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TECHNICAL EVALUATION OF THE ZUNI  
ROCKET BASE FUZE MK 191 MOD I

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UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

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TECHNICAL EVALUATION OF THE  
ZUNI ROCKET BASE FUZE MK 191 MOD 1

Prepared by:  
L. J. Shkolnik

**ABSTRACT:** Approximately 210 fuzes were subjected to various laboratory and field tests. The safety mechanism assembly was found to be effective in keeping the fuze safe during the situation in which the head may be made to tumble, such as accidental release from aircraft. The fuze had satisfactory durability and resistance to damage during transportation and rough handling tests. The reliability was good. The fuze was effective against ground, concrete targets up to three feet thick, and targets simulating wall, roof, and floor construction of typical industrial buildings.

U. S. NAVAL ORDNANCE LABORATORY  
WHITE OAK, MARYLAND

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4 December 1961

TECHNICAL EVALUATION OF THE ZUNI ROCKET BASE FUZE MK 191 MOD 1

This report describes the laboratory and field tests performed on the Fuze Mk 191 Mod 1 during the course of the technical evaluation conducted by the Naval Ordnance Laboratory, White Oak. The work was performed under Task No. RM3773-012/212-1/F008-22-004, Problem Assignment No. 2. All field tests were conducted at the Naval Weapons Laboratory, Dahlgren, Virginia and the Naval Ordnance Test Station, China Lake, California. This report summarizes the work performed and makes it available to other interested activities. The author gratefully acknowledges the contributions of the personnel at the Naval Weapons Laboratory and the Naval Ordnance Test Station, who performed the field tests.

W. D. COLEMAN  
Captain, USN  
Commander



A. APPLEBAUM  
By direction

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REFERENCES

- (a) NAVWEPS Report 7316, Technical Evaluation of the Zuni Rocket Base Fuze Mk 191 Mod 0 of 7 Nov 1960
- (b) BUORD List of Drawings No. 497047



## INTRODUCTION

1. The evaluation of the Zuni Rocket Base Fuze Mk 191 Mod 0 (reference (a)) revealed an unsafe condition. The fuze would arm and fire under circumstances in which the fuze head was made to tumble, such as accidental release from aircraft. This occurred because the fuze, which was acceleration armed, could not distinguish between the acceleration due to motor burning and the centrifugal acceleration due to tumbling. The design of the fuze was therefore modified to correct this condition.

2. The new design, known as the Fuze Mk 191 Mod 1 (Figure 1), was evaluated under the Bureau of Naval Weapons (BUWEPS) Task No. RM3773-012/212-1/F003-22-004, Problem Assignment No. 2. Figure 2 is a flow chart of the evaluation program. For reasons of economy, the fuzes used during this evaluation were assembled with Fuze Mk '91 Mod 0 parts, originally supplied by Melpar, Inc., Falls Church, Virginia, for the evaluation of that fuze and not used, and modified to conform to the new design. The safety mechanism assemblies were purchased locally by contract. The forward mechanisms were manufactured by Westclox, Inc., LaSalle, Illinois. None of the fuzes were sealed.

3. The fuze passed the MIL-STD-311 Accidental Release Test, during which the heads were made to break away and subsequently tumble. This test demonstrated that the fuze will remain safe under the condition of centrifugal acceleration due to head tumbling. The fuze passed standard transportation and rough handling tests, and a sequential rough handling test consisting of transportation vibration, jolt and aircraft vibration tests. Since sealed samples were not available, the resistance of the fuze to humidity and salt spray was not tested. Sealed samples of the Mod 0, however, passed the temperature and humidity and salt spray tests. Since the Mod 0 and Mod 1 are similar and have the same seal, it is assumed that the Mod 1 would also pass those tests. The Mod 1 passed a temperature cycling test conducted at normal humidity, and storage tests at temperature extremes. The detonator safety and firing train reliability were satisfactory. The fuze was operable against ground, concrete targets up to three feet thick, and targets simulating typical industrial wall, roof, and floor construction.

### Description of the Fuze

4. The Fuze Mk 191 Mod 1 (Figure 1) is described by reference (b). It is an electro-mechanical, acceleration arming, base fuze for use in the 5"0 Zuni General Purpose

Head Mk 24. The fuze contains two Naval Ordnance Test Station (NOTS) 507 Arming Mechanisms, and a magnetic induction generator (MIG) which supplies the energy at impact to fire a Primer Mk 134, which has a built-in delay of  $4.5 \pm 2$  milliseconds. One arming mechanism serves as an out-of-line explosive train safety device. The other arming mechanism provides additional out-of-line safety, and also releases a spring loaded plunger which breaks a shorting wire in the MIG-primer circuit on arming. A safety mechanism assembly (Figure 3) prevents arming of the forward mechanism in the event of head tumbling. The fuze is hermetically sealed with a metal injection type seal.

5. The safety mechanism assembly (Figure 3) consists of two balls linked to a bell crank assembly. This assembly is held in position inside a tube attached to the bottom of the forward arming mechanism. The bell crank arm is engaged in a notch in the rotor flange of the forward mechanism. The two balls are positioned at two specific distances from the center of gravity of the rocket head. Since the centrifugal acceleration of a mass is directly proportional to its distance from the center of rotation, the acceleration forces exerted on the two balls are unequal when the head is caused to tumble. In the accidental release situation, where the head separates from the rocket motor and tumbles about its center of gravity, the forces exerted on the two balls and the bell crank arm act to prevent the arm from disengaging from the rotor flange notch, and the rotor is locked in the safe position. Under linear rocket acceleration, the forces exerted on the two balls and the bell crank arm allow the arm to disengage from the rotor flange notch as the rotor moves to the armed position.

#### Laboratory Tests

##### Aircraft Vibration Test

6. Ten fuzes were subjected to an aircraft vibration test, after which they were X-rayed. The test consisted of fixture vibration for a period of 10 hours during which the single amplitude was held constant at 0.030 and the frequency was varied from 1100 to 3000 cpm, in 100 cpm increments. The fuzes were vibrated in three positions. After the test, five fuzes were reserved for field fired operability tests and five were disassembled and inspected. The centrifuge operability check, on the five foot centrifuge, revealed that two rear mechanisms were inoperable at 50 g's. These mechanisms were then retested on another centrifuge, at a spin radius of seven inches, to determine the minimum g's necessary for arming. One armed at 60 g's, the other did not arm at 60 g's, the limit of the test equipment. An investigation disclosed that the fuzes contained

rear mechanisms that had been cleaned and then assembled into fuzes in the dry condition. The mechanisms were lubricated with Lubricating Oil MIL-L-11734A and again centrifuge tested to determine the minimum g's necessary for arming. One armed at 17 g's and the other armed at 21 g's.

7. Since the dry rear mechanisms may have been inoperable, the five fuzes which were reserved for field fired operability tests were laboratory inspected instead. The operability check of the mechanisms on the five foot centrifuge revealed that three rear mechanisms were inoperable at 50 g's. These mechanisms were then lubricated with Lubricating Oil MIL-L-11734A and again centrifuge tested to determine the minimum g's necessary for arming. The mechanisms armed at 15-1/2, 20-1/2, and 21-1/2 g's.

8. Five fuzes containing rear mechanisms that had been lubricated with Lubricating Oil MIL-L-11734A were given the aircraft vibration test, after which they were X-rayed. The post test inspection revealed no damage. All the mechanisms were operable. It was concluded that dry mechanisms may emerge inoperable but that properly lubricated fuzes would pass the aircraft vibration test.

#### Aircraft Vibration Test at Temperature Extremes

9. Ten fuzes were subjected to the aircraft vibration test while at temperature extremes. Five were tested at +160° F. and five were tested at -65° F. After being X-rayed, the fuzes were disassembled and inspected. None were damaged. All the mechanisms were operable. It is therefore judged that the fuze passed this test.

#### Jolt Test (MIL-STD-300)

10. Ten fuzes were subjected to jolt tests; five to the MIL-STD-300 Jolt Test, and five to double the MIL-STD-300 Jolt Test. The fuzes were X-rayed after the tests, and then disassembled and inspected. Except for a little brass dust from the setback weights, no damage was noted. However, the operability check on the five foot centrifuge revealed that one forward mechanism and eight rear mechanisms were inoperable at 50 g's. The inoperable rear mechanisms were lubricated with Lubricating Oil MIL-L-11734A and then centrifuge tested at a seven inch radius to determine the minimum g's necessary for arming. All were operable. The minimum arming acceleration for the eight mechanisms ranged from 15-1/2 to 42 g's. Since all the fuzes were safe, it is judged that they passed this test.

Jumble Test (MIL-STD-301)

11. Ten fuzes were subjected to jumble tests; five to double the MIL-STD-301 Jumble Test, and five to a 1500 rpm cycle in the 24-inch box. The fuzes were X-rayed after the tests, and then disassembled and inspected. Except for a little brass dust from the setback weights, in those samples which had been tested in the 24-inch box, no damage was noted. However, the operability check on the five foot centrifuge revealed that four forward mechanisms and eight rear mechanisms were inoperable at 50 g's. The inoperable rear mechanisms were lubricated with Lubricating Oil MIL-L-11734A and then centrifuge tested at a seven inch radius to determine the minimum g's necessary for arming. All were operable. The minimum arming acceleration for the eight mechanisms ranged from 21-1/2 to 30 g's. Since all the fuzes remained safe, it is judged that they passed this test.

Transportation Vibration Test (MIL-STD-303)

12. Ten fuzes were subjected to MIL-STD-303 Transportation Vibration Tests. After being X-rayed, five fuzes were reserved for field fired operability tests and five were disassembled and inspected. There was no damage. All the mechanisms were operable.

13. Because of the difficulty encountered with dry rear mechanisms subjected to the aircraft vibration test, the five fuzes subjected to the MIL-STD-303 Transportation Vibration Test and then reserved for field fired operability tests were laboratory inspected instead. There was no damage to any component. All the mechanisms were operable. It is therefore considered that the fuze passed this test.

Sequential Handling Test

14. Five fuzes were subjected to a sequential handling safety test during which they were first given the MIL-STD-303 Transportation Vibration Test, then the MIL-STD-300 Jolt Test and then the aircraft vibration test described in paragraph 1. After being X-rayed, the fuzes were disassembled and inspected. There was a slight amount of brass dust from the mechanism setback weights. Centrifuge tests conducted with a spin radius of five feet and an acceleration of 50 g's resulted in two forward mechanisms and four rear mechanisms being found to be inoperable. The four dry rear mechanisms were lubricated with Lubricating Oil MIL-L-11734A and again centrifuge tested to determine the minimum g's necessary for arming. All were

operable. The minimum arming g's ranged from 17.0 to 50.5. Since the fuzes all remained safe, it is judged that they passed these tests.

#### Forty Foot Drop Test (MIL-STD-302)

15. Ten fuzes were given MIL-STD-302 Forty Foot Drop Tests. The service loaded fuzes were dropped in inert Heads Mk 24. Two drops were made in each of the specified orientations. The fuzes were X-rayed after the tests. The post test inspection revealed that two of the safety mechanism assemblies became unlinked from the forward mechanisms. Eight primers were found to have fired. It was concluded that the primer firings were due to poor solder connections at the primer housing terminals. The circuit breaker was in effect removed from the circuit, allowing the MIG to fire the primer. Since all the fuzes remained safe to handle and dispose of, it is judged that the fuze passed this test.

#### Modified Forty Foot Drop Tests

16. Modified forty foot drop tests were conducted to check the effectiveness of the safety mechanism assemblies. These tests were conducted so that the nose of the inert Head Mk 24 struck the edge of an I beam after dropping 25 feet and caused the head to tumble during the final 15 feet of drop. The fuzes were inert except for primers and detonators. Ten rounds were dropped. The first missed the I beam and struck the steel plate on the ground in the horizontal position. The remaining nine rounds all struck the I beam and tumbled during the remaining 15 feet of drop. None of the mechanisms, forward or rear, armed. However, several of the primers fired and several of the safety mechanism assemblies were found unlinked from the forward mechanisms. The fired primers were probably due to poor solder connections of the circuit breaker leads at the primer housing terminals. This condition would in effect remove the circuit breaker and allow the primer to be fired upon a suitable impact. The condition of the arm of the safety mechanism assembly moving from the forward mechanism could be explained by at least three possible occurrences. The mechanism hooks were distorted in several cases, indicating that those impacts were severe enough to force the arms out of linkage. It is also possible that after the arm had restrained the mechanism from arming, and tumbling had ceased, that as the setback weight was returning the rotor to the safe position a slight impact caused the arm to separate from the mechanism. A third possibility was presented by an investigation of a group of forward mechanism assemblies, which revealed that in about 10 percent of the

samples the fit of the safety mechanism assembly arm in the rotor slot was such that, if the rotor slack is taken up in the armed direction, the arm could easily be moved in and out of the rotor slot. Such a mechanism could become unlinked by a light impact. These tests did not check the effectiveness of the safety mechanism assembly and additional tests were made.

17. Ten repeat rounds were dropped with reworked fuzes. All struck the I beam and tumbled before striking the steel plate on the ground. None of the mechanisms, forward or rear, armed. None of the safety mechanism assemblies became unlinked from the forward mechanisms.

#### Vibration Test (MIL-E-272C)

18. Five fuzes, the rear mechanisms of which had previously been lubricated with Lubricating Oil MIL-L-11734A, were subjected to the vibration tests described in 4.7.12 of MIL-E-272C (ASC). The fuzes were X-rayed after the test. The post test examination disclosed that one rear mechanism was inoperable. Two safety mechanism assemblies became unlinked from the forward mechanisms. In three fuzes, some powdered bakelite was present caused by wear of the bakelite primer housing by the brass tube of the safety mechanism assembly. In four cases, the bell crank assembly had an excessive amount of movement in the safety mechanism assembly due to wear of the brass tube by the steel shaft. Some brass dust was present in three fuzes, caused by wear of the brass setback weights against the steel mechanism frames. Because of the wear in the setback weights, the rotors of three forward mechanisms could be turned several degrees toward the armed position, so that the arm of the bell crank assembly could be moved at will in and out of the rotor slot. Since one mechanism was inoperable and two safety mechanism assemblies became unlinked, it is judged that the fuze failed this test.

#### Detonator Safety Test

19. Detonator to lead safety tests were conducted to determine whether there is a significant difference in detonator safety between the Fuzes Mk 191 Mod 1 and Mk 191 Mod 0. Five fuzes were fired at rotor angles which were a continuation of the Bruceton tests conducted with the Fuze Mk 191 Mod 0. One fuze

fired at a rotor angle of 24 degrees from armed remained safe, two fired at an angle of 22 degrees remained safe, and two fired at an angle of 20 degrees were unsafe. These limited tests indicate that the 50 percent unsafe position for the Fuze Mk 191 Mod 1 is approximately 21 degrees from armed. Since the 50 percent unsafe position for the Fuze Mk 191 Mod 0 was found to be 21.93 degrees from the armed position, based on 30 samples, it is concluded that there is no significant difference in detonator safety between the two fuzes.

#### Firing Train Reliability Tests

20. Firing train reliability tests were conducted to determine whether there is a significant difference in firing train reliability between the Fuzes Mk 191 Mod 1 and Mk 191 Mod 0. Inert boosters were used. It was assumed the booster would have fired high order if the lead fired high order. Five rounds were fired at rotor angles which were a continuation of the Bruceton tests conducted with the Fuze Mk 191 Mod 0. One fuze tested with the rotors ten degrees from armed did not result in the lead firing. Three fuzes tested nine degrees from armed resulted in one lead firing high order and two not firing. One fuze tested eight degrees from armed resulted in the lead being fired high order. These limited tests indicate that the 50 percent firing position for the Fuze Mk 191 Mod 1 is approximately nine degrees from armed. Since the 50 percent firing position for the Fuze Mk 191 Mod 0 was 9.23 degrees from armed, based on 30 samples, it is concluded that there is no significant difference in firing train reliability between the two fuzes.

#### Conformance to Specifications

21. Two inert fuzes were subjected to a dimensional check. From a total of 1093 dimensions measured, 186 were found to be out-of-tolerance. It is considered that the out-of-tolerance dimensions encountered could not cause a dud or an unsafe condition, but they could contribute to wider performance variations.

#### Timing Tests

22. Timing tests were conducted with the mechanisms of 20 fuzes, to check the requirements that the mechanisms not arm when subjected to an acceleration of 13 g's, shall arm with a maximum time of 2.50 seconds at 20 g's, and shall arm within the time limits of 0.80 and 1.00 second at 50 g's. The tests were conducted with a centrifuge radius of 60 inches. Five of the forward mechanisms and five of the rear mechanisms

armed at 13 g's. At 20 g's, two forward mechanisms did not arm. The remaining 18 armed between the time limits of 1.31 and 1.55 seconds, with a mean of 1.42 and a standard deviation of 0.07 second. The 20 rear mechanisms all armed, at 20 g's, with times of 1.29 to 2.65 seconds, a mean of 1.62 and a standard deviation of 0.33 second. Only one arming time was greater than the 2.50 maximum time specification. At 50 g's, all 20 forward mechanisms armed between 0.81 and 0.98 second, with a mean of 0.90 and a standard deviation of 0.05 second. The 20 rear mechanisms all armed at 50 g's between 0.75 and 0.93 second, with a mean of 0.83 and a standard deviation of 0.04 second. Three arming times were less than the 0.80 minimum time specification.

23. The failure of two forward mechanisms to arm at 20 g's is not considered serious, since it was known, from engineering development tests, that some may not arm at a radius of 60 inches, and since all were found to be operable at 50 g's.

24. Additional timing tests were conducted to check the results obtained previously on the five foot centrifuge, during which five forward and five rear mechanisms armed, and therefore failed to meet the specification that they not arm at 13 g's. The tests were conducted with a centrifuge radius of seven inches. The safety mechanism assemblies were removed from the forward mechanisms. The tests were conducted to determine the minimum g's necessary for arming. The five forward mechanisms required 14.5 to 17.3 g's, and the five rear mechanisms required 13.6 to 14.5 g's for arming. Since all required more than 13 g's, it is considered that they passed this test.

#### Dry Temperature Cycling

25. Ten fuzes were subjected to the temperature cycling specified in the MIL-STD-304 Temperature and Humidity Test. The test was conducted at normal humidity. The fuzes were then disassembled and inspected. One primer had a bridge wire resistance of 19 ohms, which is much greater than the 1.5 to 6.0 ohms specified. This primer was fired with a 1-1/2 volt battery, as an operability check. The brass setback weights were somewhat darkened and the varnish on the leads was discolored and slightly sticky. All the mechanisms were operable. Since the fuzes remained safe and operable, it is judged that they passed this test.

#### Storage at Temperature Extremes

26. Ten fuzes were subjected to storage tests at temperature extremes. Five were stored at +150° F. for 30 days and then



-65° F. for 30 days. Five were stored at -65° F. for 30 days followed by conditioning at +160° F. for 30 days. After being X-rayed, the fuzes were disassembled and inspected. There was no damage. All the mechanisms were operable. It is judged that the fuze passed this test.

#### Field Tests

#### Accidental Release Tests (MIL-STD-311)

27. MIL-STD-311 Accidental Release Tests were conducted at the NOTS B-1-B Range. The rounds included fuzes which were inert except for primers, inert Heads Mk 24, and inert Motors Mk 16. The rounds were dropped from bomb racks, to which they were held by suspension bands. The drops were made from an AD-5N aircraft flying at an altitude of 75 to 125 feet and a velocity of approximately 130 knots. The target was a macadam runway approximately 1100 feet long. The purpose of these tests was to check the effectiveness of the fuze safety mechanism assembly. It was desired that the head break away from the motor and tumble.

28. Ten drops resulted in five instances in which the head did not break away from the motor. The fuzes in these rounds were disassembled and examined to assure that they were undamaged and operable. The rounds were then reassembled and dropped again. These five drops resulted in one case in which the head did not break away from the motor. In all, nine drops resulted in the head breaking away from the motor and subsequently tumbling. The rear mechanism armed in all nine cases. One primer was fired. In no case did the forward mechanism arm, indicating that the safety mechanism assembly is effective under these conditions.

#### Operability Tests, Air to Ground

29. Air to ground operability tests were conducted at the NOTS B-2 Range. The rounds which included service loaded Fuzes Mk 191 Mod 1, Heads Mk 24, and Motors Mk 16, were fired from LAU 10/A Launchers on an A4D Aircraft. The tests were conducted with the aircraft in a 30 degree dive, an air speed of 400 knots and a slant range of approximately 4000 feet. Twenty rounds were fired against the ground. These resulted in 20 high order functionings, indicating that the operability of the fuze is satisfactory.

#### Arming Distance Tests

30. Arming distance tests were conducted at the NOTS K-2 Range to determine whether the fuze meets the 1000 foot maximum

arming distance requirement. Thirty rounds consisting of service loaded Fuzes Mk 191 Mod 1, Heads Mk 24, and Motors Mk 16 were fired against a hill from an LAU 10/A Launcher based on the ground. Although the outdoor temperature varied from 100° F. to 114° F., the ambient magazine temperature was approximately 80° F. Ten rounds which were fired at ambient temperature all functioned high order. One impact distance was 1250 feet. The other impact distances all varied from 800 to 1100 feet. Ten rounds which were tested at +160° F. all fired high order. These impact distances all varied from 700 to 1100 feet. Ten rounds tested at -65° F. all fired high order. One round passed over the hill and functioned down range. The other nine rounds impacted at distances varying from 500 to 1100 feet. These tests demonstrate not only that the fuze meets the maximum arming distance specification but also that it is operable at +160° F. and -65° F. These 30 rounds also provide additional evidence that the operability of the fuze is satisfactory.

#### Impact Safety Tests

31. Impact safety tests were conducted to prove that the fuze is safe at the minimum specified arming distance of 400 feet. These tests were conducted at the Naval Weapons Laboratory (NWL), Dahlgren, Virginia. Five rounds consisting of service loaded fuzes in inert EX-15 (armor piercing) Heads and Zuni Motors Mk 16 were fired against four inch Class B armor targets. All the heads were stopped by the targets. None of the fuzes functioned. In addition, five rounds consisting of fuzes which were service loaded except for black powder boosters, smoke puff loaded Heads Mk 24, and Zuni Motors Mk 16 were fired against 1/2 inch mild steel targets. The fuze boosters were 10 grams of FFFG black powder. A 1/2 inch hole was drilled in the booster cup for easy passage of the booster flame. The smoke puff charge in the heads was a one pound mixture consisting of 75% dye (MIL-D-3284) and 25% FFFG black powder, by weight. Four 5/8 inch holes were drilled radially in the head for easy passage of the smoke puff. The heads all passed through the targets and continued down range. None of the fuzes functioned. It was concluded that the fuzes were not armed at the 400 foot point and that they met the minimum arming distance specification.

#### Target Operability Tests

32. Target operability tests were conducted at NWL, using the 1050 foot rocket launcher. Since these fuzes were expected to arm while the round was still on the launcher, an off-launcher arming system was used, in order to prevent fuze actuation due to launcher induced vibration.

33. The off-launcher arming gear consisted of an explosive switch (T-20 Transfer Switch with T-3 Motor) wired across the fuze primer terminals. The normally closed switch kept the primer inoperable. Two wires extended from the switch to two arming blades, which were bolted to an adaptor positioned between the head and motor. Two wire screens approximately six feet beyond the end of the launcher were electrically charged and were so positioned that the arming blades would cut through them. Voltage from the screens actuated the switch, thus arming the fuze. The rounds consisted of service loaded Fuzes Mk 191 Mod 1, adaptors, Heads Mk 24, and Zuni Motors Mk 16. An assembled round is shown in Figure 4.

34. Four rounds were fired at an obliquity of 30° from normal against eight inch cinderblock targets simulating a typical industrial wall construction. All functioned high order. The impact velocities varied from 1855 to 2033 feet per second. One delay time was excessively long. This actuation occurred beyond the range of the cameras and was greater than 30 ms in time and 50 feet in distance from impact. The remaining three delay times and distances varied from 4.4 to 5.2 ms and five to eight feet, respectively.

35. Five rounds were tested at an obliquity of 30° from normal against four-inch brick targets simulating another typical industrial wall construction. All functioned well. The impact velocities varied from 1780 to 1857 feet per second. The delay times and distances varied from 4.7 to 5.2 ms and six to seven feet, respectively.

36. Four rounds were fired at an obliquity of 60° from normal against targets consisting of two-inch concrete over 20 gauge corrugated steel, simulating a typical industrial floor construction. The impact velocities varied from 1791 to 1832 feet per second. All functioned. One delay was excessively long. It was estimated to be 49 ms and 75 feet after impact. One delay was very short. It was 1.2 ms and two feet after impact. The remaining two delay times and distances were 4.0 and 5.0 ms and seven and eight feet.

37. Three rounds were fired at an obliquity of 60° from normal against targets consisting of four thicknesses of tarpaper over one inch insulation over 20 gauge corrugated steel, simulating a typical industrial roof construction. The impact velocities varied from 1800 to 2006 feet per second. All functioned satisfactorily. The delay times varied from 4.5 to 4.6 ms. The delay distances were all eight feet.

38. Four rounds were fired at an obliquity of 60° from normal against targets consisting of four thicknesses of tarpaper over 1-1/2 inch (two inch nominal) wood, simulating another typical

industrial roof construction. The impact velocities varied from 1793 to 1937 feet per second. All functioned well, with delay times and distances varying from 4.1 to 5.0 ms and six to ten feet, respectively.

39. Four rounds were fired at normal obliquity against two foot concrete targets. One motor blew up on the launcher. The head struck the target base first with a velocity of 1485 feet per second. It functioned high order. The other three rounds struck the targets with velocities varying from 1859 to 1911 feet per second. All functioned within the targets.

40. Five rounds were fired at normal obliquity against three-foot concrete targets. The rounds all struck the targets with velocities varying from 1819 to 1889 feet per second. All functioned within the targets. Four targets were completely penetrated by the explosions. The fifth target was defeated, but the pieces of broken concrete at the rear surface were held together by the steel reinforcing bars. The delay times varied from 2.3 to 3.0 ms. Two delay times, both 2.3 ms, were less than the  $4.5 \pm 2$  ms functioning delay specification.

#### Discussion and Conclusions

41. The evaluation of the Fuze Mk 191 Mod 1 included rough handling, environmental, safety, and operability tests. Figure 2 is a flow chart of the program. The important fuze characteristics and the test results from which they were determined are discussed in the following paragraphs.

#### Safety After Tumbling

42. The fuze passed the MIL-STD-311 Accidental Release Test, during which the safety mechanism assembly was proven to be effective. Head tumbling and rear mechanism arming occurred in nine cases, but arming of the forward mechanism was prevented in every instance.

#### Effective Targets

43. Air-to-ground operability tests demonstrated that the fuze is effective against ground. Operability tests conducted against targets simulating wall, roof, and floor construction of industrial buildings indicated that the fuze is operable

against all of these targets. Tests conducted against two-foot and three-foot concrete targets resulted in satisfactory functioning. The fuze is therefore considered to be effective against military targets such as earth emplacements, brick or concrete structures, and concrete emplacements up to three feet thick. The results of tests conducted during the evaluation of the Mod 0 indicate that the Mod 1 is also effective against steel targets varying from 3/16 inch mild steel to two inch Class B armor.

#### Operability After Transportation

44. The fuze passed appropriate vibration and rough handling tests including the following: (1) MIL-STD-300 Jolt, (2) MIL-STD-301 Jumble, (3) MIL-STD-303 Vibration, (4) Aircraft Vibration (-65° F., room ambient, and +160° F.), and (5) sequential rough handling consisting of jolt, transportation vibration, and aircraft vibration. The fuze failed a high frequency and resonance vibration schedule as, of the five units tested, one arming mechanism was rendered inoperative and two of the safety mechanism assemblies became unlinked from the rotor of the arming mechanism. This test schedule was very severe and was not intended to be a simulation of vibration encountered during Fleet use. The test was conducted in an exploratory manner to determine whether severe vibration conditions, including prolonged resonance vibration, could defeat the fuze. The failures which resulted were mainly attributed to wear of the arming mechanism which has been used successfully in a number of fuzes designed for aircraft launched weapons. It is considered that the Fuze Mk 191 Mod 1 has demonstrated an adequate resistance to damage incidental with transportation and aircraft carriage. However, it is possible that prolonged aircraft carriage under extreme conditions could cause some degradation of reliability and also cause the safety mechanism assembly to become unlinked from the rotor. A drawing change has been made which will increase by approximately three degrees the rotor rotation, as measured from the safe position, required before the safety mechanism assembly can become unlinked. This change will further reduce the likelihood of it being defeated by vibration.

#### Safety After Severe Shock

45. The fuze passed the MIL-STD-300 Jolt Test, MIL-STD-301 Jumble Test, and MIL-STD-302 Forty Foot Drop Test. It can therefore be concluded that the fuze will remain safe, but not necessarily operable, after being subjected to severe shocks and vibration not normally encountered but which might be encountered by accident during transportation or use.

### Storage Characteristics

46. None of the fuzes tested during this evaluation were sealed. Sealed samples of the Mod 0, however, passed the MIL-STD-304 Temperature and Humidity Test and the MIL-STD-306 Salt Spray Test. Since the Mod 0 and the Mod 1 are similar and have the same seal, it is assumed that the Mod 1 would also pass those tests. Samples of the Mod 1 were subjected to the temperature cycling specified in the MIL-STD-304 Temperature and Humidity Test. The test was conducted at normal humidity. The fuze passed this test. The fuze also passed a storage test at temperature extremes during which one group was stored at +160° F. for 30 days and then -65° F. for 30 days, and a second group was stored at -65° F. for 30 days and then +160° F. for 30 days. Since the Mod 1 passed the temperature cycling test and the storage test at temperature extremes, and since the Mod 0 passed the MIL-STD-304 Temperature and Humidity Test and the MIL-STD-306 Salt Spray Test, it is considered that the fuze will remain safe and operable after being stored for extended periods of time under conditions of humidity from 5 percent to 100 percent, temperatures from -65° F. to +160° F., and salt spray.

### Arming Distance

47. Impact safety tests, during which rounds were fired against targets 400 feet distant, all resulted in duds, indicating that the fuzes were not armed at this distance. Operability tests conducted against a hill with a trajectory range of approximately 1000 feet all resulted in high order functionings, proving that the fuzes were armed at this distance. These tests demonstrate that the arming distance of the fuze is between 400 and 1000 feet, and that the fuze meets this requirement. Arming distance tests conducted during the evaluation of the Mod 0, with the round modified so that a smoke puff was fired at the instant of fuze arming, resulted in a mean arming distance at ambient temperature of 599 feet, with a standard deviation of 28 feet. The arming distance of the Mod 1 may be assumed to be close to this figure.

### Operating Conditions

48. It is desirable that the fuze operate effectively when released at any likely aircraft speed, at temperatures between -65° F. and +160° F., and at any expected altitude after being carried at altitudes up to 60,000 feet. The air to ground operability tests were fired at an air-speed of approximately 400 knots. All were operable, proving that the fuze operates effectively when fired at this speed. Since the operation of

the fuze is dependent upon motor acceleration, which is only slightly affected by the aircraft speed, it is considered that the fuze is effective at any expected aircraft speed. The arming distance tests included ten rounds fired at ambient temperature, ten rounds fired at +160° F., and ten rounds fired at -65° F. All functioned high order, indicating that the fuze is operable between the temperature extremes of -65° F. and +160° F. The altitude characteristic was not tested during the evaluation. However, since the fuze is hermetically sealed, and since no part is dependent upon atmospheric pressure for its operation, it is considered that the fuze can be used at any desirable altitude after having been carried at any expected altitude.

#### Rocket Acceleration

49. The fuze should be capable of withstanding the positive acceleration of the rocket (70 to 100g for 0.7 seconds) as well as the negative acceleration due to target impact which, in some cases, may occur during peak rocket acceleration. The various field firing tests (air to ground operability, and arming distance) total approximately 90 rounds during which the fuze functioned after withstanding the acceleration of the rocket and the target impact. Since ten rounds were temperature conditioned at -65° F. and ten were conditioned at +160° F., the arming distance tests included extremes in motor acceleration. They also provided impacts during peak rocket acceleration, because the impacts occurred before motor burnout. Since all functioned, it is concluded that the fuze is operable under all expected conditions of rocket acceleration.

#### Impact Velocities

50. The fuze is expected to function upon impact with the appropriate targets at all likely velocities. Impact velocities during the target operability tests were approximately 1900 feet per second. However, operability tests of the Mod O (with HVAR Motors) included impacts at 1250 feet per second which resulted in satisfactory functioning. The air to ground operability tests provided impact velocities of approximately 2600 feet per second. Since fuze functioning during these tests was satisfactory, it may be concluded that the fuze is operable at all expected impact velocities.

#### Reliability

51. A reliability of 95 percent is desired. The results of the air to ground operability tests and the arming distance tests can be used to estimate the reliability of the fuze.

Service loaded fuzes, heads and motors were used in these tests. From a total of 50 rounds fired, all functioned. It can therefore be estimated, with a confidence of 90 percent, that the reliability of the fuze is at least 95 percent.

#### Functioning Delay

52. Upon impact with appropriate targets, it is desired that the fuze provide a delay of  $4.5 \pm 2$  ms followed by warhead detonation. Tests conducted during the evaluation of the Mod 0 revealed that impacts against heavy targets may result in very short time delays. Operability tests with the Mod 1 verified these results. Five rounds fired against three-foot concrete targets resulted in two time delays of 2.3 ms, which is slightly less than the specification. Twenty rounds fired against light targets, however, resulted in one short, two long, and 17 satisfactory time delays. It can be concluded from these data that, with normal targets, approximately 85 percent of the delay times can be expected to be within the specification.

#### Firing Train Safety and Reliability

53. The evaluation of the Mod 0 determined that the firing train reliability and detonator safety of that fuze are satisfactory. Since the firing trains of the Mod 0 and Mod 1 are identical, and since none of the modifications made to the Mod 0 in designing the Mod 1 seemed likely to affect the firing train safety or reliability, full-scale tests were not conducted. Instead, token numbers of fuzes were tested to determine whether there are significant differences in these properties between the two designs. The Bruceton tests conducted during the detonator safety tests of the Mod 0 were continued with five Mod 1 Fuzes, and the Bruceton tests conducted during the firing train reliability tests of the Mod 0 were continued with five Mod 1 Fuzes. The results of both tests confirmed that there are no significant differences between the two designs. It is therefore concluded that the detonator safety and firing train reliability of the Mod 1 are satisfactory.



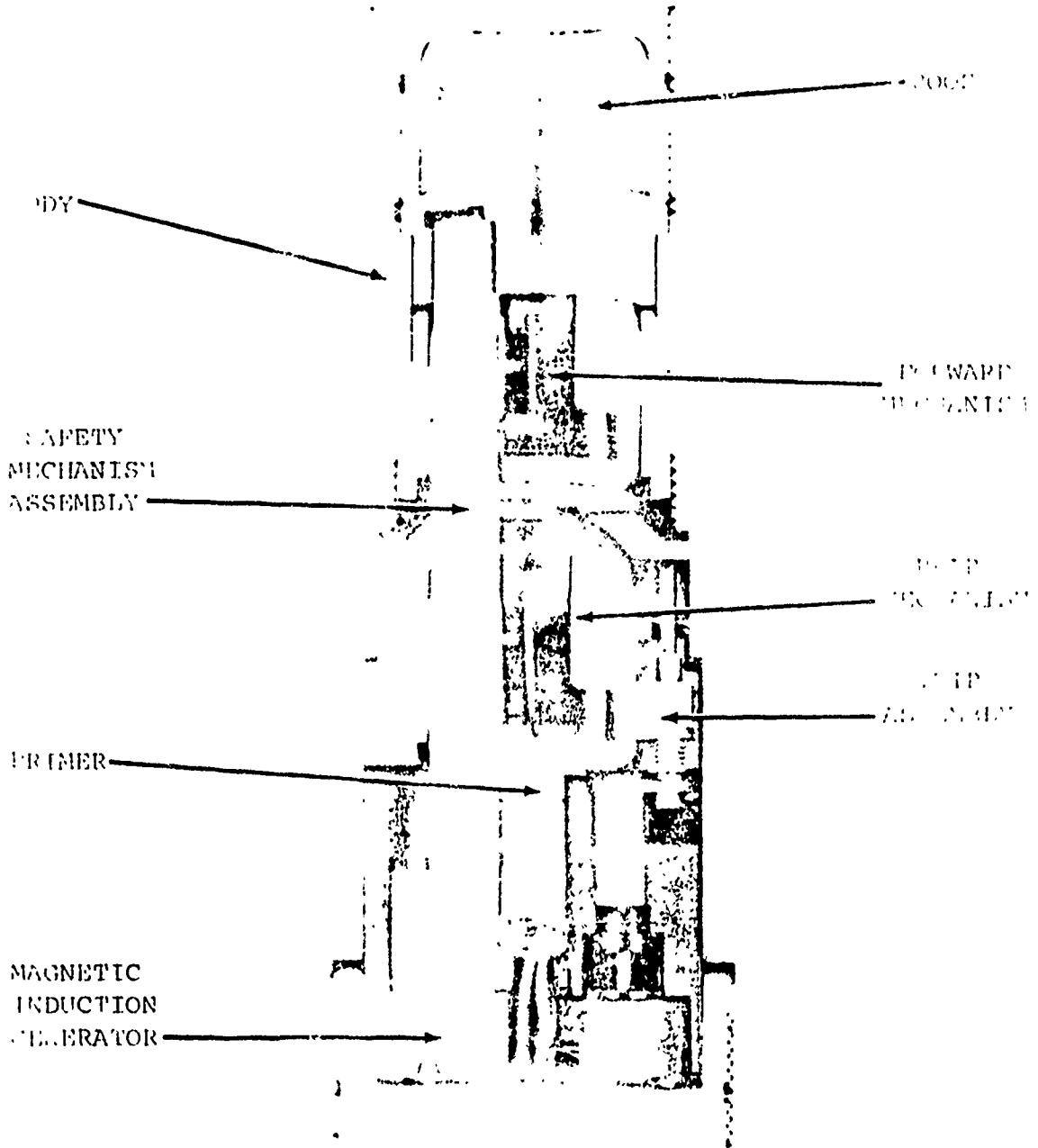


FIG. 1. RIFLE MK. 100 MODEL 1

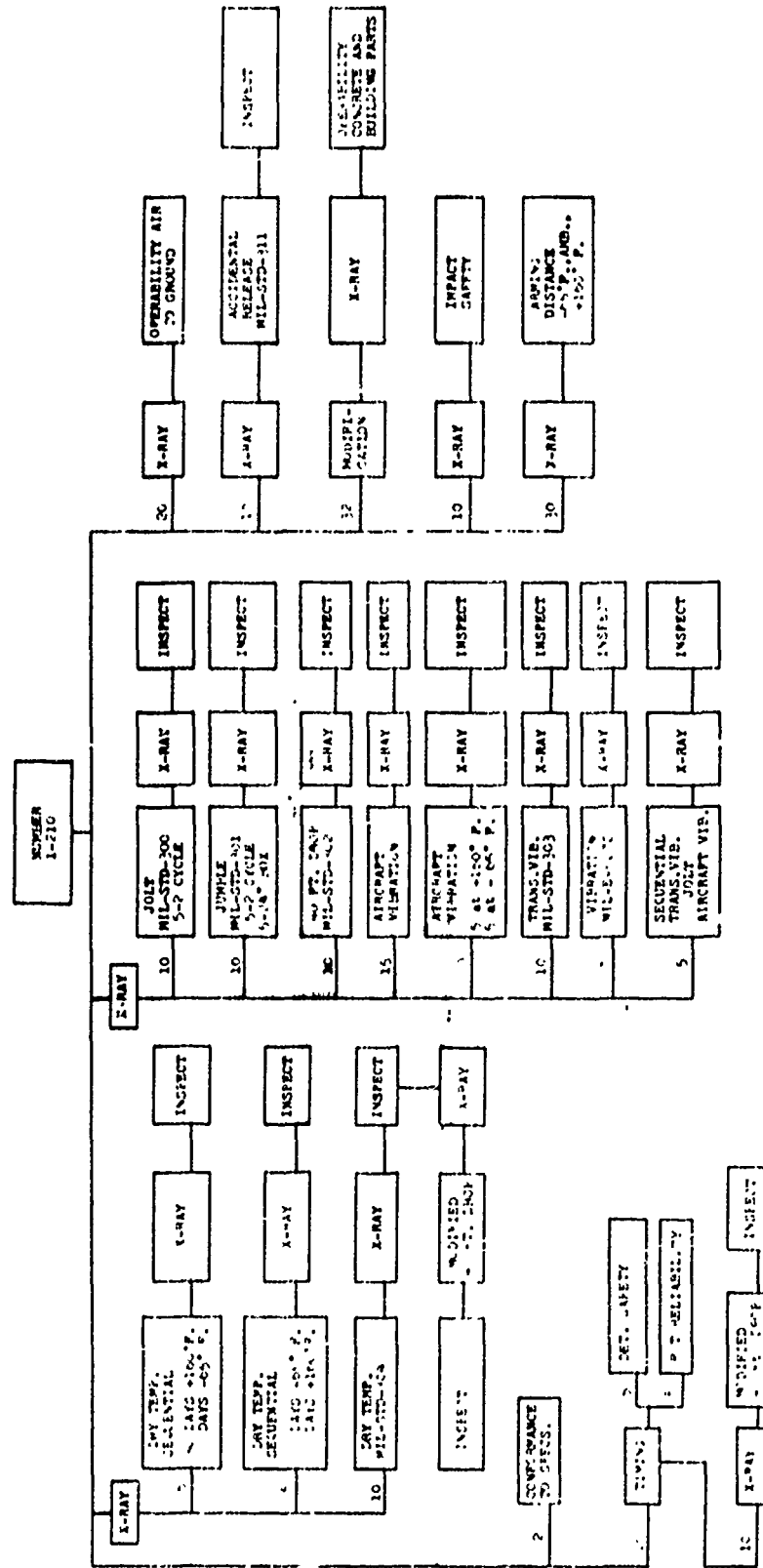


FIG. 2 FLOW CHART, FUZE MK 191 MOD 1 EVALUATION

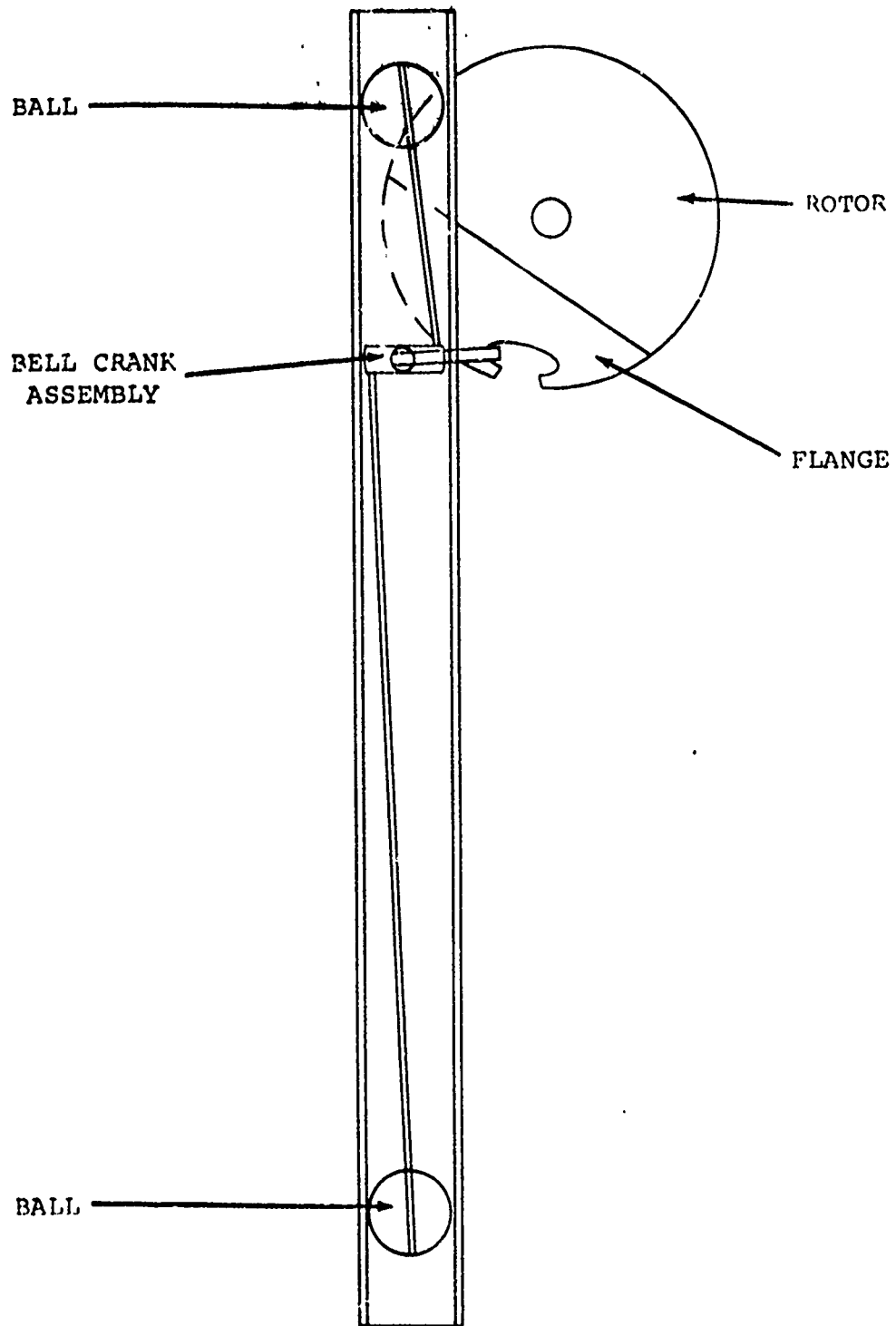
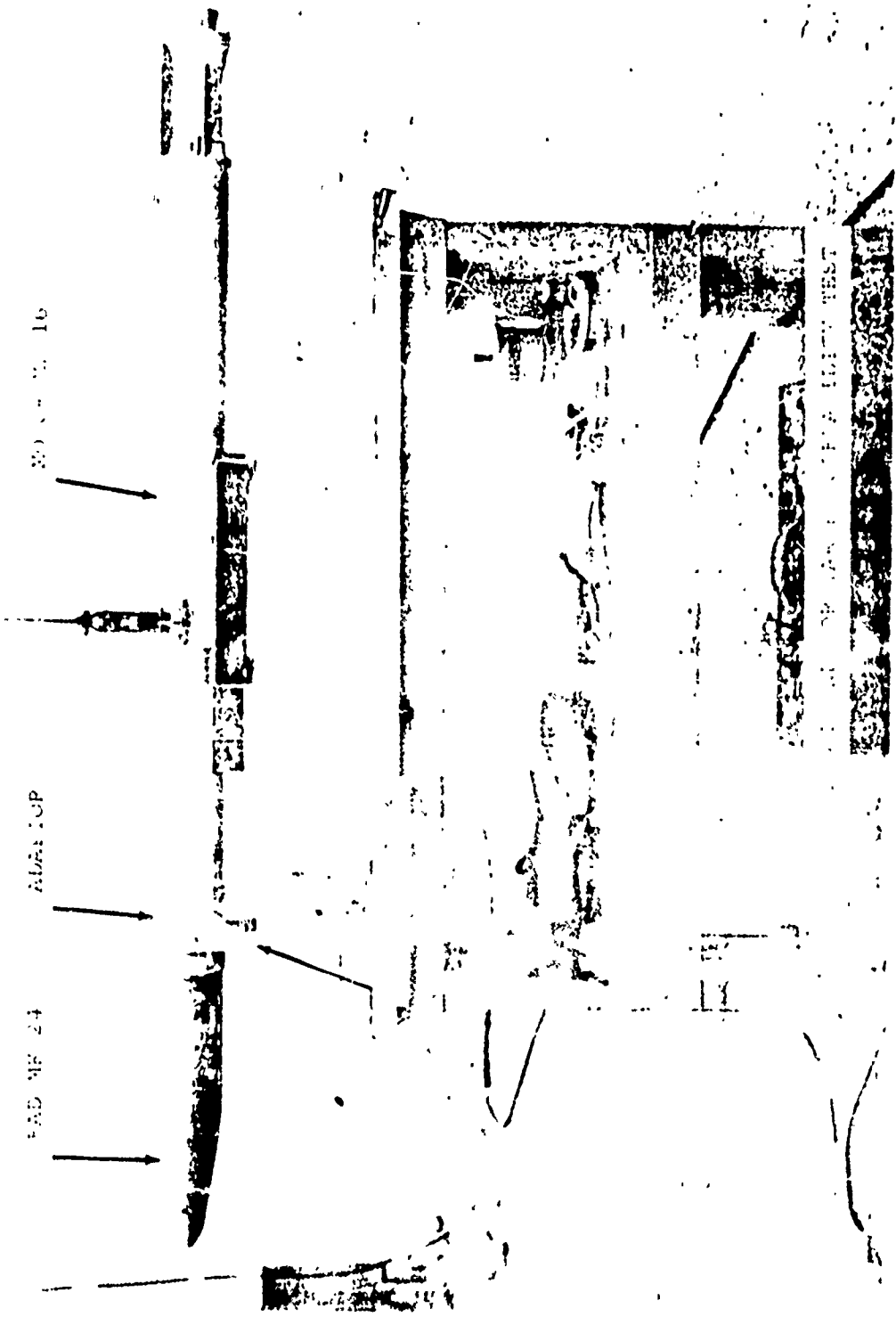


FIG. 3 SAFETY MECHANISM ASSEMBLY



NO. 16

ADJUSTOR

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