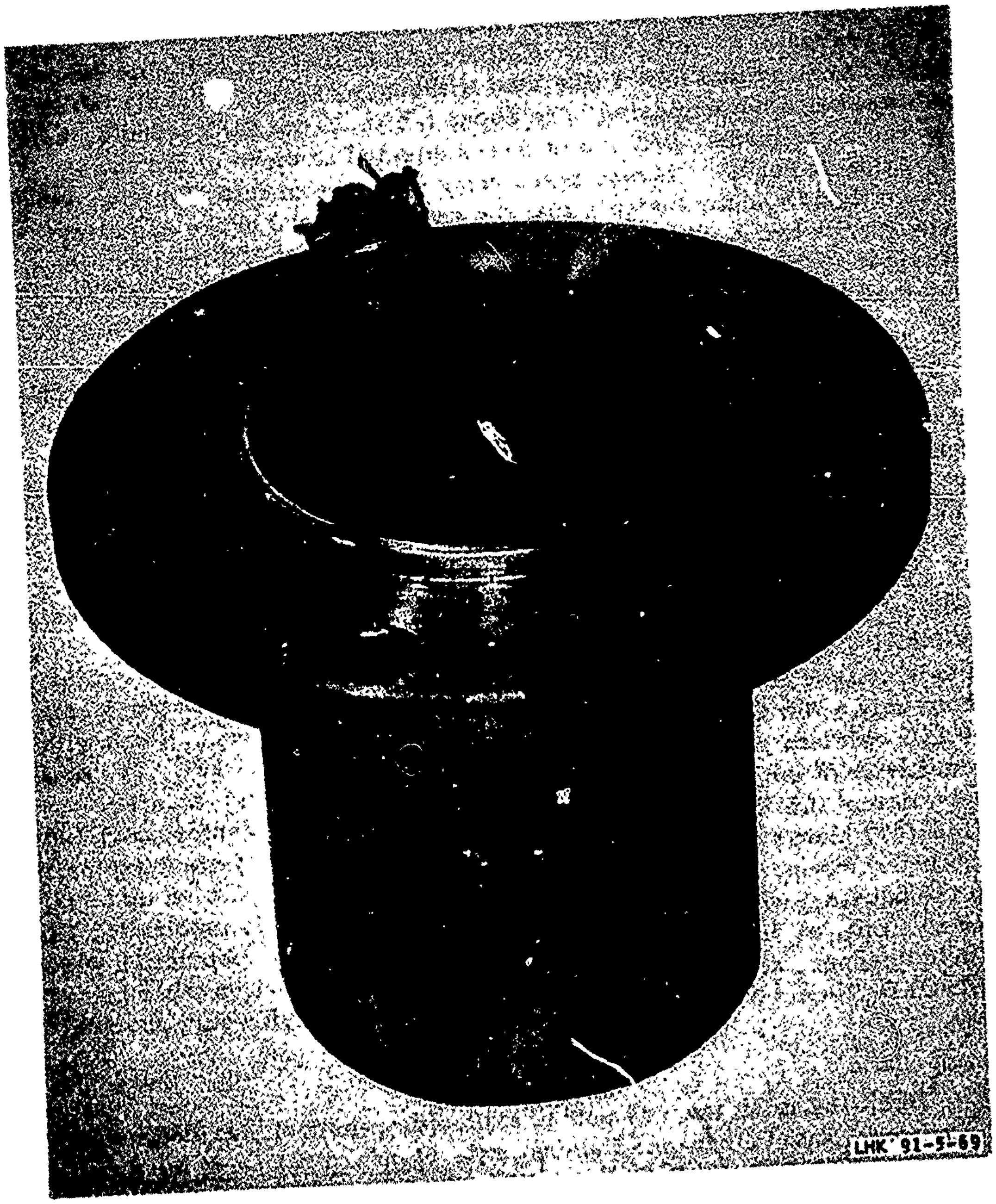

FIG. 13. Donor End of Lead After Nose-Down Drop.

resonant frequency for this unit than for the other lead. The two leads were then subjected at ambient temperature to 50 hours of sinusoidal vibration having a 5g peak acceleration and sweeping through the frequency range of 50 to 125 Hz. Following this test radiographic examination revealed that S/N 1 (the lead without the heat shrinkable tubing) had breaks in the explosive cord about 1/4 in. from each ferrule. S/N 2 showed no failures. S/N 2 was then subjected to more of the same vibration at -65°F. X-rays taken after 48 hours of this vibration and again after 58 hours indicate that the explosive cord broke sometime between the two X-rays. The break occurred about 1/4 in. from the acceptor ferrule. Both these leads were fired, and the dent values obtained (0.029 in. and 0.031 in.) indicate proper detonation occurred.

In withstanding vibration at its resonant frequency the lead demonstrated durability beyond expectations and demonstrated there was no need to support the mid-section of the lead, as was thought might be necessary. To take full advantage of this benefit of the heat shrinkable tubing, its length was increased to cover as much of the ferrules as possible.

The second test of significance during development was an explosive reliability test conducted to determine the lead-to-booster interface reliability. By reducing the sensitivity of the booster acceptor explosive into which the lead is fired, the reliability can be statistically projected from only a few tests. The acceptor explosive, RDX desensitized with 16.55% calcium stearate, was pressed into a pellet at 13 ksi. The mean sensitivity of the acceptor was 6.75 decibangs (dbg) with a standard deviation of 0.1 dbg.[1] The observed response of ten acceptors was 100%. Figure 14 shows the sensitivity curves established for the test explosive and two different lots of RDX composition CH-6 (the explosive material in the booster) which represent extremes found with this material. The lower limit, at 95% confidence, of the proportion of the population which would respond, as obtained from the limits of a proportion table in NAVORD Report 3369[2], is 74.1%. The stimulus which would provide

[1]Decibang is an inverse unit of explosive sensitivity as defined in the report: Naval Ordnance Laboratory. Standardization of the Small Scale Gap Test. White Oak, Md., NOL, 16 January 1961. (NAVWEPS Report 7342.)

[2]Naval Ordnance Test Station. Statistics Manual, by E. L. Crow, F. A. Davis, and M. W. Maxfield. China Lake, Calif., NOTS, 1955. (NAVORD Report 3369, NOTS 948.)

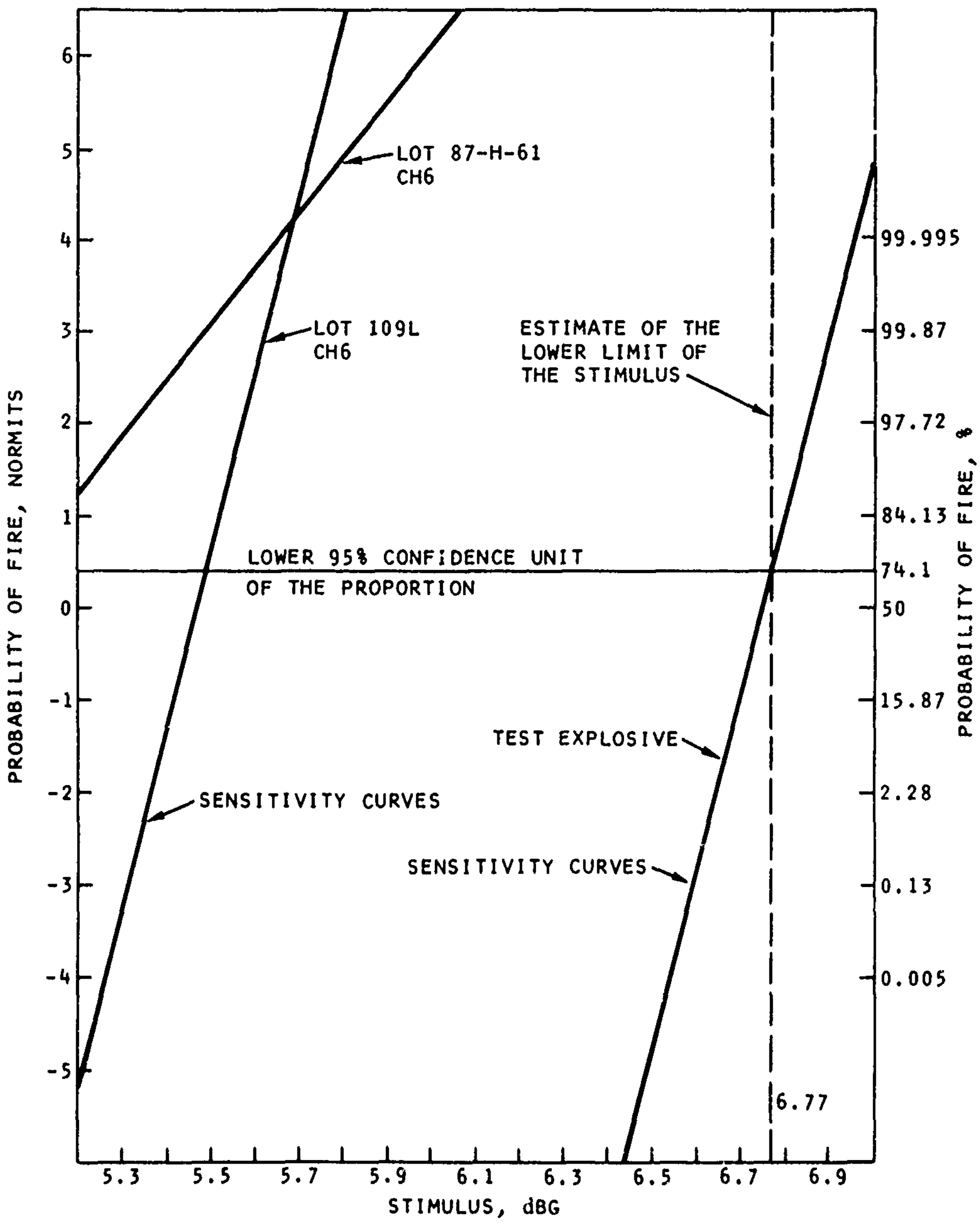

FIG. 14. Sensitivity Curves Used in Projecting Lead-to-Booster Reliability.

this proportion of responses is 6.77 dbg, the intersection of the "estimate of the lower limit of the stimulus" (6.77 dbg) and the sensitivity curve of the CH-6 will give the "probability of fire" (see Fig. 14). Thus, from this data, boosters loaded with either of the two lots of CH-6 shown in Fig. 14 would have an interface reliability in excess of six normits. However, due to uncertainty in reliability prediction in the extreme upper and lower ranges and the assumption of a normal distribution of sensitivity, it would be more reasonable to state that the reliability of this interface is in excess of four normits or 99.99% at 95% confidence. This exceeds the reliability required at this interface.

CONCLUSION

The achievement of satisfactory results from the design evaluation test program is one of the requirements that must be met before it can be recommended to NAVAIR that this lead be released for production. The success of this lead in withstanding the induced environments of the test program demonstrates the adequacy of the design and fulfills the above requirement.

Appendix

INSTRUCTIONS FOR DESIGN EVALUATION TESTING OF FLEXIBLE EXPLOSIVE LEAD EX 22 MOD O

TEST SEQUENCE

Tests shall be performed in the sequence outlined in Fig. 7.

TEST SPECIFICATIONS

1. Nondestructive Tensile Test: Apply tensile load (thru coupling nuts) of 20 pounds.

2. Transportation Vibration: MIL-STD-331, Test 104, Procedure I.

3. Temperature and Humidity: MIL-STD-331, Test 105.

4. Jolt: MIL-STD-331, Test 101.

5. Jumble: MIL-STD-331, Test 102.

6. Random Vibration: The lead shall be subjected to two hours per axis of random vibration at a power spectral density of 0.02 g^2/Hz over a bandwidth of 20 to 2000 Hz at ambient temperature.

7. Captive Flight Vibration:

a. The lead shall be vibrated along an axis normal to the missile longitudinal axis at 5 g peak-to-peak, through a frequency range from 50 to 3000 Hz. The frequency range (50 to 3000 to 50 Hz) shall be swept at a logarithmic rate and shall be traversed, in both directions, in a period of 40 minutes. Three sweeps shall be made for a total test time of 2 hours each axis.

The most severe resonant frequency shall be recorded. The most severe resonant frequency is defined as the frequency where the displacement measured on the lead being tested is the greatest.

b. At the most severe resonant frequency noted in a above, the lead shall be vibrated at 10 g peak-to-peak for 30 minutes.

c. The lead shall be rotated 90 degrees about its longitudinal axis and steps a and b shall be repeated.

d. Steps a and b shall be repeated with the vibratory force applied along the longitudinal axis of the lead.

e Steps a-d shall be conducted at 160°F, ambient temperature, and -65°F.

8. Free Flight Vibration: Vibratory excitation shall be applied parallel to each of three major axes. Frequency shall be controlled by logarithmic sweep over the range of 50-3000-50 Hz with an input amplitude of 10 g zero-to-peak. The sweep cycle (50-3000-50) shall be made in a period of 3 minutes.

9. Forty Foot Drop: This test will be performed in conjunction with the 40 ft drop testing of the Ex 334 Fuze.

10. Destructive Tensile Test: The lead shall be subjected to a tensile load, applied via the coupling nuts, until failure occurs. Failure is defined as severance of the explosive cord. This shall be monitored by electrical continuity. The point at which a discontinuity is encountered shall be considered the failure point. (Caution: Current is limited to 5 mA.)

11. Firing Test Procedure:

Pretest Checkout: Prior to use, the explosive components and the firing cable shall be tested in accordance with the following procedure:

NOTE: Resistance checks on the Mk 87 detonators must be made with instruments that limit the test current to 10 mA or less.

a. Remove the 10-A fuse from the fuse holder in the firing cable and verify the continuity of the fuse. (Resistance of the 10-A fuse shall be less than 0.2 Ω.)

b. Verify the continuity of each individual electrical lead in the firing cable. (Resistance of each lead shall be less than 0.25 Ω.)

c. Verify the electrical insulation between the leads of the firing cable. (Insulation resistance shall be greater than 50 MΩ.)

d. Replace the 10-A fuse and verify the continuity of the firing cable and the fuse holder. (Resistance of cable assembly shall be less than 0.7 Ω.)

NOTE: Any firing cable that does not satisfy the tests a through d shall not be used.

e. Visually examine the detonators and leads for physical damage and general appearance.

f. Using a suitable current-limited (10 mA or less) instrument, measure the detonator bridge wire resistance. (Reject any Mk 87 detonator whose bridge resistance does not measure between 0.3 and 0.4 Ω.)

12. Installation Procedure:

The initiation system consisting of a Mk 87 detonator, Mk 9 explosive lead, firing cable, and detonator/lead holder shall be installed in accordance with the following procedure:

a. Cement donor end in polystyrene confining sleeve (Fig. 15). End of lead shall be flush with confining sleeve (Caution: Do not get adhesive on end of Ex 22 Lead).

b. Tape detonator/lead holder (Fig. 15) to acceptor end of Flexible Lead. Be sure shoulder of holder is snug against end of lead.

c. Put cellulose tape on dent block, Fig. 15, (through center) and cement confining sleeve with lead on dent block. Be sure not to get adhesive between end of lead and dent block. Lead should be in approximate center of dent block.

d. Insert Mk 9 Lead in holder and be sure it is against end of Flexible Lead.

e. Place above assembly in firing chamber.

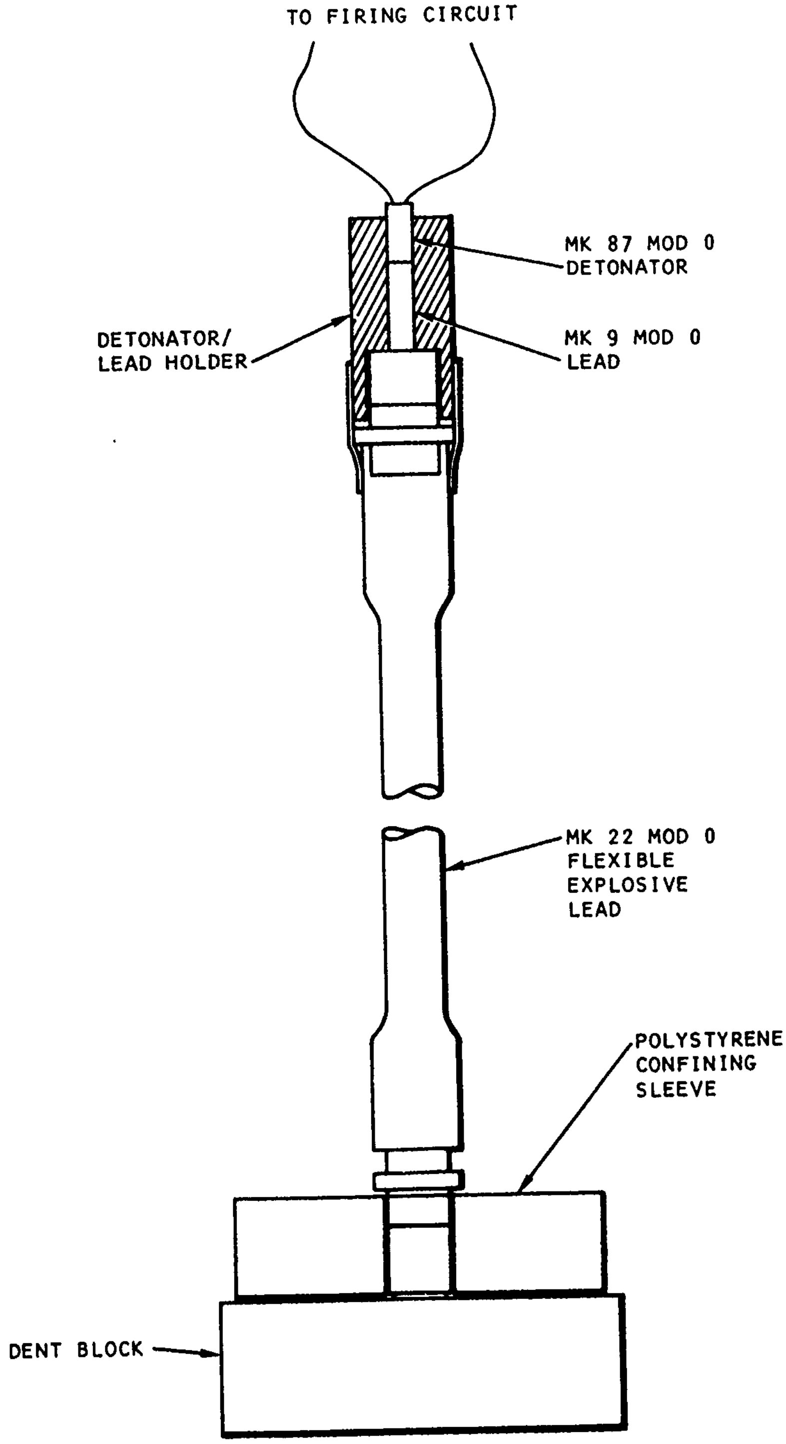

FIG. 15. **Functioning and Output Test Setup.**

f. While working behind a suitable safety barrier attach the firing cable to the Mk 87 Detonator.

g. Verify (by electrical measurement) the shorted condition of the firing lines leading to the fire-control area.

h. Place Mk 87 Detonator behind a protective barrier and attach firing cable to firing lines.

i. Insert Mk 87 Detonator in detonator/lead holder, being sure it is against Mk 9 Lead, and put a piece of tape between electrical leads of Mk 87 and secure to the holder assembly.

FIRING PROCEDURE

The following procedure is suggested for the firing of this initiating system containing a Mk 87 detonator:

1. Remove the short from the firing circuit in the safe area and verify the continuity of the circuit.

2. Apply firing energy to the circuit. The firing energy may be furnished by either: (a) A voltage source of not less than 50 V dc which is capable of supplying a minimum of 20 A (continuously), or (b) a 115-V ac, 60 Hz line capable of supplying a minimum of 20 A.

NEGATIVE NUMBERS OF ILUSTRATIONS

Fig. 1, LHK 116-5-68; Fig. 2, LHK 7-10-69; Fig. 3, LHK 6-10-69; Fig. 4, none; Fig. 5, LHK 19-4-69; Fig. 6, LHK 18-4-69; Fig. 7, none; Fig. 8, LHK 37-8-69; Fig. 9, LHK 1-6-69; Fig. 10, LHK 86-5-69; Fig. 11, LHK 18-6-69; Fig. 12, LHK 89-5-69; Fig. 13, LHK 91-5-69; Fig. 14, none; Fig. 15, none.

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ABSTRACT CARD

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A description of the design evaluation tests performed on the Ex 22 Mod 0 Flexible Explosive Lead is presented, together with the test results.

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