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THE SAFETY AND RELIABILITY OF THE S AND A MECHANISM DESIGNED FOR THE NASA/LSPE PROGRAM

Louis J. Montesi

Naval Ordnance Laboratory

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By
L. J. Montesi

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13. ABSTRACT

Under contract to the Manned Spacecraft Center, NASA/Houston, NOL developed a number of explosive charges for use in studying the surface of the moon during Apollo 17 activities. The charges were part of the Lunar Seismic Profiling Experiment (LSPE). When the Safety and Arming Device used in the previous ALSEP experiments was found unsuitable for use with the new explosive packages, NOL also designed the Safety and Arming Mechanism, and the safety and reliability tests conducted are described within.

The results of the test program indicate that the detonation transfer probability between the armed explosive components exceeds 0.9999, and is less than 0.0001 when the explosive components are in the safe position.

Details of illustrations in this document may be better studied on microfiche.

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	ROLE	WT	ROLE	WT	ROLE	WT
HNS-II						
HNS-II/Teflon (90/10)						
Heat Resistance Explosive						
LSPE						
Sensitivity						
Output						
S&A Mechanism						
PBX, Thermally Stable						
Lead, Thermally Stable						

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EXPLOSION DYNAMICS DIVISION
EXPLOSIONS RESEARCH DEPARTMENT
NAVAL ORDNANCE LABORATORY
WHITE OAK, SILVER SPRING, MARYLAND 20910

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THE SAFETY AND RELIABILITY OF THE S AND A MECHANISM DESIGNED FOR THE NASA/LSPE PROGRAM

This report describes work conducted for NASA Manned Spacecraft Center, Houston, Texas under Task NOL-998/NASA. As part of this program, a series of explosive charges was developed for the Lunar Seismic Profiling Experiments (LSPE). The ALSEP Safety and Arming Mechanism was redesigned to meet the safety and reliability requirements of the LSPE Explosive Package. This report describes the test results of the first design, the redesign of the Safety and Arming Mechanism, and the subsequent safety and reliability tests conducted on the redesigned Safety and Arming Mechanism. The results of these studies should be of interest to engineers and scientists engaged in explosive weapon design and evaluation.

The author acknowledges the assistance and cooperation of the following individuals: H. T. Simmons, Sr. for conducting the lot acceptance specification tests of HNS-II and for conducting the vacuum thermal stability and compatibility tests; C. W. Goode for conducting many of the design tests; and L. A. Roslund for determining EDC gas velocities.

The identification of commercial materials implies no criticism or endorsement of these products by the Naval Ordnance Laboratory.

ROBERT WILLIAMSON II
Captain, USN
Commander

for C. J. ARONSON
By direction

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APPENDIX A A

APPENDIX B B

THE SAFETY AND RELIABILITY OF THE S AND A MECHANISM DESIGNED FOR THE NASA/LSPE PROGRAM

1.0 INTRODUCTION AND BACKGROUND

1.1 As part of the Apollo Manned Space Program, explosive charges are to be used for studying the surface of the moon. This study, the Lunar Seismic Profiling Experiment (LSPE), is an extension of a recent seismic experiment, ALSEP*, conducted during Apollo XIV and Apollo XVI. The LSPE program differs from the ALSEP experiments mainly in the metho of explosive charge deployment.

1.2 The Naval Ordnance Laboratory (NOL) was requested by NASA to develop the high explosive charges for the LSPE program.

1.3 As in the ALSEP program, a combination of HNS-II and Teflon was to be incorporated into a thermally stable molded explosive charge. In the previous ALSEP program, this HNS/Teflon molded charge was found to be acceptable for lunar application.

1.3.1 As shown in Figure 1 the explosive charges developed for the LSPE varied in size and weight. The series of charges consisted of:

a. Cylinders of high explosive made with 1/8, 1/4, 1/2, 1, and 3 pounds of HNS-II/Teflon-7C molding powder, and

b. A block of 6 pounds of HNS-II/Teflon-7C molding powder.

1.3.2 The preparation and fabrication details of these charges are reported in references (1), (2), and (3).

1.3.3 The explosive charges are to be assembled into the housing of the LSPE hardware. Figure 2 depicts the LSPE hardware used to house the 1/4-pound and 6-pound H.E. charges. The actual electronic package (not shown here) contains the safety and arming (S&A) mechanisms. (For this illustration, the electronic package was not available, and an aluminum block was used to simulate the package.)

1.4 As part of NOL's task, the ALSEP S&A device (Figure 3) was to be assessed for safety and reliability using the Varicomp test method[4]. Unfortunately, during the safety and reliability test program, this ALSEP S&A device did not meet the safety and reliability requirements established for the LSPE explosive package. Hence the S&A was redesigned to incorporate an HNS-II lead into the explosive train between the End Detonating Cartridge (EDC) and the top of the H.E. charge. The new explosive train is shown in Figure 4.

*Apollo Lunar Surface Experiments Package.

1.5 This design was further modified. First the gap between the explosive lead and the top of the H.E. charge, originally 0.046 to 0.067 inch, was increased to 0.087 to 0.097 inch. In addition (at a later date) the open slot in the baseplate was closed by attaching a 2-mil mylar film to the rubber gasket located at the rear of the baseplate (see Figure 5). This change was made to prevent any explosive dust and/or explosive fragments from getting into the electronic package (located above the baseplate) and causing possible malfunctions of the S&A device. The gap between the lead and the H.E. charge was also increased to 0.137 inch maximum.

1.6 The majority of the safety and reliability tests conducted were on the redesigned explosive train as depicted in Figure 4. Because of the additional design changes (increased gap between the lead and H.E. charge and mylar film) a limited number of tests were conducted at the explosive lead/H.E. charge interface of Figure 5 to substantiate the safety and reliability assessment already obtained.

1.7 In addition to covering the safety and reliability tests of the S&A mechanism, this report also covers:

the development of the HNS-II Explosive Lead including sensitivity and output of the HNS-II,

the results of the safety verification tests conducted on simulated LSPE explosive packages,

the sensitivity and output data for the LSPE high explosive charges,

the vacuum thermal stability and compatibility of HNS/Teflon with the various materials and adhesives used with it in the charge packages, and

the development of a specification for the HNS/Teflon-7C, (90/10).

2.0 PROGRAM LOGISTICS

2.1 The LSPE package is being developed by Bendix Aerospace Corporation (BXA) under contract to NASA. Bendix has the responsibility for the electronic package. NOL was contracted by NASA to develop and fabricate the high explosive charges required for the LSPE packages, to develop and fabricate the explosive train for the LSPE package, and to assess the safety and reliability of the S&A mechanism including the explosive train.

2.2 The overall LSPE program was divided into three parts as follows:

2.2.1 Phase I; Proto. During this phase, the Laboratory was to design, and test the prototype LSPE explosive charges (see Figure 2). The development program was to consist of subjecting the LSPE explosive package to various environmental and surveillance tests.

All necessary test procedures and specifications required were to be developed in this phase. Also included in this phase was the safety and reliability of the S&A device.

2.2.2 Phase II; Qualification. In Phase II the qualification LSPE explosive packages (final proto design) were to be fabricated and subjected (in accordance with the procedures and specifications developed in Phase I) to the environmental and surveillance test program.

2.2.3 Phase III; Flight. In Phase III the flight explosive packages were to be fabricated and subjected to flight acceptance vibration tests. The LSPE packages were to be delivered to Cape Kennedy for use on Apollo XVII.

2.3 Throughout this program, Bendix was to supply NOL with various hardware and assemblies for conducting the above environmental and surveillance tests. Hence, reference to Bendix drawings and parts will be made often.

3.0 SAFETY AND RELIABILITY TESTING OF THE ALSEP SAFETY AND ARMING DEVICE

3.1 As part of the LSPE development program, the safety and reliability of the safety and arming device (Figure 3) used in the ALSEP charges was to be determined using the Varicomp test method along with other penalty type tests. The test program was devised to study the detonation transfer probability at the interface between the EDC detonator and the H.E. charge. The details of the EDC detonator are shown in Figure 6.

3.2 Initial reliability test results using the Varicomp test method (see Table A-1) and the explosive transfer tests using the design explosive (see data from Table A-2 for Lot BYA Detonators only) indicated that the detonation transfer at this interface was reliable. The EDC's used in these tests were from two lots of detonators identified as lot BUK and lot BYA.

3.3 During the testing, BUK and BYA EDC's were expended; flight detonators, from a third lot, lot CNH, were substituted. Two transfer failures occurred immediately (see Table A-2). Further reliability tests were terminated with the CNH lot of flight detonators, and additional tests were made to determine the type and cause of these transfer failures. These tests are reported below.

3.3.1 The Varicomp tests were repeated using CNH type detonators (see Table A-3). The CNH detonator failed to initiate the Varicomp pellet.

3.4 Therefore additional tests were run at reduced air gaps. These tests (see Table A-4) showed that the design was unreliable with the CNH detonator. The system is required to function across a 0.374-inch air gap, but the CNH detonator failed to initiate the main charge across a 0.200-inch gap.

3.5 The effort was then turned toward the detonator properties. Steel dent tests of the CNH detonator gave values of 22.5 and 23.5 mils which is well above the acceptance requirement[5].

3.6 Product gas velocities at the end of a 0.374-inch air gap were measured for two EDC detonators in order to compare their output. The results are in Table A-5. In each test the products from the detonator were driven across a 0.3125-inch diameter by 0.374-inch long air gap. Velocity measurements were made as the gases crossed the last 0.100 inch of the distance, i.e. between 0.275 inch and 0.374 inch from the end of the detonator. Since the gas velocity appeared constant in this region, it corresponds to the impact velocity of the gases against the explosive normally located at the end of the 0.374-inch gap.

3.7 The gas velocities for the CNH detonators average 20% lower than the velocity observed for the BYA detonator. Experimental error is estimated as ±2% or less for this measurement. The 20% difference suggests substantial variation in detonator performance.

3.8 In view of the above, the ALSEP safety and arming device could not be used in the LSPE explosive package. A redesign was necessary.

4.0 REDESIGN OF THE SAFETY AND ARMING MECHANISM

4.1 The conventional way to assure reliable detonation between the detonator and the H.E. charge is to employ an explosive lead in the safe/arm slide. This would reduce, considerably, the 0.374-inch maximum air gap between the EDC detonator and the explosive block.

4.2 Because of design constraints, the lead would be shorter than a conventional lead, but would function in the same way. The NOL redesign is shown as an exploded view in Figure 7. The new slide is shown in the safe position with a slot milled into the baseplate to allow movement of the extended lead housing as shown in Figure 7A. The lead/lead housing/safe and arm slide configuration is shown in Figure 7B. An enlargement of the lead and lead housing is depicted in Figure 7C and reveals a lead staked into the lead housing (mechanical upset of metal at the top periphery of the lead so that it can be retained during vibration, drop, etc.). The lead is loaded with HNS-IIA at 32 Kpsi. Figure 8 depicts the relative size of the lead, lead housing assembly, and the EDC detonator.

4.3 The development data for the lead is given in Section 5.0.

5.0 DEVELOPMENT OF THE EXPLOSIVE LEAD AND LEAD HOUSING ASSEMBLY

5.1 Since the lead is shorter than a conventional lead, a study was made of its output (depth of dent) vs its explosive column length. As was expected (Figure 9) the output is dependent on the lead length and the loading pressure. On the basis of dents, the new lead will have significantly more output than the EDCs originally supplied.

5.2 Four lots of leads were fabricated to "prove-in" the recommended design (Lot 1); to generate output data for lot acceptance and the effects of high and low temperature on output (Lot 2); to prove in the drawings, loading procedure, and specifications and to provide leads for qualification and flight hardware (Lot 3); and to provide leads for the prototype hardware (Lot 4). The output data for the four lots of leads are given in Table 1.

5.3 The HNS-II explosive leads, as per PL-71-C-1386*(see Figure 10)[6] were assembled into metal housings (Dwg 71-C-1387; see Figure 11) to form the lead housing assemblies (PL-71-C-1396)[7]. The lead housing assembly (Figure 12) is screwed into the central cavity of the safe/arm slider.

6.0 SAFETY AND RELIABILITY TESTING OF THE REDESIGNED SAFETY AND ARMING DEVICE (DESIGN NO. 2)

6.1 Because the failure to transfer detonation from the EDC detonator to the HNS-II/Teflon-7C block brought about a redesign in the LSPE safety and arming device, tests to determine the safety and reliability aspects of the redesigned S&A were carried out. The testing was conducted in accordance with the program outlined in Table 2.

6.2 Normally, from any lot of EDC detonators, 50 (or less) are available for test. Since more than 50 detonators were required for the test program, more than one lot of detonators had to be supplied to NOL. Hence, the test program was modified to include a study of the lot to lot variations of the EDC on the safety and reliability of the redesigned S&A device. Actually, two lots of EDC detonators were supplied; Lot CNH and Lot CTN. The CTN detonators are to be used in the flight hardware.

6.3 The safety and reliability tests were conducted in hardware closely simulating actual design hardware. Minimum or maximum gaps were used depending on whether a safety or a reliability test was being conducted. Based on a design tolerance study made by Bendix, the maximum/minimum gaps for each interface (Figure 4) are as follows:

a. Interface I: Bottom of EDC detonator to the top of the HNS-II explosive lead--5 to 21 mils,

b. Interface II: Bottom of HNS-II explosive lead to the top of the HNS-II/Teflon-7C (90/10) explosive charge--46 to 67 mils. (This gap was increased to 87 to 97 mils and later to 137 mils maximum.)

6.4 To facilitate reporting of the safety and reliability test data, the following table was drawn up and it relates the test with a table of results and a figure showing the test arrangement:

*NOL Drawing Number.

Test	Table for Result and Test Arrangement
Reliability Test Program	
Design	3
Varicomp: Detonator-to-lead	4
Varicomp: Lead-HE charge	5
Mis-alignment test	6
Gap test: Detonator-to-lead	7
Gap test: Lead-to-HNS/Teflon-7C Block	8
Safety Test Program	
Design	9
Varicomp	10
Mis-alignment	11

6.5 The Varicomp analysis was used to assess the safety and reliability at these two interfaces and this analysis is given in detail in Appendix B. From the tests conducted, the following are concluded:

a. The probability of detonation transfer between the in-line explosive components will exceed 0.9999 at 95% confidence. (See Tables 3, 4, and 5, and Appendix B.)

b. The probability of detonation transfer to either the HNS-II lead or the HNS-II/Teflon-7C explosive charge, when in the out-of-line position, from accidental initiation of the EDC is small, and will be less than 0.0001 at 95% confidence. The above are based on the use of Varicomp explosives in place of the design explosive. (See Tables 9, 10, and Appendix B.)

6.6 In addition, the test data also shows:

1. Detonation transfers were observed between the EDC detonator and the HNS-II explosive lead when the safe/arm slider assembly was misaligned from the in-line position by 0"125. Detonation transfer failures resulted at a misaligned distance of 0"150 (See Table 6).

2. Detonation transfers were observed between the EDC detonator and the HNS-II explosive lead at gaps up to approximately 350 mils (See Table 7).

3. Detonation transfers were observed between the HNS-II explosive lead and the HNS-II/Teflon-7C (90/10) explosive charge for gaps up to 421 mils (See Table 8).

4. Detonation transfers to either the HNS-II explosive lead or to the HNS-II/Teflon-7C (90/10) explosive charge did not occur when the HNS-II lead was in the out-of-line position or was 200 mils from the full safe position (initial safe position* = 500 mils)(See Table 11).

5. In the safety tests conducted, the explosive lead and safe/arm slider assembly were tested in both the initial safe position (#1) and the resafe position (#2) (See Figure 13).

6. There is no apparent difference in the safety or reliability test results attained for either lot of EDC detonators (Lot CNH or Lot CTN).

7.0 RESULTS OF S&A DEVICES TESTED UNDER REDUCED PRESSURE

7.1 NOL was requested by NASA/MSC to run additional functioning tests on the redesigned S&A device at a simulated pressure environment of less than 1×10^{-2} mm of Hg.

The arrangement used and the results are given in Table 12. Air gaps at the two transfer interfaces were not measured and were assumed to be comparable to those given in Table A-5. Two tests were made with the pressure surrounding the explosive train at 5.5×10^{-3} and 6.0×10^{-3} mm of Hg respectively. The output dents in the steel block were 124 and 138 mils respectively indicating good detonation of the HNS/Teflon-7C.

8.0 PRODUCT GAS VELOCITY TEST--LOT CTN DETONATOR

8.1 Product gas velocities were measured for two EDC detonators from Lot CTN. The test setup used was identical to that used previously to test EDC detonators from Lot CNH and BYA. (See Section 3.6). The results of all product gas velocity tests are given in Table 13. The product gas velocities observed across the last 0.100 inch of a nominal 0.375-inch air gap for the CTN detonators were approximately 3400 and 3175 meters/sec. These values are comparable to the product gas velocity values for the Lot CNH detonators of approximately 3200 meters/sec. but less than the value of 3900 meters/sec. for the Lot BYA detonator.

9.0 INTERFACE DIMENSION CHANGE

9.1 Originally the interface gap between the lead and the H.E. block of HNS/Teflon-7C (90/10) was 46 to 67 mils. Bendix, to facilitate assembly of the piece parts, requested that this gap be increased to

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*For the various positions that the slider assumes see note on Table 9 and Figure 13.

87 to 97 mils. The tests conducted, and the safety and reliability estimate given above are based on the original gap of 46 to 67 mils. However, detonation transfer gap tests at this lead/H.E. block interface (See Table 8) indicate successful transfers for gaps of approximately 400 mils. Hence a gap increase of 30 mils could easily be tolerated and further reliability testing was not deemed necessary.

10.0 RELIABILITY TESTING AT 200°F

10.1 Two detonation transfer tests were conducted at 200°F using the NOL test hardware. Each unit was conditioned at this temperature for a minimum of four hours inside an aluminum tube heated by nichrome wire. The gap between the lead and the HNS-II/Teflon-7C pellet was approximately 0.090 inch for each test*. Successful initiation of the base charge resulted in both tests, and the resulting dents in steel witness blocks were approximately 135 mils. These test shots are summarized in Table 14.

11.0 REDESIGN OF BASEPLATE FOR EXPLOSIVE PACKAGE (LSPE)

11.1 During LSPE environmental testing it was discovered that thermal cycling caused cracking of the explosive charges. Because it was feared that the cracked charges might produce explosive dust and small explosive fragments that could hinder the motion of the safe/arm slider during arming, a redesign of the baseplate was proposed. This new design (Figure 5) uses a 2-mil thick mylar film to separate and seal off the explosive charge from the S&A. The mylar is attached to the rubber gasket of the baseplate with RTV adhesive. Because the RTV adhesive layer is about 0".030 thick, it was estimated that the redesign could increase the gap between the lead and the explosive charge by as much as 0".040.

11.2 To prove-in the reliability of this redesign, it was proposed that additional reliability tests be run between the lead and the explosive charge as follows:

a. five Varicomp shots with an insensitive explosive replacing the HNS-II/Teflon-7C,

b. five shots of the actual redesign.

11.3 It was also proposed that compatibility tests be conducted between the HNS-II/Teflon-7C and the mylar; between the HNS-II/Teflon-7C, the mylar, and the RTV; and between the HNS-II/Teflon-7C and the RTV. (Results of these tests are summarized in Section 16.0.)

11.4 The test configuration utilized hardware from both BXA and NOL, and was assembled in accordance with the procedures received from NASA, Houston.

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*Prior safety and reliability tests were conducted with interface gaps of 0.047 to 0.067 inch between the lead and the base charge pellet. This gap was increased to 0.087 to 0.097 inch by BXA Engineering Change Notice 2348555.

11.5 A total of 10 test shots were made: five tests used the Varicomp technique to assess the reliability; and five tests used the design explosives. In all tests the air gap between the bottom of the explosive lead and the top of the H.E. charge was between 0.136 and 0.144 inch. (The maximum air gap for this redesign was to be 0.137 inch.) The explosive lead fired through a nominal 2-mil mylar sheet attached (with Dow Corning 140 RTV adhesive) to the rubber gasket located at the rear of the baseplate. The redesigned baseplate test arrangement is shown in Figure 5 while Table 15 summarizes the results of these 10 tests.

11.6 Using the Varicomp data given above and the procedure of Appendix B, the detonation transfer probability at this interface still exceeds 99.99%, at 95% confidence.

12.0 SAFETY VERIFICATION TESTS ON MOCK-UP EXPLOSIVE CHARGES

12.1 As part of the overall test program, two safety verification tests were to be conducted. The test configuration consisted of using a Bendix baseplate/safe and arm slide/detonator housing assembly merged with an NOL simulation of the H.E. charge housing assembly.

12.2 In these tests, the EDC detonator was fired into the attenuation cavity of the safe/arm slide containing the lead housing assembly. The slide was tested in the position #1 or initial safe position (see Figure 13). For these tests a 1/8-pound charge and a 6-pound charge were used in the charge housing. Gaps between the bottom of the lead to the top of the H.E. Block were set at approximately 0".090. Pre-test photos of the explosive charge mock-ups are shown in Figure 14. In post test examination the following were noted:

a. In both test shots the metal beneath the rubber-filled cavity sheared and impacted the explosive charge located below the attenuation cavity. This was an unintended result and is considered a safety failure. (See Figure 15.)

b. The impact of the metal disc on the 6-pound charge caused several cracks on the surface of the charge (See Figure 16).

c. The impact of the metal disc on the 1/8-pound charge shattered the pellet into many smaller pieces (See Figure 17).

d. The HNS-II/Teflon-7C charges showed no signs of burning due either to the impacting metal disc or to the detonator gases venting through this cavity.

12.3 As a result of these safety failures a number of the expended test slides(supplied by Bendix)(see Figure 18) were re-examined for stress patterns on the back side. None were evident. However, major differences were found between the Bendix supplied safe/arm test slide and the Bendix proto-slide and are:

a. Bendix test slide (BXA Dwg 2348307) has a 0".025 corner radius inside the cavity.

b. The safe/arm slide drawing (BXA Dwg 2364705) has no such radius called out, and measured values of the corner radius were <0".005.

c. The Bendix proto-slide supplied was not heat treated to the specified drawing conditions.

12.4 As a result of these observations, several additional tests were proposed:

Test 1 - The Bendix proto-slide in the NOL test arrangement.

Test 2 - The Bendix Qual/Flight (Lot #1) slide in the NOL test arrangement. The Bendix Qual/Flight (Lot #1) slide is heat treated, but still has a corner radius of <0.005 radius.

The following resulted:

Test 1 - The metal below the cavity sheared.

Test 2 - In two test shots, the bottom of the Qual/Flight slide showed the bulge typical of the bulge observed on the Bendix test slide.

12.5 In discussion with NASA/Houston and Bendix, it was agreed that the Qual/Flight slide (heat treated but with 0".005 corner radius) would be used in the proto-test hardware if the results of eight additional tests with the Qual/Flight (Lot #1) slide showed no detrimental effects after the safety tests. The new Qual/Flight slide (Lot #2) was to be redesigned to have a nominal 0".040 corner radius. Additional tests were to be run on the Qual/Flight (Lot #1) slide:

a. four additional tests at ambient on the NOL hardware,

b. two tests at +200°F with the NOL test hardware,

c. two safety verification tests at ambient using the NOL hardware in a mock-up with both a 6-pound and 1/8-pound charge.

12.6 Of the eight tests above only five were run, with the following results:

a. In all four ambient safety tests the bottom of the slide showed the characteristic bulge after detonator initiation (See Figure 18). There were no visual signs of metal shearing.

b. In one safety test at 200°F the metal below the rubber-filled cavity sheared out. All further planned tests were discontinued.

12.7 The failure of the Qual/Flight Slide Lot #1, (BXA No. 2348593 Rev. x 3) caused rejection of this lot of slides for use with the proto hardware. It was decided that Qual/Flight Slide Lot #2

(BXA No. 2348593 Rev. x 4) would be used with the proto hardware and a third lot of safe/arm slides would be made for the qualification and flight hardware.

12.8 The tests needed to verify the redesigned safe/arm slides (0.040 corner radius and heat treated) were:

a. One safety test shot at +200°F with the Qual/Flight slide (Lot #2) in the NOL test arrangement.

b. Two safety verification tests using Bendix supplied baseplates, reworked detonator housings, and the Qual/Flight slides (Lot #2) in conjunction with an NOL simulated base charge housing containing a 1/8-pound and a 6-pound explosive charge.

c. Two safety verification tests using Bendix supplied baseplates, detonator housings, and the Qual/Flight slides (Lot #3) with an NOL simulated base charge housing containing the same two explosive charges used in b above.

12.9 The results of this testing were:

The 200°F shot showed that the metal below the rubber-filled cavity had again sheared. However, it was discovered that a Qual/Flight slide Lot #1 (BXA No. 2348593 Rev. x 3) had been used erroneously. Hence, safety data at the redesigned slide was not obtained.

12.10 In the safety verification tests with the lot 2 slide, and the 1/8-lb charge, the bottom of the redesigned Qual/Flight slide (BXA No. 2348593 Rev. x 4) had the characteristic bulge, and because of the impact of the baseplate and slider assembly against the H.E. pellet, the charge cracked in several places. There were, however, no signs of hot gases or metal fragments from the detonator or slide having impinged against the H.E. pellet (See Figure 19A).

With the 6-pound charge, the safe/arm slide in the initial safe position, and the gap between the lead and the H.E. at 0.090 inch the bottom of the redesigned Qual/Flight slide showed the characteristic bulge, but the impact of the baseplate and slide assembly did not damage the surface of the H.E. charge (See Figure 19B).

12.11 The final two safety verification tests were conducted with the Qual/Flight safe/arm slides (Lot #3)(BXA P.N. 2348593 Rev. D). The test arrangement was similar to the safety verification test arrangement reported previously in Sections 11.1 and 11.2, except, the final design as depicted in Figure 5 was used.

The bottom of this safe/arm slide had the characteristic bulge and the baseplate and the slide assembly impacted and cracked the 1/8-pound H.E. charge pellet (see Figure 20A), but did not damage the surface of the 6-pound H.E. charge (see Figure 20B).

12.12 These two safety verification test shots concluded this part of the LSPE test program. Even though the 1/8-pound explosive was cracked, the severity of the cracks was considerably less than those observed initially (Section 12.2), and no safety problems were anticipated. In addition, both the qualification safe/arm slide, (Lot 2), and the Qual/Flight safe/arm slide (Lot 3), stayed intact.

12.13 A summary of all the safe/arm slide tests is given in Table 16.

13.0 PROCUREMENT OF THE HNS-IIA EXPLOSIVE FOR LSPE EXPLOSIVE CHARGES

13.1 To fabricate the HNS-II/Teflon high explosive charges for the LSPE packages, a 200-lb lot of HNS-IIA was purchased. The HNS was to be tested by NOL to assure that it was in accordance with Specification WS 5003E.[8] A representative sample was taken from this lot (identified as X-756, ID 1479) and the specification tests were conducted.

13.1.1 The melting point range, surface moisture, bulk density, SSGT sensitivity, and output tests were satisfactorily met, but the HNS failed to meet the vacuum stability, water-soluble material, and insoluble material tests. However, because of the stringent time schedule for the overall program and the minor deviations in the tests failed, this lot of HNS-II explosive was accepted with the concurrence of NASA.

13.2 A second procurement of an additional 150 pounds of HNS-II was made. Again a representative sample (identified as ID 1543 of Lot X-766) was taken and the specification tests conducted. This lot passed all the tests except the bulk density test. The HNS was rejected and returned to the manufacturer.

13.3 A third lot of HNS-II was obtained and tested. This lot identified as X-774, passed all the specification tests.

13.4 These data are summarized in Table 17.

14.0 PREPARATION OF THE HNS-II/TEFLON SAMPLES

14.1 The explosive charges for the ALSEP and LSPE program were both made from a 90/10 mixture (by weight) of HNS-II and Teflon. However the type of Teflon powder used and the blending process differed.

14.2 The preparation and processing for the LSPE explosive charge material is described in references (1) and (2), but a brief description is given below:

14.2.1 The HNS/Teflon molding powder used in the ALSEP program was made by mixing aqueously dispersed Teflon 30 with HNS-II. A precipitation with acetone followed the mixing procedure.

14.2.2 For the LSPE explosive charges, the HNS/Teflon molding powder was made by mechanically dry blending the appropriate proportions of HNS-II with 35 micron Teflon-7C powder. This new process not only simplified the manufacture of the mixture, but also yielded a more homogeneous product.

14.3 During the development of this new procedure for HNS and Teflon, two batches of HNS-II/Teflon-7C, were made. The first batch was limited in size to approximately 10 pounds, and is identified as ID 1462. The second batch of HNS-II/Teflon-7C molding powder was made by dry blending the 200-pound sample of HNS-II (X-756) with 20 pounds of Teflon-7C powder. The resulting HNS-II/Teflon-7C powder was identified as X-757 and ID 1493.

14.4 Small scale gap tests and output tests were conducted (See Section 15.0) on the above materials and compared with the HNS-II/Teflon-30 used in the ALSEP program.

15.0 SENSITIVITY AND OUTPUT RESULTS FOR HNS-II AND HNS-II/TEFLON-7C

15.1 SSGT and the steel dent output tests were conducted on the following HNS-II and HNS/Teflon (90/10) explosive samples:

a. HNS-II

1. NOL Identification X-756 (ID 1479)
2. NOL Identification X-766 (ID 1543)
3. NOL Identification X-774 (ID 1557)

b. HNS-II/Teflon-7C (90/10)

1. NOL Identification -- (ID 1462)
2. NOL Identification X-757 (ID 1493)

15.2 The results of these tests are summarized in Tables 18 through 21.

15.2.1 The SSGT sensitivity and output test results obtained for the lots of HNS-IIA are given in Table 18. The SSGT sensitivity results of the three samples are comparable. The steel dent output for these samples was a minimum of 50 mils.

15.2.2 HNS-II/Teflon-7C, (90/10), (ID 1462), Proto sample-- SSGT sensitivity and output test results were determined at 16K and 32 Kpsi loading pressure. Results are given in Table 19. Also included in this table are SSGT sensitivity values for the HNS/Teflon-30 used in the ALSEP program. The HNS/Teflon molding powder appears to be slightly more sensitive than the ALSEP HNS/Teflon emulsion. However, these sensitivity differences may be due to lot differences of the raw materials rather than process differences.

15.2.3 The outputs of the LSPE and ALSEP explosives were measured and compared. Both samples gave dents in steel of approximately 50 mils.

15.2.4 The results for HNS-II/Teflon-7C (90/10)(X-757, ID 1493) are given in Table 20. Additional tests were run at 32 Kpsi to measure the scatter of the test results. The scatter observed for both the SSGT sensitivity and output was extremely small.

15.2.5 HNS-II/Teflon-7C, (90/10), Machinings--sensitivity and output test results were determined for a batch of HNS-II/Teflon-7C, (90/10), (ID 1541). This material was made from blending the HNS-II/Teflon-7C (X-757, ID 1493) machinings obtained from the fabrication of the H.E. blocks. These machinings were given the identification number of 1541. The results are also given in Table 20. The SSGT sensitivity and output are both slightly less than obtained for the virgin HNS-II/Teflon-7C sample.

15.3 All the above data are summarized in Table 21.

16.0 VACUUM THERMAL STABILITY AND COMPATIBILITY TESTS

16.1 Vacuum thermal stability and compatibility tests were run on the HNS/Teflon-7C (90/10) molding powder alone and with various materials and adhesives with which it might make contact in the LSPE arrangement.

16.2 The maximum temperature to which the LSPE explosive hardware will be exposed is 90°C (194°F). Tests were conducted on samples in accordance with the procedures specified in reference (9) and at temperatures of 100°C and 150°C. Results of tests are given in Table 22. They indicate that the materials are stable and compatible (usually 2.0 cc of gas/gm/48 hours must be exceeded to indicate any difficulty).

17.0 PREPARATION OF A SPECIFICATION FOR PROCUREMENT OF HNS-II/TEFLON-7C (90/10)

17.1 Much of the data generated within was used to prepare a working specification document for procuring and testing lots of HNS-II/Teflon-7C, (90/10). This document has been prepared and given the designation NOLS 1015.[10]

18.0 CONCLUSIONS

18.1 A safe and reliable safety and arming mechanism has been developed for the LSPE hardware.

18.1.1 The probabilities of detonation transfers between the in-line explosives components were determined by the Varicomp test method and exceeded 0.9999 at 95% confidence for the following interfaces:

a. between the NASA-EDC and the HNS-II explosive lead,

b. between the HNS-II explosive lead and the HNS-II/ Teflon-7C charge.

18.1.2 When the explosive train is unarmed the probability of detonation transfer to either the HNS-II or the HNS-II/Teflon-7C explosive charge from the NASA/EDC is small, and is less than 0.0001 at 95% confidence.

18.2 The S&A mechanism was redesigned to incorporate an explosive lead. This redesign greatly enhanced the reliability over that of the ALSEP S&A. This lead is 0.250 long and contains HNS-II explosive pressed at 32,000 psi.

18.3 A specification has been prepared for the manufacture of HNS-II/Teflon-7C (90/10; NOLS 1015).

REFERENCES

1. Carroll C. Misener, "Explosives for Lunar Seismic Profiling Experiment (U)", NOLTR 72-95, 15 May 1972

2. A. Bertram, H. Heller, "HNS/Teflon, A New Heat Resistant Explosive (U)", NOLTR 72-293, 28 December 1972

3. W. Elban, "The Development of an Inert Simulant for HNS/Teflon Explosive (U)", NOLTR 72-255, 14 November 1972

4. J. N. Ayres, et al, "Varicomp, A Method for Determining Detonation Transfer Probabilities (U)", NAVWEPS Report 7411, 30 June 1961

5. Grumman Specification LSP 320-307D, "Landing Gear Uplock and Cutting Assembly", 13 August 1970

6. NOL Drawing PL 71-C-1386, Lead, Explosive, LSPE Assembly

7. NOL Drawing PL 71-C-1396, Lead Housing Assembly

8. Weapons Specification WS 5003, "Purchase Description, HNS Explosive"

9. H. T. Simmons, Sr., "The Vacuum Thermal Stability Tests for Explosives (U)", NOLTR 70-142, 28 Oct 1970

10. Naval Ordnance Laboratory Specification NOLS 1015, "HNS/Polytetrafluoroethylene, (90/10)"

Table 1

STEEL DENT OUTPUT DATA FOR THE VARIOUS
LSPE EXPLOSIVE LEAD LOTS

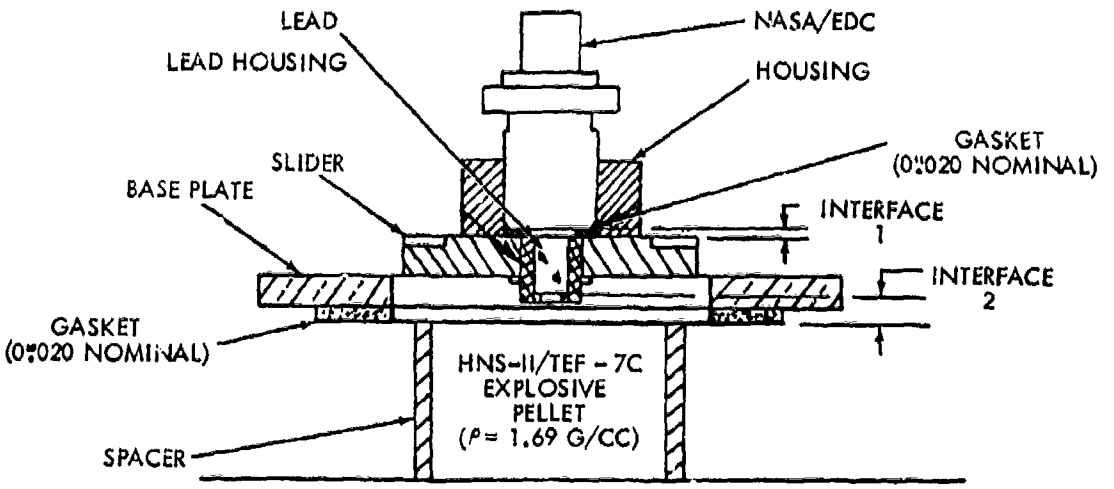
Lot Number	Number Tested	Average Dent ($\bar{X}$) (mils)	Standard Deviation (mils)	CV (%)	Steel Dent (mils)		Test Condition
					Minimum	Maximum	
1	10	30.5	1.11	3.64	28.4	31.6	Ambient
2	25	31.7	0.52	1.64	30.3	35.1	Ambient
	10	34.1	0.86	2.52	32.6	35.1	+160°F
	10	27.6	0.66	2.39	26.5	28.7	-65°F
3	20	31.5	0.58	1.84	30.3	32.4	Ambient
4	10	32.1	1.39	4.33	29.0	34.0	Ambient

Table 2

LSPE - EXPLOSIVE TRAIN REDESIGN - SAFETY AND RELIABILITY TEST PROGRAM

Type of Test	Number of EDC Detonators Required if Detonators are to be from a Single Lot	Number of EDC Detonators Required for Test Program if EDC Detonators Supplied are from more than 1 Lot
Reliability Test Program		
Design (Design Hardware)	10	5/lot
Varicomp (Between detonator and lead)	5	4/lot
Varicomp (Lead to HNS/ Teflon charge) (PBXN-4 Pellet)	5	3/lot
Alignment (Vary alignment of slide to detonator)	6	3/lot
Gap Test (Vary gap between detonator and lead, and lead to HE block)	4 ea. interface	3 ea. interface/lot
Fragment Velocity (Output of detonator in plastic sleeve. High speed photography)	2	2/lot
Temperature	2	1/lot
Misc. (Contingency)	10	5/lot
Safety Test Program		
Design (Fire into safe/arm slide in safe position and also resafe position)	5 total	5/lot, total
Varicomp	5	4/lot
Alignment	6	3/lot
Temperature	2	1/lot
Misc.	5	3/lot
S&A Verification	2	1/lot

TABLE 3
TEST ARRANGEMENT AND RELIABILITY TEST RESULTS, DESIGN EXPLOSIVE



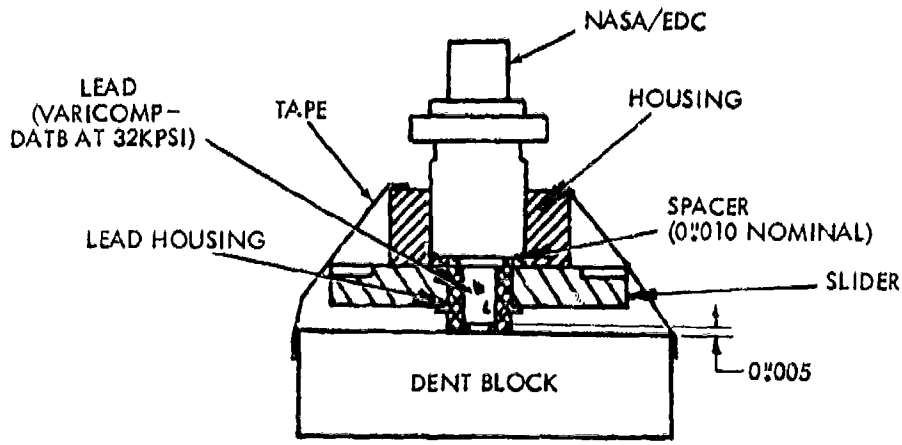
(A) ARRANGEMENT USED FOR RELIABILITY TEST

TEST NUMBER	TYPE DETONATOR		INTERFACE GAPS (MILS)		STEEL DENT OUTPUT (MILS)
	LOT	NO.	BOTTOM OF LEAD TO EXPL. PELLET	BOTTOM OF DETONATOR TO LEAD	
103	CNH	1448	66	20	141
104	CNH	1458	68	19	150
105	CNH	1460	65	19	140
106	CNH	1468	64	21	137
107	CNH	1475	65	20	140
116	CTN	1513	65	19	137
117	CTN	1514	66	18	137
118	CTN	1515	65	20	138
119	CTN	1516	69	20	137
120	CTN	1521	70	17	141

(B) RELIABILITY TEST RESULTS, DESIGN EXPLOSIVE

TABLE 4

DETONATION TRANSFER TEST ARRANGEMENT AND RESULTS BETWEEN THE DETONATOR AND THE VARICOMP LEAD



(A) DETONATOR TO LEAD VARICOMP TEST ARRANGEMENT

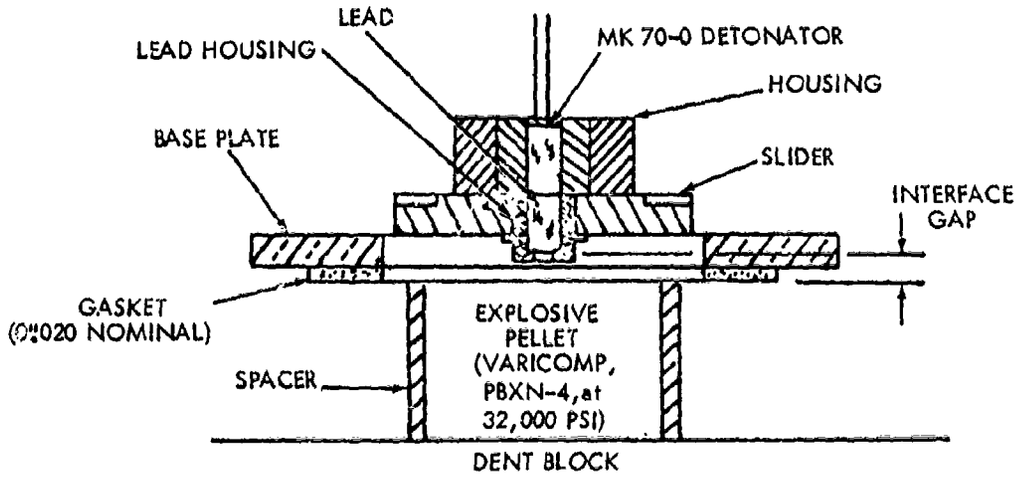
TEST NUMBER	DETONATOR LOT	DETONATOR NO.	INTERFACE GAP (DETONATOR TO LEAD)(1) (MILS)	STEEL DENT OUTPUT (MILS)
112	CNH	1477	16	26
113	CNH	1485	17	31
114	CNH	1486	21	32
115	CNH	1493	22	31
124	CTN	1522	15	32
125	CTN	1525	19	31
126	CTN	1526	18	31
127	CTN	1527	20	30

(1) LEAD CONTAINS DATB (X315) PRESSED AT 32,000 PSI

(B) VARICOMP TRANSFER TEST RESULTS

TABLE 5

DETONATION TRANSFER TEST ARRANGEMENT AND RESULTS BETWEEN THE LEAD AND THE VARICOMP PELLET



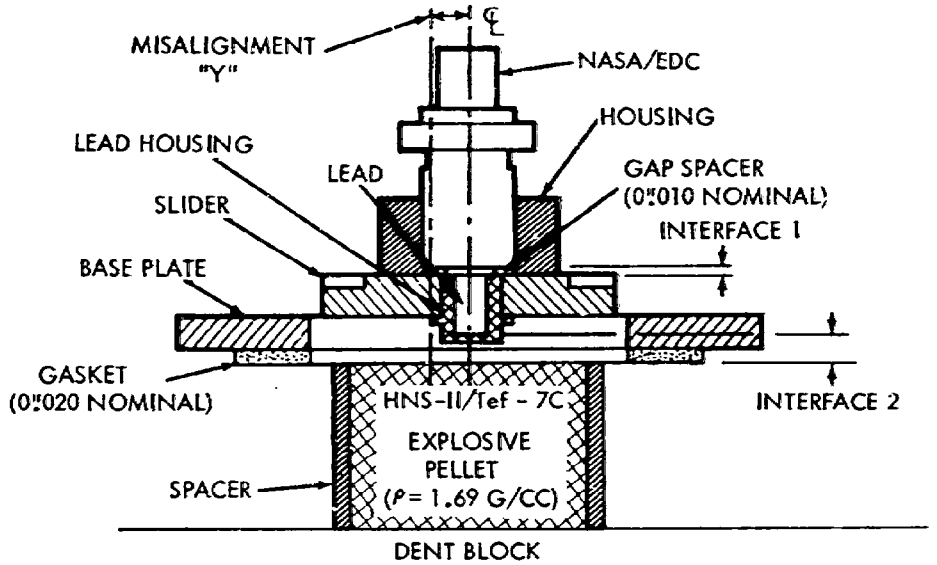
(A) LEAD TO EXPLOSIVE PELLET VARICOMP TEST ARRANGEMENT

SHOT NUMBER	GAP BOTTOM OF LEAD TO TOP HE PELLET (1) (MILS)	DENSITY VARICOMP PELLET (PBXN-4) G/CC	STEEL DENT (MILS)
108	58	1.63	120
109	64	1.60	113
110	65	1.64	119
111	65	1.64	127
121	63	1.62	123
122	66	1.61	130
123	67	1.59	111

NOTE (1) THE PELLET WAS MADE OF PBXN-4(X699) PRESSED AT 32,000 PSI ($\rho \cong 1.66$ G/CC)

(B) TRANSFER TEST RESULTS

TABLE 6
DETONATOR TO LEAD MISALIGNMENT TEST ARRANGEMENT AND RESULTS



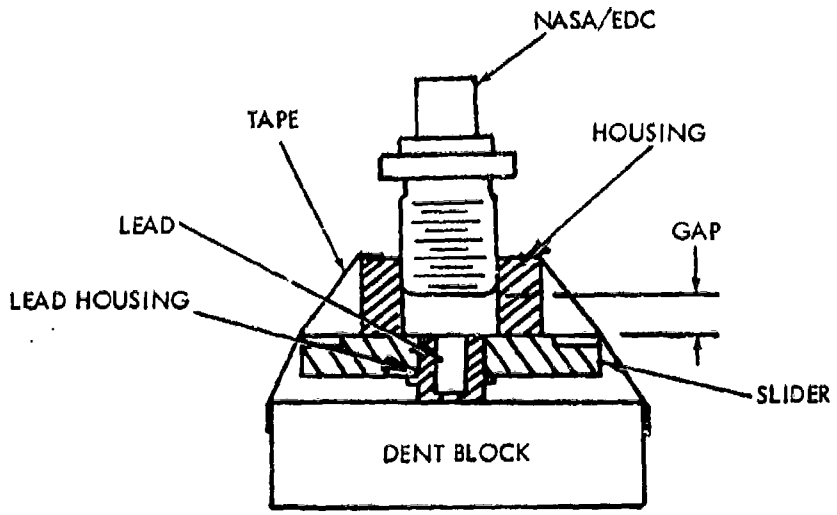
(A) ARRANGEMENT USED FOR RELIABILITY TEST-MISALIGNMENT

SHOT NUMBER	DETONATOR		GAPS (MILS)		MISALIGNMENT "Y" DISTANCE (MILS)	REMARKS
	LOT	NO.	BOTTOM OF LEAD TO EXPL. PELLET	TOP OF LEAD TO DETONATOR		
158	CNH	1387	66	19	150	LEAD FAILED TO GO; BOTTOM BULGED
159	CNH	1391	66	16	100	TRANSFERRED; DENT - 146 MILS
160	CNH	1393	71	22	125	TRANSFERRED; DENT - 134 MILS
161	CTN	1518	72	23	150	LEAD GOES LOW ORDER; EXPL. PELLET PITTED
162	CTN	1539	71	15	100	TRANSFERRED; DENT - 127 MILS
163	CTN	1543	70	16	125	TRANSFERRED; DENT - 142 MILS

(B) MISALIGNMENT TEST RESULTS

TABLE 7

DETONATOR TO LEAD GAP TEST ARRANGEMENT AND RESULTS



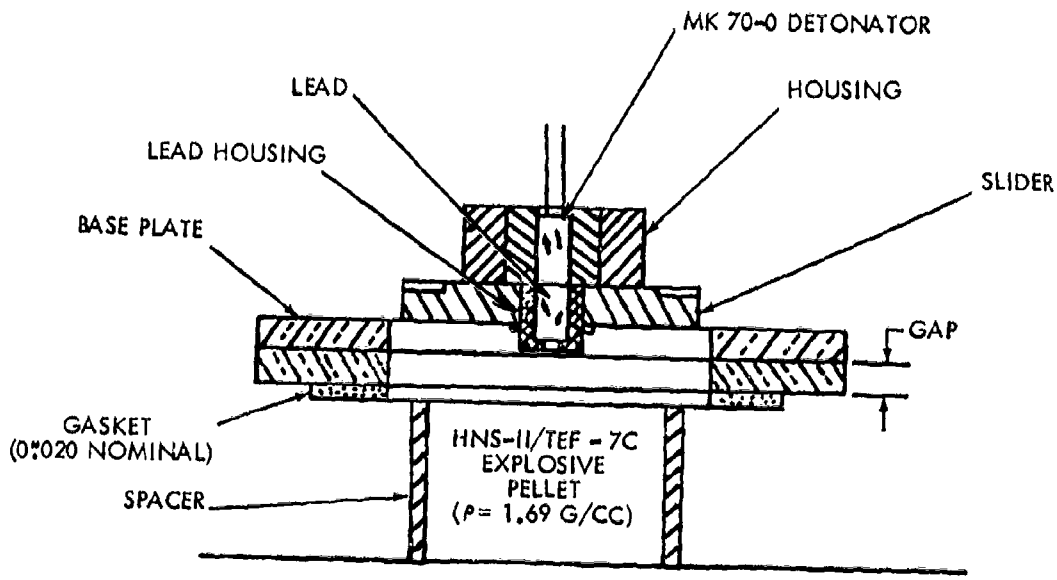
(A) ARRANGEMENT FOR DETONATOR TO LEAD GAP TEST

SHOT NUMBER	DETONATOR		GAP BETWEEN DETONATOR AND LEAD (MILS)	OUTPUT DENT (MILS)
	LOT	NO.		
152	CNH	1380	150	TRANSFERRED, DENT - 23 MILS
153	CNH	1381	250	TRANSFERRED, DENT - 26 MILS
154	CNH	1386	350	TRANSFERRED, DENT - 29 MILS
155	CTN	1528	150	TRANSFERRED, DENT - 31 MILS
156	CTN	1536	250	TRANSFERRED, DENT - 23 MILS
157	CTN	1542	350	TRANSFERRED, DENT - 23 MILS

(B) GAP TEST RESULTS

TABLE 8

LEAD TO EXPLOSIVE PELLET GAP TEST ARRANGEMENT AND RESULTS



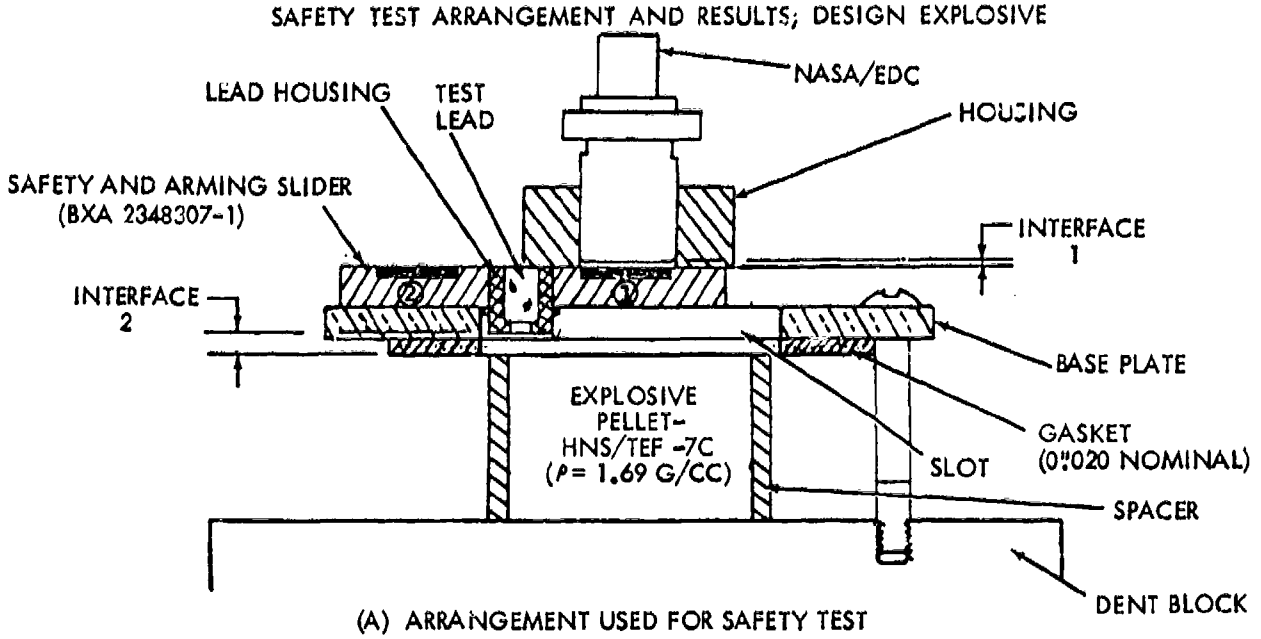
(A) ARRANGEMENT FOR LEAD TO EXPLOSIVE PELLET GAP TEST

SHOT NUMBER	GAP, BOTTOM OF LEAD TO SPACER PLATE (MILS)	THICKNESS SPACER PLATE (MILS)	TOTAL TRANSFER GAP (MILS)	RESULTS
164	50	125	175	TRANSFERRED, DENT - 151 MILS
165	41	250	291	TRANSFERRED, DENT - 140 MILS
166	37	375	412	TRANSFERRED, DENT - 137 MILS
167	53	125	178	TRANSFERRED, DENT - 137 MILS
168	43	250	293	TRANSFERRED, DENT - 140 MILS
169	46	375	421	TRANSFERRED, DENT - 143 MILS

(B) GAP TEST RESULTS

TABLE 9

SAFETY TEST ARRANGEMENT AND RESULTS; DESIGN EXPLOSIVE



(A) ARRANGEMENT USED FOR SAFETY TEST

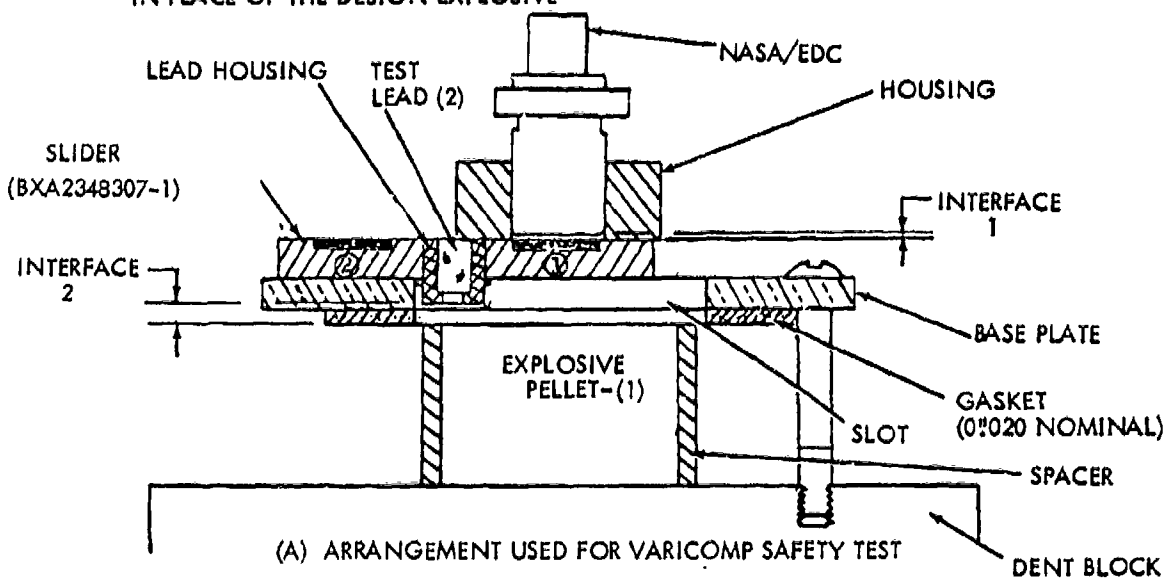
TEST NUMBER	DETONATOR		INTERFACE GAPS (MILS)		POSITION OF LEAD*	REMARKS
	LOT	NO.	TOP OF LEAD TO DETONATOR	BOTTOM OF LEAD TO EXPL. PELLET		
128	CNH	1436	7	49	INITIAL SAFE	FAILED SAFE
129	CNH	1443	10	54	INITIAL SAFE	FAILED SAFE
130	CNH	1454	10	33	INITIAL SAFE	FAILED SAFE
131	CNH	1459	11	49	RE-SAFE	FAILED SAFE
132	CNH	1464	8	54	RE-SAFE	FAILED SAFE
133	CTN	1529	9	51	INITIAL SAFE	FAILED SAFE
134	CTN	1530	12	46	INITIAL SAFE	FAILED SAFE
135	CTN	1531	7	43	INITIAL SAFE	FAILED SAFE
136	CTN	1533	8	50	RE-SAFE	FAILED SAFE
137	CTN	1534	8	45	RE-SAFE	FAILED SAFE

NOTE THE SAFETY AND ARMING DEVICE IS DESIGNED SO THAT THE SLIDER CONTAINING THE LEAD AND LEAD HOUSING WILL GO FROM AN INITIAL SAFE OUT-OF-LINE POSITION (POSITION #1) TO AN ARMED POSITION, AND AFTER A CERTAIN TIME SEQUENCE TO A RE-SAFE OUT-OF-LINE POSITION (POSITION #2). THE AMOUNT OF LEAD COVERED BY THE DETONATOR HOUSING DIFFERS IN THE SAFE AND RE-SAFE POSITION. THE LEAD IS APPROXIMATELY 1/2 COVERED IN THE SAFE POSITION AND 1/3 COVERED IN THE RE-SAFE POSITION. SEE FIG. 13

(B) SAFETY TEST RESULTS

TABLE 10

SAFETY TEST ARRANGEMENT AND RESULTS USING VARICOMP EXPLOSIVE (PETN) IN PLACE OF THE DESIGN EXPLOSIVE



(A) ARRANGEMENT USED FOR VARICOMP SAFETY TEST

TEST NUMBER	DETONATOR		INTERFACE GAPS (MILS)		POSITION OF LEAD (3)	REMARKS
	LOT	NO.	TOP OF LEAD TO DETONATOR	BOTTOM OF LEAD TO EXPL. PELLET		
138	CNH	1467	9	50	INITIAL SAFE	FAILED SAFE
139	CNH	1470	10	51	INITIAL SAFE	FAILED SAFE
140	CNH	1478	6	46	INITIAL SAFE	FAILED SAFE
141	CNH	1492	9	44	RE-SAFE	FAILED SAFE
142	CTN	1535	10	49	INITIAL SAFE	FAILED SAFE
143	CTN	1538	9	52	INITIAL SAFE	FAILED SAFE
144	CTN	1540	8	54	INITIAL SAFE	FAILED SAFE
145	CTN	1541	11	46	RE-SAFE	FAILED SAFE

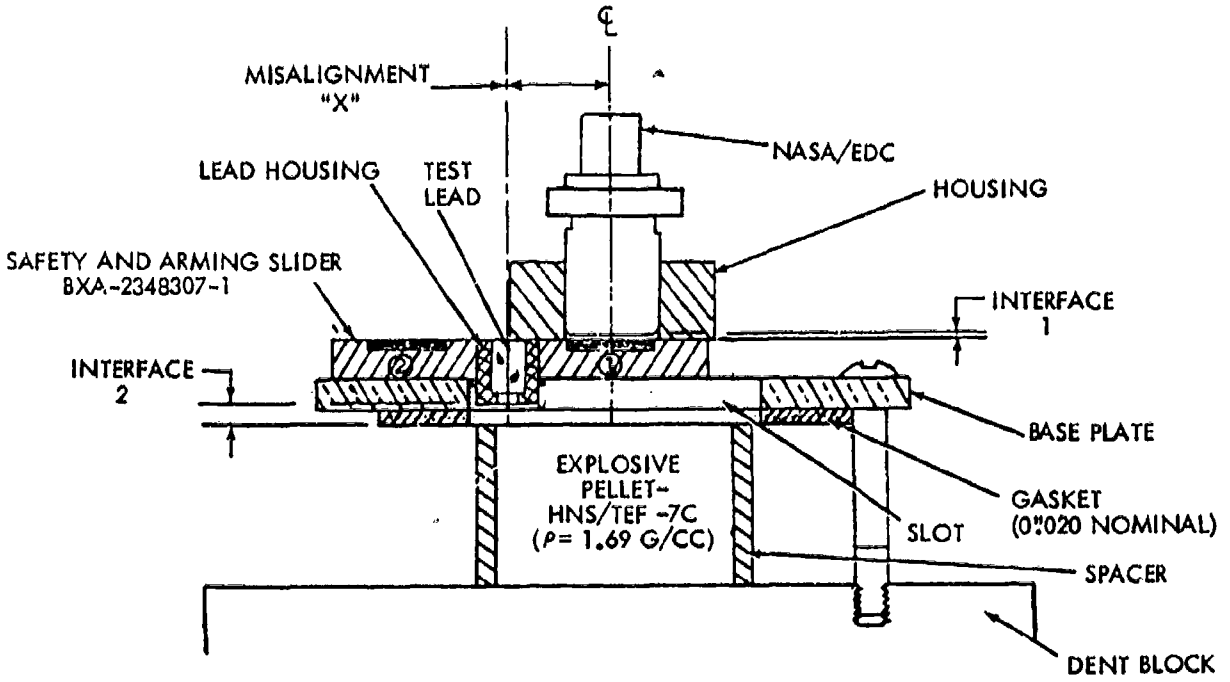
(1) THE DENSITY OF THE VARICOMP PELLET, PETN (AT 32,000 PSI) WAS APPROXIMATELY 1.67 G/CC

(2) THE DENSITY OF THE VARICOMP LEAD (PETN) (AT 8,000 PSI) WAS APPROXIMATELY 1.51 G/CC

(3) SEE FIG. 13

(B) VARICOMP SAFETY TEST RESULTS

TABLE 11
SAFETY TEST ARRANGEMENT AND RESULTS OF THE SLIDER MISALIGNED FROM THE SAFE POSITION



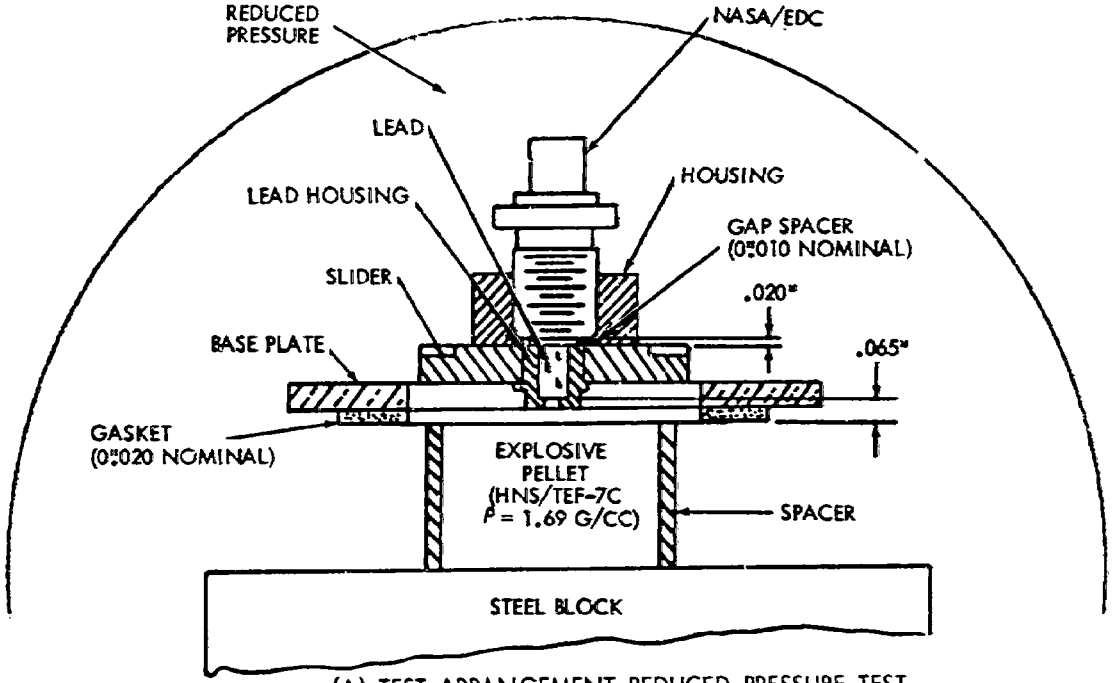
(A) ARRANGEMENT USED FOR RELIABILITY TEST - MISALIGNMENT

SHOT NUMBER	DETONATOR		GAPS (MILS)		MISALIGNMENT DISTANCE "X" (MILS) (SEE NOTE 1)	REMARKS
	LOT	NO.	TOP OF LEAD TO DETONATOR	BOTTOM OF LEAD TO EXPL. PELLET		
147	CNH	1367	11	50	400	FAILED SAFE
148	CNH	1368	6	53	300	FAILED SAFE
149	CTN	1508	7	50	400	FAILED SAFE
150	CTN	1509	9	51	300	FAILED SAFE

NOTE 1 WHEN THE LEAD IS IN THE INITIAL SAFE, OR RE-SAFE POSITION, X IS 0.500 INCH.

(B) MISALIGNMENT SAFETY TEST RESULTS

TABLE 12
ARRANGEMENT AND RESULTS OF REDUCED PRESSURE TEST



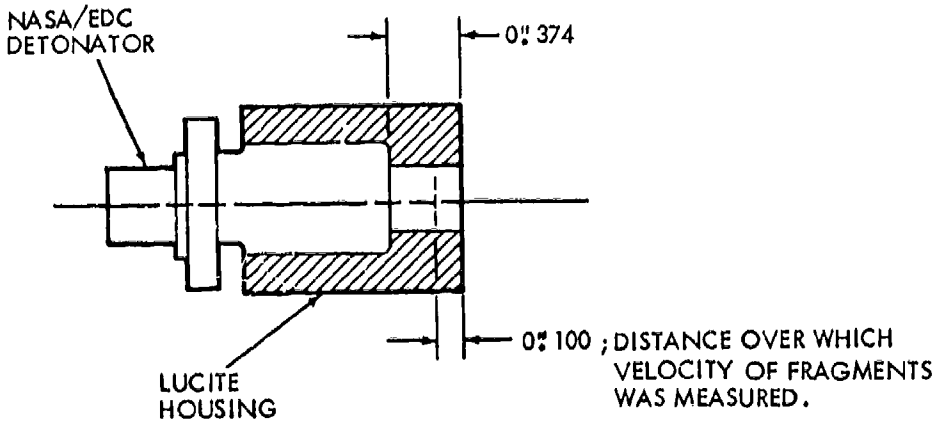
(A) TEST ARRANGEMENT-REDUCED PRESSURE TEST

TEST NUMBER	TYPE DETONATOR		INTERFACE GAPS (MILS)		STEEL DENT OUTPUT (MILS)	REMARKS
	LOT	NO.	BOTTOM OF LEAD TO EXPL. PELLET	BOTTOM OF DETONATOR TO LEAD		
101	CNH	1466	-	-	124	TESTED IN VACUUM OF 0.0055 MM MERCURY
102	CNH	1471	-	-	138	TESTED IN VACUUM OF 0.0060 MM MERCURY

(B) RESULTS OF REDUCED PRESSURE TESTS

TABLE 13

GAS VELOCITY TEST RESULTS FOR VARIOUS LOTS OF EDC DETONATORS



TEST NUMBER	LOT	DETONATOR SERIAL NUMBER	GAS VELOCITY (METERS/SEC)
1	BYA	635	3990
2	CNH	1452	3110
3	CNH	1489	3270
4	CTN	1547	3400
5	CTN	1549	3175

Table 14

RESULTS OF RELIABILITY TESTING AT 200°F

Shot No.	Gap (Lead to H.E. Surface)	Temperature	Remarks
181	88 mils	195°F--200°F	Fired--Dent 137 (mils)
182	87 mils	195°F--200°F	Fired--Dent 135 (mils)

Table 15

RELIABILITY TEST RESULTS OF REDESIGNED BASEPLATE

No. of Shots	Type Test	Test Explosive	Gap[1] (inches)	Steel Dent Output (mils)	Results (Ratio of Fires/No. Tested)
5	Varicomp	PBXN-4 (32 Kpsi)	0.139 to 0.144	≅110	2/5
5	Design	HNS-II/TEF-7C (32 Kpsi)	0.136 to 0.143	≅120	5/5

[1]This gap is the gap between the bottom of the lead and the top of the H.E. charge.

TYPE SLIDE	B X A DRAWING NO.	DESCRIPTION	RESULTS (SUCCESSES TO NUMBER TESTED)
TEST SLIDE	NO. 2348507	0".025 RADIUS, HEAT TREATED	18/18
PROTO. SLIDE	NO. 2348593	<0".005 RADIUS, ANNEALED	0/2
QUAL-FLIGHT (LOT 1)	NO. 2348593 REV x 3	<0".005 RADIUS, HEAT TREATED	6/6 AT AMBIENT 0/2 AT 200° F. 6/8
QUAL-FLIGHT (LOT 2)	NO. 2348593 REV x 4	0".040 RADIUS, HEAT TREATED	2/2
QUAL-FLIGHT (LOT 3)	NO. 2348593 REV x D	0".040 RADIUS, HEAT TREATED	(2/2)

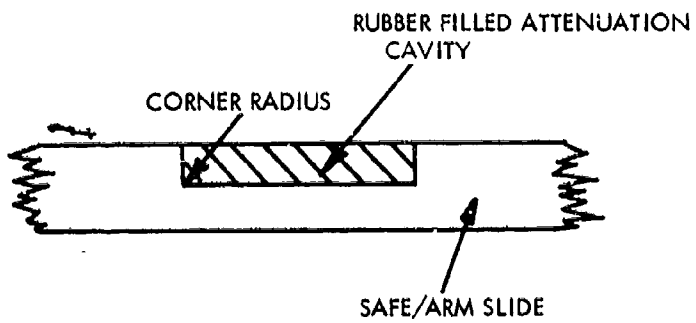


TABLE 16 SUMMARY OF SAFE/ARM SLIDE RESULTS

TABLE 17

SPECIFICATION TEST RESULTS FOR HNS-II

	Lot 1 (X756; ID 1479)	Lot 2 (X766; ID 1543)	Lot 3 (X774; ID 1557)
Passed	Melting Point Surface Moisture Bulk Density SSGT Sensitivity Output	Melting Point Surface Moisture SSGT Sensitivity Output Vacuum Stability Water-Soluble Matl Insoluble Matl	All Tests Passed
Failed	Vacuum Stability Water-soluble Matl Insoluble Matl	Bulk Density	None
Status	Accepted	Rejected	Accepted

TABLE 18

SSGT Sensitivity and Output Test Results of
Various HNS-II Samples Procured for the LSPE Program

NOL Identification Number	Loading Pressure (Kpsi)	Density (g/cc)			SSGT Sensitivity (DBg)			Output (mils)		
		Number	Ave	Std Dev	Number	Ave	(g)[1]	Number	Ave	Std Dev
X-756 ID 1479	32	25	1.628	0.0039	20	5.32	0.098	5	50.72	1.12
X-766 ID 1543	32	25	1.633	0.0032	20	5.54	0.049	5	53.59	1.33
X-774 ID 1557	32	25	1.646	0.0038	20	5.48	0.035	5	50.69	2.31

[1] This value (g) is the estimate of gamma of the logit distribution used for the analysis of the test data. This g is to the logistic distribution as the standard deviation (σ) is to the normal distribution. A correlation of g and σ for various percent points is given below:

Normal Distribution	Percent	Logistic Distribution
$\bar{x}$	50	$\bar{x}$
$\bar{x} + 1.28\sigma$	90	$\bar{x} + 2.20g$
$\bar{x} + 1.65\sigma$	95	$\bar{x} + 2.94g$
$\bar{x} + 2.33\sigma$	99	$\bar{x} + 4.60g$
$x + 3.09\sigma$	99.9	$x + 6.90g$

Table 19

SENSITIVITY AND OUTPUT OF HNS/TEFLON-7C (90/10)

A. SSGT

Loading Pressure (Kpsi)	ALSEP HNS/TEFLON (90/10) X-581				LSPE HNS/TEFLON-7C (90/10) (ID 1462)			
	Density (g/cc)		Sensitivity (DBg)		Density (g/cc)		Sensitivity (DBg)	
	Ave	Std Dev (s)	Ave	(g)[1]	Ave	Std Dev (s)	Ave	(g)[1]
4	1.427	0.0025	4.85	0.023	-	-	-	-
8	1.506	0.0047	5.07	0.029	-	-	-	-
16	1.618	0.0035	5.55	0.047	1.640	0.0019	5.13	0.002
32	1.700	0.0018	6.25	-	1.714	0.0023	6.05	0.056
32(1)	-	-	-	-	1.715	0.0036	6.10	0.018
64	1.756	0.0030	7.34	0.023	-	-	-	-

[1] see note Table 18.

B. Output

Loading Pressure (Kpsi)	Number of tests	Steel Dent Output (mils)			
		ALSEP HNS/TEFLON (90/10) X-581		LSPE HNS/TEFLON-7C (90/10) ID 1462	
		Ave($\bar{X}$)	(s)	$\bar{x}$	s
4	5	43.4	2.23	-	-
8	5	44.1	1.86	-	-
16	5	48.3	1.92	49.6	1.74
32	5	48.5	1.75	51.0	2.36
32(1)	-	-	-	48.16	1.96
64	5	50.2	2.09	-	-

(1) These samples were conditioned at a temperature of 250°F for 25 hours cooled to ambient, and then tested.

TABLE 20
SMALL SCALE GAP TEST (SSGT) DATA FOR HNS-II/TEFLON-7C (90/10), x 757

EXPLOSIVE	(90/10) HNS-II/Tef-7C	NOL IDENTIFICATION X NO.	x757
TMD		I. D. NO.	1493

LOADING PRESSURE (KPSI)	DENSITY (GM/CM³)		SENSITIVITY (DBG)				STEEL DENT OUTPUT (MILS) (2)			REMARKS
	AVG.	s	AVG.	g	s_m (1)	N	AVG.	STD DEV	N	
4	1.396	0.0062	4.50	-	-	20	43.1	1.53	4	
8	1.502	0.0047	4.75	0.026	0.0178	20	43.9	1.61	3	
16	1.625	0.0027	5.18	0.030	0.0234	20	46.4	1.11	5	
32	1.703	0.0026	5.83	0.050	0.0330	20	49.7	2.15	5	
32	1.704	0.0045	5.89	0.040	0.0316	20	49.6	2.04	5	Retest for reproducibility
32	1.700	0.0024	6.28	0.093	0.0520	20	47.7	2.13	5	Reblend (see Note(3), ID 1541
64	1.752	0.0024	7.01	0.040	0.0237	20	50.5	1.33	2	

NOTE 1 STANDARD DEVIATION OF THE MEAN.
NOTE 2 AVERAGE DENT CORRECTED FOR BLOCK HARDNESS DIFFERENCES; SEE PROCEDURE OUTLINED IN WS5003E.
NOTE 3 SAMPLE (ID 1541) MADE BY BLENDING MACHINGINGS FROM FABRICATION OF HE BLOCKS.

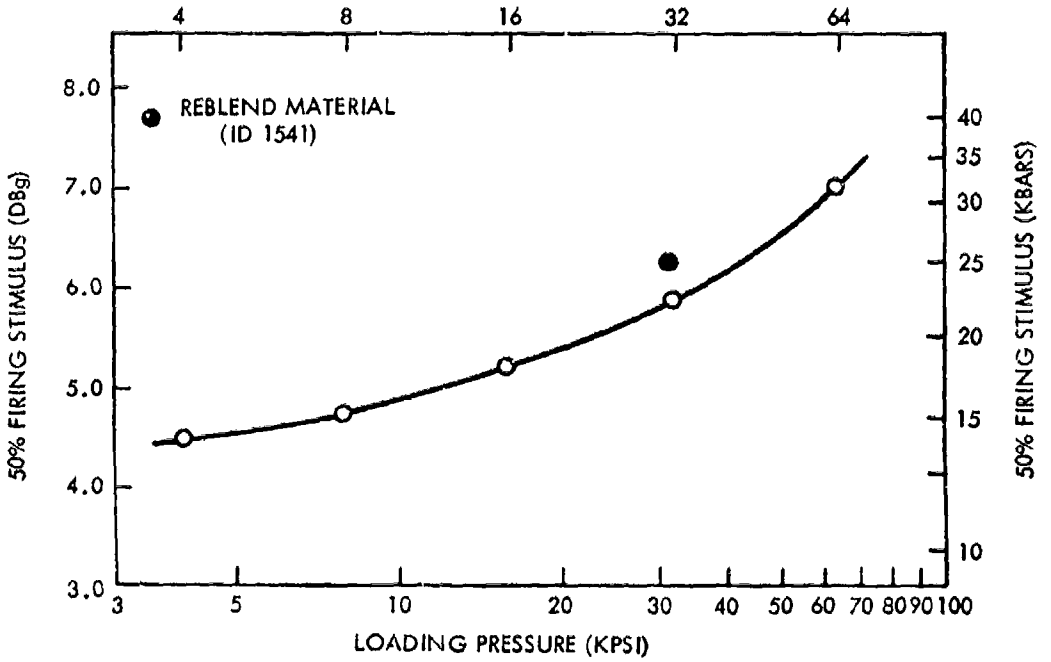


TABLE 21

COMPARISON OF THE SENSITIVITY AND OUTPUT RESULTS OF THE LSPE HNS-II/TEFLON-7C (90/10) WITH THE ALSEP HNS-II/TEFLON-30 (90/10)

Consolidation Pressure(Kpsi)	ALSEP Expl. (X581)	LSPE Expl. (ID 1462)[1]	LSPE Expl. (X757)
	DENSITY (g/cc)		
4	1.427	-	1.396
8	1.506	-	1.502
16	1.618	1.640	1.625
32	1.700	1.714	1.704 (1.700)[2]
64	1.756	-	1.752
	SSGT SENSITIVITY (DBg)		
4	4.85	-	4.50
8	5.07	-	4.75
16	5.55	5.13	5.18
32	6.25	6.05	5.83 (5.89)[2]
64	7.34	-	7.01
	STEEL DENT OUTPUT (mils)		
4	43.4	-	43.1
8	44.1	-	43.9
16	48.3	49.6	46.4
32	48.5	51.0	49.7 (47.7)[2]
64	50.2	-	50.5

[1]Pilot production lot.
[2]Retested at 32K to get measure of variability.

Table 22

VACUUM STABILITY AND COMPATIBILITY TEST RESULTS

Sample (Sample Weight 0.2 gm in all tests)	Test Temperature (°C)	Gas Evolved ml/g/48 hrs	Remarks
HNS-II/Teflon-7C (ID 14)	230	-	0.15 ml/g/hr for a 2 hr period
HNS-II/Teflon-7C (ID 1462)/DC-92-024[1] 50/50	150	0.6	
HNS-II/Teflon-7C (ID 1462)/Cohrlastic[1] 50/50		0.3	
HNS-II/Teflon-7C (ID 1462)/Eccofoam[1] 50/50		<0.1	
HNS-II/Teflon-7C (ID 1462)/DC-92-024/ Cohrlastic 50/25/25		0.9	
HNS-II/Teflon-7C (ID 1462)/Eccofoam/ Cohrlastic 50/25/25		<0.1	
HNS-II/Teflon-7C (ID 1493)/Mylar 80/20	100	0.17	Tests continued for 4 weeks with no additional gas evolved, and no evidence of chemical interaction
HNS-II/Teflon-7C (IS 1493)/Mylar/DC-92-024/ Cohrlastic 70/10/10/10		0.16	

[1]Trade names of adhesives and gaskets used in LSPE and furnished by Bendix Aerospace. Covered by specification and drawing but lot numbers unknown.

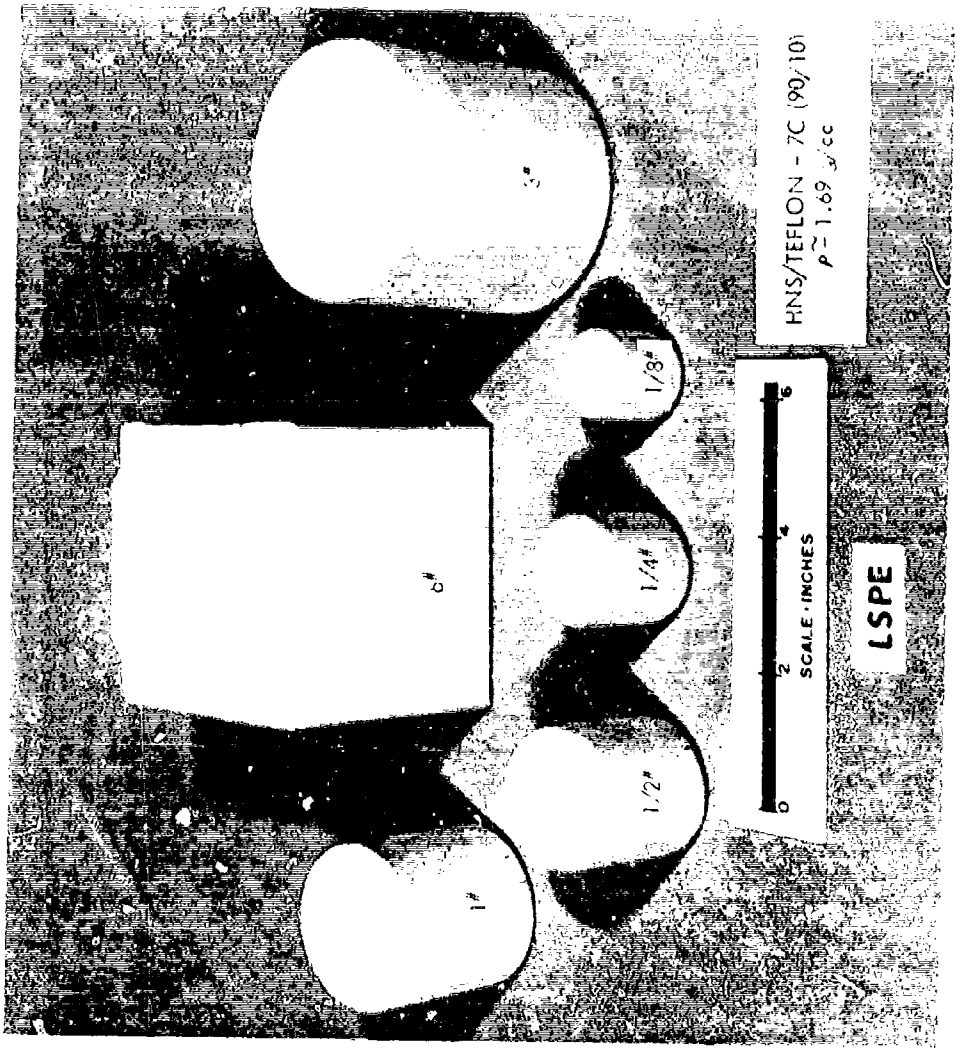
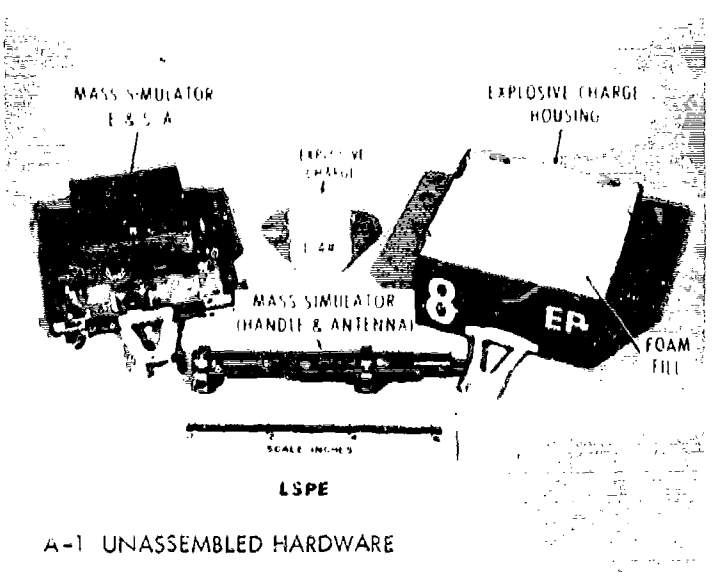
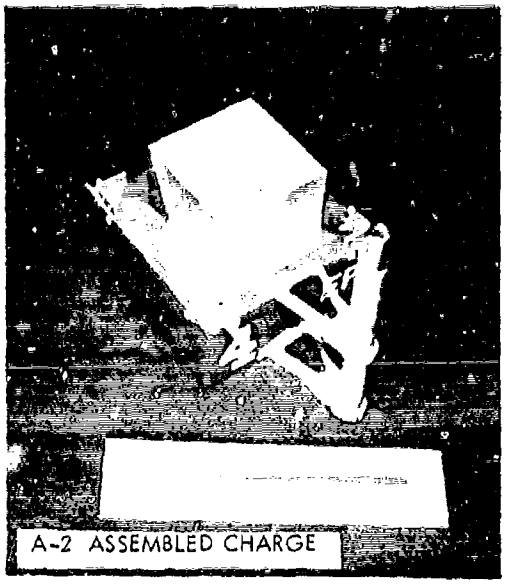


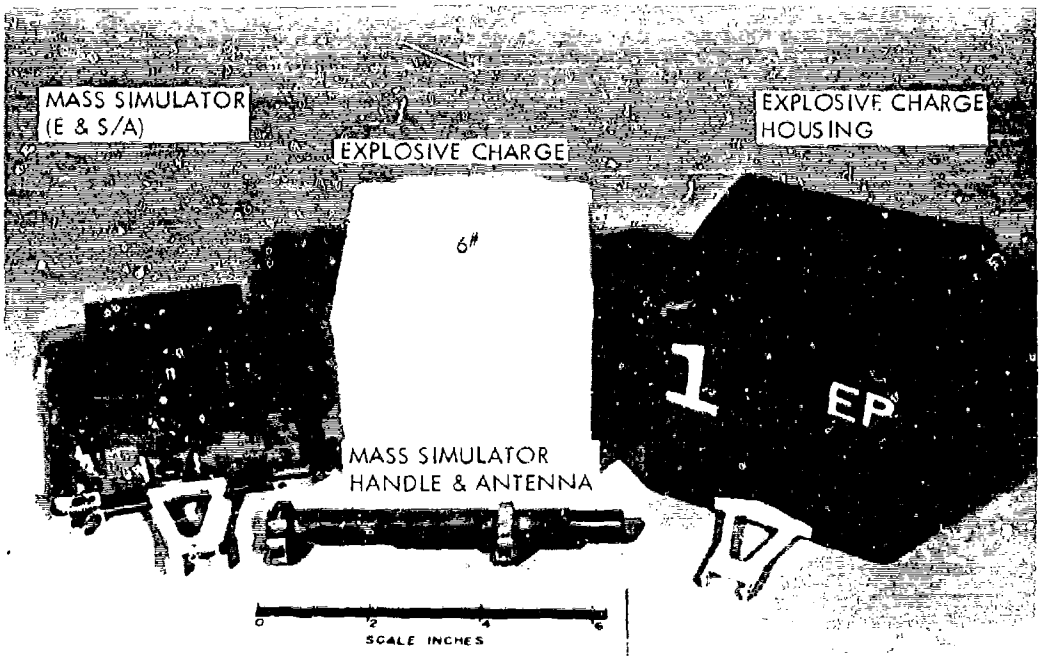
FIG. 1 LSPE EXPLOSIVE CHARGES



A-1 UNASSEMBLED HARDWARE



A COMPONENTS FOR THE 1/4-LB LSPE EXPLOSIVE CHARGE



B. COMPONENTS FOR THE 6-LB LSPE EXPLOSIVE CHARGE

FIG. 2 COMPONENTS FOR THE LSPE EXPLOSIVE PACKAGES

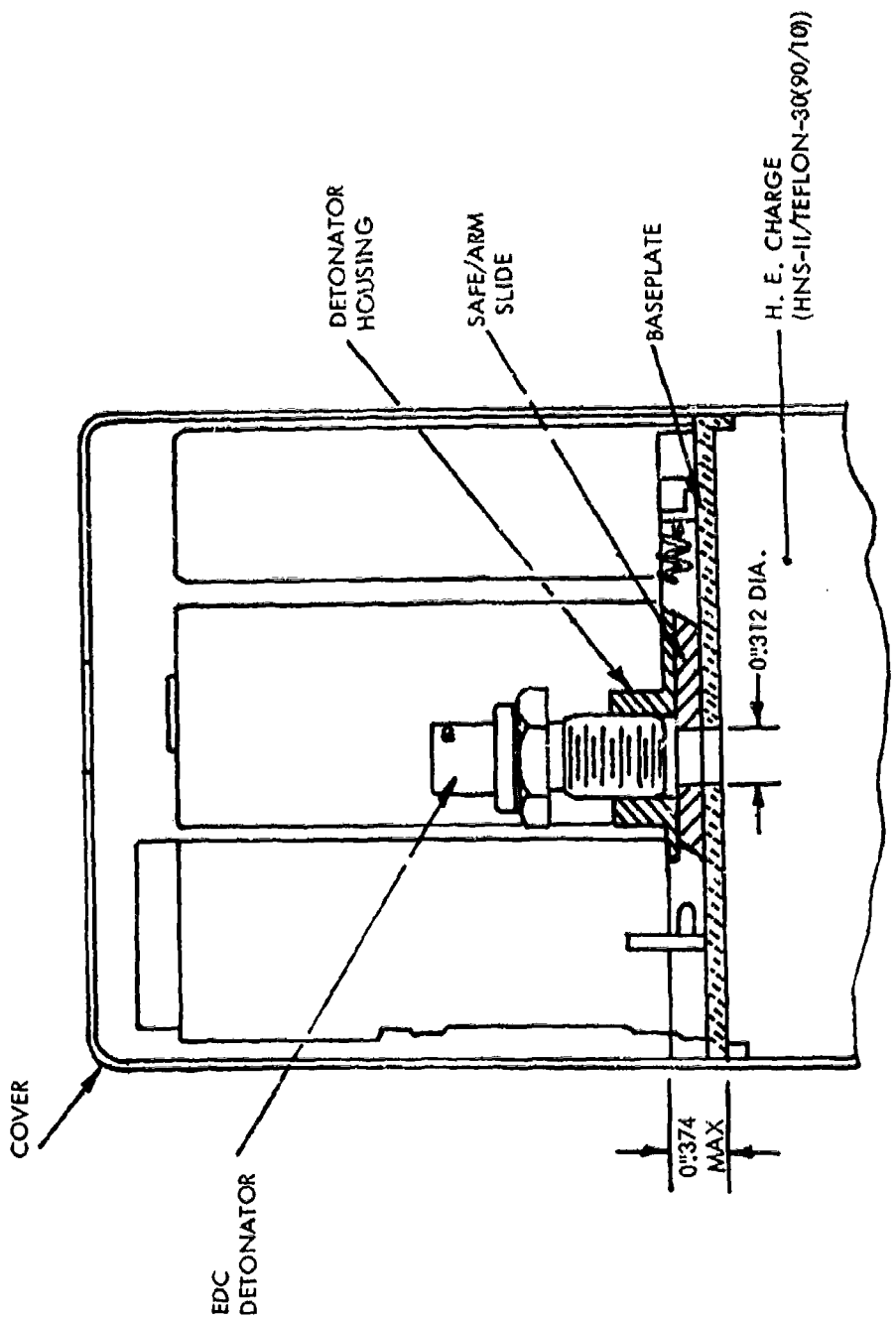
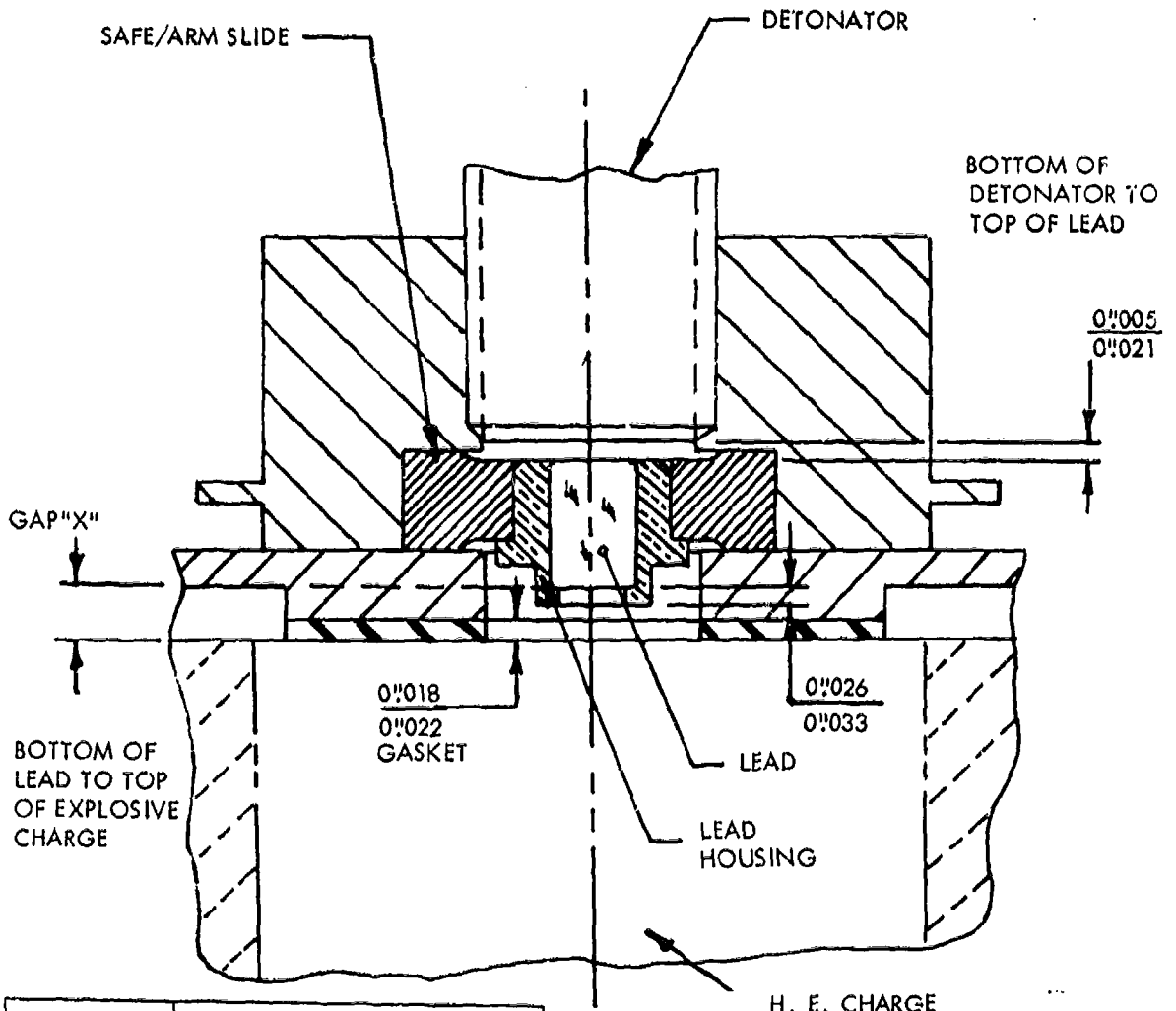


FIG. 3 SAFETY AND ARMING MECHANISM USED IN ALSEP EXPLOSIVE CHARGES



DESIGN NUMBER	"X GAP" DIMENSION (MILS)	
	MIN.	MAX.
#1	46	67
#2	87	97

FIG. 4 SAFETY AND ARMING DEVICE DESIGNED FOR LSPE EXPLOSIVE CHARGES

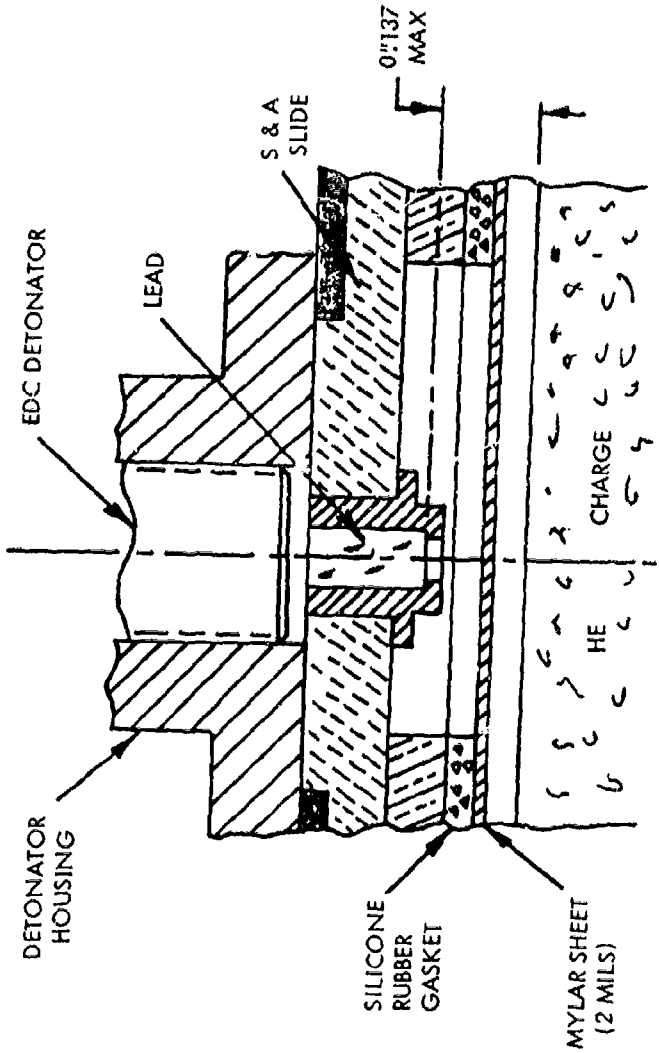


FIG. 5 BASEPLATE REDESIGN FOR LSPE EXPLOSIVE PACKAGE

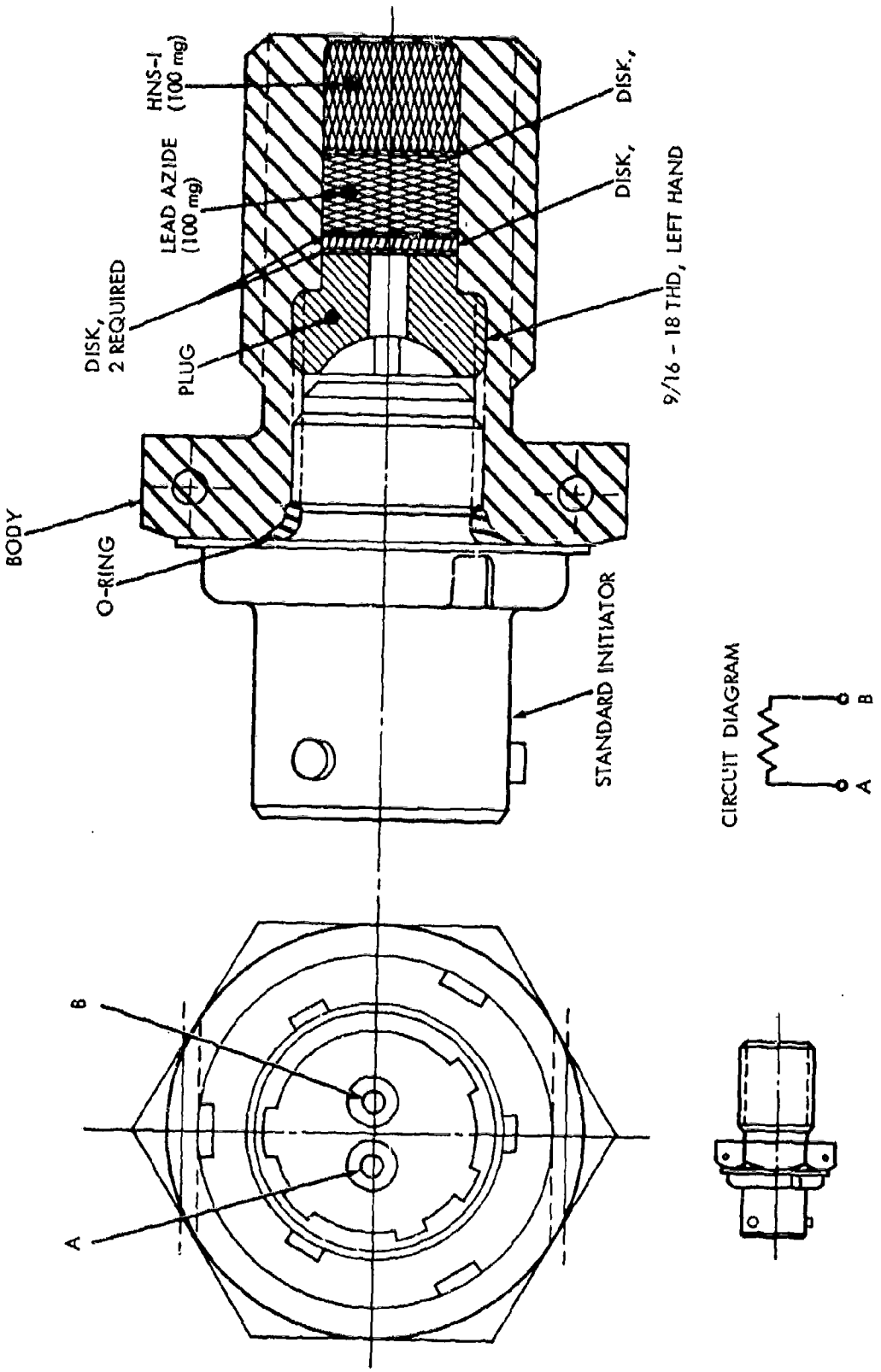


FIG. 6 DETONATOR ASSEMBLY, (SOS DWG NO. 15-10198-15)

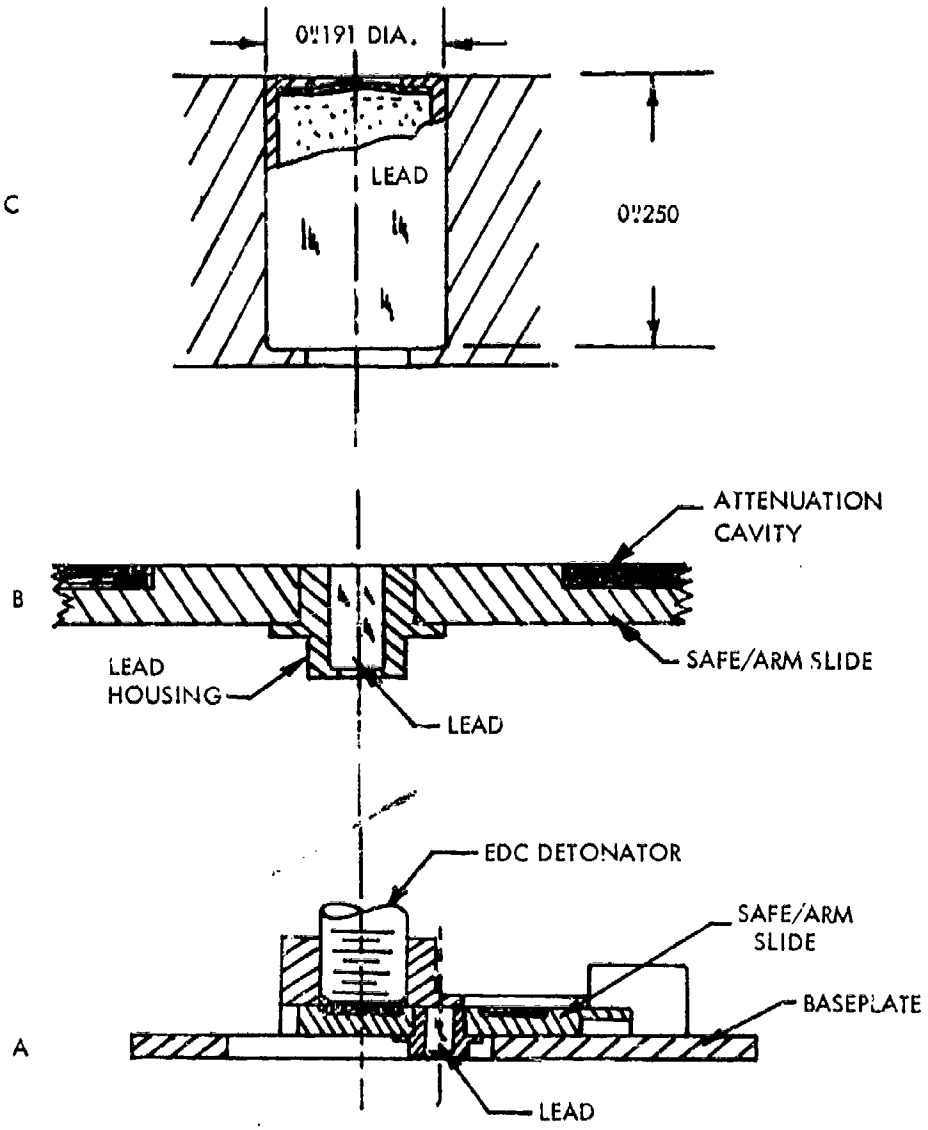


FIG. 7 RECOMMENDED REDESIGN OF S & A DEVICE USING AN HNS-II EXPLOSIVE LEAD

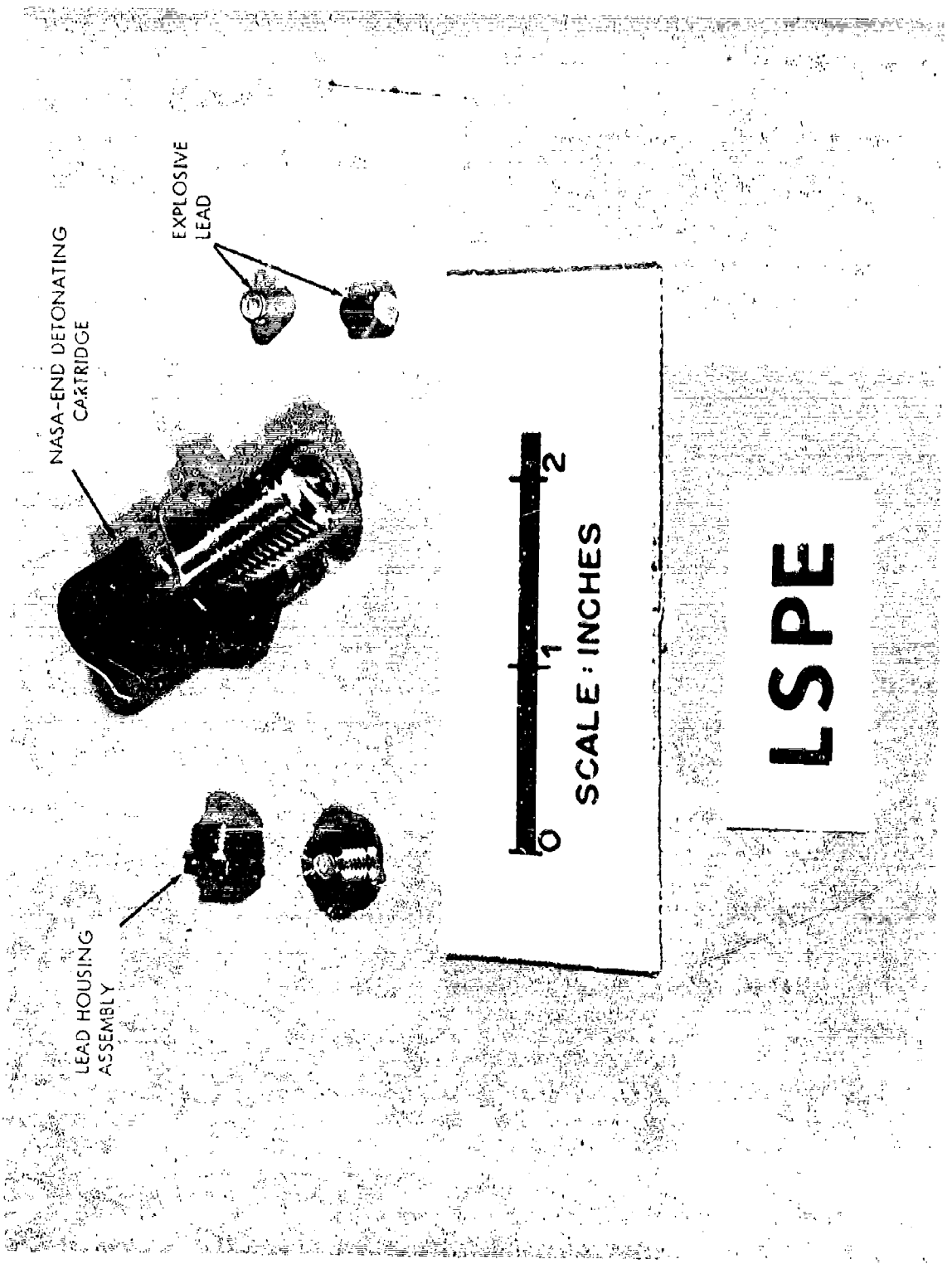


FIG. 8 PHOTOGRAPH OF THE ACTUAL EXPLOSIVE LEAD, LEAD HOUSING ASSEMBLY, AND THE EDC DETONATOR

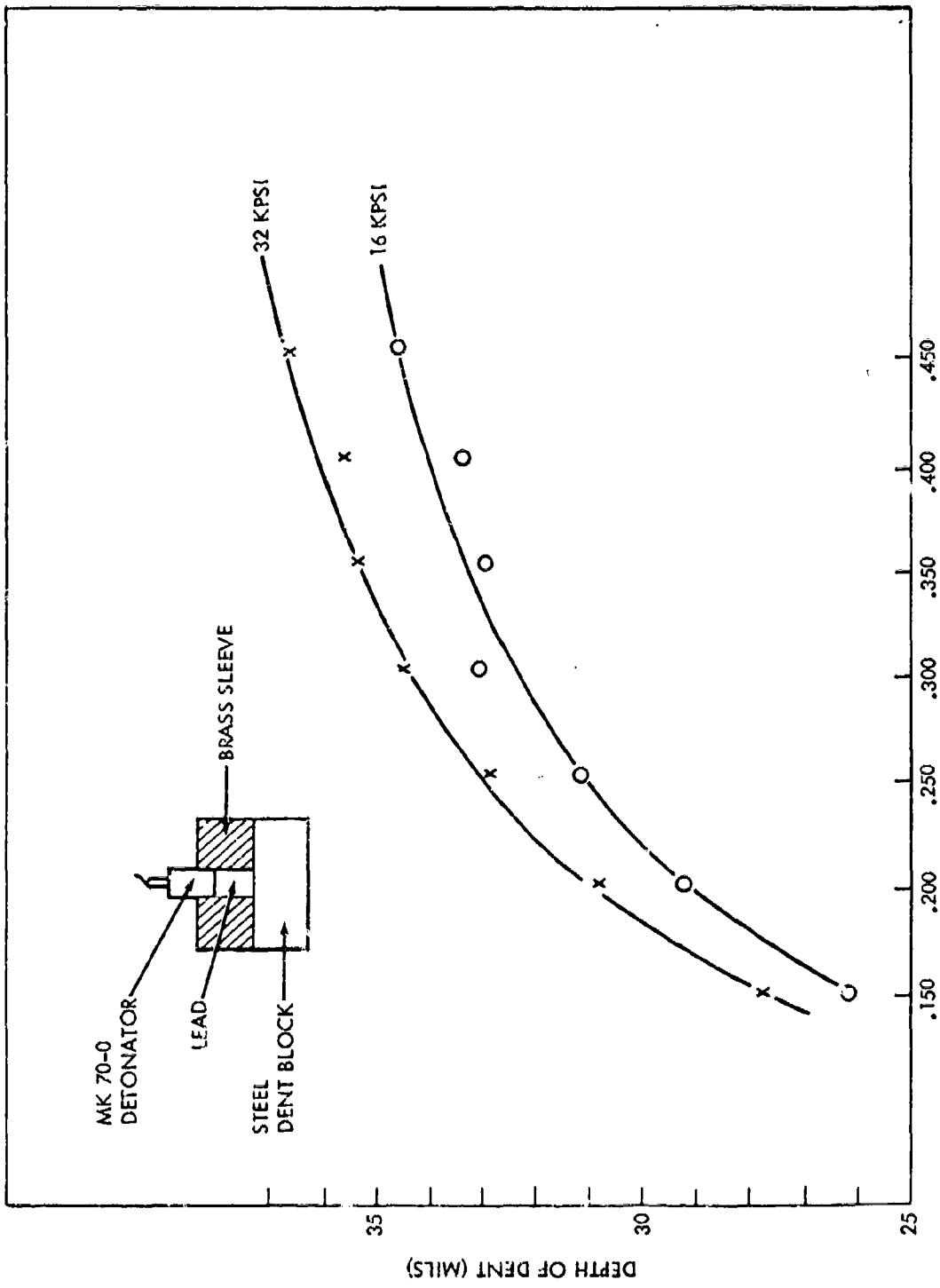
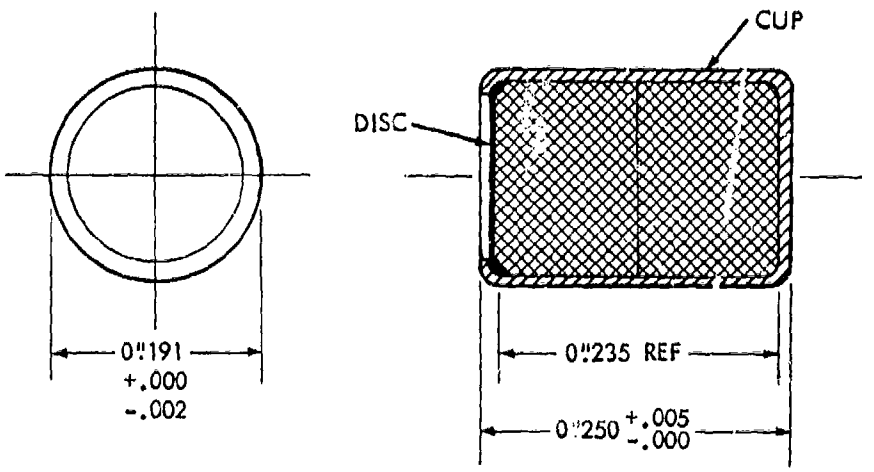


FIG. 9 OUTPUT VS COLUMN LENGTH FOR LSPE LEAD

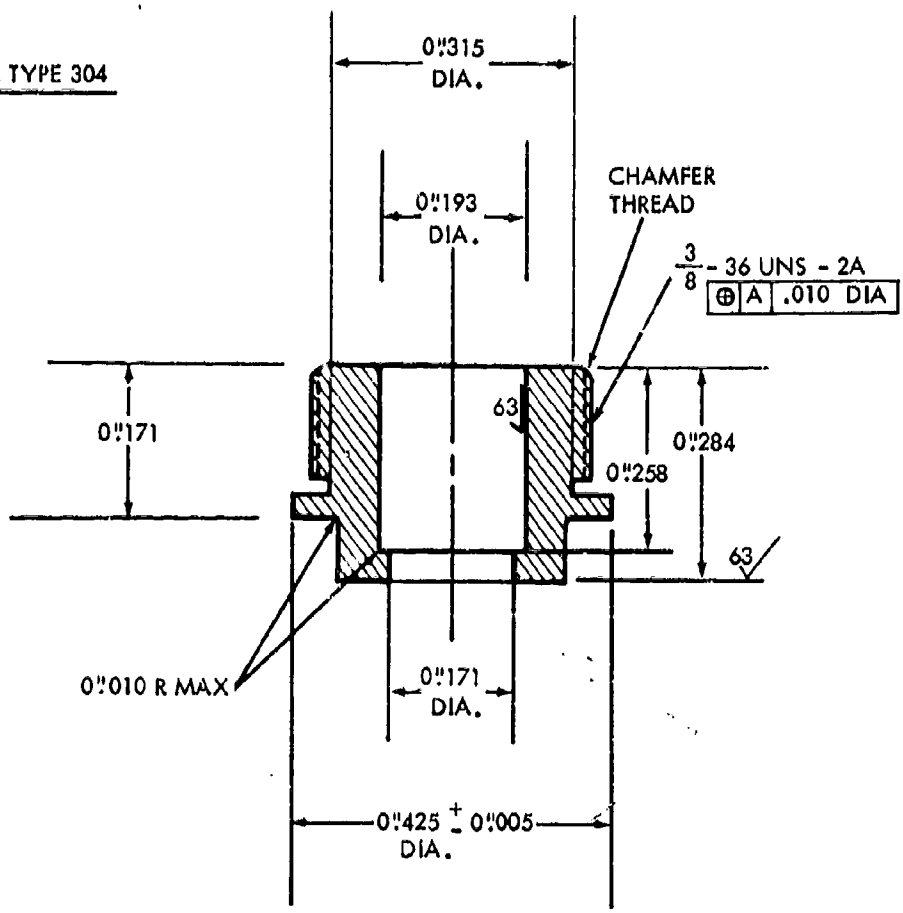


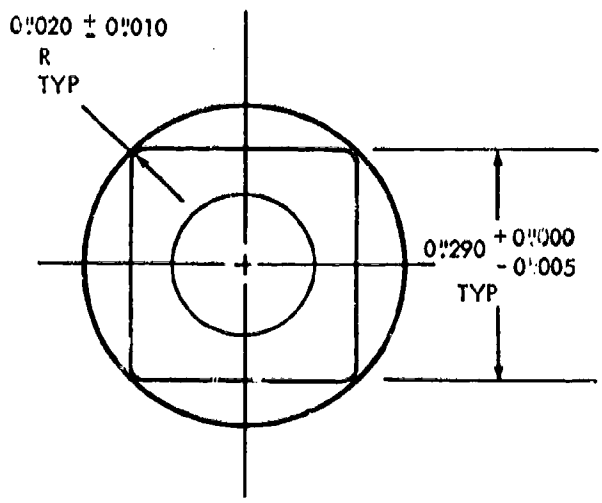
NOTES:

1. INTERPRET DRAWING IN ACCORDANCE WITH MIL-D-1000.
2. HNS-IIA PER WS 5003. PRESSED IN TWO EQUAL INCREMENTS AT 32,000 ± 1000 PSI. INCREMENT WEIGHT TO BE APPROX. 79 MILLIGRAMS. COLUMN LENGTH OF EXPLOSIVE TO BE 0".235 ± 0".002. MOISTURE CONTENT AT TIME OF LOADING SHALL NOT EXCEED 0.2%.
3. THE DISC AND CUP SHALL BE FREE FROM SPLITS, CRACKS OR ANY OTHER DELETERIOUS IMPERFECTIONS OF MANUFACTURE. IT SHALL BE NEITHER PERFORATED NOR BUCKLED AFTER THE ASSEMBLY OPERATIONS.
4. SLIGHT BULGE DESIRED BUT NOT TO EXCEED 3/4 OF THICKNESS OF CRIMPED OVER CUP.
5. DISC TO BE FIRMLY HELD BY CRIMP.
6. THERE SHALL BE NO EXPLOSIVE VISIBLE ON THE OUTSIDE OF THE EXPLOSIVE LEAD.
7. INSPECTION AND ACCEPTANCE OF THE LEAD SHALL BE IN ACCORDANCE WITH SHEET 2 OF THIS DRAWING.

FIG. 10 LEAD, EXPLOSIVE LSPE ASSEMBLY

STAINLESS STEEL TYPE 304





NOTES:

1. INTERPRET DRAWING IN ACCORDANCE WITH MIL-D-1000.
2. PASSIVATE PER QQ-P-35.
3. UNLESS OTHERWISE SPECIFIED:

   REMOVE BURRS AND SHARP EDGES 0".010 R (OR CHAMFER) MAX 125 ALL OVER.

FIG. 11 LEAD HOUSING

NOTES:

1. INTERPRET DRAWING IN ACCORDANCE WITH MIL-D-1000.
2. EXPLOSIVE LEAD TO BE INSERTED WITH DISC END AT SURFACE A.
3. THE EXPLOSIVE LEAD SHALL BE STAKED SECURELY IN PLACE USING STAKING TOOL DEPICTED IN A DEAD LOAD OF 570 LBS ± 25 LBS SHALL BE USED FOR STAKING.
4. THE EXPLOSIVE LEAD, WHEN STAKED SHALL WITHSTAND A FORCE OF 5 LBS ON THE BOTTOM SURFACE (SURFACE B). THE DIAMETER OF THE PUSH OUT TEST TOOL SHOULD BE $0.165^{+.000}_{-.005}$.
5. IF ANY EXPLOSIVE IS VISIBLE AFTER STAKING THE LEAD HOUSING ASSEMBLY SHALL BE REJECTED. I.E. PUNCTURING OF CUP OR DISC.
6. ALL STAKING HOLES SHALL BE ON THE LEAD HOUSING.
7. THE EXPLOSIVE LEAD SHALL BE FLUSH TO 0.008 BELOW FLUSH WITH SURFACE A AFTER STAKING AND PUSH OUT TEST OF NOTE 4.
8. THREAD TO BE 100% CHECKED AFTER STAKING BY PASSING THROUGH DIE.

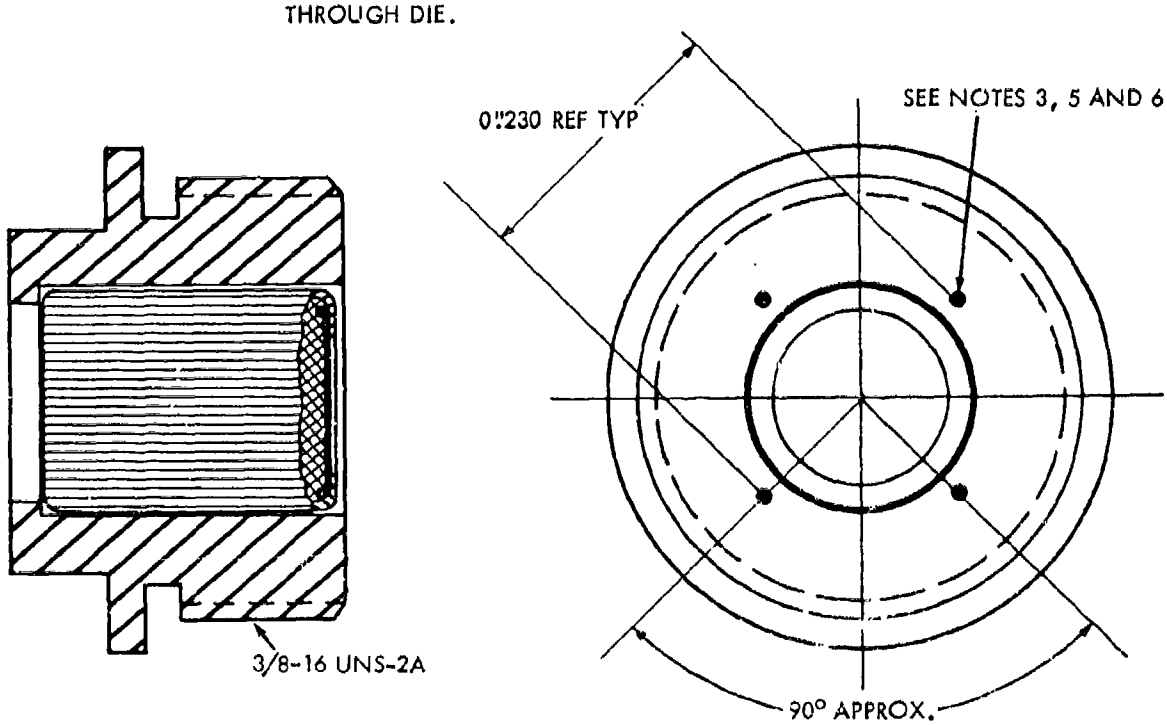


FIG. 12 LEAD HOUSING ASSEMBLY

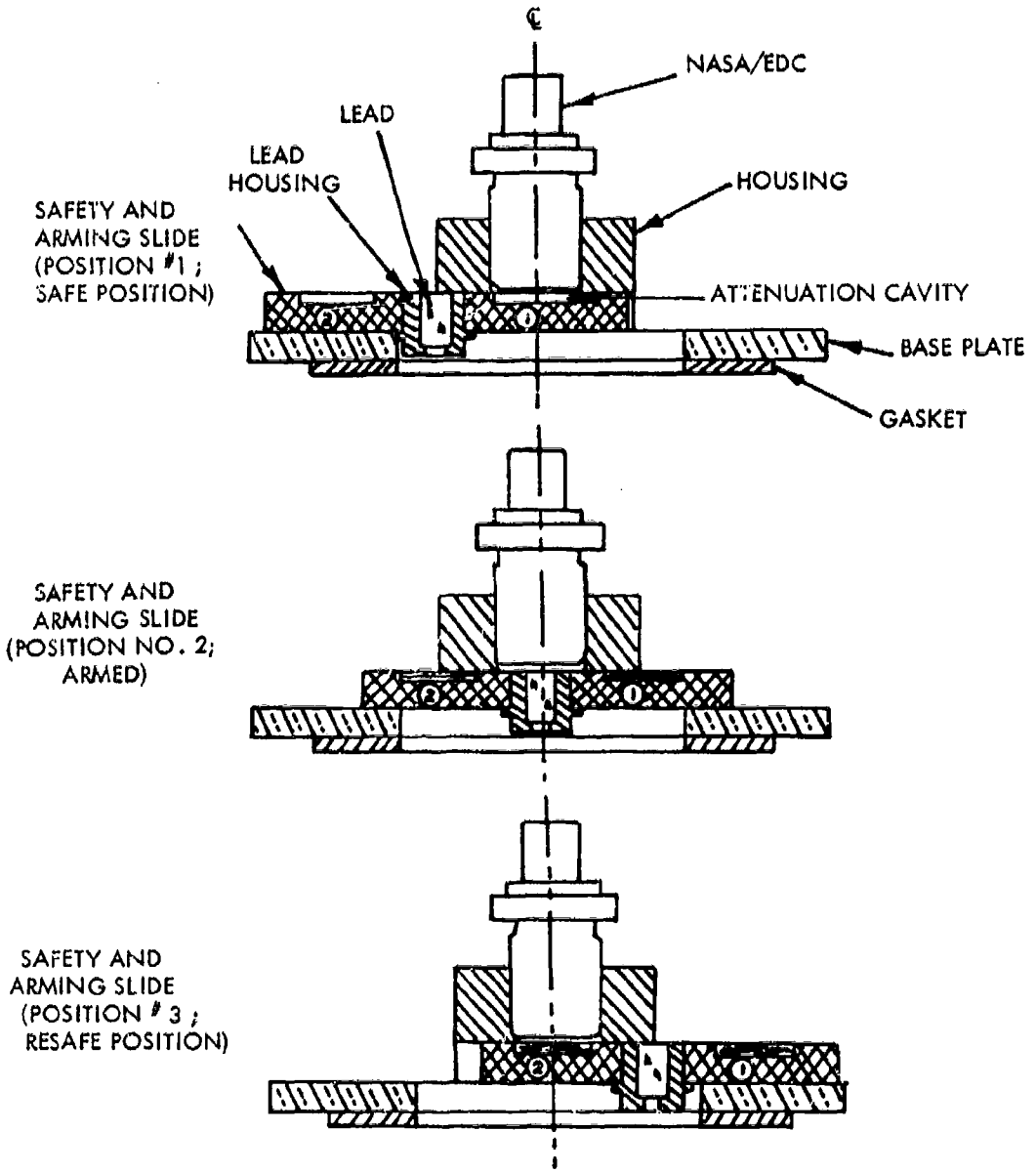
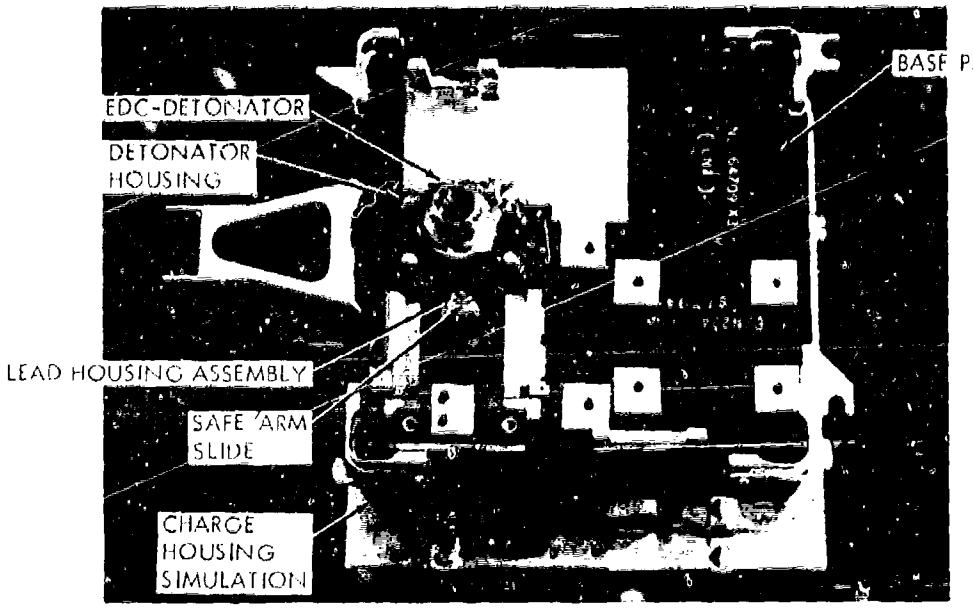
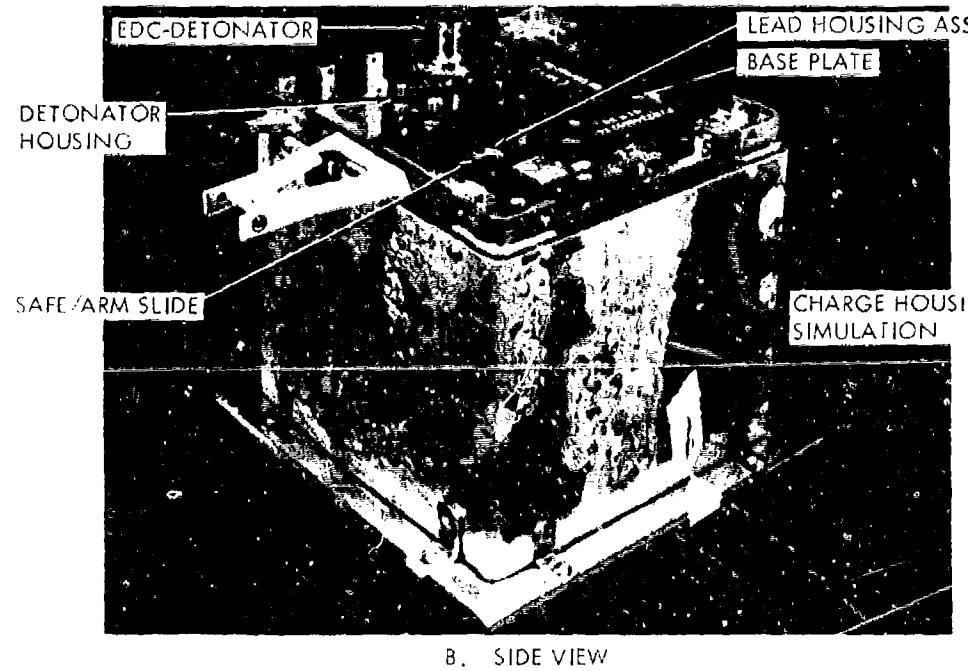


FIG. 13 ARRANGEMENT SHOWING VARIOUS SLIDER POSITIONS

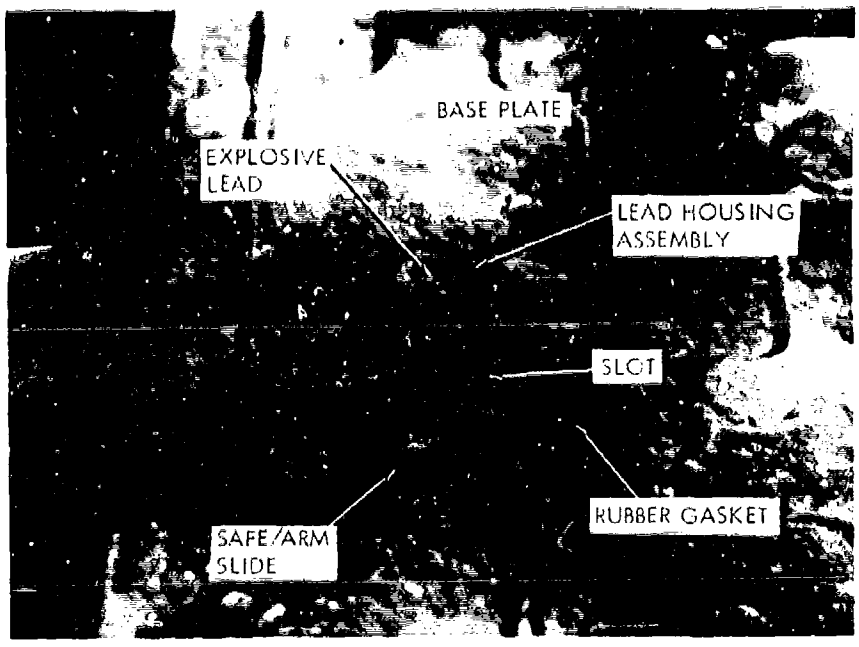


A. TOP VIEW

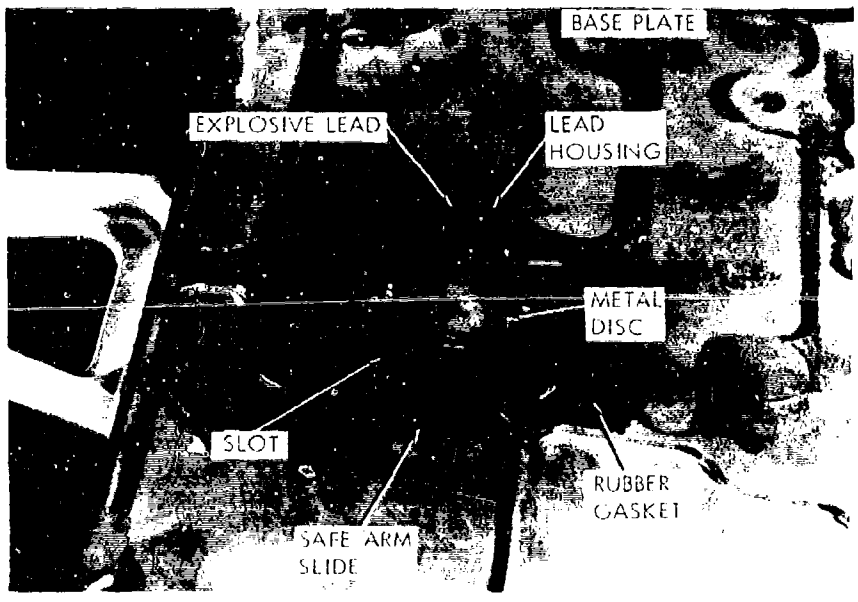


B. SIDE VIEW

FIG. 14 SIMULATED EXPLOSIVE PACKAGES USED FOR SAFETY VERIFICATION TESTS



A. REAR VIEW OF THE BASE PLATE OF THE 1/8-LB CHARGE



B. REAR VIEW OF THE BASE PLATE OF THE 6-LB CHARGE

FIG. 15 REAR VIEW OF BASE PLATES AFTER SAFETY VERIFICATION TESTS USING THE INITIAL PROTO SAFE ARM SLIDE

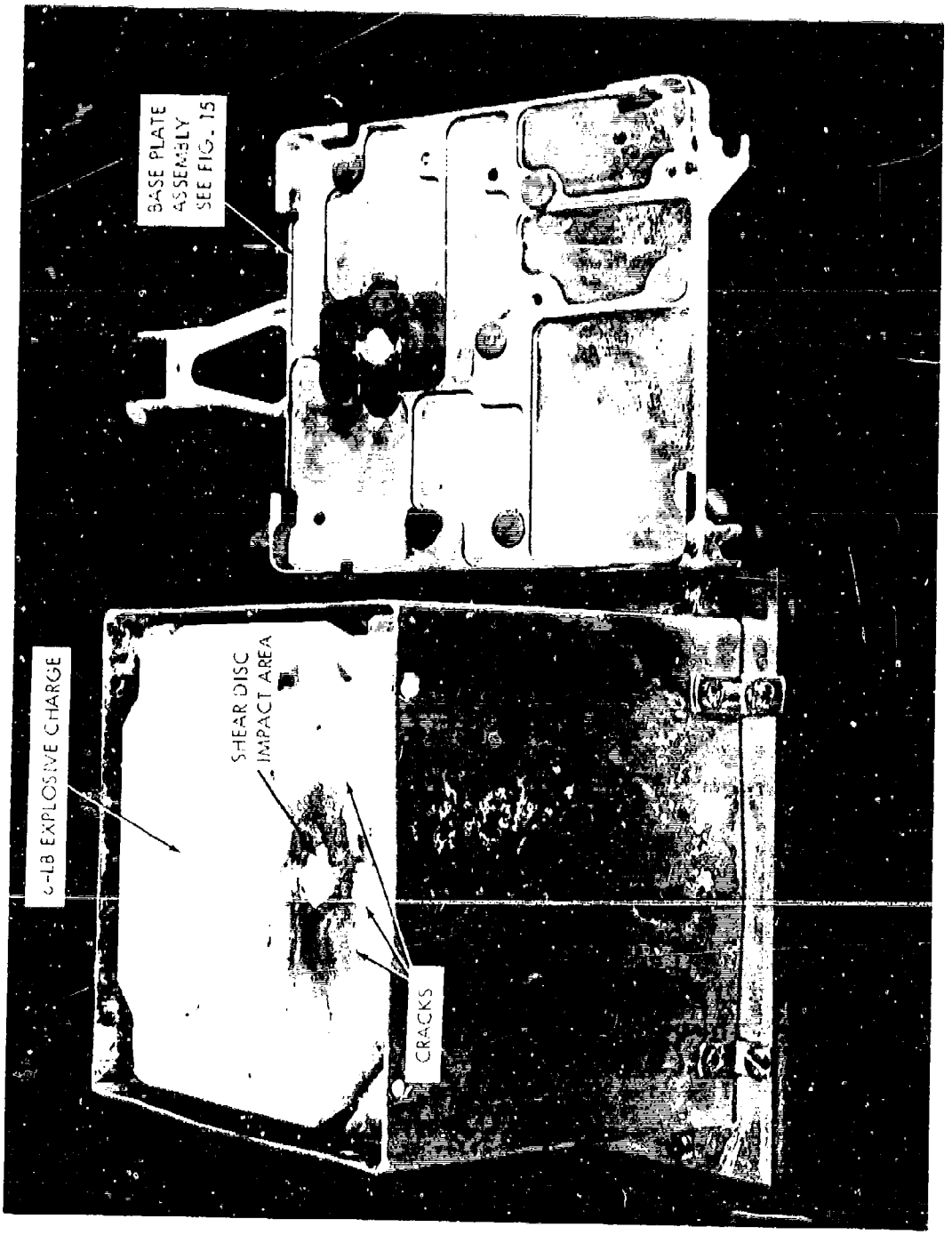
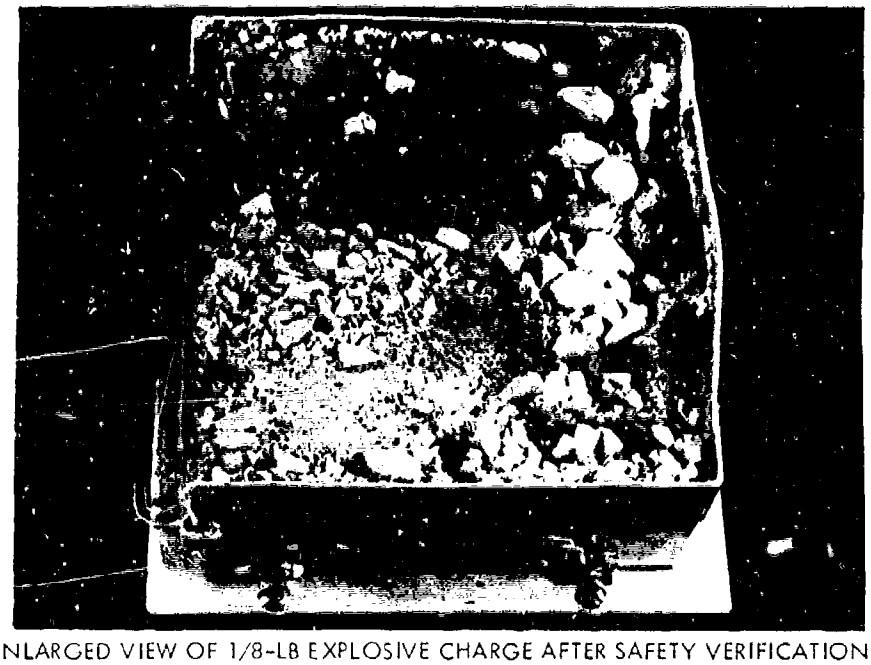


FIG. 16 TOP VIEW OF 6-LB EXPLOSIVE CHARGE AFTER SAFETY VERIFICATION TESTS WITH INITIAL PROTO SAFE/ARM SLIDE.

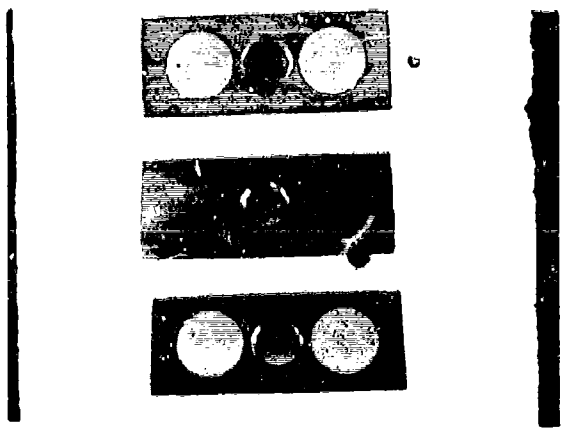


A. EXPLOSIVE CHARGE (1/8-LB) AFTER SAFETY VERIFICATION TEST

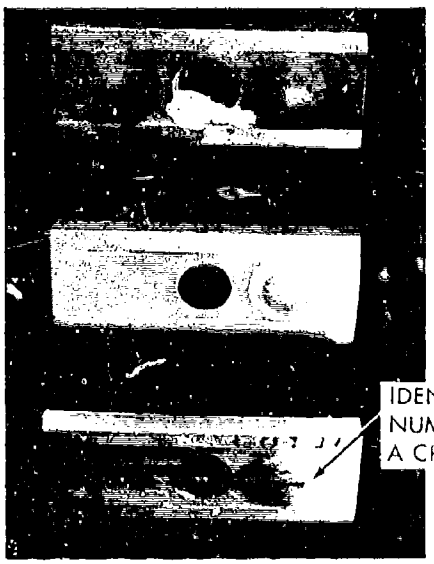


B. ENLARGED VIEW OF 1/8-LB EXPLOSIVE CHARGE AFTER SAFETY VERIFICATION TEST

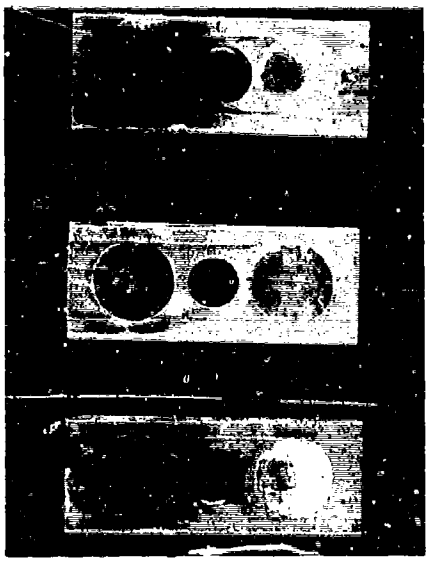
FIG. 17 INTERNAL VIEW OF 1/8-LB EXPLOSIVE CHARGE AFTER SAFETY VERIFICATION TEST WITH INITIAL PROTO SAFE/ARM SLIDE



(a) BEFORE

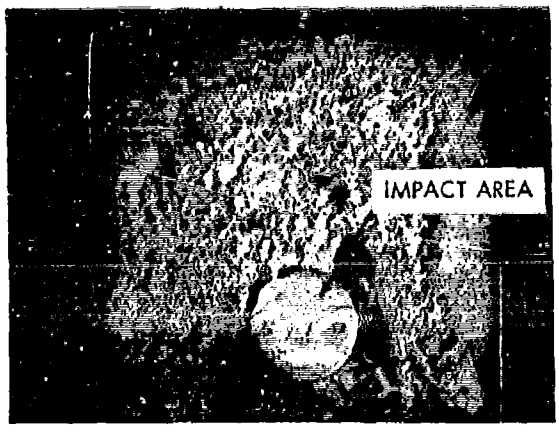


(b) AFTER - REAR OF SLIDE

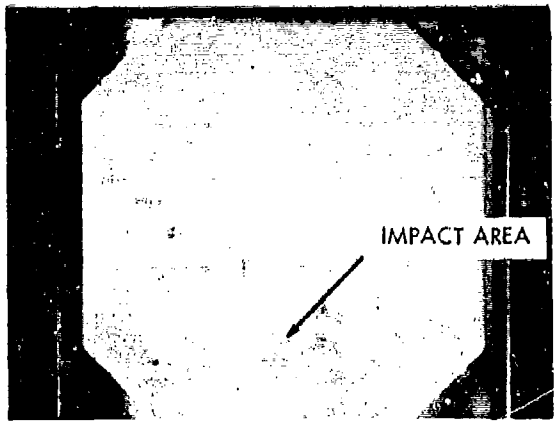


(c) AFTER - FRONT OF SLIDE

FIG. 18 TYPICAL SAFE/ARM SLIDES AFTER SAFETY TESTS

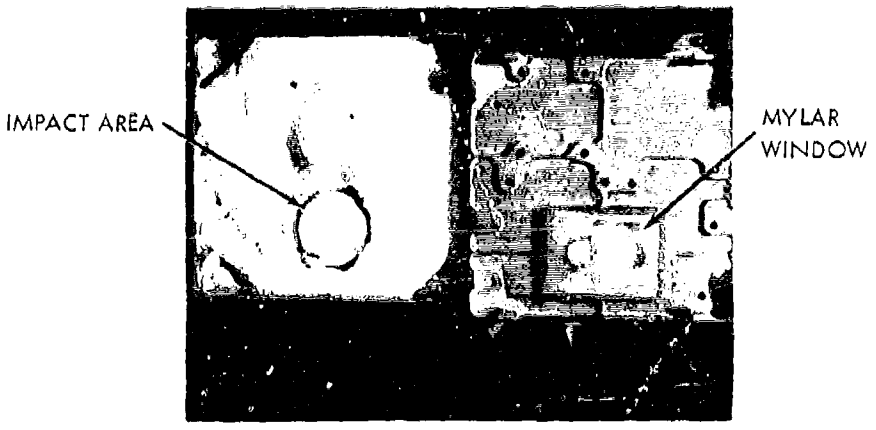


(a) 1/8-LB EXPLOSIVE CHARGE - AFTER TEST

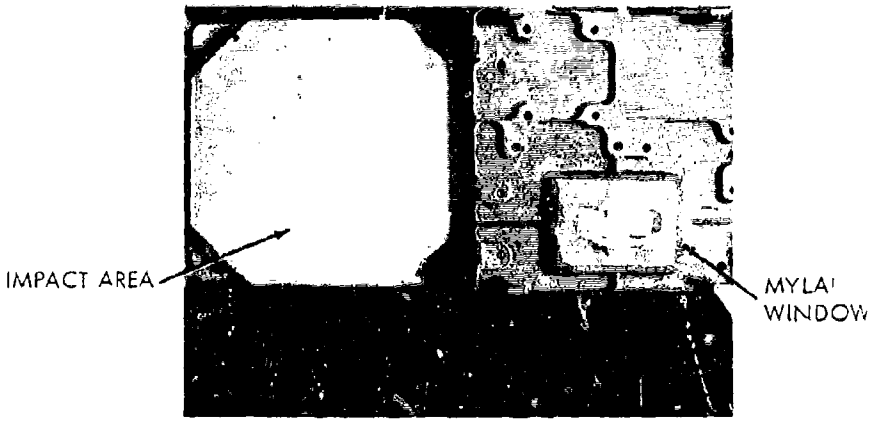


(b) 6-LB EXPLOSIVE CHARGE SURFACE - AFTER TEST

FIG. 19 INTERNAL VIEW OF EXPLOSIVE CHARGE SURFACES (1/8-LB AND 6-LB CHARGE) AFTER SAFETY VERIFICATION TEST WITH QUAL/FLIGHT SAFE/ARM SLIDE (LOT #2)



(a) 1/8-LB EXPLOSIVE CHARGE AFTER TEST



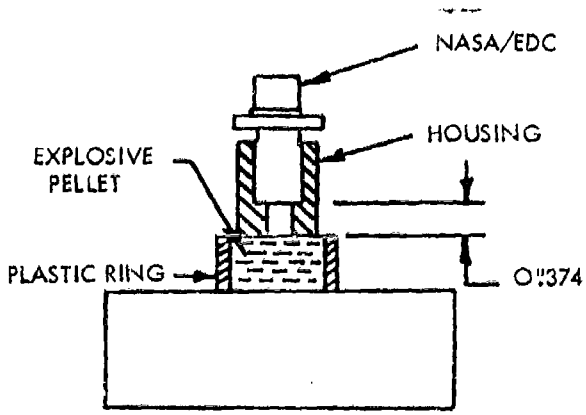
(b) 6-LB EXPLOSIVE CHARGE SURFACE AFTER TEST

FIG. 20 INTERNAL VIEW OF THE EXPLOSIVE CHARGE SURFACES (1/8-LB AND 6-LB CHARGE) AFTER SAFETY VERIFICATION TEST WITH FLIGHT SAFE/ARM SLIDE IN FINAL LSPE HARDWARE

APPENDIX A

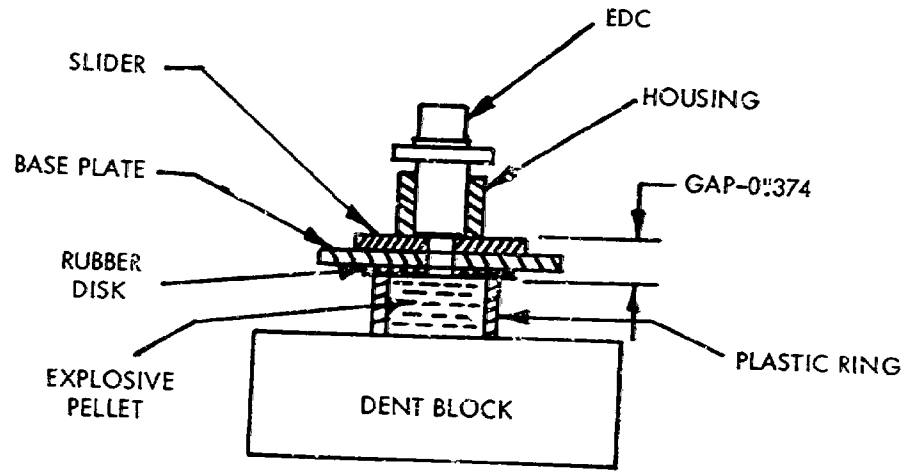
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A-2	Test Arrangement and Design Test Results for Safety and Arming Mechanism (ALSEP Design)	A-2
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A-5	Gas Velocity Test Results for Various Lots of EDC Detonators	A-5



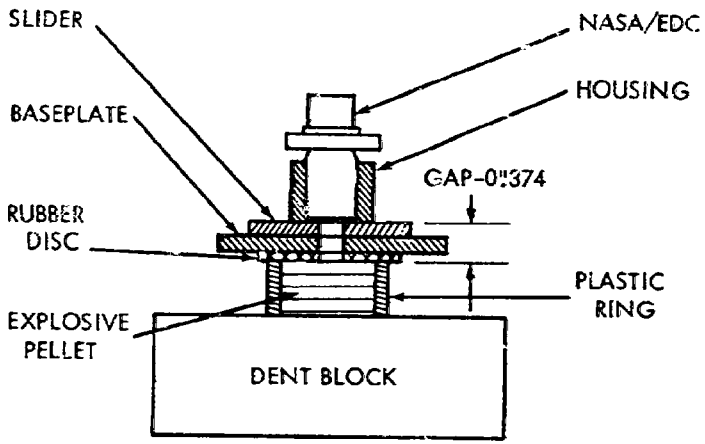
DETONATOR LOT	ACCEPTOR EXPLOSIVE (G/CC)	GAP BETWEEN DETONATOR & PELLET (INCH)	RATIO OF FIRES TO NUMBER TESTED
BYA OR BUK	PBXN-4 ρ =1.60 TO 1.64	0.200	1/1
		0.374	3/3
	TATB ρ=1.71, TO 1.76	0.200	1/1
		0.374	0/1

TABLE A-1 TEST ARRANGEMENT AND VARICOMP TEST RESULTS FOR THE SAFETY AND ARMING MECHANISM (ALSEP DESIGN) - DETONATOR LOTS BUK AND BYA



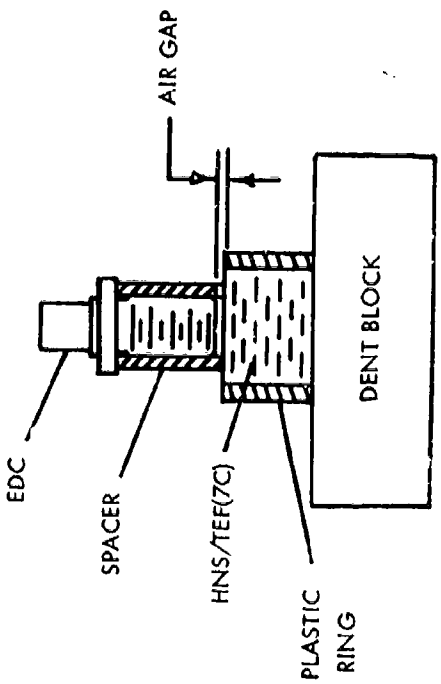
DETONATOR LOT	S/N	EXPLOSIVE PELLET	RESULT	SUMMARY
BYA	632 637 638 639 643 651	HNS/TEF-7C ρ = 1.69 G/CC	FIRED FIRED FIRED FIRED FIRED FIRED	6/6
CNH	1434 1435	HNS/TEF-7C ρ = 1.69 G/CC	FAILED FAILED	0/2

TABLE A-2 TEST ARRANGEMENT AND DESIGN TEST RESULTS FOR SAFETY AND ARMING MECHANISM (ALSEP DESIGN)



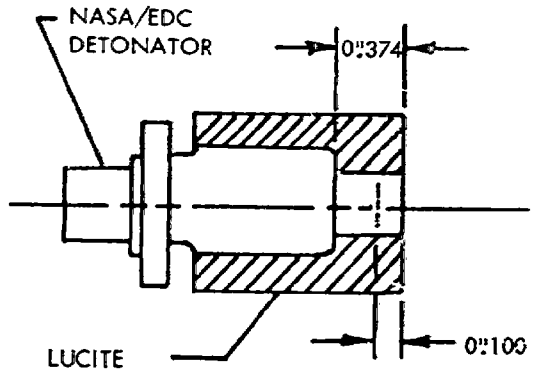
DETONATOR LOT	ACCEPTOR EXPLOSIVE	SUMMARY (RATIO OF FIRES TO NUMBER TESTED)
CNH	PBXN-4 1.60 TO 1.64 G/CC	0/5

TABLE A-3 TEST ARRANGEMENT AND VARICOMP TEST RESULTS OF THE SAFETY AND ARMING DEVICE USING NASA/EDC's FROM LOT CNH



DETONATOR LOT	S/N	GAP (MILS)	RESULT
CNH	1447	0	FIRED
	1480	100	FIRED
	1474	200	FAILED

TABLE A-4 AIR GAP TEST RESULTS



TEST NUMBER	LOT	DETONATOR SERIAL NUMBER	GAS VELOCITY (METERS/SEC)
1	BYA	635	3990
2	CNH	1452	3110
3	CNH	1489	3270

TABLE A-5 GAS VELOCITY TEST RESULTS FOR VARIOUS LOTS OF EDC DETONATORS

APPENDIX B

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B-1 Graphical Presentation of Reliability and Safety Estimates for the NASA/EDC to the HNS-II Explosive Lead B-13

B-2 Graphical Presentation of the Reliability and Safety Estimates for the Explosive Lead to the HE Block B-14

APPENDIX B

B1.0 SAFETY AND RELIABILITY ANALYSIS OF THE REDESIGNED SAFETY AND ARMING DEVICE

B1.1 The Varicomp test technique[1] was used to estimate the probability of detonation transfer at the two explosive interfaces of the safety and arming device:

a. Between the NASA-EDC and the HNS-II explosive lead.

b. Between the HNS-II explosive lead and the HNS-II/ Teflon-7C explosive charge.

The Varicomp tests were conducted at the minimum/maximum gaps (see Figure 4) and with the slider armed or unarmed, depending on whether reliability or safety tests were being conducted.

B1.2 In running Varicomp reliability tests the explosive in the acceptor is replaced with an explosive of lesser but known shock sensitivity. The reliability of the donor component to transfer detonation to the desensitized acceptor is then measured and the reliability of the actual system is predicted from this measured reliability and the known sensitivities of the desensitized (Varicomp) explosive and the design explosive. Safety is studied by substituting a more sensitive explosive for the design explosive of the acceptor components; the firing being conducted in the unarmed position. The sensitivity of each explosive, design or Varicomp, is measured by the SSGT[2].

B1.3 The SSGT sensitivity of each explosive was determined using the Bruceton test plan[3] and the assumption that the logistic distribution function[4] describes the relationship between the stimulus (strength of the shock impinging on the explosive) and the response (probability of firing). The equation for the cumulative form of the logistic distribution function is

$$\ell = \text{logit } p(x) = \ln\left[\frac{p(x)}{100-p(x)}\right] = \frac{x-\mu}{\gamma}$$

where $p(x)$ is the probability of response (%) at a stimulus x; μ is the value of the stimulus at which 50% of the population will respond; and γ is inversely proportional to the slope of the cumulative distribution function describing the population response. Since we do not know the population parameters but only estimates of them, we will use x_{50}, the estimate of μ; g, the estimate of γ; and $_{o}x$ as the expected value of the stimulus. The observed parameters, x_{50} and g, are determined by the SSGT experiment on the explosives. Because they are the observed values they will, in the absence of other information, be the most

likely or expected values for μ and γ. Using the symbols which denote real life observations rather than population parameters, the preceding equation becomes

$$\ell = \frac{{}_{o}x - x_{50}}{g}$$

which can be solved for ${}_{o}x$ to give

$${}_{o}x = \ell g + x_{50}.$$

B1.4 Three groups of detonation transfer studies were conducted at the interfaces listed above in (B1.1) and are:

a. Between the NASA-EDC and the explosive lead which contained the Varicomp explosive (DATB at 32,000 psi). Tests were conducted at the maximum interface gap (approximately 65 mils) and with the safety and arming slider fully aligned.

b. Between the HNS-II explosive lead and the H.E. charge using the Varicomp explosive PBXN-4 in lieu of the HNS-II/Teflon-7C charge. Again, the tests were performed at the maximum interface gap.

c. Between the NASA-EDC and the explosive lead and between the lead and the H.E. charge using the Varicomp explosive PETN in place of the design explosives. Safety tests were conducted at the minimum interface gap, (approximately 45 mils) and with the safety and arming slider in the out-of-line position (slider was tested in both the initial safe and resafe slider positions).

B1.5 The SSGT shock sensitivity of the design explosive for the lead (HNS-II at 32,000 psi) and the H.E. Block (HNS-II/Teflon-7C, 90/10) and the Varicomp explosives of DATB (at 32,000 psi), PBXN-4 (at 32,000 psi), and PETN (at both 8,000 and 32,000 psi) are given in Tables B-1 to B-6 respectively for each explosive. The Varicomp transfer test results are summarized in Table B-7. With this information, one can estimate either by a graphical presentation (see Figures B-1 and B-2) or by algebraic computation, the detonation transfer probability at each interface for the explosive components. These analyses are given below for each interface.

B2.0 DETONATION TRANSFER PROBABILITY BETWEEN THE NASA-EDC AND THE HNS-II EXPLOSIVE LEAD

B2.1 In the reliability tests conducted between the NASA-EDC and the HNS-II explosive lead, eight trials were made in which the performance of the acceptor component (lead) was observed with the

Varicomp explosive, DATB (at 32,000 psi) substituted for the design explosive HNS-II (at 32,000 psi). Eight successes in eight trials were observed. Thus the observed response is 100%. From binomial statistics[5], the single-sided lower limit of response (at 95% confidence) associated with this observation is 68.8%. This corresponds to 0.79 logits where ℓ, in logits was computed from

$$\ell = \ln \left[\frac{p(x)}{100-p(x)} \right]$$

B2.2 The stimulus, or explosive drive available (represented on Figure B-1 by line A) at this interface, associated with this lower limit of the observed response using DATB in the simulated design, is then 8.07 DBg. This number was computed using the logit equation found in Table B-3. With the design explosive HNS-II used in the lead, and a shock stimulus of approximately 8.07 DBg available at this interface, a detonation transfer probability well in excess of 99.999% is predicted for this interface. This probability estimate (represented by the intersection of line A and line B of Figure B-1) falls beyond the limits of this graph.

B2.3 The reliability can also be computed algebraically by substituting the drive shock stimulus of 8.07 DBg into the logit equation for the design explosive (HNS-II) in Table B-1

$$\ell = \frac{o^{x-\bar{x}}}{g} = \frac{8.070-5.322}{0.0982} = 27.98$$

This large value of approximately 27.98 logits corresponds to a reliability well in excess of 99.9999% and demonstrates the large margin of reliability that exists between the components (EDC/Lead) at this interface.

B2.4 For the determination of safety at this same interface, a more sensitive explosive (PETN at 8,000 psi) was loaded into the acceptor components. The analysis is given below:

a. Eight test shots were made at this interface. The EDC detonator was initiated and the safe/arm slider was fully misaligned (both safe positions, initial safe and resafe, were tested). No burning of the acceptor component was observed in the eight tests.

b. The single-sided upper limit of response (95% confidence) associated with 0/8 fires is 31.2%. This corresponds to -.79 logits.

c. The maximum stimulus available (line C of Figure B-1) at this interface based on the upper limit of response for PETN is then 2.40 DBg. (The logit equation for PETN is given in Table B-5.)

d. With the design explosive HNS-II used in the lead, and a shock stimulus of approximately 2.40 DBg available at this interface, a detonation transfer probability of less than 0.0001% is predicted when the lead is misaligned from the NASA/EDC (represented by the intersection of line C and line D, which falls beyond the limits of this graph.

e. The detonation transfer probability for this system is computed algebraically by substituting the shock stimulus of 2.40 DBg into the logit equation for HNS-II (Table B-1).

The resulting value of -29.75 logits corresponds to a detonation transfer probability of much less than 0.0001% and demonstrates the large safety margin that exists between the EDC and the lead in the unarmed position.

B3.0 DETONATION TRANSFER PROBABILITY BETWEEN THE HNS-II EXPLOSIVE LEAD AND THE H.E. CHARGE

B3.1 The same procedure was used to determine the reliability and safety estimates at the interface between the HNS-II explosive lead and the H.E. charge. At this interface (for the reliability study) seven transfer tests were made in which a PBXN-4 pellet (32,000 psi) was substituted for the HNS/Teflon-7C (90/10) pellet (32,000 psi). All seven trials were successful; thus the observed response was 100%. The single-sided lower limit of response (95% confidence) associated with this observation is 65.2% or 0.63 logits.

B3.2 The stimulus (see line A, Figure B-2) associated with the lower limit of response with PBXN-4 in the simulated design, is then 8.38 DBg (computed from logit equation on Table B-4). With the design explosive HNS-II/Teflon-7C (90/10) as the H.E. charge material and a shock stimulus of approximately 8.38 DBg available, a detonation transfer probability well in excess of 99.9999% is predicted. The graphical solution is the intersection of lines A and B in Figure B-2. Algebraically, (substitution of the shock stimulus of 8.38 DBg in the logit equation found in Table B-2 for the design explosive of HNS/Teflon-7C (90/10)) the resulting logit value of 51.0 corresponds to a predicted reliability of much greater than 99.9999%.

B3.3 For the safety study, eight tests were made in which a PETN pellet (32K) was used in place of the design explosive. These tests are part of the safety test arrangement of part c of paragraph 2.4. No transfer was observed in eight trials. This corresponds to a single-sided upper limit of response (95% confidence) of 31.2% or -0.79 logits. The maximum stimulus available (line C, Figure B-2) based on the upper limit of response for PETN (32K) is then 3.48 DBg. (Computed from the logit equation for PETN (32K); Table B-5.) The detonation transfer probability for this system is less than 0.0001% based on either the graphical solution (intersection of line C and line D of Figure B-2) or algebraically (substitution of the measured shock stimulus of 3.48 DBg into the logit equation (see Table B-2) for the design explosive of HNS/Teflon-7C (90/10)) where the resulting value of -47 logits was computed. This available drive corresponds to a predicted detonation transfer much less than 0.0001% for this interface.

APPENDIX B REFERENCES

1. J. N. Ayres, et al, "Varicomp, A Method for Determining Detonation Transfer Probabilities", NAVWEPS Report 7411, 30 Jun 1961

2. J. N. Ayres, "Standardization of the Small Scale Gap Test Used to Measure the Sensitivity of Explosives", NAVWEPS Report 7342, 16 Jan 1961

3. The Statistical Research Group, Princeton University, "Statistical Analysis for a New Procedure in Sensitivity Experiments", AMP Report No. 101-1R SRG-P N040, Jul 1944

4. L. D. Hampton and G. D. Blum, "Maximum Likelihood Logistic Analysis of Scattered GO/NOGO (Quantal) Data", NOLTR 64-238, 26 Aug 1965

5. Binomial Reliability Table (Lower Confidence Limits for the Binomial Distribution)", NOTS, China Lake, Calif. Rpt NOTSTP 3140, NAVWEPS 8090, Jan 1964

Table B1 - Small Scale Gap Test of HNS-II (x756)
Loaded at 32,000 psi

Response		Sensitivity of HNS-II (DPg)		
Percent	Logits	Expected	Lower Limit (95% confidence)	Upper Limit (95% confidence)
1	-4.60	4.871	4.481	--
5	-2.94	5.033	4.774	--
50	0	5.322	5.238	5.406
95	+2.94	5.611	--	5.869
99	+4.60	5.773	--	6.163

$g = 0.0982$

Density = 1.628 g/cc

Logit Equation $\ell = \frac{{}_0x - \bar{x}}{g} = \frac{{}_0x - 5.322}{0.0982}$

or

${}_0x = 0.0982\ \ell + 5.322$

Table B2 - Small Scale Gap Test of HMS-II/Teflon-7C 90/10 (x757)
Loaded at 32,000 psi

Response		Sensitivity of HMS-II/Teflon-7C (kbs)		
Percent	Logits	Expected	Lower Limit (95% confidence)	Upper Limit (95% confidence)
1	-4.60	5.601	5.433	--
5	-2.94	5.684	5.568	--
50	0	5.831	5.776	5.886
95	+2.94	5.979	--	6.095
99	+4.60	6.062	--	6.230

$g = 0.0502$

Density = 1.703 g/cc

Logit Equation $\quad \ell = \frac{{}_{o}x - \bar{x}}{g} = \frac{{}_{o}x - 5.831}{0.0502}$

or

$${}_{o}x = 0.0502\ \ell + 5.831$$

Table B3 - Small Scale Gap Test of DATB (x315)
Loaded at 32,000 psi

Response		Sensitivity of DATB (DBg)		
Percent	Logits	Expected	Lower Limit (95% confidence)	Upper Limit (95% confidence)
1	-4.60	7.777	7.590	7.964
5	-2.94	7.866	7.739	7.993
50	0	8.023	7.971	8.075
95	+2.94	8.181	8.054	8.308
99	+4.60	8.269	8.081	8.457

$g = 0.0535$

Density = 1.665 g/cc

Logit Equation $\quad t = \frac{{}_{o}x - \bar{x}}{g} = \frac{{}_{o}x - 8.023}{0.0535}$

or

${}_{o}x = 0.0535\ t + 8.023$

Table 84 - Small Scale Gap Test of PBXN-4 (x699)
Loaded at 32,000 psi

Response		Sensitivity of PBXN-4 (DBG)		
Percent	Logits	Expected	Lower Limit (95% confidence)	Upper Limit (95% confidence)
1	-4.60	8.140	7.990	8.290
5	-2.94	8.215	8.109	8.321
50	0	8.350	8.295	8.405
95	+2.94	8.485	8.380	8.590
99	+4.60	8.560	8.410	8.710

σ = 0.0456

Density = 1.640 g/cc

Logit Equation $\ell = \frac{{}_{0}x - \bar{x}}{\sigma} = \frac{{}_{0}x - 8.350}{0.0456}$

or

${}_{0}x = 0.0456\ \ell + 8.350$

Table B5 - Small Scale Gap Test of PETN (x321)
Loaded at 8,000 psi

Response		Sensitivity of PETN (DBg)		
Percent	Logits	Expected	Lower Limit (95% confidence)	Upper Limit (95% confidence)
1	-4.60	2.045	1.659	2.431
5	-2.94	2.200	1.943	2.457
50	0	2.476	2.385	2.567
95	+2.94	2.753	2.496	3.010
99	+4.60	2.908	2.523	3.294

σ = 0.0939

Density = 1.440 g/cc

Logit Equation $\ell = \frac{\sigma x - \bar{x}}{\sigma} = \frac{\sigma x - 2.476}{0.0939}$

or

$\sigma x = 0.0939\ \ell + 2.476$

Table B6 - Small Scale Gap Test of PETN (x321)
Loaded at 32,000 psi

Response		Sensitivity of PETN (DBg)		
Percent	Logits	Expected	Lower Limit (95% confidence)	Upper Limit (95% confidence)
1	-4.60	3.133	2.791	3.475
5	-2.94	3.285	3.056	3.511
50	0	3.555	3.481	3.628
95	+2.94	3.825	3.598	4.052
99	+4.60	3.977	3.634	4.320

σ = 0.0918

Density = 1.706 g/cc

Logit Equation $\ell = \frac{x - \bar{x}}{\sigma} = \frac{x - 3.555}{0.0918}$

or

$x = 0.0918\ \ell + 3.555$

TABLE B-7

SUMMARY OF SAFETY AND RELIABILITY TEST RESULTS

Interface	Type of Test	Donor Component	Acceptor Component	Varicomp Explosive	Ratio of Transfers to Number Tested
NASA-EDC/ Lead	Reliability	NASA-EDC	Lead, contains HNS-II at 32K psi	-	10/10
	Reliability	NASA-EDC	Lead, normally contains HNS-II at 32K psi	DATB at 32K psi	8/8
	Safety	NASA--EDC	Lead, normally contains HNS-II at 32K psi	PETN at 8K psi	0/8
Lead/H.E. Block	Reliability	Lead, HNS-II	H.E. Block, HNS-II/ Teflon-7C (90/10) at 32K psi	-	10/10
	Reliability	Lead, HNS-II	H.E. Block, normally HNS-II/Teflon-7C (90/10) at 32K psi	PBXN-4 at 32K psi	7/7
	Safety	Lead, HNS-II	H.E. Block, normally HNS-II/Teflon-7C (90/10) at 32K psi	PETN at 32K psi	0/8

(1) Of these tests one-half were made with each lot of detonators (CTN and CNH). However, since there appears to be no significant differences in lot behavior, the lots are assumed to be similar, and the data for each detonator at the detonator/lead interface will be additive.

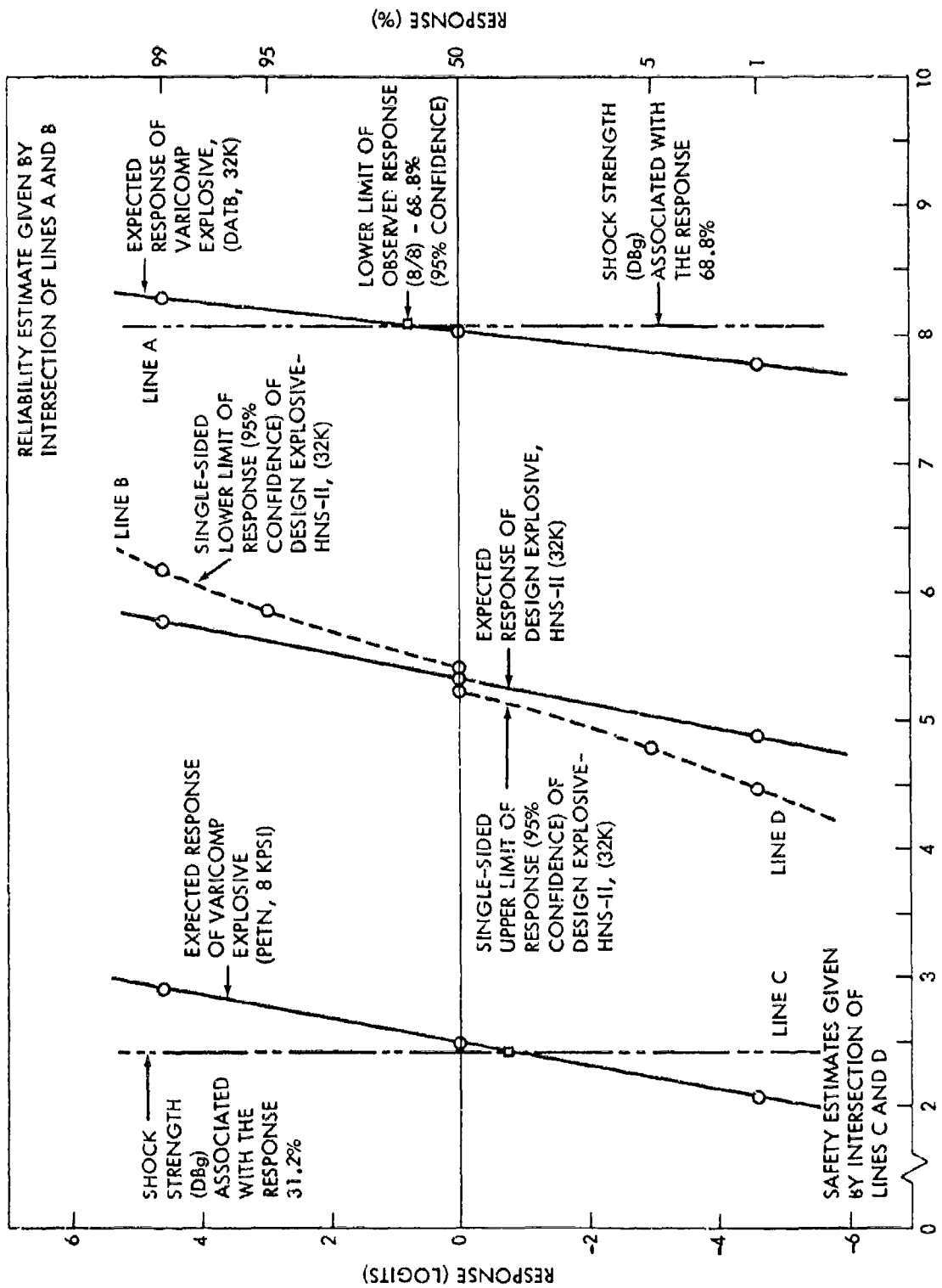


FIG. B-1 GRAPHICAL PRESENTATION OF RELIABILITY & SAFETY ESTIMATES FOR THE NASA/EDC TO THE HNS-II EXPLOSIVE LEAD

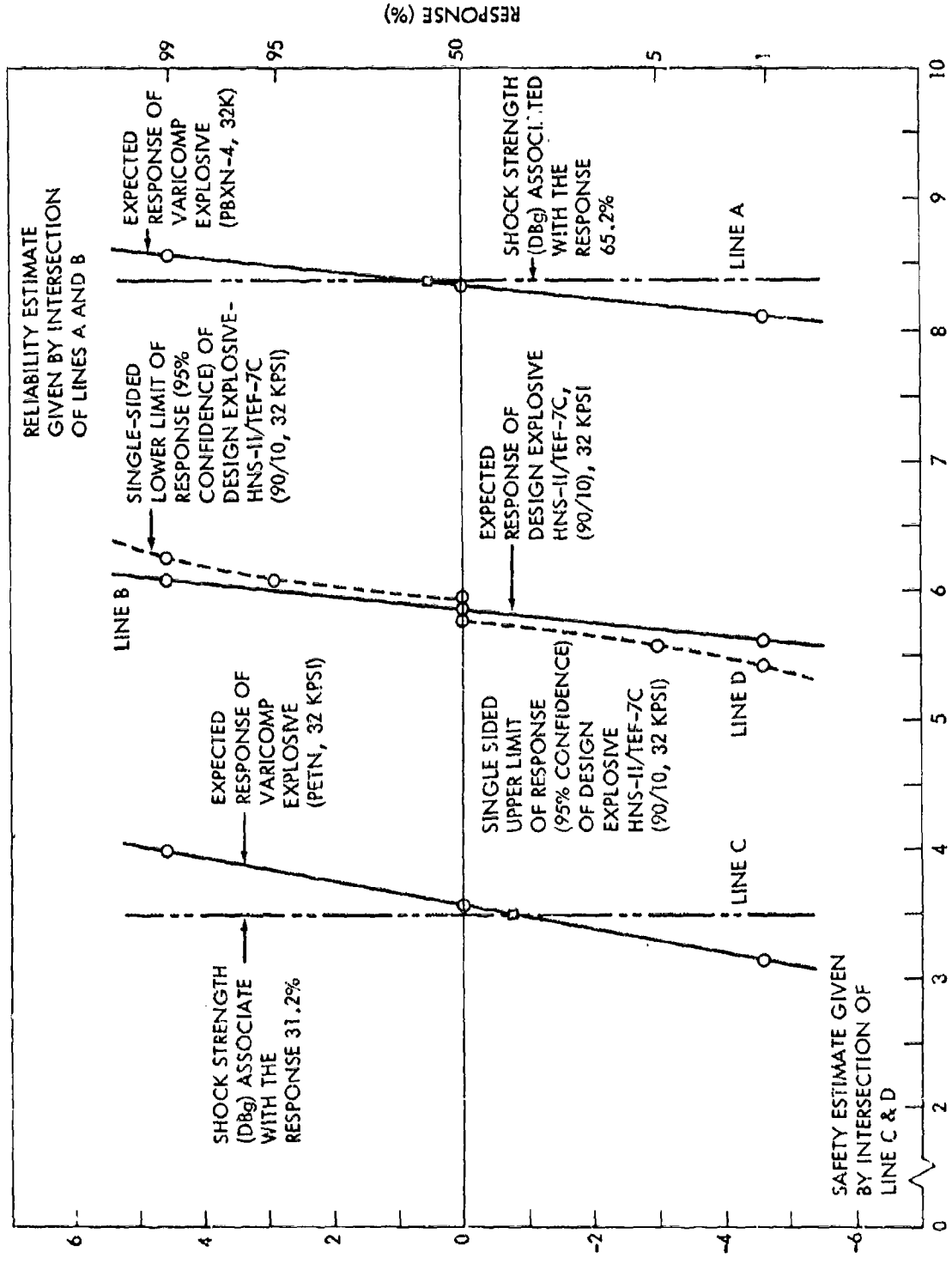


FIG. B-2 GRAPHICAL PRESENTATION OF THE RELIABILITY & SAFETY ESTIMATES FOR THE EXPLOSIVE LEAD TO THE HE BLOCKS