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DETERMINATION OF MINIMUM NONPROPAGATION DISTANCE OF 105 MM M1 PROJECTILES GROUPED 16 ON A PALLET

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A series of 119 tests were conducted with pallets containing 16 105 mm, M1 (composition B loaded) projectiles. Tests were performed with and without funnels used to fill the projectiles with explosives. This effort was in direct support of the modernization of the 105 mm LAP line at Lone Star Army Ammunition Plant but is also applicable to other similar loading lines. The test results indicate that

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20. Abstract (Continued)

pallets with 16 projectiles with funnels cannot safely be spaced at a distance as large as 40 feet without propagation of an explosive event. The safe nonpropagative spacing can be reduced to 20 feet when 3/4-inch thick steel plate blast shields are attached to the acceptor pallets. The tests also demonstrated that the initiation of a detonation of one projectile on a pallet results in a high order detonation of the remaining 15 projectiles. Pallets with 16 projectiles without funnels can safely be spaced at a 30-foot clear distance without propagation of an explosive event.

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ABSTRACT

A series of 119 tests were conducted with pallets containing sixteen 105-MM, M1 (Composition B loaded) projectiles. Tests were performed both with and without the funnels used to fill the projectiles with explosives. This effort was in direct support of the modernization of the 105-MM LAP line at Lone Star Army Ammunition Plant but is also applicable to other similar loading lines. The test results indicate that pallets with 16 projectiles with funnels cannot safely be spaced at a distance as large as 40 feet without propagation of an explosive event. The safe non-propagative spacing can be reduced to 20 feet when 3/4-inch thick steel plate blast shields are attached to the acceptor pallets. The tests also demonstrated that the initiation of a detonation of one projectile on a pallet results in a high order detonation of the remaining 15 projectiles. Pallets with 16 projectiles without funnels can safely be spaced at a 30-foot clear distance without propagation of an explosive event.

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SUMMARY

The tests described in this report were performed as part of an overall safety engineering program entitled "Safety Engineering in Support of Ammunition Plants" conducted under the guidance of the Manufacturing Technology Directorate, Picatinny Arsenal, Dover, New Jersey, for the U.S. Army Armament Command (ARMCOM).

A carriage carrying a pallet of sixteen 105-MM, HE, M1 projectiles loaded with Composition B, complete with funnels, is intended for use in the modernized load, assembly and packout production line at the Lone Star Army Ammunition Plant. Since the data relating to the safe spacing between ammunition on conveyors presently contained in Army Materiel Command Regulation AMCR 385-100 applied to 32 projectiles on a pallet, a series of propagation tests simulating the 16-projectile pallet arrangement was initiated. 5.08#/proj.

The tests were performed in several phases during April, May, June, September and October of 1974 and April of 1975 at the Tooele Army Depot, Tooele, Utah. The first group of tests showed that the safe spacings shown in AMCR 385-100 were optimistic and would not provide safe spacing for the pallet under investigation. This group of tests also showed that 1-3/4-inch diameter aluminum interrupter bars on the transfer carriages would not be effective in reducing the required non-propagative spacing. This, and subsequent tests showed that initiation of a single donor projectile on a 16-projectile pallet resulted in high order detonation of all projectiles on the pallet. They also showed that safe spacing of projectiles with the funnels was greater than for projectiles without the funnels.

Explosive propagation was observed at a 15-foot separation distance with a 3/4-inch thick aluminum shield on the acceptor pallet when funnels were used. Propagation of the projectiles was also observed when the clear distance between pallets, without shields, was increased to 40 feet. A safe spacing of 20 feet was established with 3/4-inch thick steel plate shields on the acceptor pallets. A safe spacing of 30 feet was established without shields when funnels were not present.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

(1) Initiation of a single projectile on a pallet will result in high order detonation of all the projectiles on a pallet.

(2) The funnels contribute significantly to increasing the hazard of explosive propagation and thereby increasing the required safe separation between pallets.

(3) The use of 1-3/4-inch interrupter bars is only minimally effective in reducing the required safe separation distance.

(4) The use of 3/4-inch thick aluminum shields on the acceptor pallets has been shown to be effective in reducing severity of attack on the projectiles, but a safe separation distance with aluminum shields was not found.

(5) No safe spacing, up to and including 40 feet, was found without shields when funnels were present.

(6) The minimum safe spacing with funnels was established as 20 feet with 3/4-inch thick steel shields attached to the acceptor pallets, as discussed under "Application of Test Results."

(7) The minimum safe spacing without funnels was established as 30 feet.

Recommendations

Methods are now available for propagation suppression on a conveyor system at a facility. These may include:

(1) Shields (3/4-inch thick steel) on potential acceptors.

(2) 30-foot spacing between carriers without funnels.

(3) Avoidance of line-of-sight between a potential donor and a candidate acceptor beyond a ramp terminus.

(4) Barricades at ramp turns or branches.

(5) Blast shields carried by turntables to interrupt potential propagation paths.

Any combination of these techniques may be used to insure that propagation from ramps to buildings will not occur without unduly penalizing the plant production capability or economics. Viewed in this light, the present test results define minimum parameters to be met in the context of protecting the 105-MM production facility at LSAAP.

INTRODUCTION

Background

At the present time, an army-wide modernization program is underway to upgrade existing and develop new explosive manufacturing, loading, assembly and packaging facilities. This effort will enable the Army to achieve increased production cost effectiveness with improved safety. As a part of this overall program, the Manufacturing Technology Directorate of Picatinny Arsenal, Dover, New Jersey, under the direction of the U.S. Army Armament Command (ARMCOM) is engaged in the development of safety criteria as an activity entitled "Safety Engineering in Support of Ammunition Plants". These criteria will be used as part of the basis for the design of all explosive production installations due for modernization including Government-owned contractor-operated ammunition plants. The activities covered in this report provide safety data to support modernization activities in the manufacturing of 105-MM projectiles at Lone Star AAP, Kansas AAP and the new facility at Bay St. Louis, Mississippi.

The projected melt-pour facilities at LSAAP will utilize a carriage and track conveyance system to transport 16 projectiles, complete with pouring funnels, loaded with Composition B at 1-inch spacing between projectiles on a specially designed carriage. This carriage, with holding fixtures attached, is to be loaded with projectiles and funnels in an inert metal parts area and transported to the melt-pour area where the projectiles are loaded. They are then transferred to cooling areas along special tracks designed for this purpose. The funnels are removed from the projectiles at a subsequent work station. The pallets are then transported to additional work stations. Document AMCR 385-100 (Table 17-1) gives a safe separation distance of 109 inches for pallets containing thirty-two 105-MM projectiles loaded with Composition B. Since this pallet configuration differs significantly from that intended for use at LSAAP, it is necessary to experimentally establish safe separation distances for these carriages.

Objectives of Test Program

A test program was developed to experimentally determine the minimum non-propagative clear spacing between two transport carriages, each containing sixteen 105-MM, HE, M1 projectiles loaded with Composition B under several conditions. These conditions were:

a. without funnels

b. with funnels

c. with blast interrupter bars

d. with an aluminum plate blast shield

e. with a steel plate blast shield

f. unshielded.

The program may be considered as consisting of two phases. The first phase involved exploratory testing for the purpose of establishing the required clear spacing between carriages. The second phase consisted of confirmatory testing as required to establish statistical confidence in the results.

Criteria for Tests

Initially, the tests were conducted in such a manner as to simulate, as closely as possible, the transfer carriage configuration to be used at LSAAP. The transfer carriage, holding fixtures and projectile arrangements were all reproduced in the test arrangements. As the test results accumulated, it became apparent that the AMCR 385-100 specified safe distance was highly optimistic and that the explosive donor event was of so energetic a character that the details of the projectile supports could only contribute to the results as a second order effect so that simplifications could be introduced to substantially reduce costs. The majority of tests were conducted with the projectiles on wooden pallets supported on empty ammunition boxes. All tests were conducted with the projectiles in the vertical position with a 1-inch spacing between projectiles at their widest points. The holding fixtures assured this spacing for the early tests while a loading fixture was constructed for this purpose for the remaining tests. One donor carriage and one acceptor carriage were used for approximately the first third of the tests. The remaining two thirds of the tests utilized one donor pallet and two acceptor pallets, one on each side of the donor.

For the exploratory phase of the program, tests were conducted with varying spacings between the donor and acceptor pallets in order to establish the required safe distance. A total of 58 tests were conducted in this phase of the program. These tests yielded data on 87 acceptor pallets. A summary of the configurations tested is presented in Table I. All of the test results are given in Table II. Either of two results was sufficient to regard a given configuration as unsafe. The first, of course, was an observation of either a detonation or fire at the acceptor. The second was the occurrence of penetrations or holes in the acceptor projectiles. Such penetrations were observed on several occasions without the occurrence of detonation. It was assumed, however, that communication of this kind between donor and acceptor implied a much higher risk of propagation than was acceptable even without the observance of detonation or fire. Since the casting funnels are made of substantially lighter weight metals than the projectiles, they sustained considerable damage, including penetrations in all the tested configurations. It was felt, however, that such damage to the acceptor funnels did not constitute a significant propagation hazard. This was borne out by the confirmatory tests in which no propagation was observed despite substantial damage to the funnels.

Three sequences of confirmatory tests were conducted during the second phase of the program. These were:

(a) No shields - with funnels - 40-foot spacing.

(b) 3/4-inch steel plate shield - with funnels - 20-foot spacing.

(c) No shields - no funnels - 30-foot spacing.

Detonations occurred on two of the acceptor pallets for the first of these sequences. Since 37 pallets were tested (N = 37), statistical analysis indicates that the probability of propagation for this configuration lies between 1 and 18 percent with 95 percent confidence or between 1 and 23 percent with 99 percent confidence.

A total of 47 pallets were tested in the second confirmatory sequence without the occurrence of detonation propagation. This establishes the probability of propagation between 0 and 7.5 percent for 95 percent confidence and between 0 and 11 percent for 99 percent confidence.

The third sequence tested a total of 38 pallets. The upper confidence limits for this sequence are 8 percent for the 95 percent confidence level and 12.5 percent for the 99 percent confidence level. The lower confidence limit for both levels is 0 since propagation did not occur.

TEST DESCRIPTIONS

General

The tests were performed in several series during April, May, June, September and October of 1974 and April of 1975 at the Tooele Army Depot, Tooele, Utah. All tests were conducted by personnel of the Ammunition Equipment Office at Tooele Army Depot. Picatinny Arsenal personnel developed the tests and provided engineering support during their performance. The exploratory phase of the program may be viewed as comprising five test sequences. The first dealt with interrupter bars mounted on the carriages. The second examined propagation of an explosive event on a single pallet or carriage. A third series of tests was initiated to evaluate the safe spacing required without shielding. The use of aluminum plate blast shields mounted on the pallets was examined in the fourth test sequence. Finally, a fifth series of tests explored the required spacing when steel plate blast shields were used.

The confirmatory phase of the program consisted of three sequences of tests. The first of these attempted to establish the non-propagative spacing with funnels but without shields. The second confirmatory test sequence demonstrated the safe spacing required with steel shields mounted on the acceptors. The third established the safe spacing with neither funnels nor shields.

It should be pointed out that the various test sequences were not necessarily conducted in either chronological or serial order. Because of the long time period and large number of tests involved in this program, the grouping of the tests into related sequences was necessary for purposes of review and analysis. In actual fact, the several configurations and test sequences were intermingled.

Test Sequence I - Interrupter Bars

A total of 9 tests were conducted to evaluate the use of 4 aluminum blast interrupter bars mounted on the carriages. Tests numbered 1, 3, 5, 7, 9, 11, 13, 23 and 24 made up this sequence.

Test Set-Up

For this test series, one carriage of 16 projectiles acted as donor while a second carriage of 16 projectiles acted as acceptor. The carriages were placed on 1'-6" wide by 5' long sections of steel roller conveyor and supported by wooden horses at a distance of 2'-9" from the ground. For each test, the donor carriage and acceptor carriage were located at varying exploratory distances apart as measured from projectile to projectile. Figure 1 is representative of the test arrangement. The tests were viewed from a bunker 2,400 feet distant from the point of detonation. Propagation into the acceptor carriage was determined by careful examination of the debris collected from the area surrounding the test site.

Test Specimens and Detonation

The fixtures and carriages used in these tests were fabricated in accordance with Picatinny Arsenal Assembly Drawing No. 9280958 of aluminum alloy 6061-T6. They were intended to simulate the carriages to be used at LSAAP as closely as possible. Figure 2 shows a representative carriage assembly with blast interrupter bars attached. The carriage assembly consists of a weldment of aluminum sections to which is attached aluminum alloy projectile holding fixtures. These fixtures are intended to hold the projectiles in proper position for the cooling cycle used in the manufacturing process. In actual use at LSAAP, the base plate would be attached to a transport vehicle. Tests were conducted with:

a. 1-3/4-inch diameter aluminum blast interrupter bars attached to the donor carriage

b. aluminum interrupter bars attached to the acceptor carriage.

The interrupter bars were of the same height (23 inches) as the plate shields tested later.

The projectiles used for this test sequence were manufactured at Joliet AAP in July 1973 and designated Lot JA-SR-3-73. The supplementary charges and liners were omitted from the projectiles. For the first 16 test trials, all donors were primed by filling the supplementary charge cavities with approximately 1/4 pound of Composition C4 explosive per projectile. Initiation was accomplished by inserting a suitable length of Prima-Cord into the Composition C4 in conjunction with a 9-inch length fuse, a No. 8 blasting cap and a manual fuse lighter. This arrangement is shown in Figures 3 and 4. A second set of tests was conducted with only one of the donor projectiles primed. One of these tests was conducted with pouring funnels in place. The funnels used contained Composition B as would be the case for the risers in the actual production line. For this test, the priming charge was placed in a funnel at the location shown in Table II. This test set-up is shown in Figures 5 and 6.

Test Results

High order detonation of all projectiles on the donor carriages was observed for both groups of test trials. Detonations or significant penetrations of the projectile casings were observed on the acceptor carriages for all tests but one. In some cases, acceptor projectiles were propelled as far as 300 feet from their original location. The aluminum test fixtures were reduced to shrapnel, severely contorted and in some cases, melted. In Test No. 23 where propagation was not observed, the interrupter bars were located on the donor carriage only with a spacing of 109 inches between carriages. It should be noted that though no projectiles were penetrated, three were severely attacked. Typical test results are depicted in Figures 7 through 13.

Test Sequence II - Donor Carriage Detonation

Two tests, Numbers 17 and 18, were conducted in order to determine whether or not a detonation of one projectile on a carriage would propagate to any of the remaining 15 projectiles on the carriage. This bears on the interpretation of the test results in terms of a distinction made between initiating one donor projectile on the carriage as opposed to all 16 as well as to determine whether the detonation of one projectile on the acceptor carriage will propagate into the rest of the projectiles on that carriage.

Test Set-Up and Detonation

The physical arrangement used for this test sequence was similar to that used for Sequence I. The supplementary charges were omitted from the projectiles. One projectile on the carriage was selected as the donor and primed with approximately 1/4 pound of Composition C4 and detonated as for the previous test sequence. Figure 14 shows the test arrangement. For both of these tests, all the acceptor projectiles experienced high order detonations. Figure 15 shows the crater and debris from one of these tests.

Test Sequence III - Unshielded Clear Spacing Tests

The results of Test Sequence I gave clear evidence that the determination of the safe spacing between carriages required a significantly larger number of tests than were anticipated. The clear spacing given in Table 17-1 of AMCR 385-100 for thirty-two 105-MM (M1) projectiles on pallets (109 inches) is obviously too small for safe use. This apparent discrepancy is at least partially explained by the fact that the 105-MM projectiles used in the tests to determine safe spacing as reported in AMCR 385-100 had thicker steel casings than those presently being manufactured and used for the current tests. A series of somewhat simpler tests were, therefore, conducted to determine the minimum required safe spacing. These tests were designated Numbers 2, 4, 6, 8, 10, 12, 14-16, 19-22, 36 and 44-59.

Test Set-Up and Detonation

In order to simplify the arrangements, save set-up time and improve cost effectiveness, the carriages and fixtures used in Test Sequences I and II were replaced with wooden pallets for this series. Sixteen 105-MM, HE (M1) projectiles loaded with Composition B were contained on each pallet. The projectiles were placed in the vertical position in a square grid pattern with a minimum spacing of 1 inch between projectiles at their widest points. A sketch of the pallets is shown in Figure 16. Further economics were realized by supporting the pallets approximately 29 inches above ground on empty ammunition boxes. Three pallets were used for each test trial. The center pallet served as donor. The two acceptor pallets used for each test trial were positioned on either side of the donor pallet in a manner similar to that shown in Figure 17. The two acceptor pallets were each located at different distances from the donor pallet. Tests were conducted both with and without funnels in place. The supplementary charges and liners were omitted from the projectiles. One projectile on each donor pallet was primed with approximately 1/4 pound of Composition C4 in the fuze well cavity or in the funnel when they were used. A No. 8 blasting cap was inserted into the Composition C4 and attached to a suitable length of Prima-Cord. Initiation was obtained with a manual fuze lighter.

Test Results

High order detonations were observed with the acceptors at 25 feet and at 30 feet distant from the donor pallet when funnels were used (Test No. 29). All donor projectiles experienced high order detonations even though only one projectile on the donor pallet was primed. Penetration of acceptor projectiles was observed without funnels at 13-1/2-foot, 18-foot, 20-foot and 25-foot spacings. These penetrations were regarded as demonstrating a relatively high likelihood of propagation. Typical results are shown in Figure 18.

Test Sequence IV - Aluminum Shields

The exploratory tests indicate that the safe spacings required, particularly when funnels were used, are quite large (more than 40 feet with funnels, 30 feet without funnels). Such spacings are likely to be prohibitive when translated into manufacturing facility design constraints. The use of deflector bars was shown in Test Sequence I to be relatively ineffective in preventing propagation or reducing required safe spacing. A sequence of tests, Numbers 60 through 66, were therefore initiated with aluminum plates mounted on one side of the acceptor pallets to act as blast shields. These exploratory tests were intended to determine the minimum required safe distance between pallets when a 3/4-inch thick aluminum shield is used between pallets.

Test Set-Up and Detonation

Each wooden pallet, as shown in Figure 16, contained 16 105-MM, HE (M1) projectiles in a square grid with 1-inch spacing between projectiles. A special fixture was fabricated to facilitate the placement of the projectiles on the pallets. A 3/4-inch thick T6 aluminum alloy plate was bolted to the acceptor pallet frames. Figure 19 is typical of the acceptor pallets. Donor pallets were unshielded. The acceptor pallets were located on either side of the donor pallet with the shields centrally oriented as shown in Figure 17. The pallets were supported on empty ammunition boxes at a height of 29 inches from the ground. Sections of steel roller conveyor were placed under the donor pallets to more closely simulate actual plant conditions and introduce additional shrapnel emissions. Priming and initiation of the tests were similar to the previous test sequences. All projectiles used in this series had funnels attached.

Test Results

At the 5-foot distance, a high order propagation was observed on an acceptor pallet, while at the 10-foot distance, the shield was severely damaged and experienced numerous large penetrations. The shield experienced minor damage at the 15-foot distance although the projectiles were essentially blemish free. An optimistic view was taken relative to this distance and six successful tests were conducted. However, the next test produced a high order detonation. Typical test results are shown in Figures 20 and 21.

Test Sequence V - Steel Shield

Four tests, identical to those of Test Sequence IV except for the use of 1020 steel in lieu of the aluminum shield, were conducted at separation distances of 5, 10 and 15 feet. A typical view of the test arrangement for all the tests of steel shields is shown in Figure 22. The shields were penetrated for the 10- and 15-foot separations and severely bent at the 5-foot distance. A large number of funnels were damaged at the 10- and 15-foot spacings while all the funnels were either burned or damaged at the 5-foot spacing. Representative photographs of the test results are shown in Figures 23 through 25.

Test Sequence VI - Unshielded Confirmatory

The exploratory tests indicated that no explosive propagation would occur between pallets containing sixteen 105-MM (Composition B loaded) M1 projectiles with funnels when the pallets are separated by a clear distance of 40 feet. Confirmatory tests were, therefore, initiated to establish this spacing. Nineteen tests, Numbers 30 through 35, 37 through 43, and 86 through 91 were conducted with a total of 37 acceptor pallets located 40 feet from the donor pallet. The test arrangements and procedures were the same as in the previous test sequences.

A detonation of three acceptor projectiles occurred in Test No. 97 fifteen minutes after donor initiation due to a fire which had propagated to one of them. Test No. 91 resulted in a high order detonation of an acceptor pallet. For most tests, the funnels experienced more damage than did the projectiles with holes being observed in them for most of the pallets. Representative test results are shown in Figures 26 through 28.

Test Sequence VII - Steel Shield Confirmatory

A sequence of 25 tests were conducted to confirm that propagation between pallets would not occur when the pallets were separated by a 20-foot clear distance and 3/4-inch steel plate blast shields were attached to the acceptor pallets. Funnels were used in all tests. All the tests utilized two acceptor pallets and one donor pallet so that a total of 49 pallets were tested for this sequence. Figures 29 through 31 illustrate the test results. Only one projectile was observed to have been dented. Holes were noted in six of the shields.

Test Sequence VIII - No Funnels, Unshielded, Confirmatory

A sequence of 19 tests were conducted to confirm that propagation between pallets would not occur when the pallets were separated by a 30-foot clear distance and no funnels were present. All the tests utilized two acceptor pallets and one donor pallet. The results of Test No. 44 may also be included for statistical purposes so that a total of 39 pallets were tested for this sequence. No detonation, penetrations or fires were observed on any of the acceptor pallets.

DISCUSSION OF RESULTS

General

Either detonation, burning or penetration of the acceptor projectiles was observed for all configurations tested except for the 30-foot spacing without shields or funnels and the 20-foot spacing with steel shields. The test results suggest that the presence of the funnels significantly increases the potential propagation hazard and thus results in increasing the required safe spacing. It should also be noted that funnels were found with considerable damage, including penetrations, for most tests. It appears that the funnels themselves do not detonate on the acceptors but they do contribute to the propagation causing shrapnel. The test program conclusively demonstrated that detonation of one projectile on a pallet results in high order detonation of all the projectiles on the pallet. This, of course, yields an explosive event of a highly energetic character. Even 3/4-inch thick steel plate shields mounted on acceptor pallets 20 feet from the donor were penetrated by shrapnel.

The confirmatory test results showed neither propagation nor penetration of the acceptor projectiles with either a 30-foot clear spacing between unshielded pallets without funnels or a 20-foot clear distance when the acceptor pallet is shielded with 3/4-inch thick steel plate and funnels are present.

Analysis of Confirmatory Test Results

The results shown in Table II do not justify the categorical conclusion that propagation of an explosive incident can be prevented even though no propagation was observed in two confimatory test series. If each projectile, pallet, fixture, etc., were absolutely identical, it would be reasonable to assume that the test results justify such a categorical judgement. In actuality, of course, variations in manufacturing tolerances, materials, wear, etc., require that statistical reasoning be enlisted in the interpretation of the test data. Such reasoning allows that the actual probability of the propagation of an explosive incident is a function of the number of propagation occurrences in the test series and the number of tests conducted.

In statistical terms, the probability of propagation at any given level of confidence is a function of the measured probability and the sample size. The level of confidence referred to is a reflection of the fact that all possible projectiles cannot be tested. As the theoretical sample size decreases from infinity, there is a decreasing confidence that the sample represents the total population, i.e., all projectiles. In practice, a sample size is selected to yield an acceptable confidence level. For a given measured probability of an event, there are fixed maximum and minimum probabilities associated with the specific confidence level. These values are referred to as confidence limits. These confidence limits depend on the specific probability distribution governing the event.

It may be stated that only two conditions of the acceptor projectiles after a test are possible. These are detonated or undetonated. This corresponds to the occurrence of propagation or non-propagation, respectively. Since the presence or absence of propagation for one acceptor is independent of that for another, the binomial probability distribution applies. Figure 32 shows the relationship between sample size, confidence level and the probability of detonation when the measured probability is 0 (no observed propagation). Since two acceptors were used for each tests of Test Sequence VII (with steel shields), there were 48 observations provided. Since the probability of detonation for each acceptor may be considered independent of the other, the sample size for this test sequence is 48. Since there was no observation of propagation, the lower limit for the probability of propagation is zero for all confidence levels. Referring to Figure 32, the upper limit on the probability of propagation is 7.4 percent at the 95 percent confidence level. This is equivalent to stating that in a large number of tests, 95 out of 100 times, the probability of propagation of an explosive event will be less than or equal to 7.4 percent. Similarly, a 99 percent confidence level corresponds to an upper probability limit of 10.5 percent. These values indicate the quality of the tests and the reliance that can be placed on the conclusions drawn from the testing.

A total of 20 tests were conducted in the confirmatory sequence for the 30-foot unshielded distance. One of these tests (No. 44) utilized one acceptor pallet at the 30-foot spacing while the remaining 19 utilized two pallets. By reasoning similar to that outlined above, the sample size for this sequence is 39. Again referring to Figure 32, the upper limit on the probability of propagation at the 95 percent confidence level is 10 percent. At the 99 percent confidence level, the upper limit on the probability of propagation is 13.5 percent. The lower limit of propagation probability is, of course, zero for all confidence levels.

Application of Test Results

The test results clearly demonstrate the energetic personality of explosive events on pallets of sixteen 105-MM projectiles. Complete prevention of propagation of such an event from pallet to pallet in an actual production facility would impose very severe design constraints. Either very large spacings, incompatible with established production goals, would be required between projectile carriers or large shields would have to be added to the carriers. The latter requirement would impose power and acceleration penalties on the conveyance system that would be difficult, if not impossible, to meet. Other design alternatives, however, are available from a facility point of view. These alternatives involve adopting design objectives consistent with both safety requirements and production constraints. Such a design objective for the LSAAP or similar facility may be simply stated as the confinement of an explosive event to the building or tunnel in which it is initiated. The problem is thus defined as preventing explosive propagation beyond any ramp terminus.

Several methods are available for propagation suppression through a ramp terminus. These include:

a. shields (3/4-inch thick steel) on potential acceptors

b. 30-foot spacing between carriers without funnels

c. avoidance of line-of-sight between a potential donor and a candidate acceptor beyond a ramp terminus

d. barricades at ramp turns or branches

e. blast shields carried by turntables to interrupt potential propagation paths.

Any combination of these techniques may be used to insure that propagation from ramps to buildings will not occur without unduly penalizing the plant production capability or economics. Viewed in this light, the present test results define minimum parameters to be met in the context of protecting the 105-MM production facility at LSAAP.

NOTES TO TABLES I AND II

1. Spacing dimensions are given as clear distance between rounds.

2. All projectiles in the vertical position.

3. Tests Nos. 1 through 28 conducted on aluminum carriages mounted on steel conveyor sections 33 inches above the ground.

4. All remaining tests conducted on wooden pallets supported by empty ammunition boxes. Donor pallets placed on sections of steel conveyors.

5. All projectiles on donor carriages and/or pallets experienced high order detonation.

6. All projectiles and funnels loaded with Composition B.

7. All projectiles were tested without supplementary charges.

8. All projectiles were spaced 1 inch apart on the carriages/pallets.

9. Tests Nos. 1 through 16 were conducted with 16 donor projectiles primed. All other tests were conducted with one donor projectile primed.

10. In Test No. 95, one pallet spaced 20 feet from the donor fell over prior to detonation. Data was disregarded.

11. The value "n" indicates the total number of acceptor pallets tested for a given configuration and spacing.

TABLE I

TEST CONFIGURATION SUMMARY

Base Configuration	Shield Description	Shield Location	Funnels	Spacing	Test No.	Sequence	Notes
Aluminum Weldment	1-3/4" dia. aluminum rods	Acceptor	No	1'-8"	1	I	Tests No. 1-15, 16 projectiles primed (n=1) (Propagation)
Aluminum Weldment	1-3/4" dia. aluminum rods	Acceptor	No	5'-0"	7	I	Hole in projectile (n=1)
Aluminum Weldment	1-3/4" dia. aluminum rods	Acceptor	No	6'-8"	9	I	Hole in projectile (n=1)
Aluminum Weldment	1-3/4" dia. aluminum rods	Acceptor	No	7'-6"	13	I	(n=1)
Aluminum Weldment	1-3/4" dia. aluminum rods	Acceptor	No	9'-1"	24	I	1 projectile primed (n=1) Detonation
Aluminum Weldment	1-3/4" dia. aluminum rods	Donor	No	3'-4"	3, 5	I	1 detonation hole in projectile (n=2)

TABLE I (continued)

TEST CONFIGURATION SUMMARY

Base Configuration	Shield Description	Shield Location	Funnels	Spacing	Test No.	Sequence	Notes
Aluminum Weldment	1-3/4" dia. aluminum rods	Donor	No	7'-6"	11	I	(n=1)
Aluminum Weldment	1-3/4" dia. aluminum rods	Donor	No	9'-1"	23	I	(n=1)
Aluminum Weldment	None	N/A	No	N/A	17, 18	II	All detonated (n=2)
Aluminum Weldment	None	N/A	No	3'-4"	2	III	Detonation (n=1)
Aluminum Weldment	None	N/A	No	5'-0"	4, 6, 19, 20	III	(2) Detonation (1) Fire (1) Hole in projectile (n=4)
Aluminum Weldment	None	N/A	No	6'-8"	8	III	Detonation (n=1)
Aluminum Weldment	None	N/A	No	8'-4"	10	III	Detonation (n=1)

TABLE I (continued)

TEST CONFIGURATION SUMMARY

Base Configuration	Shield Description	Shield Location	Funnels	Spacing	Test No.	Sequence	Notes
Aluminum Weldment	None	N/A	No	9'-2"	12, 14, 21, 22	III	(4) Holes in projectile (1) Fire (n=4)
Aluminum Weldment	None	N/A	No	10'-10"	15, 16	III	Hole in projectiles (Both tests) (n=2)
Pallets	None	N/A	No	13'-6"	45, 46, 47	III	Holes in projectile in 1 of 3 pallets (n=3)
Pallets	None	N/A	No	18'-0"	45-49, 51	III	Burning on 1 pallet (n=9)
Pallets	None	N/A	No	20'-0"	50, 52, 53	III	Penetration on 1 pallet (n=6)
Pallets	None	N/A	No	25'-0"	44, 54-59	III	Penetration on 1 pallet (n=13)
Pallets	None	N/A	No	30'-0"	44, 67-85	III, VIII	(n=37)

TABLE I (continued)

TEST CONFIGURATION SUMMARY

Base Configuration	Shield Description	Shield Location	Funnels	Spacing	Test No.	Sequence	Notes
Aluminum Weldment	None	N/A	Yes	10'-10"	25	III	Detonation (n=1)
Aluminum Weldment	None	N/A	Yes	11'-8"	26	III	Detonation (n=1)
Aluminum Weldment	None	N/A	Yes	13'-4"	27	III	Detonation (n=1)
Aluminum Weldment	None	N/A	Yes	14'-2"	28	III	Detonation (n=1)
Pallets	None	N/A	Yes	25'-0"	29	III	(n=1) Detonation
Pallets	None	N/A	Yes	30'-0"	29	III	(n=1) Detonation
Pallets	None	N/A	Yes	35'-0"	30	III	(n=1) Holes in funnels
Pallets	None	N/A	Yes	40'-0"	30-35, 37-43 86-91	VI	(34) Funnel holes (2) Detonations (n=37)
Pallets	Plate 3/4-inch aluminum	Acceptor	Yes	5'-0"	61	IV	Detonation (n=1)

TABLE I (concluded)

TEST CONFIGURATION SUMMARY

Base Configuration	Shield Description	Shield Location	Funnels	Spacing	Test No.	Sequence	Notes
Pallets	Plate 3/4-inch aluminum	Acceptor	Yes	10'-0"	61	IV	Holes in funnels (n=1)
Pallets	Plate 3/4-inch aluminum	Acceptor	Yes	15'-0"	60, 62-65	IV	(3) Holes in funnels (1) Fire (n=9) (1) Detonation
Pallets	Plate 3/4-inch aluminum	Acceptor	Yes	20"-0"	60, 66	IV	(1) Funnel broken (1) Funnel hole (n=3)
Pallets	Plate 3/4-inch steel	Acceptor	Yes	5'-0"	93, 94	V	4 Fires (n=4)
Pallets	Plate 3/4-inch steel	Acceptor	Yes	10'-0"	92	V	Broken funnels (n=1)
Pallets	Plate 3/4-inch steel	Acceptor	Yes	15'-0"	92, 95	V	Broken funnels (n=2)
Pallets	Plate 3/4-inch steel	Acceptor	Yes	20'-0"	96-119	VII	(n=47)

TABLE II

TEST DATA SUMMARY

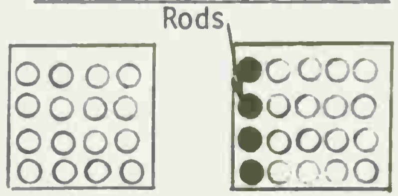
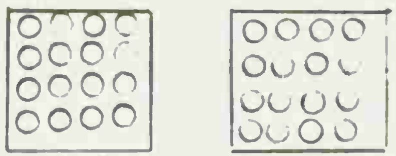
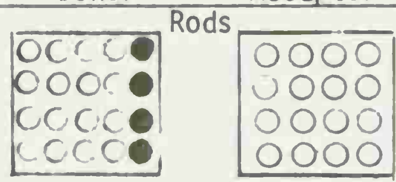
Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
1	1'-8"	 Donor Acceptor	(4) 1-3/4" diameter aluminum rods	Acceptor	0	(5) Low order detonation (3) Major dents (1) 3/4" dia. hole in projectile
2	3'-4"	 Donor Acceptor	0	0	0	(1) Low order detonation (3) Major dents (2) 3/4" dia. hole in projectile
3	3'-4"	 Donor Acceptor	(4) 1-3/4" diameter aluminum rods	Donor		(4) Major dents (1) 3/4" dia. hole in projectile (1) 1/4" dia. hole in projectile
4	5'-0"	Same as Test No. 2	0	0	0	(6) High order (2) Cracked and flattened

TABLE II (continued)

TEST DATA SUMMARY

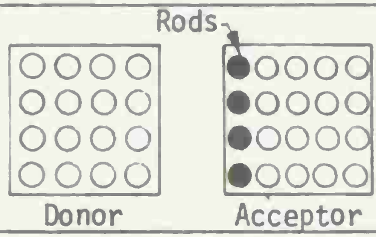
Test No.	Separation (feet)	Geometry	Shields		Funnels	Results
			Description	Location		
5	3'-4"	Same as Test No. 3	(4) 1-3/4" diameter aluminum rods	Donor	0	(4) High order (3) Major dents (1) Cracked and broken
6	5'-0"	Same as Test No. 2	0	0	0	(1) Major dents (3) 3/4" dia. hole in projectile
7	5"-0"		(4) 1-3/4" diameter aluminum rods	Acceptor	0	(3) Major dents (1) 3/4" dia. hole in projectile
8	6'-8"	Same as Test No. 2	0	0	0	(5) High order (1) 3/4" dia. hole in projectile (1) Cracked and flattened

TABLE II (continued)

TEST DATA SUMMARY

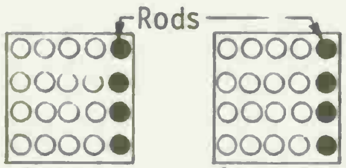
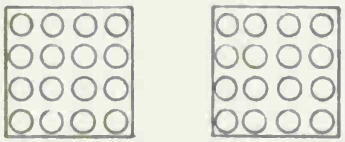
Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
9	6'-8"	Same as Test No. 7	(4) 1-3/4" diameter aluminum rods	Acceptor	0	(4) Major dent (1) 1/2" dia. hole in projectile
10	8'-4"	Same as Test No. 2	0	0	0	All high order detonation
11	7'-6"		(4) 1-3/4" diameter aluminum rods	Acceptor Donor	0 0	(3) Projectiles, major dents (2 of which flattened) No penetrations
12	9'-2"		0	0	0	(3) Projectiles, major dents (1) Projectile 1-1/2" dia. x 1" hole

TABLE II (continued)

TEST DATA SUMMARY

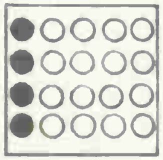
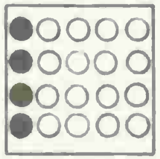
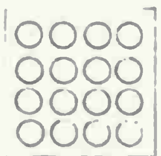
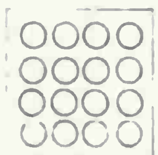
Test No.	Separation (feet)	Geometry		Shields Description	Shields Location	Funnels	Results
13	7'-6"	 Donor	 Acceptor	(4) 1-3/4" diameter aluminum rods	Acceptor Donor	0 0	(3) Projectiles, major dents
14	9'-2"			0	0	0	(1) Projectile, major dents (2) Burned - 1-1/2" x 3/4" x 1" hole and 1/4" dia. hole
15	10'-10"			0	0	0	(2) Projectiles, major dents (1) Projectile - 1" x 1/2" x 2" deep hole
16	10'-10"	Donor	Acceptor	0	0	0	(3) Projectiles, major dents (1) Projectile - 1/2" dia. hole

TABLE II (continued)

TEST DATA SUMMARY

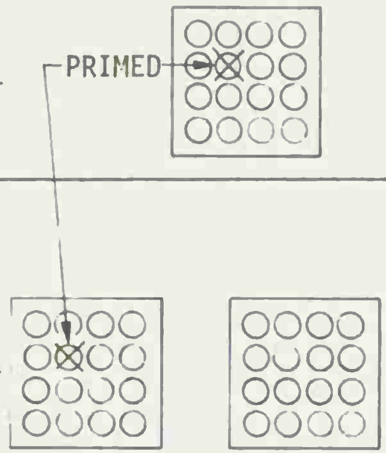
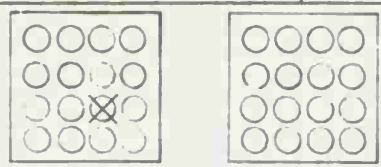
Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
17	-		0	0	0	All high order detonation
18	-		0	0	0	All high order detonation
19	5'-0"		0	0	0	(3) Projectiles, major dents (1) Burned - 1-1/2" x 1/2" x 1" deep hole (1) 3/4" x 1/16" hole
20	5'-0"	Donor Acceptor	0	0	0	(3) High order (3) Low order (2) Projectiles, major dents, 1-1/2" x 1" deep hole
21	9'-1"	 Donor Acceptor	0	0	0	(3) Projectiles, major dents (1) 1-1/4" dia. x 1-1/2" deep hole

TABLE II (continued)

TEST DATA SUMMARY

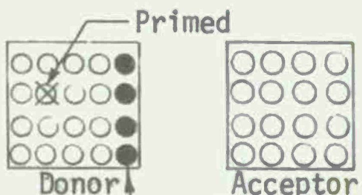
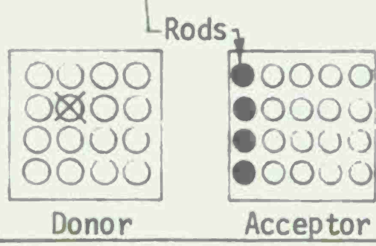
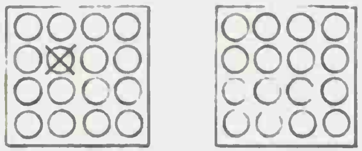
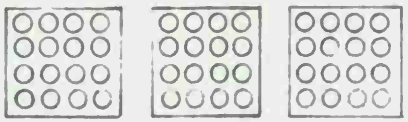
Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
22	9'-1"	Same as Tests Nos. 19 and 20				(4) Projectiles, major dents (1) 1/4" dia. x 3/4" deep hole
23	9'-1"		(4) 1-3/4" diameter aluminum rods	Donor		(3) Projectiles, major dents No penetrations
24	9'-1"		(4) 1-3/4: diameter aluminum rods	Donor Acceptor	0 0	(2) Projectiles, major dent No penetrations (1) High order detonation - audible 10 sec Post Test

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields: Description	Shields: Location	Funnels	Results
25	10'-10"		0	0	32	All high order detonation
26	11'-8"		0	0	32	All high order detonation
27	13'-4"		0	0	32	(2) Projectiles, major dent No penetrations (1) Projectile low order detonation
28	14'-2"	Donor Acceptor	0	0	32	All high order detonation Secondary fragments up to 2,400 ft.
29	25 30		0	0	48	High order detonation High order detonation
30	35 40		0	0	48	P-5 dents, F-2 holes P-3 dents, F-1 holes

NOTE: P = Projectiles, F = Funnels

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
	40	Same as Test No. 29	0		48	P-3 dents, F-3 holes
31	40					P-2 dents, F-3 holes
	40	Same as Test No. 29	0		48	P-3 dents, F-4 holes
32	40					P-4 dents, F-2 holes
	40	Same as Test No. 29	0		48	P-4 dents, F-2 dents, 1 hole
33	40					P-4 dents, F-2 dents, 2 holes
	40	Same as Test No. 29	0		48	P-7 dents, F-3 holes
34	40					P-2 dents, F-0
	40	Same as Test No. 29	0		48	P-5 dents, F-2 holes
35	40					P-1 dent, F-0
	35	Same as Test No. 29	0		48	P-6 dents, F-3 holes
36	35					P-1 dent, F-2 holes
	40	Same as Test No. 29	0		48	P-4 dents, F-1 hole
37	40					P-5 dents, F-3 holes

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
	40	Same as Test No. 29	0		48	P-4 dents, F-2 holes
38	40					P-4 dents + 1 rotating band broken, F-3 holes
	40	Same as Test No. 29	0		48	P-5 dents, F-0
39	40					P-4 dents, F-1 hole
	40	Same as Test No. 29	0		48	P-6 dents, F-2 holes
40	40					P-4 dents + 1 rotating band broken, F-3 holes
	40	Same as Test No. 29	0		48	P-6 dents, F-4 holes
41	40					P-4 dents, F-2 holes
	40	Same as Test No. 29	0		48	P-6 dents, F-6 holes
42	40					P-4 dents, F-3 holes
	40	Same as Test No. 29	0		48	P-5 dents, F-3 holes
43	40					P-6 dents, F-2 holes
	25	Same as Test No. 29	0		0	P-5 dents
44	30				0	P-6 dents

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
	13-1/2	Same as Test No. 29	0	0	0	P-9 dents, 2 holes
45	18		0	0	0	P-7 dents
	13-1/2	Same as Test No. 29	0	0	0	10 dents
46	18		0	0	0	5 dents
	13-1/2	Same as Test No. 29	0	0	0	8 dents
47	18		0	0	0	6 dents
	18	Same as Test No. 29	0	0	0	P-8 dents
48	18		0	0	0	P-8 dents, 1 rotating band broken
	18	Same as Test No. 29	0	0	0	P-6 dents
49	18		0	0	0	P-6 dents
	20	Same as Test No. 29	0	0	0	P-7 dents
50	20		0	0	0	P-4 dents
	18	Same as Test No. 29	0	0	0	P-7 dents
51	18		0	0	0	P-5 dents + 1 penetration resulted in burning action

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
	20	Same as Test No. 29	0	0	0	P-5 dents + 2 rotating bands broken
52	20		0	0	0	P-3 dents + 1 (1/4" dia. penetration)
	20	Same as Test No. 29	0	0	0	P-5 dents
53	20		0	0	0	P-7 dents
	25	Same as Test No. 29	0	0	0	P-6 dents
54	25		0	0	0	P-5 dents
	25	Same as Test No. 29	0	0	0	P-3 dents
55	25		0	0	0	P-3 dents
	25	Same as Test No. 29	0	0	0	P-5 dents
56	25		0	0	0	P-4 dents
	25	Same as Test No. 29	0	0	0	P-5 dents
57	25		0	0	0	P-3 dents
	25	Same as Test No. 29	0	0	0	P-4 dents
58	25		0	0	0	P-1 dent + 2 rotating bands broken

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
	25	Same as Test No. 29	0	0	0	P-2 dents + 1 (3/8" penetration)
59	25		0	0	0	P-5 dents + 1 rotating band broken
	20	Same as Test No. 29	3/4" aluminum plate	Acceptor	48	F-7 broken off
60	15		3/4" aluminum plate	Acceptor		F-12 broken off and 3 penetrations, numerous penetrations thru shield
	10	Same as Test No. 29	3/4" aluminum plate	Acceptor	48	F-2 penetrations, numerous large penetrations thru shield
61	5		3/4" aluminum plate	Acceptor		High order detonation

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
	15	Same as Test No. 29	3/4" aluminum plate	Acceptor	48	No action
62	15		3/4" aluminum plate	Acceptor		F - post test fire burned explosive in and melted 2 funnels on ground - hot fragment possible initiation source
	15	Same as Test No. 29	3/4" aluminum plate	Acceptor	48	P-1 rotating band broken
63	15		3/4" aluminum plate	Acceptor		P-1 dent
	15	Same as Test No. 29	3/4" aluminum plate	Acceptor	48	No action
64	15		3/4" aluminum plate	Acceptor		F-1 penetration

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
	15	Same as Test No. 29	3/4" aluminum plate	Acceptor	48	High order detonation
65	15		3/4" aluminum plate	Acceptor		P-2 dents
	20	Same as Test No. 29	3/4" aluminum plate	Acceptor	48	F-1 penetration
66	20		3/4" aluminum plate	Acceptor		No action
	30	Same as Test No. 29	0	0	0	P = 3 dents
67	30		0	0	0	P = 1 dent
	30	Same as Test No. 29	0	0	0	P = 4 dents
68	30		0	0	0	P = 2 dents
	30	Same as Test No. 29	0	0	0	P = 4 dents
69	30		0	0	0	P = 4 dents

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
	30	Same as Test No. 29	0	0	0	P = 5 dents
70	30		0	0	0	P = 6 dents
	30	Same as Test No. 29	0	0	0	P = 4 dents
71	30		0	0	0	P = 6 dents
	30	Same as Test No. 29	0	0	0	P = 8 dents
72	30		0	0	0	P = 5 dents
	30	Same as Test No. 29	0	0	0	P = 3 dents
73	30		0	0	0	P = 5 dents
	30	Same as Test No. 29	0	0	0	P = 0
74	30		0	0	0	P = 4 dents
	30	Same as Test No. 29	0	0	0	P = 0
75	30		0	0	0	P = 4 dents
	30	Same as Test No. 29	0	0	0	P = 3 dents
76	30		0	0	0	P = 2 dents
	30	Same as Test No. 29	0	0	0	P = 6 dents
77	30		0	0	0	P = 8 dents

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields		Funnels	Results
			Description	Location		
78	30	Same as Test No. 29	0	0	0	Only primed projectile on donor pallet low order detonation. No action to acceptors.
	30	Same as Test No. 29	0	0	0	P = 4 dents
79	30		0	0	0	P = 5 dents
	30	Same as Test No. 29	0	0	0	P = 3 dents
80	30		0	0	0	P = 6 dents
	30	Same as Test No. 29	0	0	0	P = 4 dents
81	30		0	0	0	P = 8 dents
	30	Same as Test No. 29	0	0	0	P = 4 dents
82	30		0	0	0	P = 2 dents
	30	Same as Test No. 29	0	0	0	P = 6 dents
83	30		0	0	0	P = 6 dents
	30	Same as Test No. 29	0	0	0	P = 5 dents
84	30		0	0	0	P = 2 dents

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields: Description	Shields: Location	Funnels	Results
	30	Same as Test No. 29	0	0	0	P = 5 dents
85	30		0	0	0	P = 6 dents
	40	Same as Test No. 29	0	0	48	P = 8 dents
86						F = 3 penetrations
	40		0	0		P = 8 dents, F = 3 dents
	40	Same as Test No. 29	0	0	48	P = 6 dents, F = 4 dents
						P = 3 detonated 15 min. after donor detonation
87						due to a fire in one of the three
	40		0	0		P = 8 dents
						F = 5 penetrations
	40	Same as Test No. 29	0	0	48	P = 7 dents
88						F = 5 penetrations
	40		0	0		P = 0, F = 2 penetrations
	40	Same as Test No. 29	0	0	48	P = 3 dents
						F = 1 penetration
89	40		0	0		P = 5 dents
						F = 1 penetration

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
	40	Same as Test No. 29	0	0	48	P = 1 dent F = 1 penetration
90	40		0	0		P = 4 dents, F = 1 torn apart - no detonation
	40	Same as Test No. 29	0	0	48	P = 2 dents F = 2 penetrations
91	40		0	0		P&F = high order detonation
	10	Same as Test No. 29	3/4" steel plate	Acceptor	48	1 hole (3/4" x 1/2") thru shield, 12 funnels broken
92	15		3/4" steel plate	Acceptor		6 funnels broken
	5	Same as Test No. 29	3/4" steel plate	Acceptor	48	All funnels burned or damaged, shield bent
93	5		3/4" steel plate	Acceptor		All funnels burned or damaged, shield bent
	5	Same as Test No. 29	3/4" steel plate	Acceptor	48	All funnels burned or damaged, shield bent
94	5		3/4" steel plate	Acceptor		All funnels burned or damaged, shield bent

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields: Description	Shields: Location	Funnels	Results
	15	Same as Test No. 29	3/4" steel plate	Acceptor	48	6 funnels broken, hole thru top of shield
95	20		3/4" steel plate	Acceptor		No action, pallet fell over prior to donor detonation
	20	Same as Test No. 29	3/4" steel plate	Acceptor	48	1 hole (3/4" x 1/2") thru shield
96	20		3/4" steel plate	Acceptor		No action
	20	Same as Test No. 29	"	Acceptor	48	No action
97	20		"	Acceptor		No action
	20	Same as Test No. 29	3/4" steel plate	Acceptor	48	1 hole (1/4") thru shield
98	20		3/4" steel plate	Acceptor		No action
	20	Same as Test No. 29	3/4" steel plate	Acceptor	48	2 holes (1/2") thru shield, 1 dent on projectile
99	20		3/4" steel plate	Acceptor		No action

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields: Description	Shields: Location	Funnels	Results
100	20	Same as Test No. 29	3/4" steel plate	Acceptor	48	No action
	20		3/4" steel plate	Acceptor		No action
101	20	Same as Test No. 29	"	Acceptor	48	No action
	20		"	Acceptor		No action
102	20	Same as Test No. 29	"	Acceptor	48	1 hole (3/4") thru shield
	20		"	Acceptor		No action
103	20	Same as Test No. 29	"	Acceptor	48	No action
	20		"	Acceptor		No action
104	20	Same as Test No. 29	"	Acceptor	48	No action
	20		"	Acceptor		No action
105	20	Same as Test No. 29	"	Acceptor	48	No action
	20		"	Acceptor		No action
106	20	Same as Test No. 29	"	Acceptor	48	No action
	20		"	Acceptor		No action

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields Description	Shields Location	Funnels	Results
107	20	Same as Test No. 29	3/4" steel plate	Acceptor	48	No action
	20		3/4" steel plate	Acceptor		No action
108	20	Same as Test No. 29	"	Acceptor	48	No action
	20		"	Acceptor		No action
109	20	Same as Test No. 29	"	Acceptor	48	No action
	20		"	Acceptor		No action
110	20	Same as Test No. 29	"	Acceptor	48	No action
	20		"	Acceptor		No action
111	20	Same as Test No. 29	"	Acceptor	48	No action
	20		"	Acceptor		No action
112	20	Same as Test No. 29	"	Acceptor	48	No action
	20		"	Acceptor		No action
113	20	Same as Test No. 29	"	Acceptor	48	1 hole (1") thru shield
	20		"	Acceptor		No action

TABLE II (continued)

TEST DATA SUMMARY

Test No.	Separation (feet)	Geometry	Shields: Description	Shields: Location	Funnels	Results
114	20	Same as Test No. 29	3/4" steel steel	Acceptor	48	2 holes (3/4", 1/8") thru shield
	20		3/4" steel steel	Acceptor		No action
115	20	Same as Test No. 29	"	Acceptor		No action
	20		"	Acceptor		No action
116	20	Same as Test No. 29	"	Acceptor		No action
	20		"	Acceptor		No action
117	20	Same as Test No. 29	"	Acceptor		No action
	20		"	Acceptor		No action
118	20	Same as Test No. 29	"	Acceptor		No action
	20		"	Acceptor		No action
119	20	Same as Test No. 30	"	Acceptor		No action
	20		"	Acceptor		No action

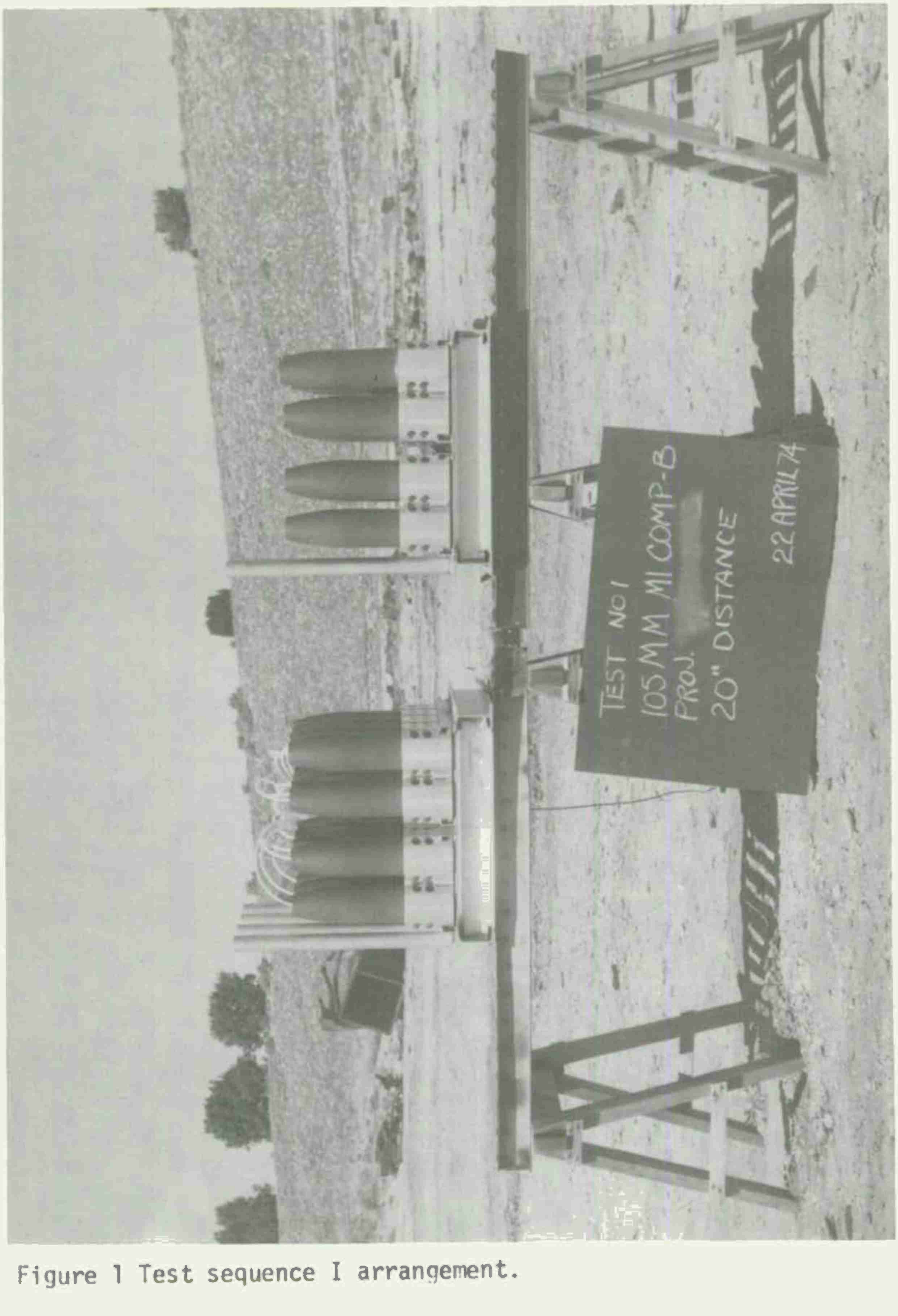


Figure 1 Test sequence I arrangement.

Figure 2 Test sequence I carriage with interrupter bars.

Figure 3 Test arrangement with 16 projectiles primed

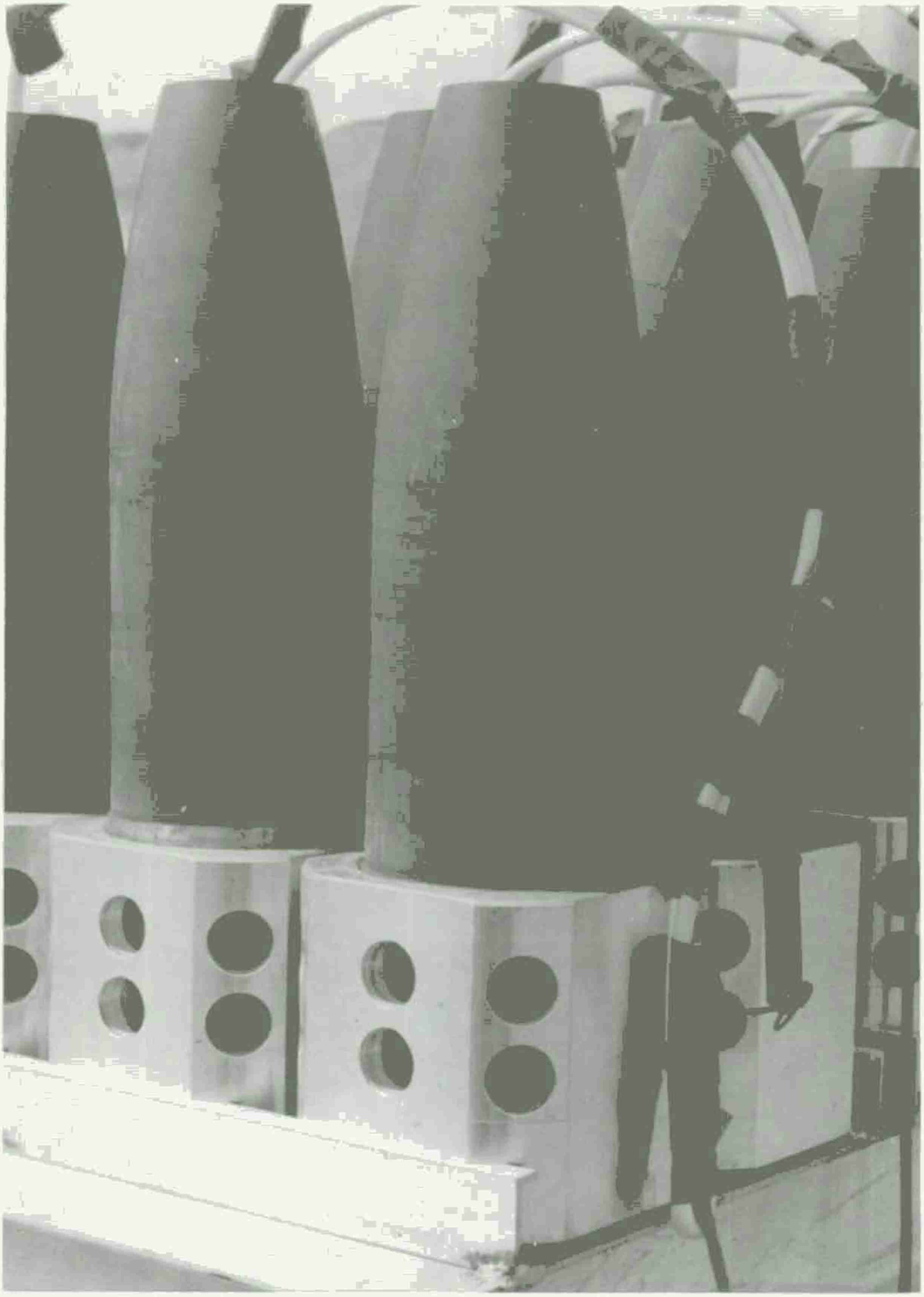


Figure 4 Donor carriage with 16 projectiles primed.

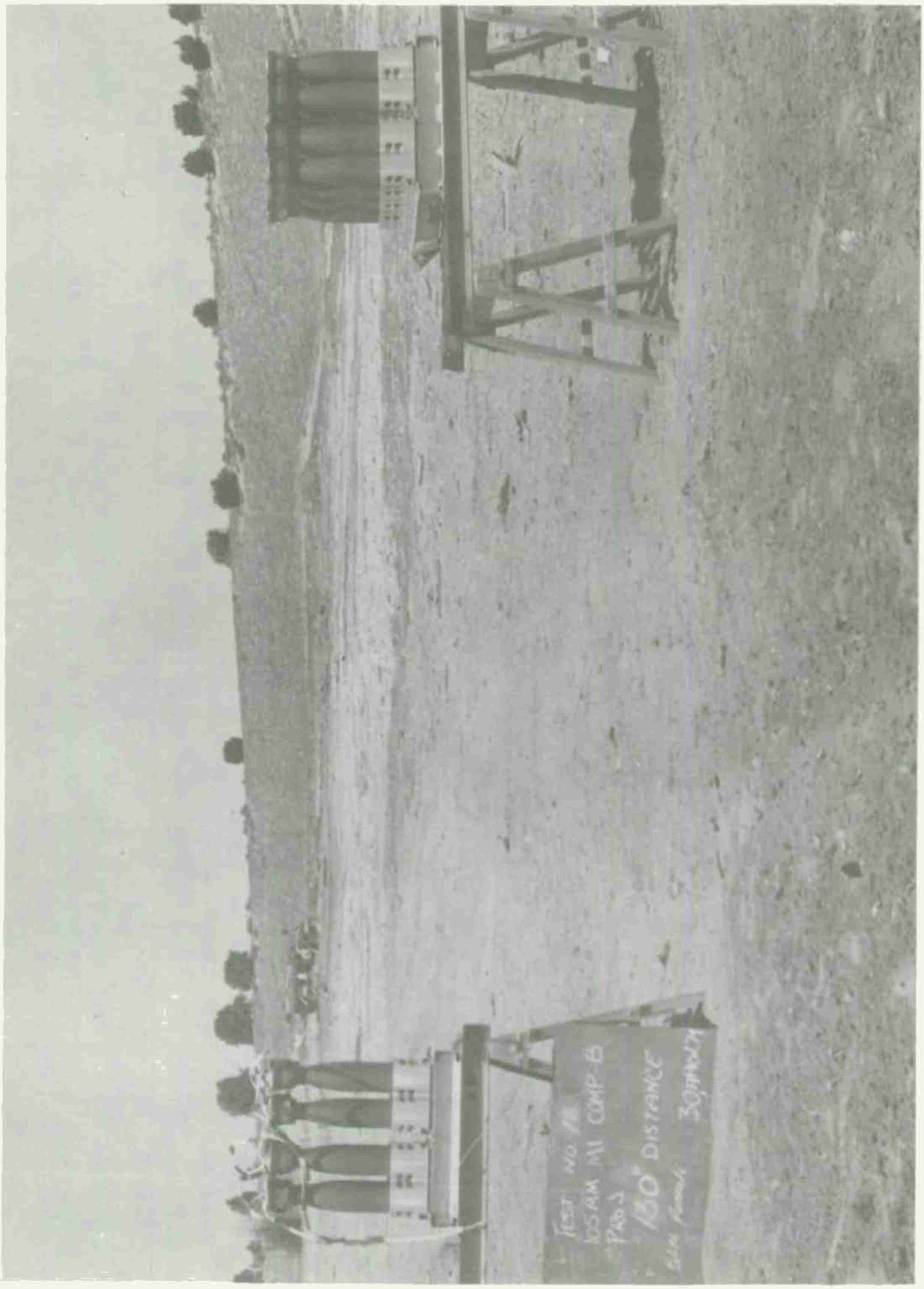


Figure 5 Test arrangement with funnels.

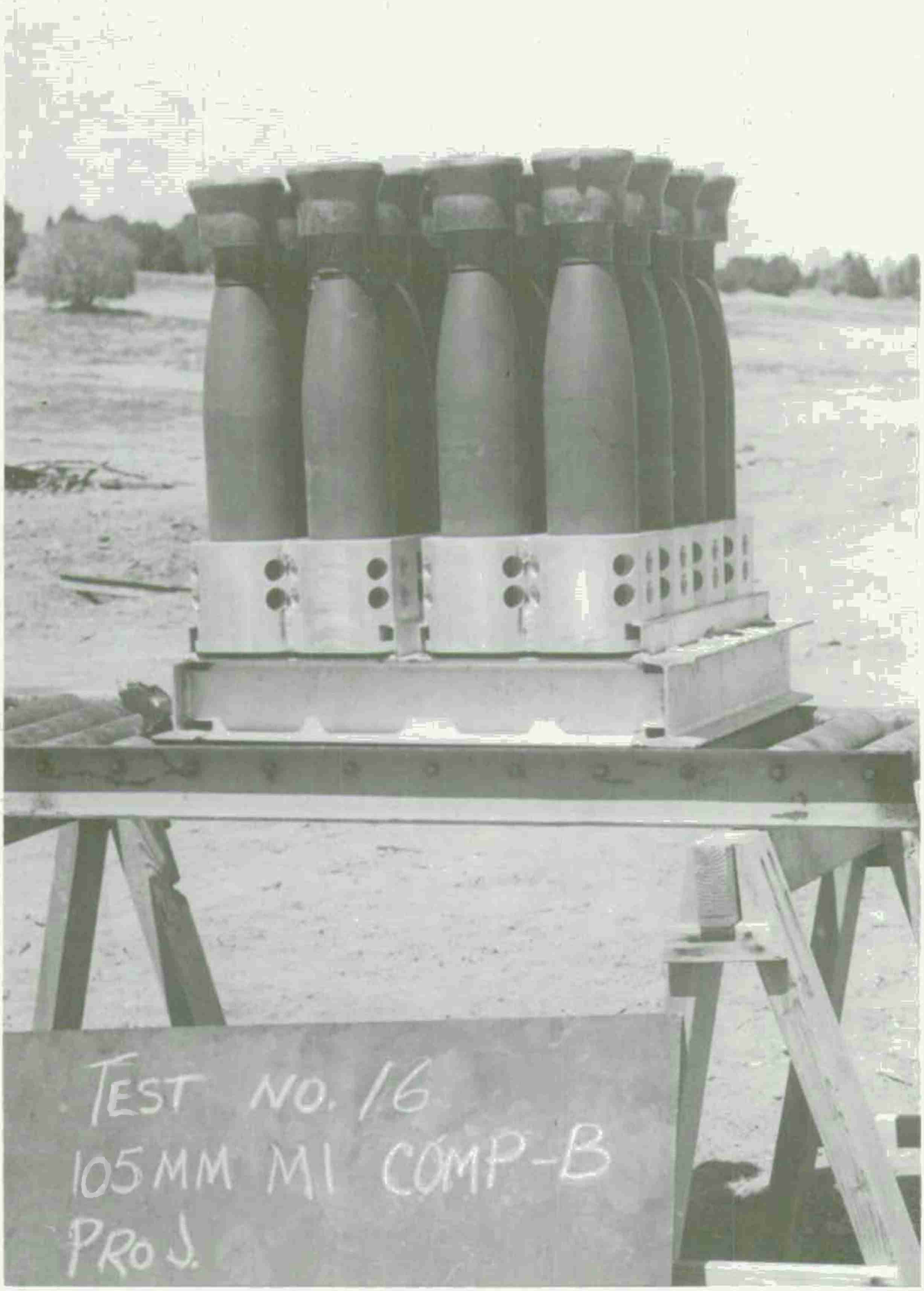
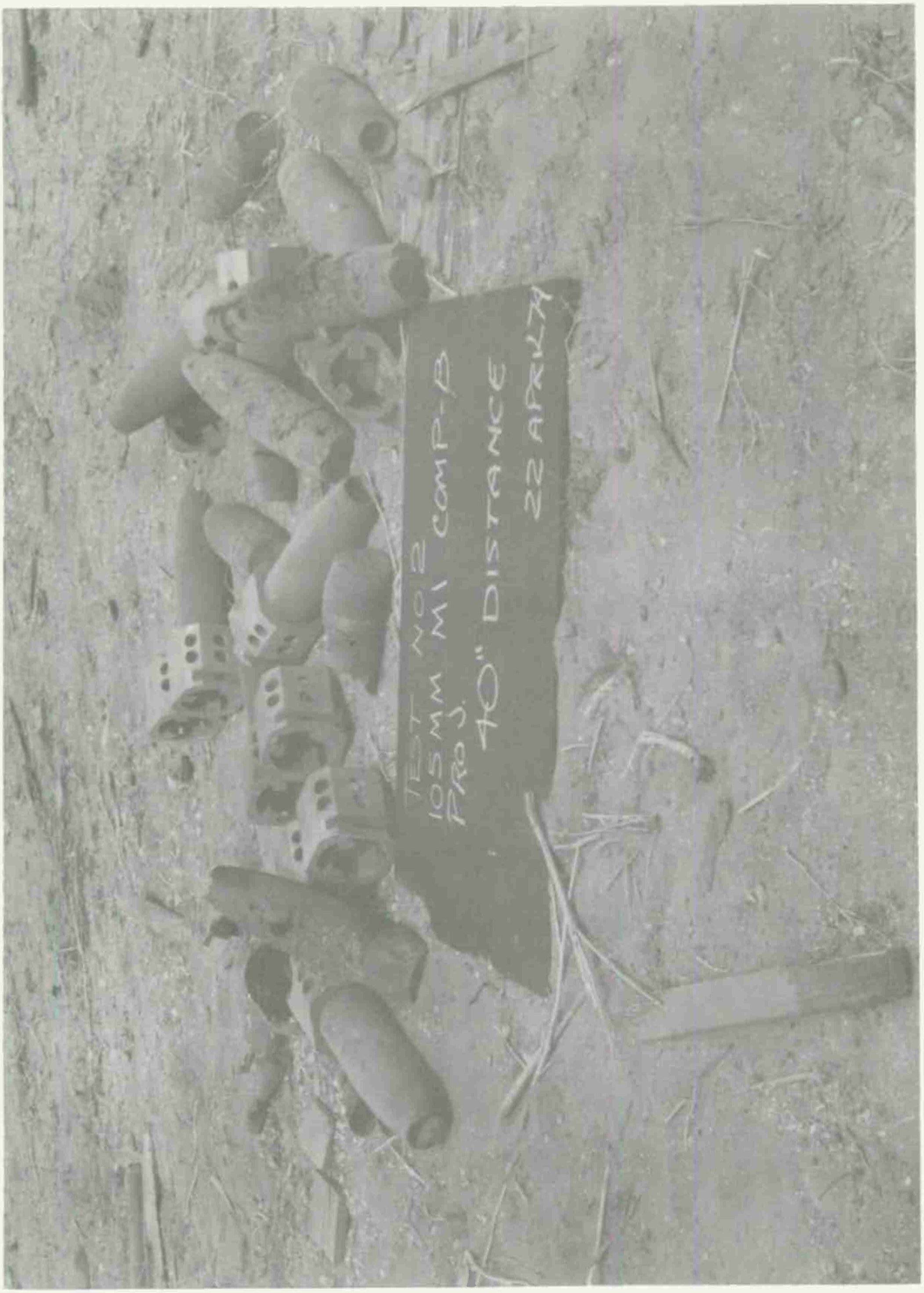


Figure 6 Carriage with funnels.



Fiqure 7 Typical test results - test No. 2.

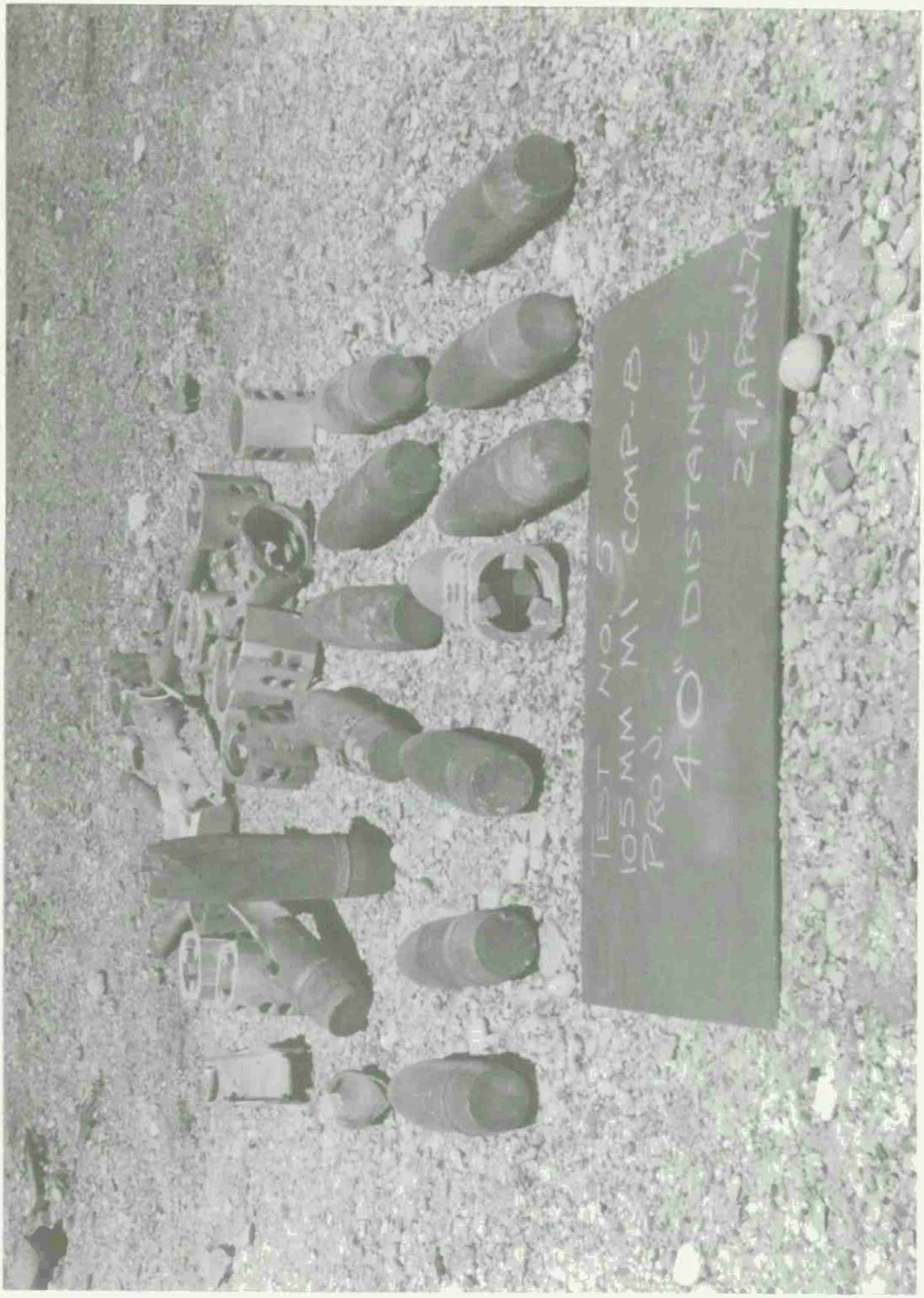


Figure 8 Typical test results - test No. 5.

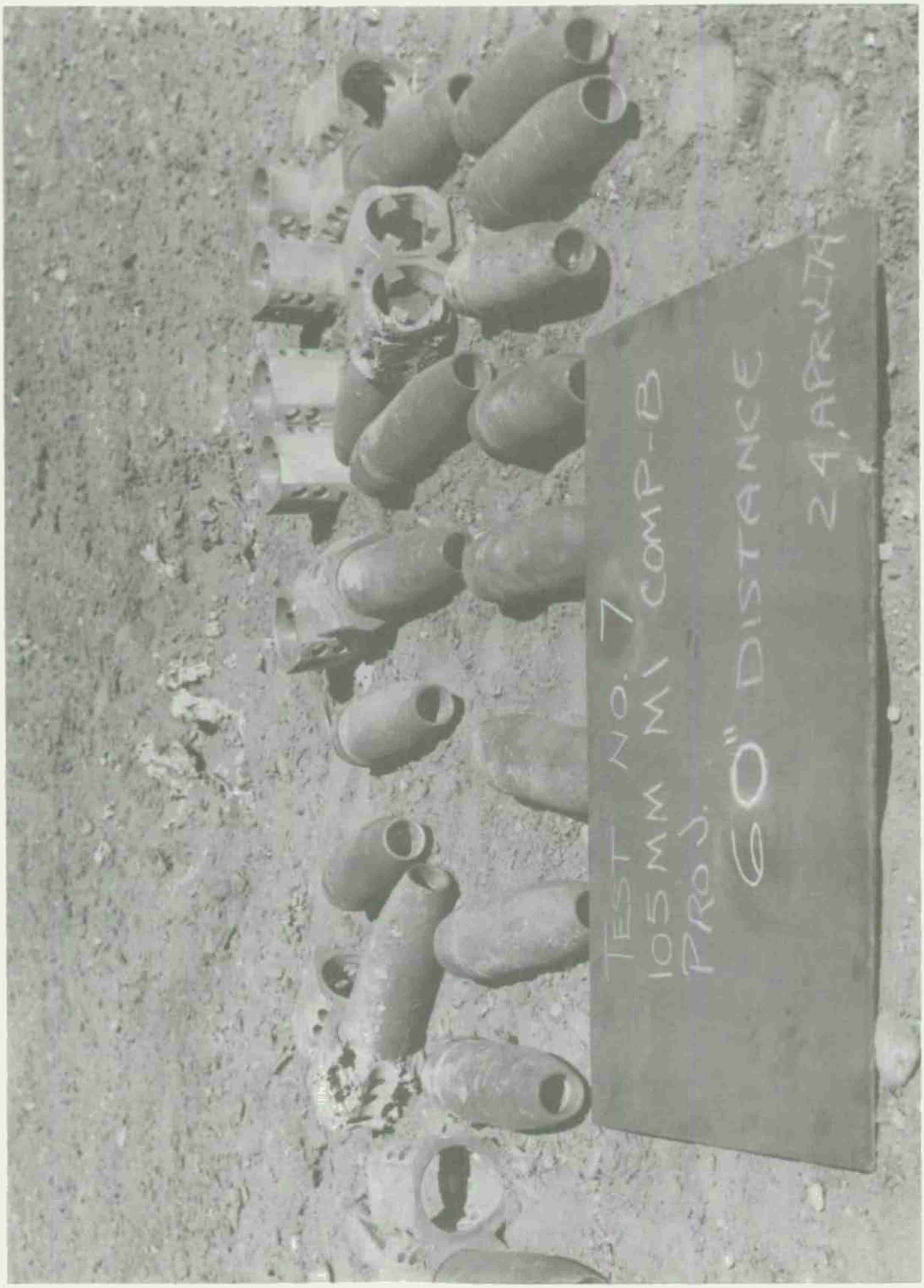


Figure 9 Typical test results - test No. 7.

Figure 10 Typical test results - test No. 8.

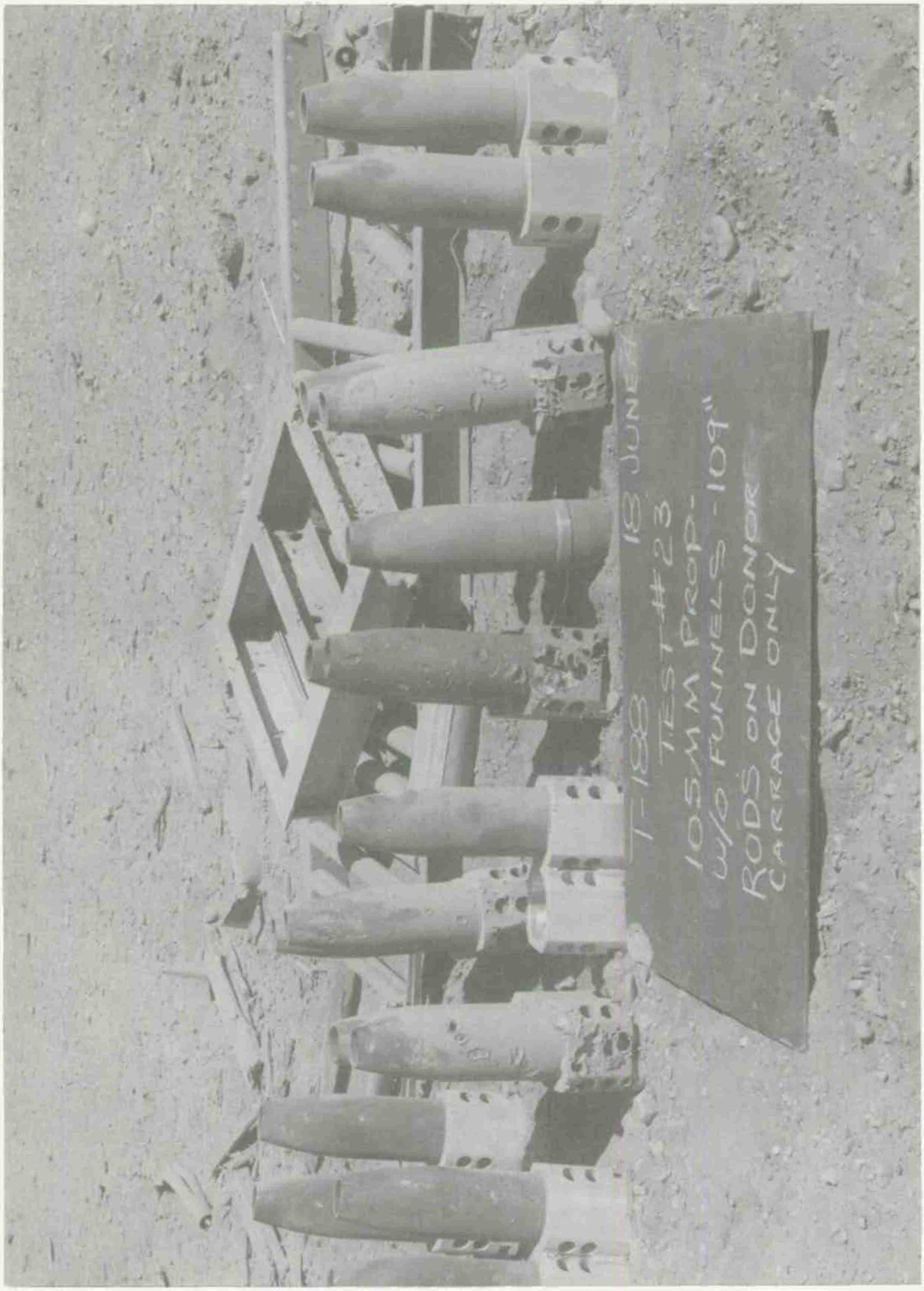


Figure 11 Typical test results - test NO. 23.

Figure 12 Typical test results - test No. 24.

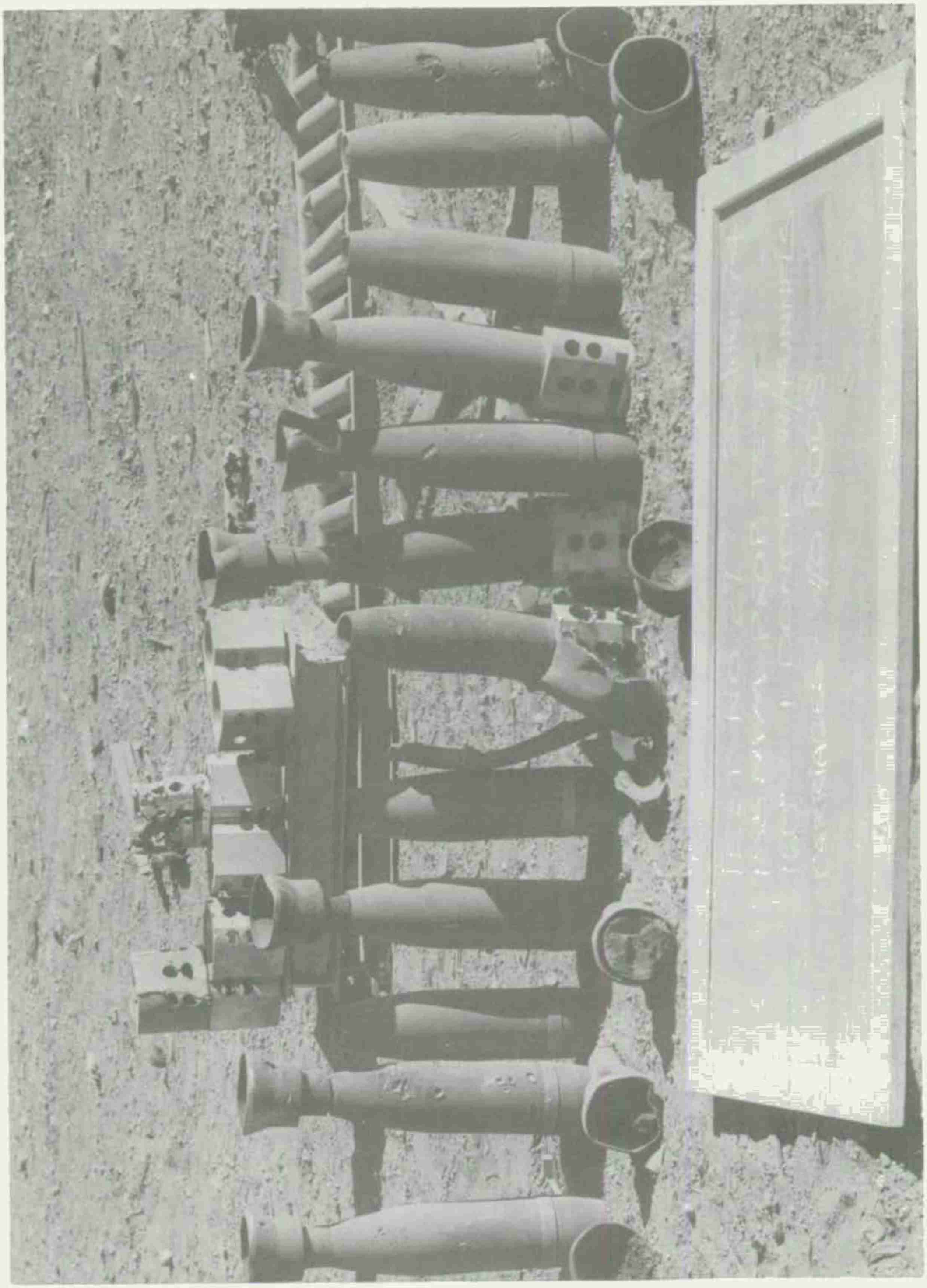


Figure 13 Typical test results - test No. 27.

Figure 14 Test sequence II arrangement.

Figure 15 Test sequence II crater and debris.

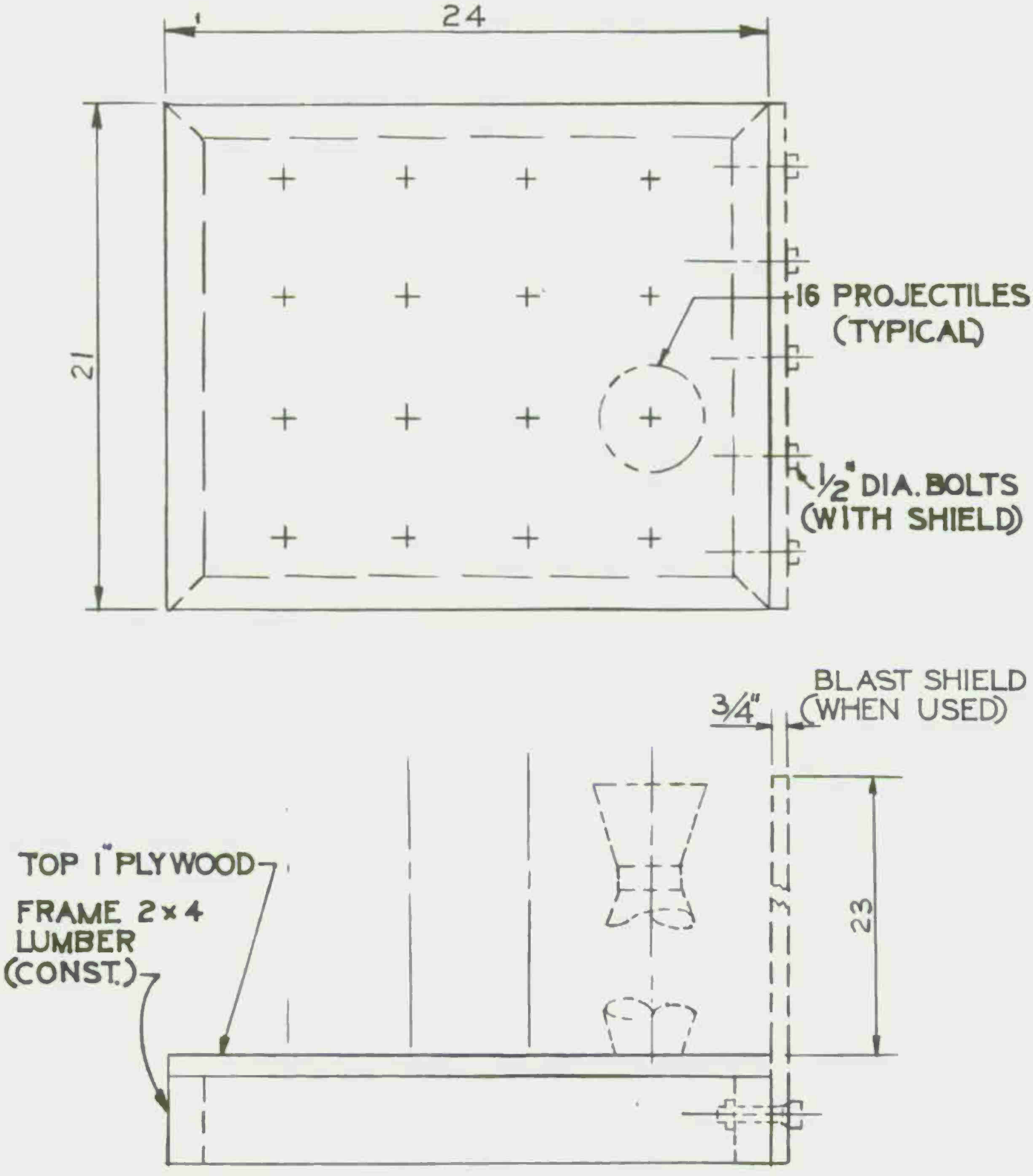


Figure 16 Pallet arrangement.

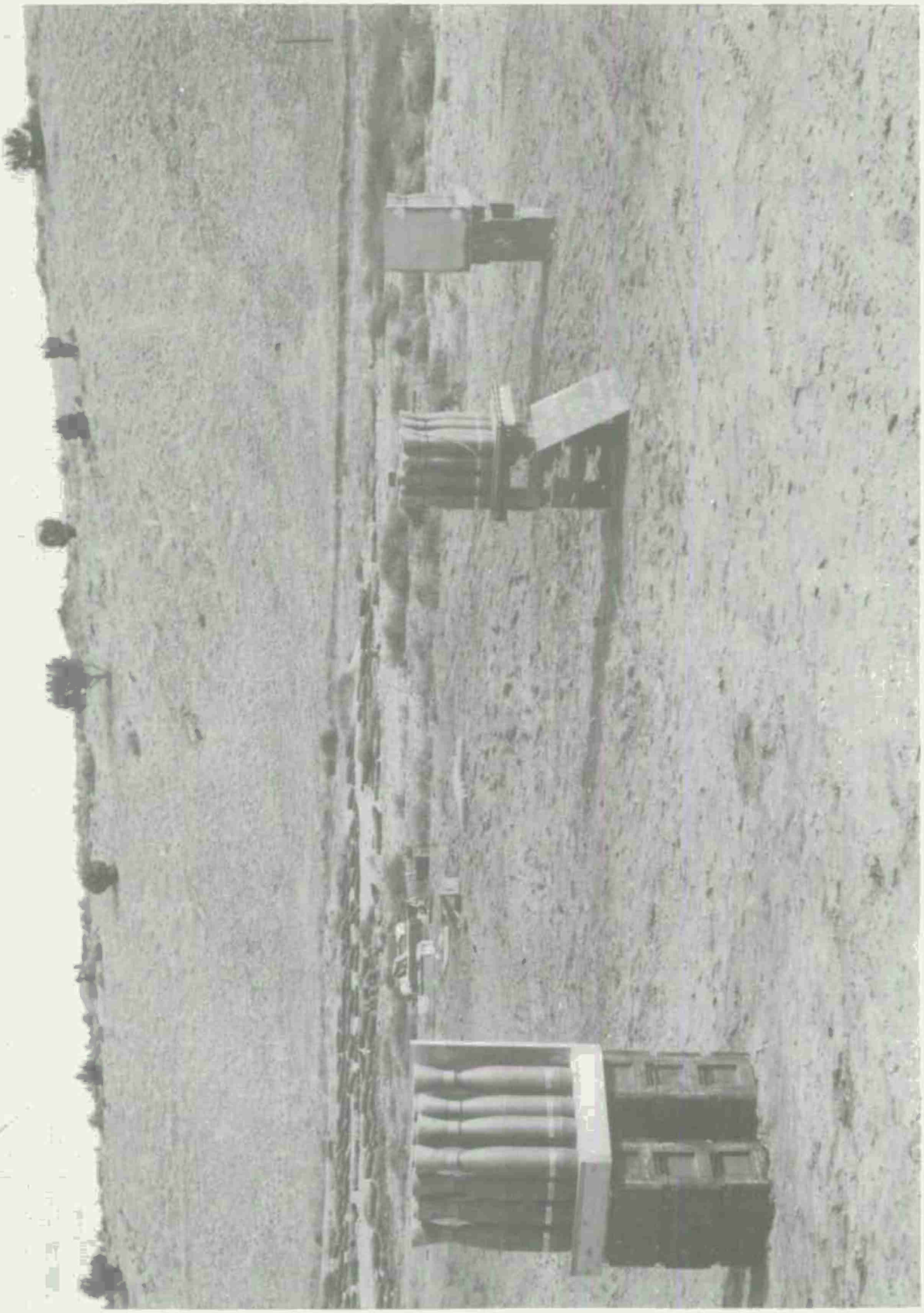


Figure 17 Test arrangement with three pallets.

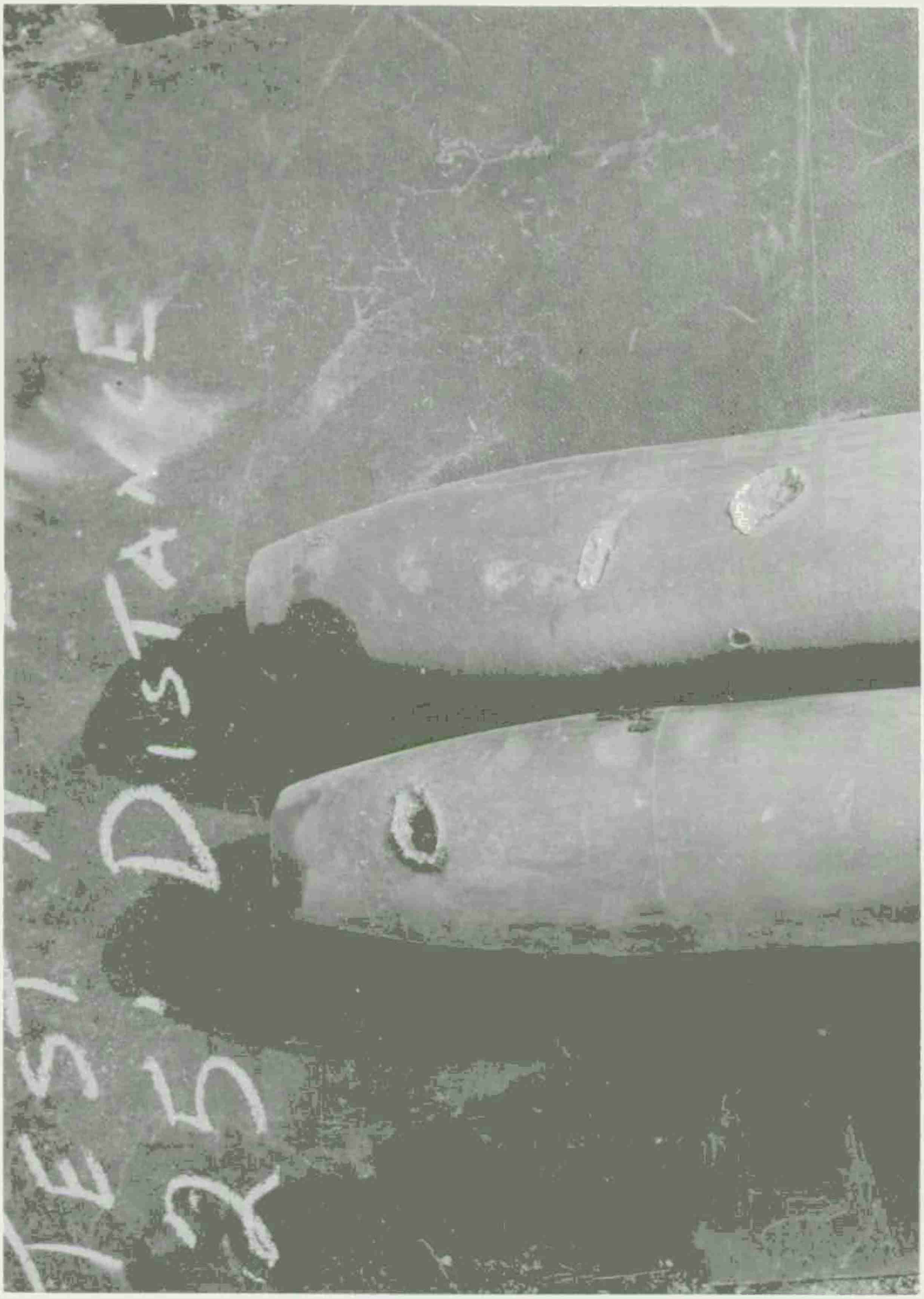


Figure 18 Typical test sequence III results - test No. 59.

Figure 19 Typical shielded pallet.

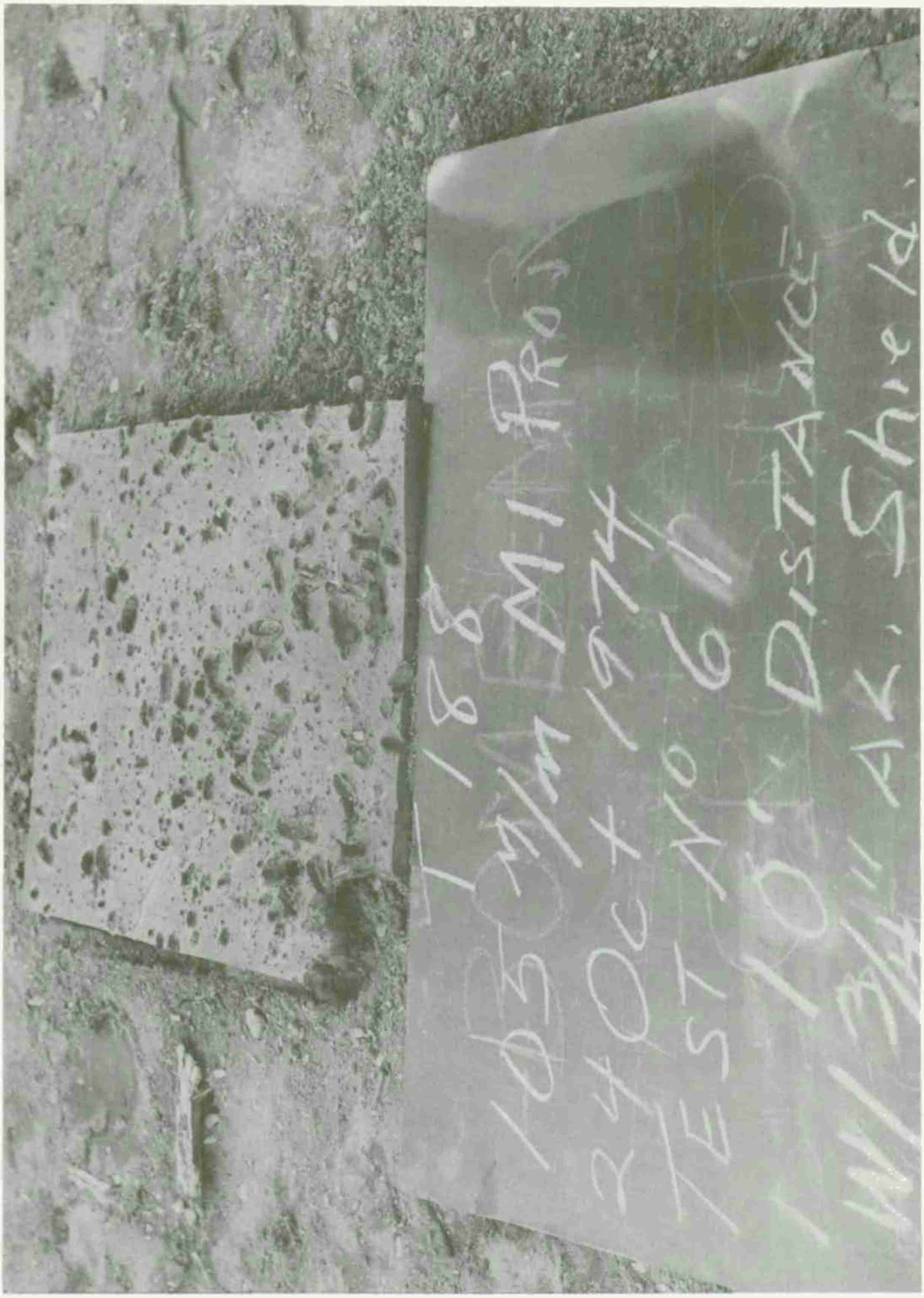


Figure 20 Typical test sequence IV results - test No. 61.

Figure 21 Typical test sequence IV results - test No. 62.

Figure 22 Test sequence V arrangement.

Figure 23 Typical test sequence V results - test No. 70.

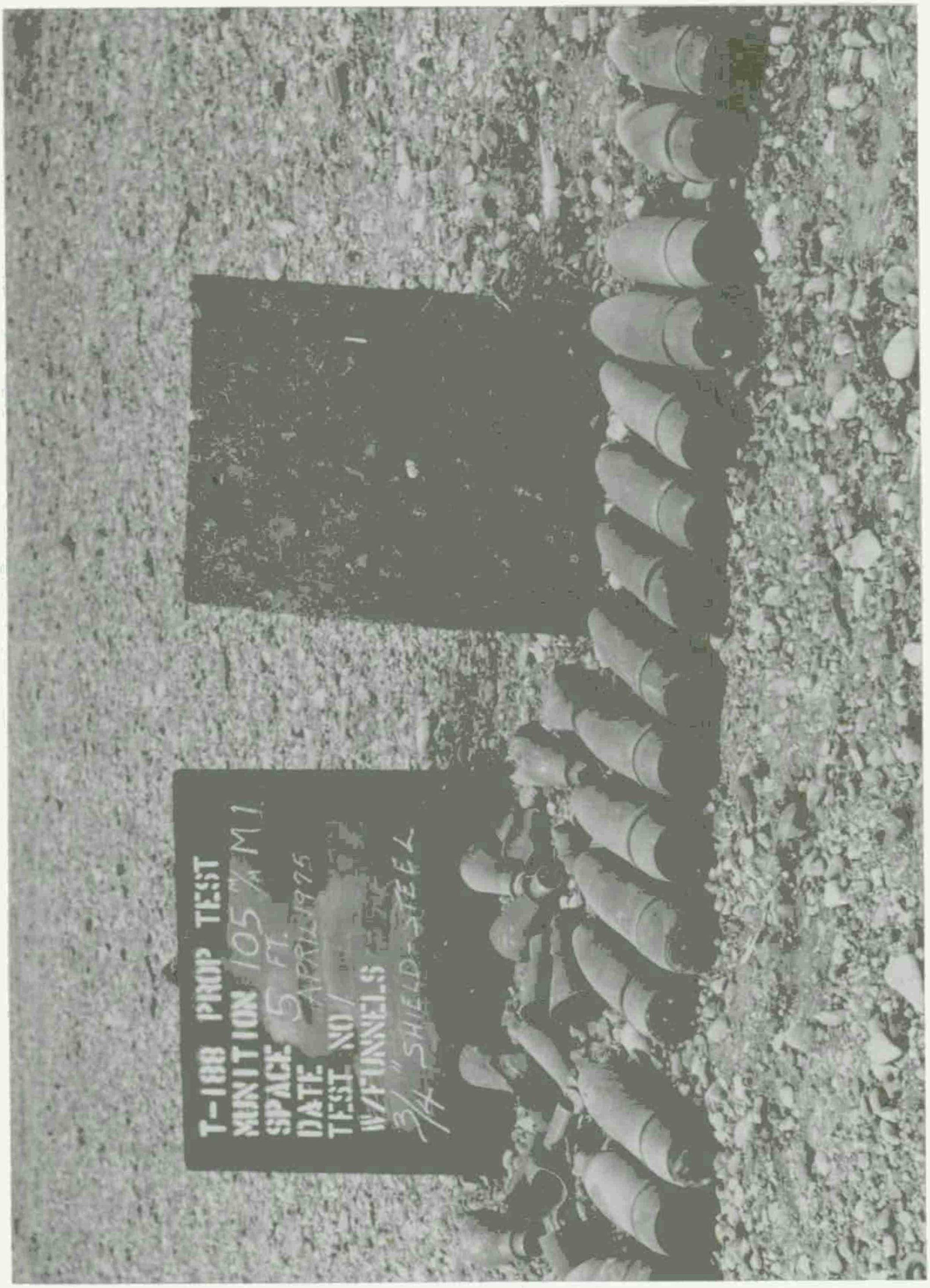


Figure 24 Typical test sequence V results - test No. 67.

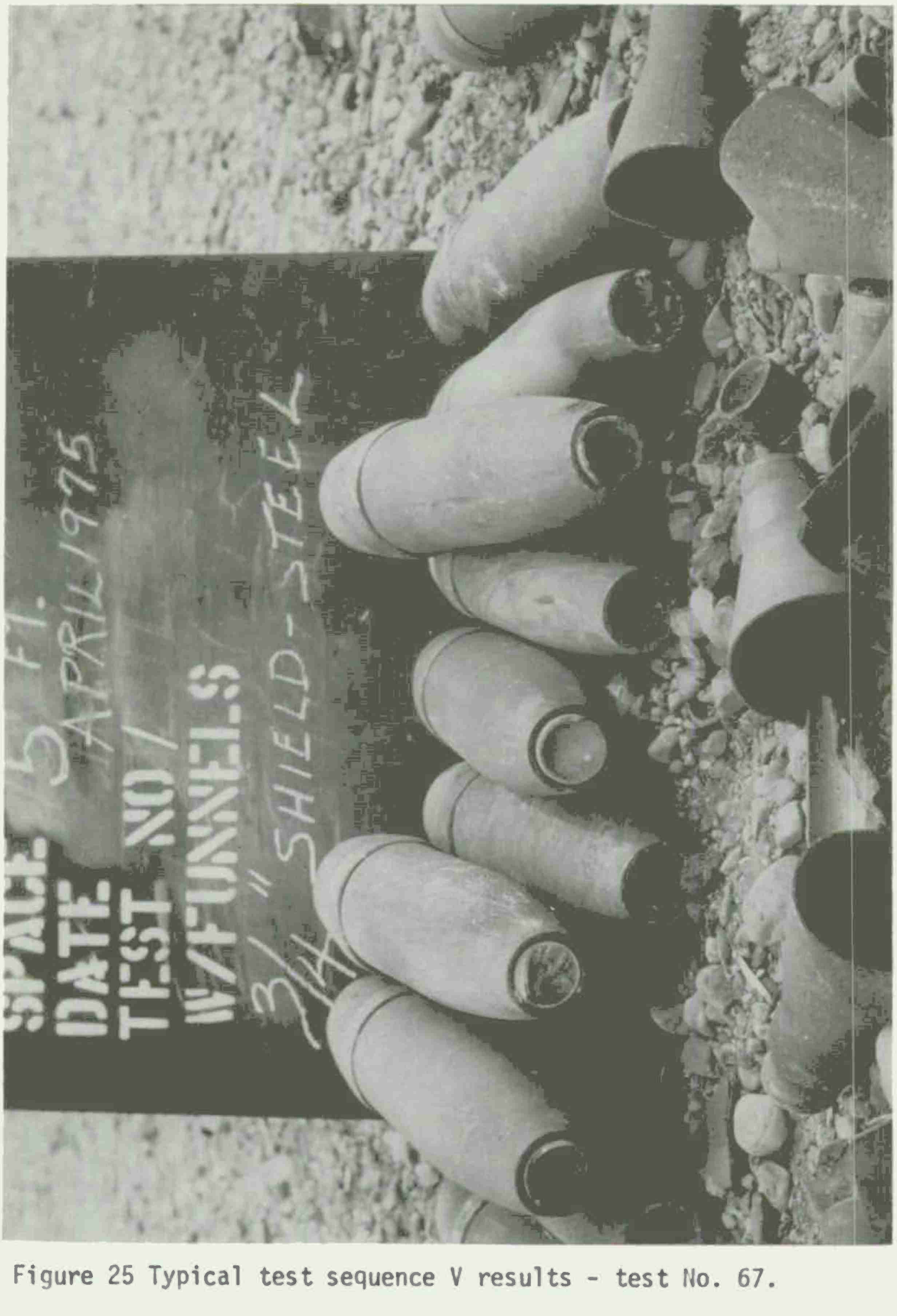


Figure 25 Typical test sequence V results - test No. 67.

Figure 26 Typical test sequence VI results - test No. 34.

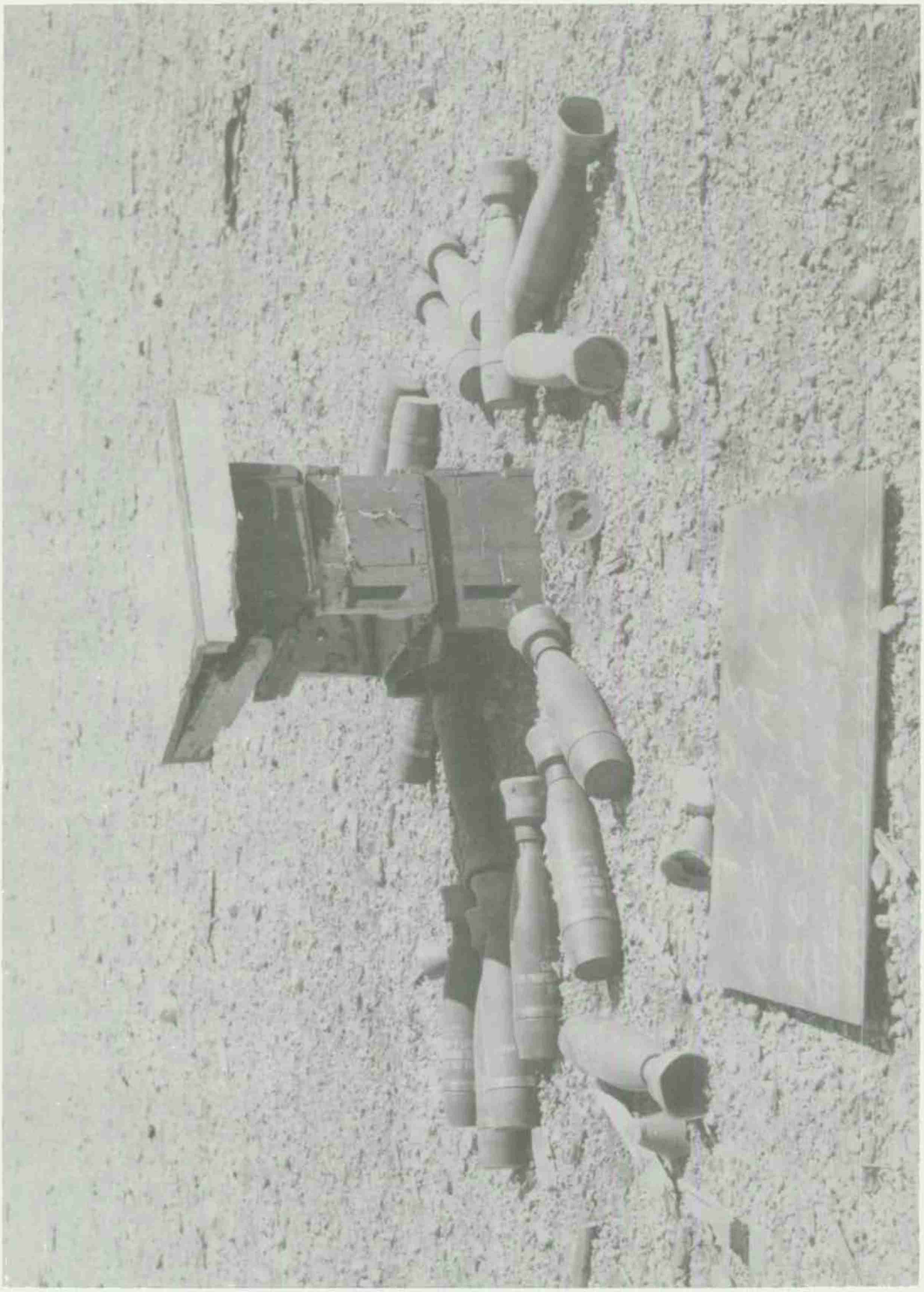


Figure 27 Typical test sequence VI results - test No. 38.

Figure 28 Typical test sequence VI results - test No. 39.

Figure 29 Typical test sequence VII results - test No. 73.

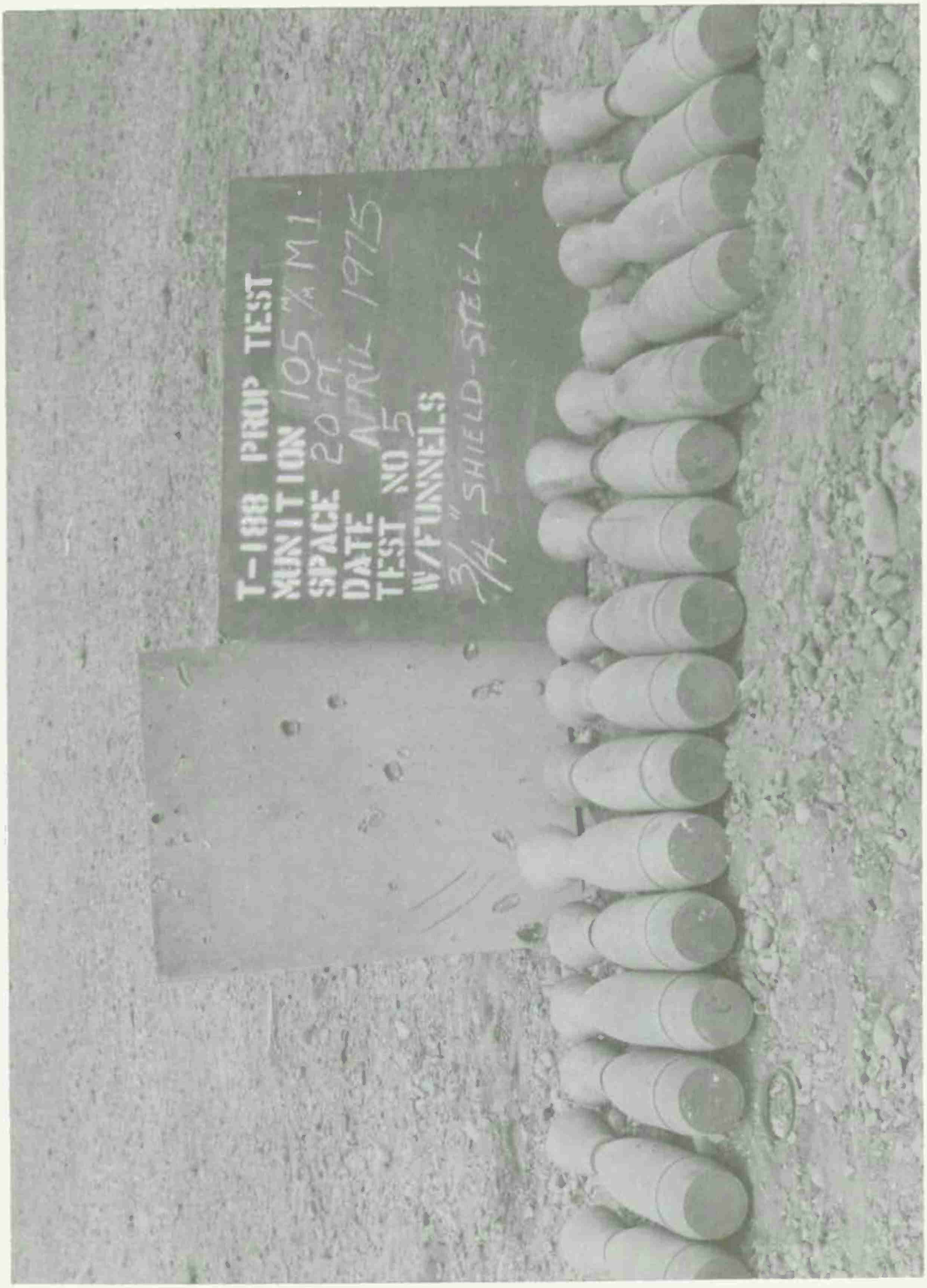


Figure 30 Typical test sequence VII results - test No. 71.

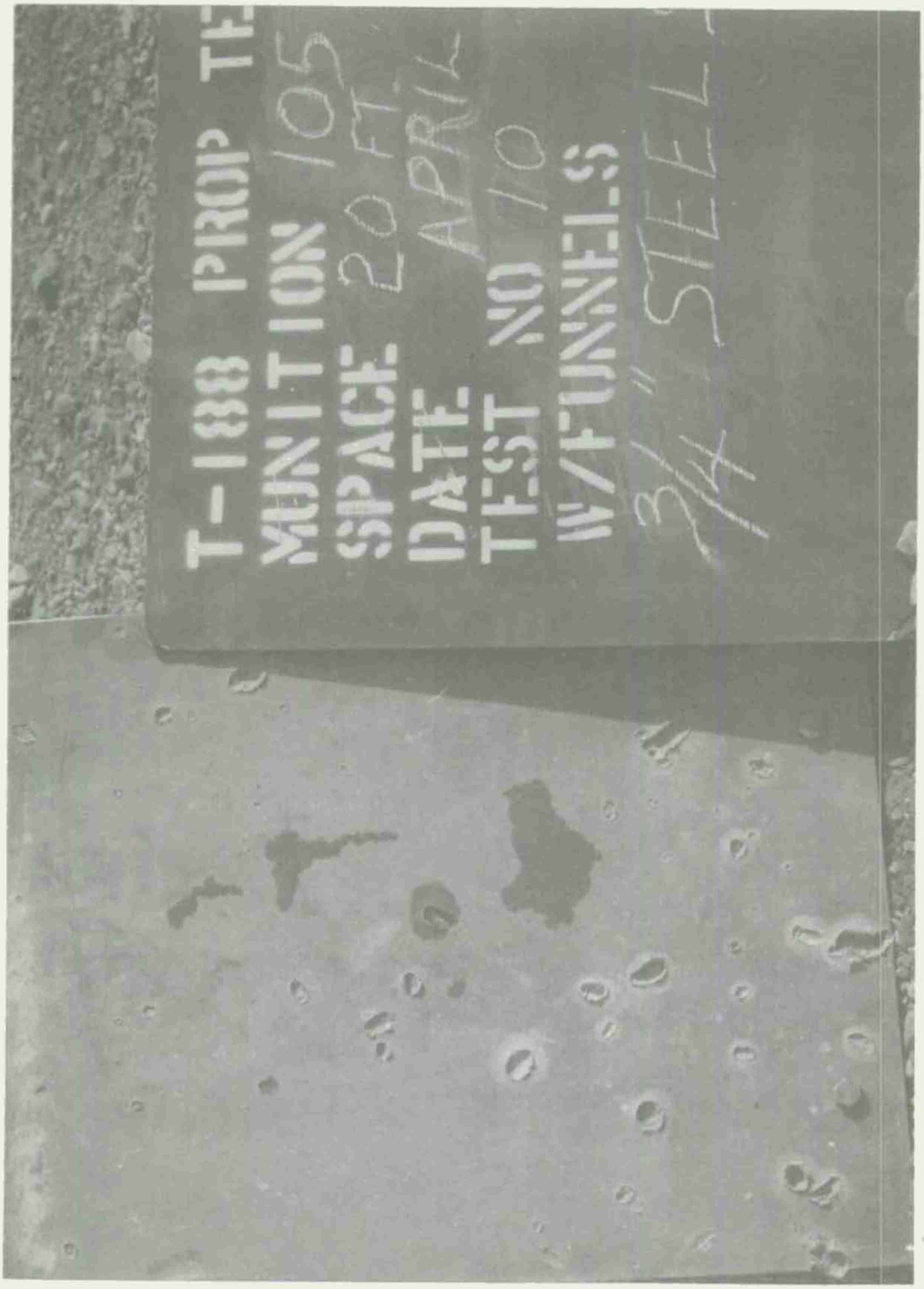


Figure 31 Typical test sequence VII results - test No. 76.

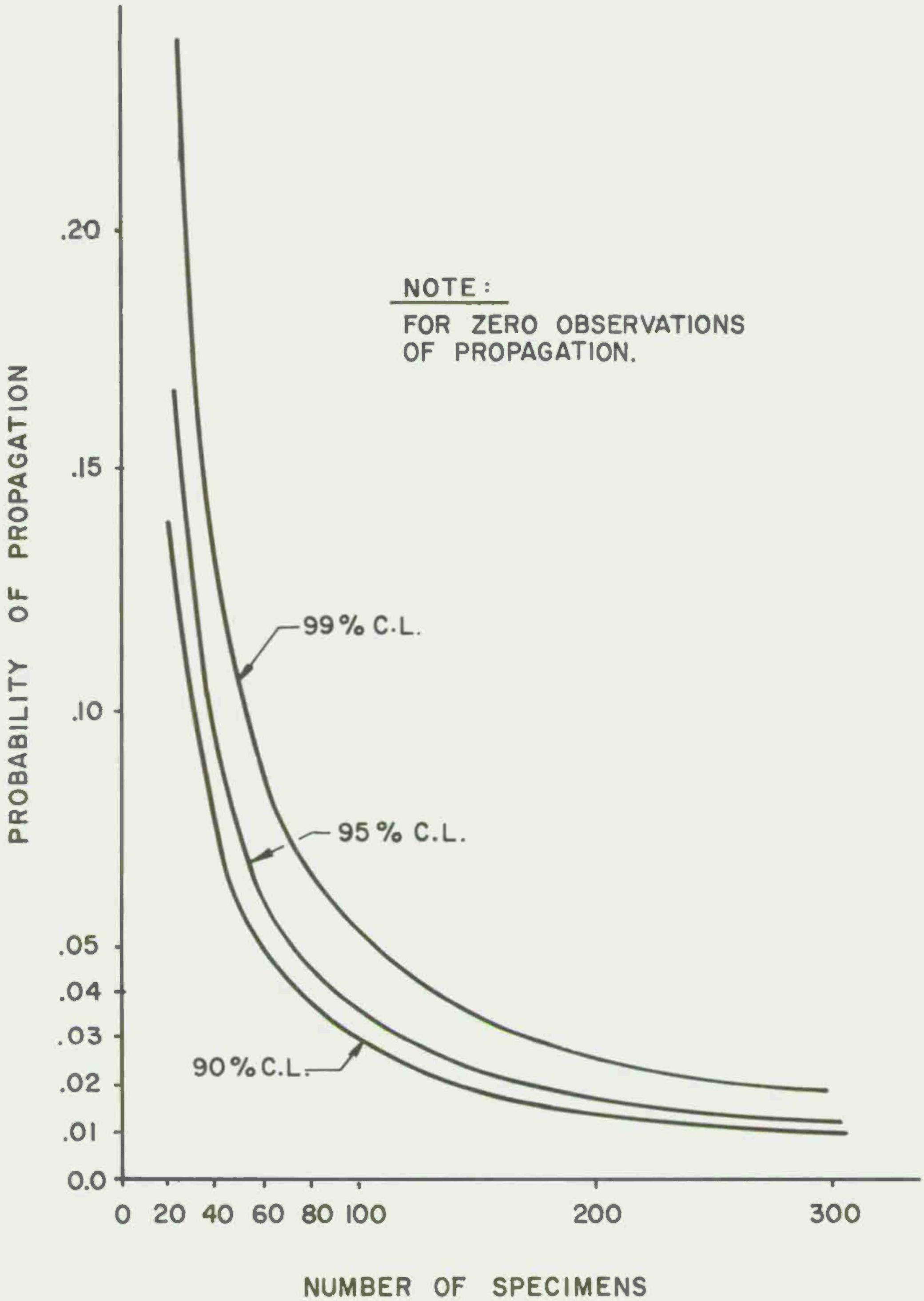


Figure 32 Maximum probability of propagation vs. number of specimens at a given confidence level

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