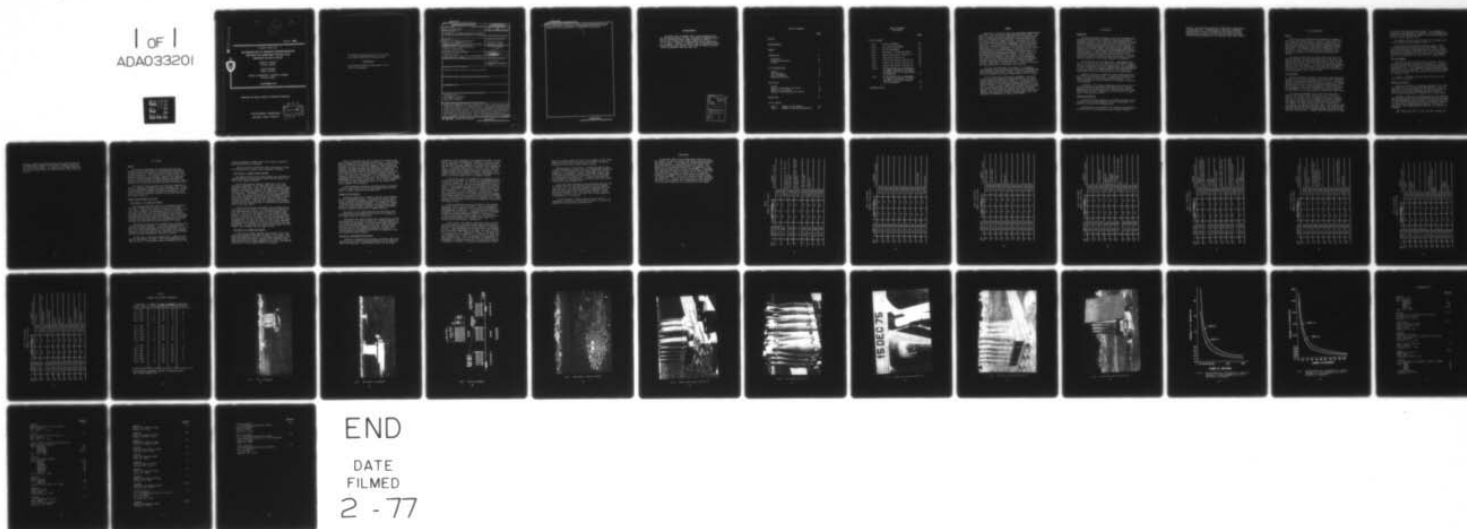


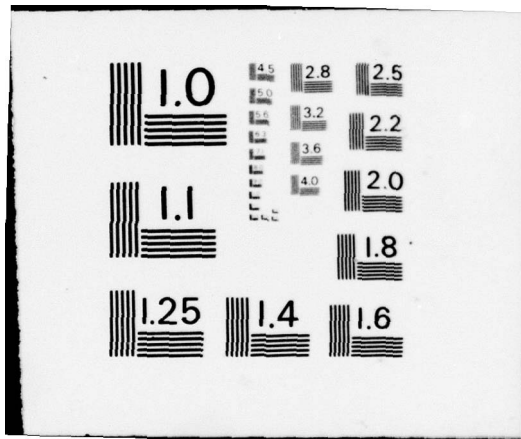
AD-A033 201

PICATINNY ARSENAL DOVER N J  
DETERMINATION OF MINIMUM NONPROPAGATION DISTANCE OF 155MM M107 --ETC(U)  
SEP 76 R S KUKUVKA, D KOSOVER, R M RINDNER DAAA21-75-C-0222  
PA-TR-5008 NL

UNCLASSIFIED

1 of 1  
ADA033201





ADA 033201

12

COPY NO. 26

TECHNICAL REPORT 5008

DETERMINATION OF MINIMUM NONPROPAGATION  
DISTANCE OF 155MM M107 PROJECTILES  
GROUPED 24 ON A PALLET



ROBERT S. KUKUVKA  
PICATINNY ARSENAL

DAVID KOSOVER  
AMMANN & WHITNEY

PROJECT COORDINATOR: RICHARD M. RINDNER  
PICATINNY ARSENAL

SEPTEMBER 1976

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

PICATINNY ARSENAL  
DOVER, NEW JERSEY

DDC  
RECEIVED  
DEC 8 1976  
RECEIVED  
A

The findings in this report are not to be construed  
as an official Department of the Army position.

#### DISPOSITION

Destroy this report when no longer needed. Do not  
return to the originator.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER Technical Report 5008	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 14 PA-TR-5008	
4. TITLE (and Subtitle) DETERMINATION OF MINIMUM NONPROPAGATION DISTANCE OF 155MM M107 PROJECTILES GROUPED 24 ON A PALLET.		5. TYPE OF REPORT & PERIOD COVERED	
7. AUTHOR(s) Robert S./Kukuvka, Picatinny Arsenal David/Kosover, Ammann & Whitney Richard M./Rindner, Project Coordinator (PTA)		8. CONTRACT OR GRANT NUMBER(s) 5 DAAA-21-75-C-0222	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Ammann & Whitney, Consulting Engineers Two World Trade Center New York, New York 10048		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 12 38p.	
11. CONTROLLING OFFICE NAME AND ADDRESS Picatinny Arsenal Manufacturing Technology Directorate (SARPA-MT-S) Dover, New Jersey 07801		12. REPORT DATE 11 September 1976	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 36	
		15. SECURITY CLASS. (of this report) Unclassified	
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
18. SUPPLEMENTARY NOTES			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Propagation tests Safe separation distances 155mm (M107) projectiles Projectiles on pallets			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A series of propagation tests was conducted with pallets containing twenty-four 155mm (M107), Composition-B loaded projectiles. Tests were performed with and without loading funnels to determine the safe, non-propagative, clear spacing between two transport carriages. The test results indicated that pallets with 24 projectiles without funnels can be safely spaced at 33.5 metres (110 feet). When funnels were installed in each round, a safe separation distance of 42.7 metres (140 feet) was established. A steel plate blast shield was ineffective, up to a separation distance of 33.5 metres, in preventing detonation propagation			

282 900

→ next page  
mt

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

between pallets when funnels were present. These projectile tests were performed specifically for operations at the Louisiana Army Ammunition Plant; however, the results are applicable to other similar loading lines.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

### ACKNOWLEDGMENTS

The authors wish to express their sincere appreciation to the following personnel for their assistance and guidance during the test performance and/or report preparation: Messrs. I. Forsten and J. Canavan of Picatinny Arsenal, Dover, New Jersey; Lt. D. Grundt, D. Johnson, J. Martinez and Test Personnel of Yuma Proving Ground, Yuma, Arizona; and N. Dobbs of Ammann & Whitney, Consulting Engineers, New York, New York.

ACCESSION for	
NTIS	White Section <input checked="" type="checkbox"/>
DDC	Buff Section <input type="checkbox"/>
UNANNOUNCED	<input type="checkbox"/>
JUSTIFICATION	
BY	
DISTRIBUTION/AVAILABILITY CODES	
Dist.	AVAIL. and/or SPECIAL
A	

## TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	
ACKNOWLEDGMENTS	
SUMMARY	1
INTRODUCTION	2
Background	2
Purpose and Objective	2
Criteria	3
TEST CONFIGURATIONS	4
General	4
Test Specimens	4
Test Arrangements	5
Method of Initiation	5
TEST RESULTS	7
General	7
Results of Individual Test Series	7
Summary of Test Results	9
Analysis of Confirmatory Test Results	9
CONCLUSIONS	12
LIST OF TABLES	
Table 1	13
Table 2	21

TABLE OF CONTENTS  
(Continued)

	<u>Page</u>
LIST OF FIGURES	
Fig 1	Pallet arrangement 22
Fig 2	Test Series arrangement 23
Fig 3	Pallet arrangement 24
Fig 4	Test Series 1 crater and debris 25
Fig 5	Typical test results--Test No. 18 26
Fig 6	Test result--Test No. 41 27
Fig 7	Typical test results--Test No. 40 28
Fig 8	Typical test results--Test No. 35 29
Fig 9	Typical test results--Test No. 63 30
Fig 10	Maximum probability of propagation vs. number of specimens at a given confidence level for no observations of propagation 31
Fig 11	Maximum probability of propagation vs. number of specimens at a given confidence level for one observa- tion of propagation 32
DISTRIBUTION LIST	33

## SUMMARY

155mm (M107) projectile tests were requested by DARCOM Safety specifically for the Louisiana Army Ammunition Plant (LAAP). The plant was loading TNT-filled projectiles with and without funnels under a safety waiver which permitted a separation distance of 30.5 metres (100 feet) between carriers. The operation at LAAP was later extended to loading of Composition-B which was used in these tests. The present plant arrangement, and for which these tests were simulated, entails a carrier containing 24 vertical projectiles in a 4 x 6 arrangement. The carriers are floor mounted and powered by an overhead conveyor track (drag line). A propagation test program was developed by Picatinny Arsenal and was performed during November and December of 1975 at the U. S. Army Yuma Proving Ground in Yuma, Arizona. These experiments were conducted to determine the minimum safe (non-propagative) spacing which can be maintained between two adjoining transport carriages containing 24 projectiles with or without loading funnels. Conditions in the melt/pour area, as well as the assembly and pack-out areas of the plant, were simulated.

The tests were conducted in two phases: An exploratory phase whereby a possible minimum safe distance was determined and the confirmatory phase where a number of tests were performed to verify the minimum safe distance established in the first phase.

In all, three series of tests were performed. The first series showed that projectiles without funnels could be safely spaced at 33.5-metre (110-foot) intervals. The next series, involving funnels, established a safe separation distance at 42.7 metres (140 feet). It was thought that the addition of a 19.1mm (3/4 in.) thick structural steel blast shield for the projectiles with funnels would reduce the required 42.7-metre separation. However, this was not the case and the final series could not establish a safe separation distance although numerous tests were conducted for separations as large as 33.5 metres.

## INTRODUCTION

### Background

An Army-wide expansion program is under way to upgrade existing and develop new explosive manufacturing loading/assembly/packaging facilities. This effort will enable the Army to achieve increased production cost effectiveness with improved safety as well as to provide manufacturing facilities for new weaponry. 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 future explosive production installations scheduled for expansion.

At the present time, the 155mm (M107) load/assembly/pack facility at the Louisiana Army Ammunition Plant (LAAP) is operating on a safety waiver which has expired and will not be renewed. In order to remedy this situation, DARCOM Safety has requested that a series of tests be performed whereby the safe separation distance between pallets of 155mm projectiles can be determined.

Presently the plant is capable of loading 155mm projectiles with TNT as the explosive filler. A separation distance of 30.5 metres (100 feet) is used between adjoining carriers. Each carrier transports 24 vertical projectiles arranged in a four-by-six orientation.

In addition to TNT, future operations at the plant will require the loading of projectiles with Composition-B. Because Composition-B is the more sensitive of the two explosives it has been selected for use in these tests; the results will be applicable to both explosive fillers.

### Purpose and Objective

The purpose of the program was to eliminate the need of safety waivers in all future loadings at LAAP of 155mm (M107) projectiles with either TNT or Composition-B.

The objective of the program was to determine experimentally the minimum safe (non-propagative) spacing between transport

carriers, each containing twenty-four 155mm (M107), Composition-B, loaded projectiles. A determination of these safe separations was required for carriers of projectiles with funnels, without funnels and for carriers of projectiles with funnels which were afforded additional protection by structural steel plate shields.

## TEST CONFIGURATIONS

### General

These tests were performed during November and December of 1975 at the Yuma Proving Ground in Arizona. Two phases of testing, exploratory and confirmatory, were conducted in order to establish safe separation distances between transport carriers, each containing twenty-four 155mm (M107), Composition-B loaded projectiles. The program may be viewed as comprising three test series, namely: (1) projectiles without funnels; (2) projectiles with funnels; and (3) projectiles with funnels and shields.

It should be noted that the various phases and test series were not conducted in either chronological or series order. Because of the long time period and large number of tests involved, the grouping of tests into related series was necessary for purposes of review and analysis. In fact, the several configurations and test series were intermingled. Note that the test numbers designated in this report do not correspond to the captions within the photographs (Figs 1, 2 and 4 to 9).

### Test Specimens

Each test specimen consisted of twenty-four 155mm projectiles arranged in a four-by-six orientation with individual projectiles having a center-to-center spacing of 0.18m (7 in.). Originally, each set of projectiles (test specimens) was supported on a wooden shipping pallet which in turn was supported on empty wooden ammunition boxes. After fires were produced in the first few tests by the embedment of hot metal fragments into the wood supports, the individual sets of projectiles were supported on cinder blocks.

The testing arrangements of the first and second series differed only insofar as the funnels were used in Series No. 2 (Fig 2). On the other hand, in addition to the use of funnels, each test of the third series utilized plate shields to protect the acceptor specimens from the fragment impact associated with the breakup of the donor projectile casing. Each shield was 1.2m high by 1.2m wide by 19.1mm thick (4 ft x 4 ft x 3/4 in.) and was constructed of SAE 1020 structural steel. One shield was positioned on the support of one acceptor specimen and placed on the side that faced the donor. Another shield was mounted on the donor

item support and faced the other acceptor. This acceptor did not have a shield mounted on its support. This arrangement simulated a facility configuration where a shield would be mounted on the rear of each conveyor carrier.

An integral schematic layout for the test arrangement used in all three series is presented in Figure 3.

All projectiles and funnels tested were loaded at LAAP (lot number LOP-E-101) specifically for this program. The projectiles, without their supplementary charges, and the funnels were shipped separately to the test site. Just prior to testing, the funnels were inserted into the projectiles. No attempt was made to match projectiles with their original loading funnels.

#### Test Arrangements

Each test of the first and second test series consisted of three test specimens arranged in a straight line. The center specimen served as the donor while the two end specimens were the acceptor items. This arrangement produced two acceptor test results for each test performed. The separation distance between each acceptor and the donor item varied in given tests, as well as from test to test.

Figure 1 illustrates a typical setup for any one of the tests of the first series.

#### Method of Initiation

There was some doubt as to whether propagation of an explosion would occur to all projectiles when only one in a set of twenty-four on the donor pallet was initiated by a charge. The test results conclusively indicated that the initiation of a single projectile detonated all projectiles on a donor pallet.

The donor projectile (initiated projectile) was primed with approximately 0.23 kg (8 oz.) of Composition-C4 which was placed into the supplementary charge cavity. The primer was initiated by an M6 blasting cap which in turn was initiated by an electrical charge from a standard blasting machine. The blasting machine was located approximately 1.2km (3/4 mi.) from the test specimens.

When funnels were used in a test, the donor specimen was

primed by removing the funnel from one projectile and inserting the Composition-C4 primer in the cavity in a manner similar to the tests without funnels. The location of the donor projectile, both in tests with funnels and without funnels, varied from test to test.

## TEST RESULTS

### General

As previously mentioned, the simulated tests have been grouped into three series based on the manufacturing processes, i.e., projectiles with funnels, projectiles without funnels and shielded projectiles. The latter series of tests was not in the original test plan for this program. However, past separation tests of individual rounds of 155mm projectiles had indicated that the use of shielding would reduce minimum separation. Consequently, the testing was extended to determine shielding effects.

The results of the individual tests have been summarized in Table 1. Separation distances and test arrangements used, as well as damage incurred by acceptor specimens, are presented. In addition, a summary of the number of high-order detonations corresponding to various separation distances of the three test series are listed in Table 2.

### Results of Individual Test Series

#### Test Series 1 - No Funnel or Shields

The separation distances used in the exploratory testing of this series ranged from 7.6 metres (25 feet) to 33.5 metres (110 feet). A detonation occurred at separation distances of 7.6, 15.2, and 22.9 metres. The detonations in the 15.2- and the 22.9-metre separation tests were attributed to the previously mentioned fires produced in the wood supports used in these tests. Test specimens utilizing cinder block supports, which were tested at these two latter separations, did not propagate an explosion, although severe denting of acceptor projectiles did occur.

Confirmatory testing was first performed at a separation distance of 27.4 metres (90 feet). After the performance of ten tests (20 acceptor specimens), a high-order detonation (Fig 4) of one of the two acceptor specimens in the eleventh test occurred. Therefore, it was concluded that this separation was not adequate and that additional confirmatory testing was required.

A second set of tests was performed using a separation distance of 33.5 metres (110 feet). None of the twenty-four specimens (12 tests) in the exploratory and confirmatory tests at this

distance propagated, although some of the acceptor projectiles were displaced from their support.

Typical results of confirmatory tests, performed at a separation distance of 33.5 metres, are illustrated in Figure 5.

#### Test Series 2 - Funnels without Shields

The second series of tests, where funnels were utilized, considered separation distances which ranged from 15.2 metres (50 feet) to 42.7 metres (140 feet).

Each of the acceptors tested at separations of 15.2 and 22.9 metres detonated. On the other hand, none of the twelve acceptors tested at 30.5, 33.1, and 38.1 metres underwent a propagation of an explosion. However, the number of tests performed at these three larger distances was not sufficient to establish a safe separation. Furthermore, it was realized that a separation of at least 27.4 metres was needed to preclude propagation of explosion for projectiles without funnels and, therefore, a separation distance somewhat larger than this would be required for funneled projectiles. Based upon this reasoning it was decided to select an even larger distance for performing the confirmatory phase of this test series.

A total of 20 tests were performed using a selected separation distance of 42.7 metres. Of the 40 acceptors involved, one high-order detonation occurred, one low-order detonation took place and, in one test, the explosive in four acceptor funnels burned. In the case of the latter, the burning explosive melted portions of funnels (Fig 6) before being self-extinguished without detonating. As seen from Table 1, in many of the tests where propagation did not occur, the funnels of the acceptor specimens were penetrated by fragments (Fig 7) from the casing of the donor projectiles. In most tests one or more acceptor projectiles (with funnels) were dislodged from the support (Fig 8).

#### Test Series 3 - Funnels and Shields

A total of 28 acceptor specimens were tested in this series. Separation distances varied from 7.6 metres to 33.5 metres. One high-order detonation occurred at the largest separation at which twelve specimens were tested. Because of the relatively large separation distance at which propagation did occur, it was decided that this part of the program would be discontinued.

Figure 9 illustrates the typical results of the shield tests where a propagation of an explosion did not occur. It may be noted that the surface of the protective shield at the acceptor was perforated by the impact of the donor fragments. When a shield was located at the donor specimen, the blast pressures produced by the detonation completely distorted the shield and, in many cases, translated the shield debris a considerable distance from the test area. There was also a possibility that the protective shield fragments contributed to propagation. It is theorized that the one propagation which occurred in this series was produced by a sideward displacement of the shield by the blast. This, in turn, produced a direct line-of-sight (unobstructed path) for the flight of the donor fragments to the acceptor.

A more advantageous method of shielding would be to position a shield at each end of the carrier and thereby assure that the shield is always located at the acceptor item.

#### Summary of Test Results

High-order detonations of acceptor specimens were observed for all configurations tested. The presence of funnels significantly increased the propagation potential and thus resulted in increased *minimum* spacing requirements. The presence of shields at the 33.5-metre separation distances did not preclude a propagation of an explosion and, therefore, the method of shielding used would require a modification to become effective.

The results of the program demonstrated conclusively that the detonation of one projectile on a carrier will propagate to all other projectiles on the carrier.

Confirmatory test results showed that no detonations occurred when projectiles were without funnels and a minimum separation of 33.5 metres was maintained. In the test series where funnels were used, one high-order detonation of the forty acceptor specimens tested at the 42.7-metre separation occurred. As shown later, the occurrence of this detonation reduces the reliability of minimum spacing for projectiles with funnels as compared to that for projectiles without funnels.

#### Analysis of Confirmatory Test Results

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. The results shown in Table 2 indicate that high-order detonations occurred in all sequences of tests. Confirmatory sample sizes, for Series 1 and 2 (with and without loading funnels respectively, but no shields) were considered adequate for acceptable statistical conclusions. The damage inflicted to the acceptors in Series 3 precluded the testing of a sufficient sample size for acceptable results.

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 and correspond 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. Figures 10 and 11 show the relationship between sample size, confidence level and the maximum probability of detonation when there is no detonation and one detonation, respectively.

In Test Series 1 (no funnels), there was a total of 46 observations which are usable and include separation distances of 33.5 metres (24 acceptor pallets) and 27.4 metres (22 acceptor pallets). Since the probability of detonation for each acceptor may be considered independent of the other, the sample size for this test series is 46. Referring to Figure 11, the upper limit on the probability of propagation is 11.0 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 11.0 percent. Similarly, a 99 percent confidence level corres-

ponds to an upper probability limit of 15.0 percent. These values indicate the quality of the tests and the reliance that can be placed on the conclusions drawn from the testing.

Had the results in Test Series 1 included the data for the 33.5-metre separation distance only with no detonations occurring, a sample size of 24 would yield a different upper limit on the probability of propagation. Figure 10 indicates an upper limit of 14 percent at the 95 percent confidence level and 20 percent at the 99 percent confidence level. A sample size of 46, with the occurrence of one detonation, as previously described, yields significantly lower probabilities.

Forty tests were conducted in the confirmatory phase for the 42.7-metre separation and unshielded projectiles with funnels (Test Series 2). One high-order detonation occurred indicating that the upper limit on the probability of propagation at the 95 percent confidence level is 12.5 percent (Fig 11). At the 99 percent confidence level, the upper limit on the probability of propagation is 17.0 percent.

A similar analysis indicates that the lower limit of propagation probability for Test Series 1 and 2 is less than one percent for the 99 percent confidence level.

## CONCLUSIONS

A sufficient sample size of 155mm (M107) projectile tests was obtained in order to determine the minimum safe spacing with and without funnels. The minimum safe spacing without funnels was established at 33.5 metres (110 feet) as a result of an upper limit of 15.0 percent probability of propagation at the 99 percent confidence level for 46 test specimens. The minimum safe spacing with funnels was found to be 42.7 metres (140 feet). This conclusion was based on an upper limit of 17.0 percent probability of propagation at the 99 percent confidence level for 40 test specimens. The use of a structural steel shielding was ineffective. Finally, the initiation of a single projectile, regardless of its location within the grouping of 24, resulted in a high-order detonation of all projectiles in that group.

Table 1  
Summary of test results

Test No.	Separation- metres (feet)	Test arrangement		Results (P=Projectiles, F=Funnels)
		Funnels	Shields	
1	30.5 (100) 30.5 (100)	No	No	P-1 dent P-1 dent
2	15.2 (50) 15.2 (50)	No	No	P-8 dents High-order detonation 17 min. post-test due to wood support fire
3	22.9 (75) 22.9 (75)	No	No	P-5 dents (one-6mm deep) P-1 dent
4	22.9 (75) 22.9 (75)	No	No	2 projectiles detonated 30 min. post-test due to wood support fire P-3 dents
5	15.2 (50) 22.9 (75)	No	No	P-2 dents (one-12mm deep) P-2 dents
6	7.6 (25) 22.9 (75)	No	No	High-order detonation P-3 dents
7	27.4 (90) 27.4 (90)	No	No	No action P-2 dents
8	27.4 (90) 27.4 (90)	No	No	P-3 dents P-4 dents

Table 1 (Continued)

Summary of test results

Test No.	Separation- metres (feet)	Test arrangement		Results (P=Projectiles, F=Funnel's)
		Funnel's	Shields	
9	27.4 (90) 27.4 (90)	No	No	No action P-2 dents
10	27.4 (90) 27.4 (90)	No	No	P-1 dent P-2 dents
11	27.4 (90) 27.4 (90)	No	No	P-1 dent P-2 dents
12	27.4 (90) 27.4 (90)	No	No	P-4 dents P-1 dent
13	27.4 (90) 27.4 (90)	No	No	P-2 dents P-2 dents
14	27.4 (90) 27.4 (90)	No	No	P-4 dents P-1 dent
15	27.4 (90) 27.4 (90)	No	No	P-4 dents P-1 dent
16	27.4 (90) 27.4 (90)	No	No	P-3 dents (one-6mm deep) P-8 dents
17	27.4 (90) 27.4 (90)	No	No	P-2 dents High-order detonation

Table 1 (Continued)  
Summary of test results

Test No.	Separation-metres (feet)	Test arrangement		Results (P=Projectiles, F=Funnels)
		Funnels	Shields	
18	33.5 (110) 33.5 (110)	No	No	One rotating band broken P-2 dents
19	33.5 (110) 33.5 (110)	No	No	P-1 dent, one band broken P-3 dents
20	33.5 (110) 33.5 (110)	No	No	P-3 dents P-3 dents
21	33.5 (110) 33.5 (110)	No	No	No action P-1 large deep dent
22	33.5 (110) 33.5 (110)	No	No	No action No action
23	33.5 (110) 33.5 (110)	No	No	P-1 dent P-3 dents
24	33.5 (110) 33.5 (110)	No	No	P-1 dent No action
25	33.5 (110) 33.5 (110)	No	No	P-3 dents No action
26	33.5 (110) 33.5 (110)	No	No	No action P-2 dents

Table 1 (Continued)

Test No.	Separation-metres (feet)	Test arrangement		Results (P=Projectiles, F=Funnels)
		Funnels	Shields	
27	33.5 (110) 33.5 (110)	No	No	P-3 dents P-2 dents
28	33.5 (110) 33.5 (110)	No	No	No action P-2 dents
29	33.5 (110) 33.5 (110)	No	No	P-1 dent, one band broken P-2 dents
30	15.2 (50) 38.1 (125)	Yes	No	High-order detonation F-1 penetration
31	22.9 (75) 38.1 (125)	Yes	No	High-order detonation P-2 dents, F-2 dents
32	30.5 (100) 30.5 (100)	Yes	No	P-1 dent, F-2 dents P-3 dents, F-3 dents and 12mm diameter penetration
33	42.7 (140) 42.7 (140)	Yes	No	P-2 dents F-3 dents
34	42.7 (140) 42.7 (140)	Yes	No	F-1 dent F-1 dent
35	42.7 (140) 42.7 (140)	Yes	No	F-2 dents F-2 dents

Table 1 (Continued)  
Summary of test results

Test No.	Separation-metres (feet)	Test arrangement		Results (P=Projectiles, F=Funnels)
		Funnels	Shields	
36	33.5 (110) 33.5 (110)	Yes	No	P-4 dents, F-3 dents P-2 dents, F-4 dents and one penetration
37	33.5 (110) 33.5 (110)	Yes	No	F-2 dents and 12mm diameter penetration into Comp. B P-1 dent, F-1 dent
38	33.5 (110) 33.5 (110)	Yes	No	P-1 dent, F-2 dents P-1 dent, F-3 dents
39	33.5 (110) 33.5 (110)	Yes	No	F-1 penetration and 2 dents F-1 dent
40	42.7 (140) 42.7 (140)	Yes	No	F-1 large penetration (6mm x 25mm long) F-2 dents
41	42.7 (140) 42.7 (140)	Yes	No	No action F-4 burned, melted but self-extinguished
42	42.7 (140) 42.7 (140)	Yes	No	P-2 dents, F-8 dents and low-order detonation P-1 dent, F-1 dent
43	42.7 (140) 42.7 (140)	Yes	No	P-2 dents, F-1 dent F-1 dent and 1 penetration

Table 1 (Continued)  
Summary of test results

Test No.	Separation- metres (feet)	Test arrangement		Results (P=Projectiles, F=Funnels)
		Funnels	Shields	
44	42.7 (140) 42.7 (140)	Yes	No	No action F-3 dents and one penetration
45	42.7 (140) 42.7 (140)	Yes	No	P-2 dents, F-3 dents F-2 dents
46	42.7 (140) 42.7 (140)	Yes	No	P-1 dent, F-1 penetration and 1 dent F-1 dent and one penetration
47	42.7 (140) 42.7 (140)	Yes	No	F-2 dents and 2 penetrations P-1 dent
48	42.7 (140) 42.7 (140)	Yes	No	F-3 dents P-1 dent
49	42.7 (140) 42.7 (140)	Yes	No	No action P-1 dent
50	42.7 (140) 42.7 (140)	Yes	No	No action P-1 dent, F-2 dents and one penetration
51	42.7 (140) 42.7 (140)	Yes	No	F-1 dent High-order detonation
52	42.7 (140) 42.7 (140)	Yes	No	F-3 dents No action

Table 1 (Continued)  
Summary of test results

Test No.	Separation-metres (feet)	Test arrangement		Results (P=Projectiles, F=Funnels)
		Funnels	Shields	
53	42.7 (140) 42.7 (140)	Yes	No	P-1 dent, F-12 dents No action
54	42.7 (140) 42.7 (140)	Yes	No	P-2 dents, F-2 dents P-1 dent, F-1 dent
55	42.7 (140) 42.7 (140)	Yes	No	No action P-2 dents
56	42.7 (140) 42.7 (140)	Yes	No	P-2 dents P-1 dent
57	7.6 (25) 22.9 (75)	Yes	Yes	No action P-2 dents, F-2 penetrations
58	15.2 (50) 15.2 (50)	Yes	Yes	F-2 detonations and 3 penetrations F-some damaged
59	30.5 (100) 30.5 (100)	Yes	Yes	No action No action
60	24.4 (80) 24.4 (80)	Yes	Yes	P-1 dent, F-4 dents P-2 dents, F-4 dents
61	27.4 (90) 27.4 (90)	Yes	Yes	F-3 penetrations No action

Table 1 (Continued)  
Summary of test results

Test No.	Separation-metres (feet)	Test arrangement		Results (P=Projectiles, F=Funnels)
		Funnels	Shields	
62	27.4 (90) 27.4 (90)	Yes	Yes	P-2 dents, F-4 dents F-1 dent
63	27.4 (90) 27.4 (90)	Yes	Yes	Possible low-order detonation, F-1 large hole (6mm x 50mm long) F-1 dent
64	27.4 (90) 27.4 (90)	Yes	Yes	F-8 dents and one melted No action
65	33.5 (110) 33.5 (110)	Yes	Yes	F-2 penetrations No action
66	33.5 (110) 33.5 (110)	Yes	Yes	F-2 penetrations No action
67	33.5 (110) 33.5 (110)	Yes	Yes	F-1 dent No action
68	33.5 (110) 33.5 (110)	Yes	Yes	F-1 penetration No action
69	33.5 (110) 33.5 (110)	Yes	Yes	F-6 dents, one penetration No action
70	33.5 (110) 33.5 (110)	Yes	Yes	High-order detonation No action

Table 2  
Summary of high-order detonations

Separation metres (feet)	Number of acceptors	Test arrangement		High-order detonations
		Funnels	Shields	
7.6 (25)	1	No	No	1
15.2 (50)	3	No	No	1*
22.9 (75)	6	No	No	0
27.4 (90)	22	No	No	1
33.5 (110)	24	No	No	0
15.2 (50)	1	Yes	No	1
22.9 (75)	1	Yes	No	1
30.5 (100)	2	Yes	No	0
33.5 (110)	8	Yes	No	0
38.1 (125)	2	Yes	No	0
42.7 (140)	40	Yes	No	1
7.6 (25)	1	Yes	Yes	0
15.2 (50)	2	Yes	Yes	0
22.9 (75)	1	Yes	Yes	0
24.4 (80)	2	Yes	Yes	0
27.4 (90)	8	Yes	Yes	0
30.5 (100)	2	Yes	Yes	0
33.5 (110)	12	Yes	Yes	1

\*This high-order detonation occurred 17 minutes post-test due to wooden support fire.

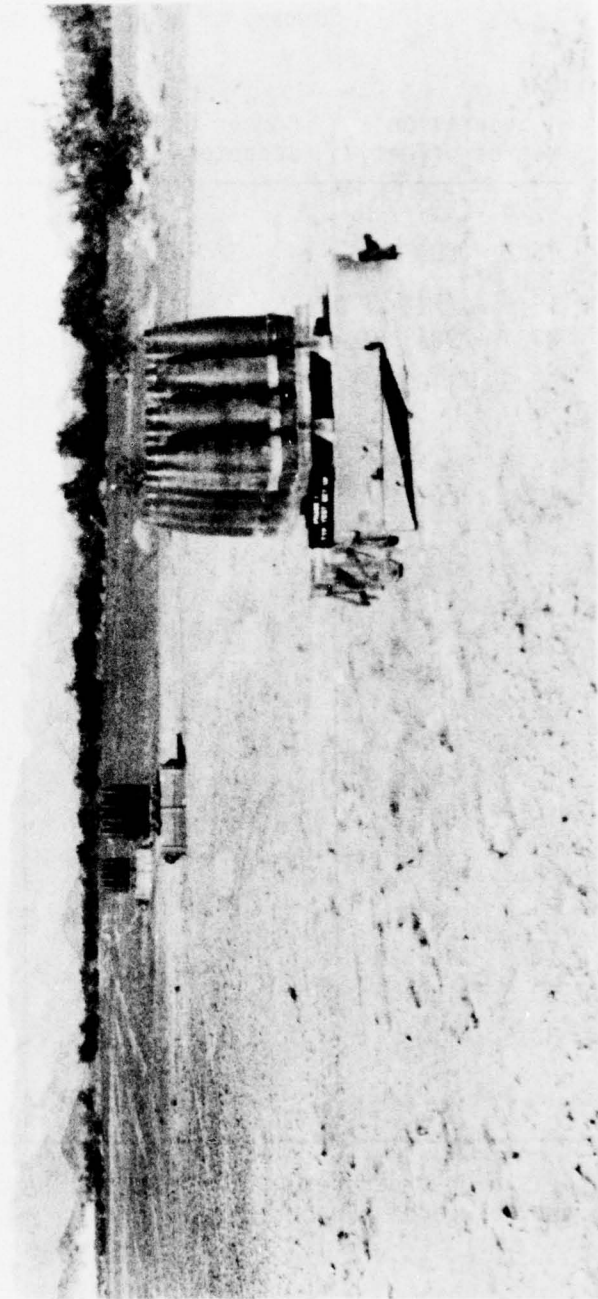


Fig 1 Pallet arrangement



Fig 2 Test Series 2 arrangement

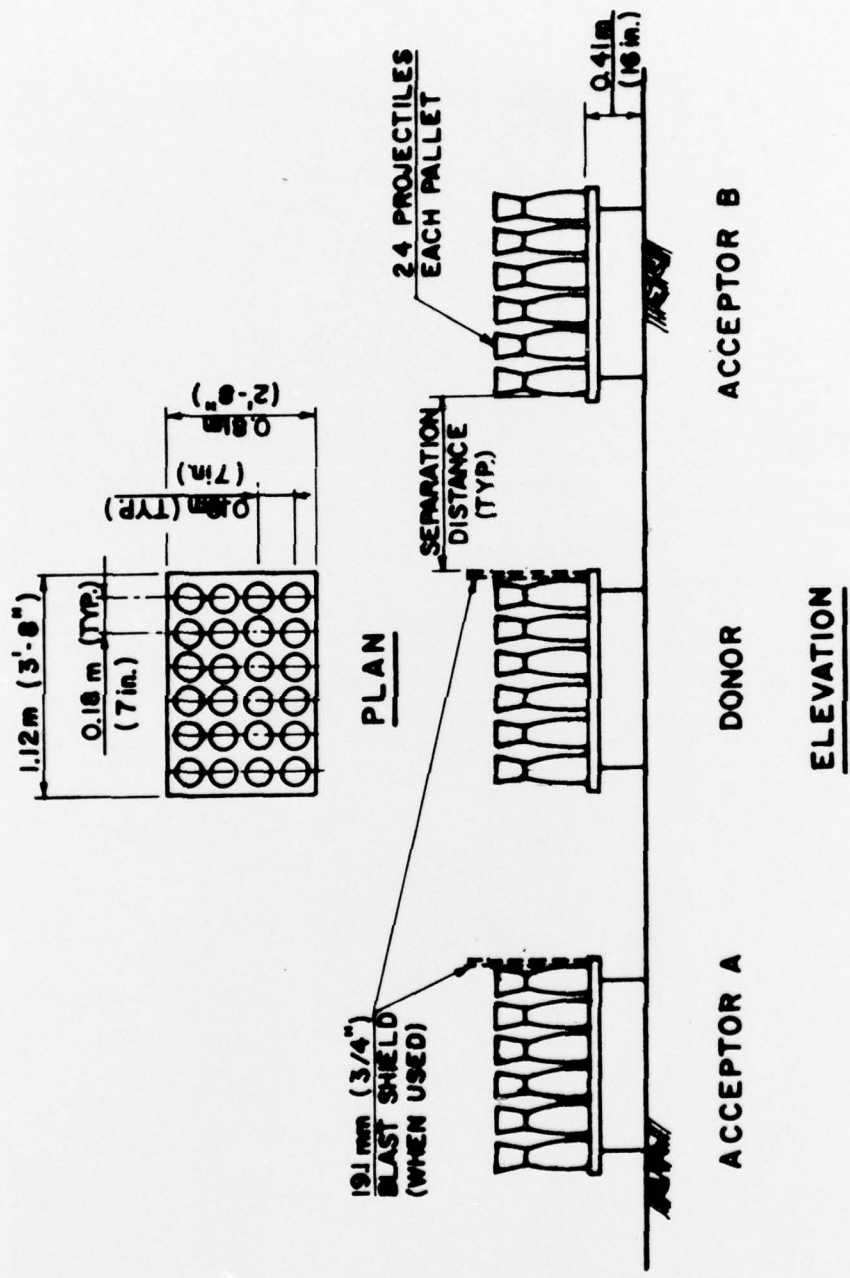


Fig 3 Pallet arrangement



Fig 4 Test Series 1 crater and debris

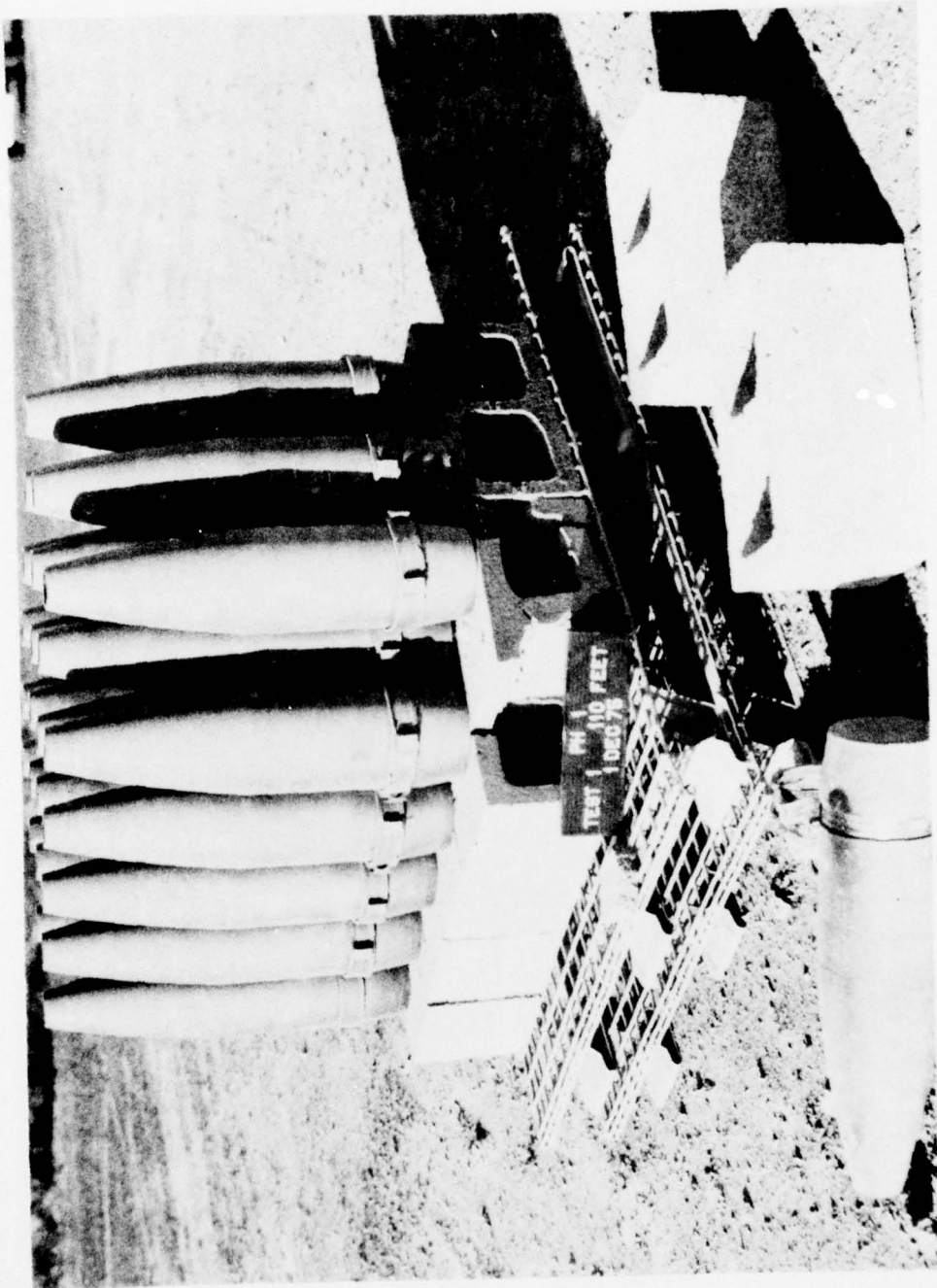


Fig 5 Typical test results--Test No. 18

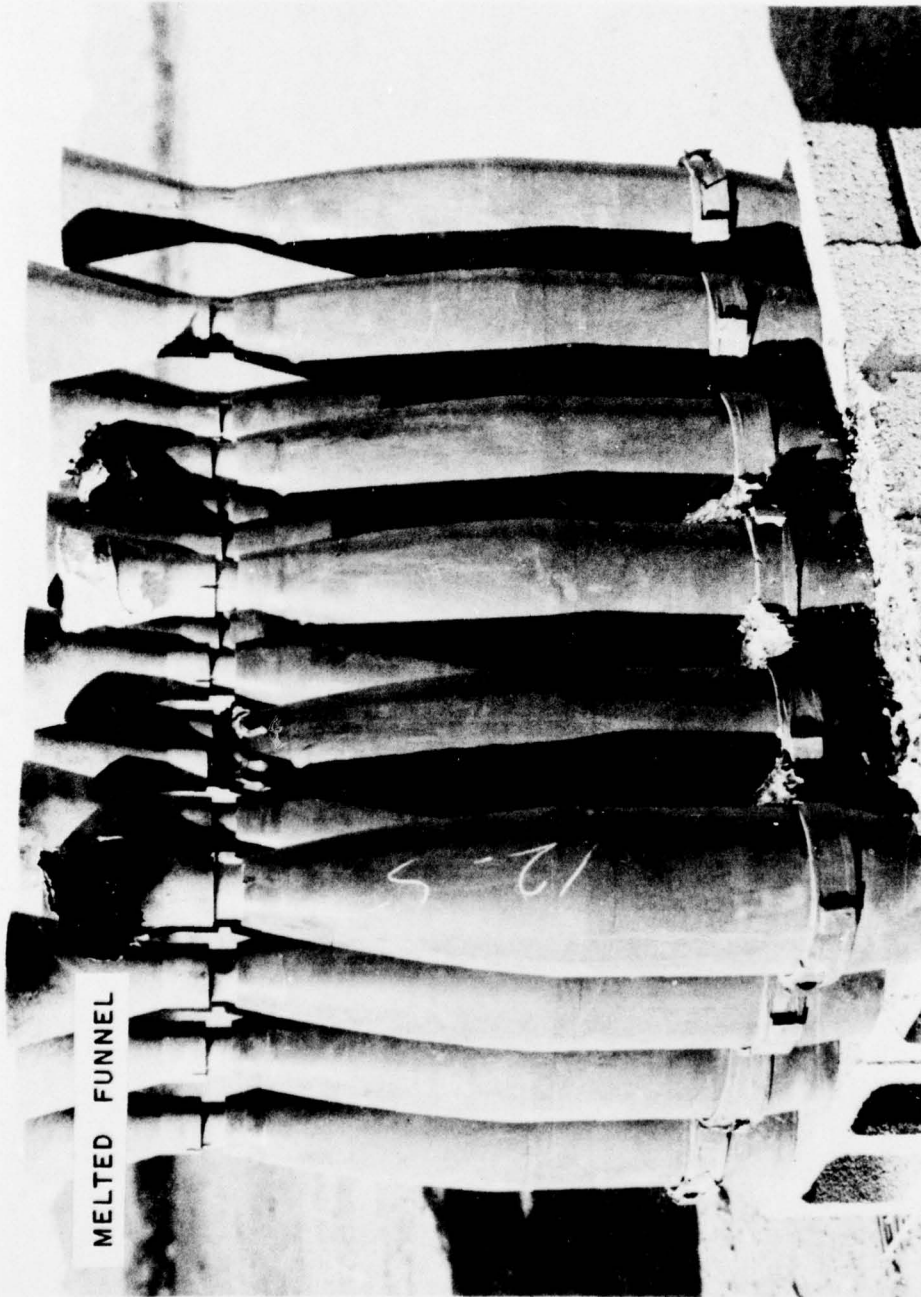


Fig 6 Test result--Test No. 41



Fig 7 Typical test results--Test No. 40

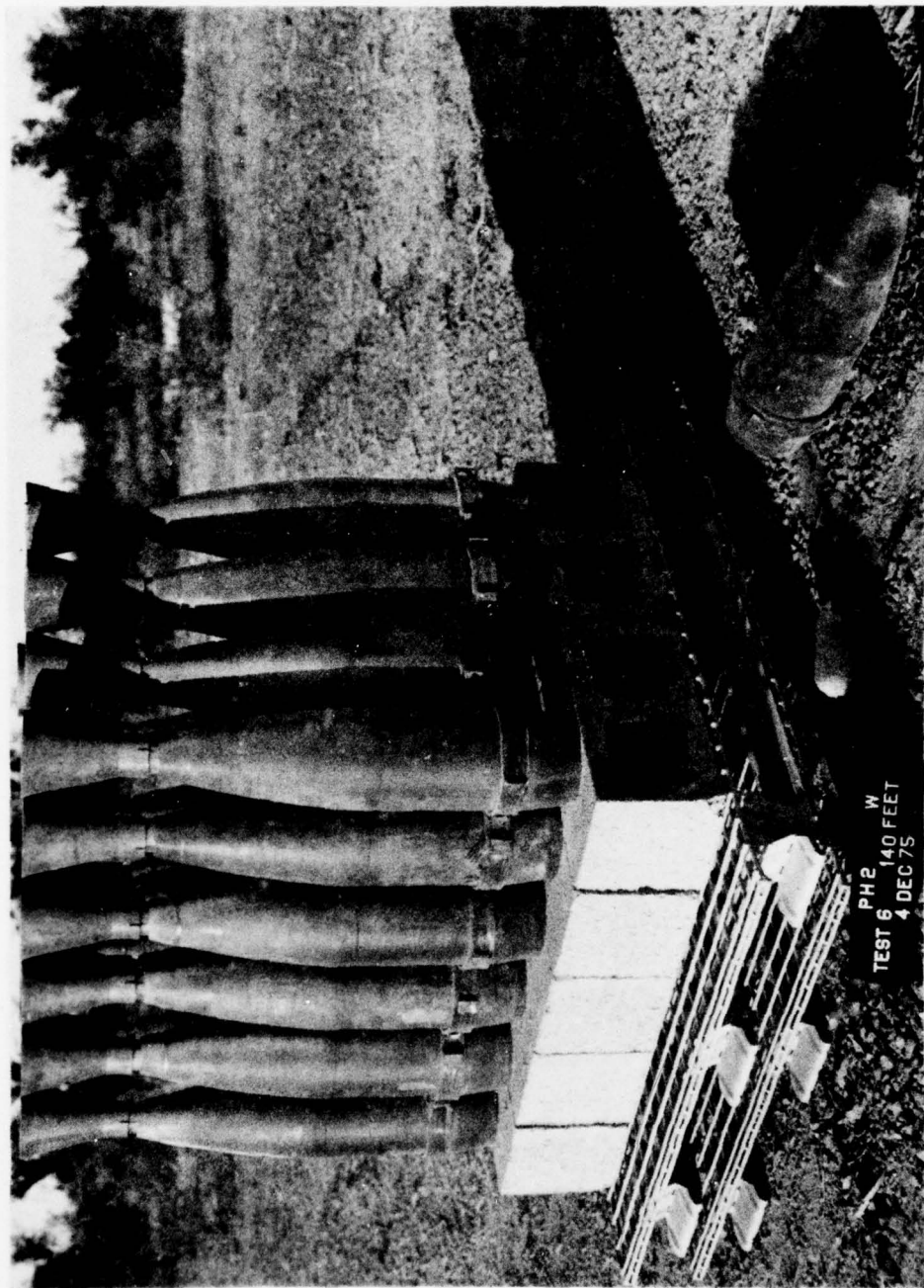


Fig 8 Typical test results--Test No. 35

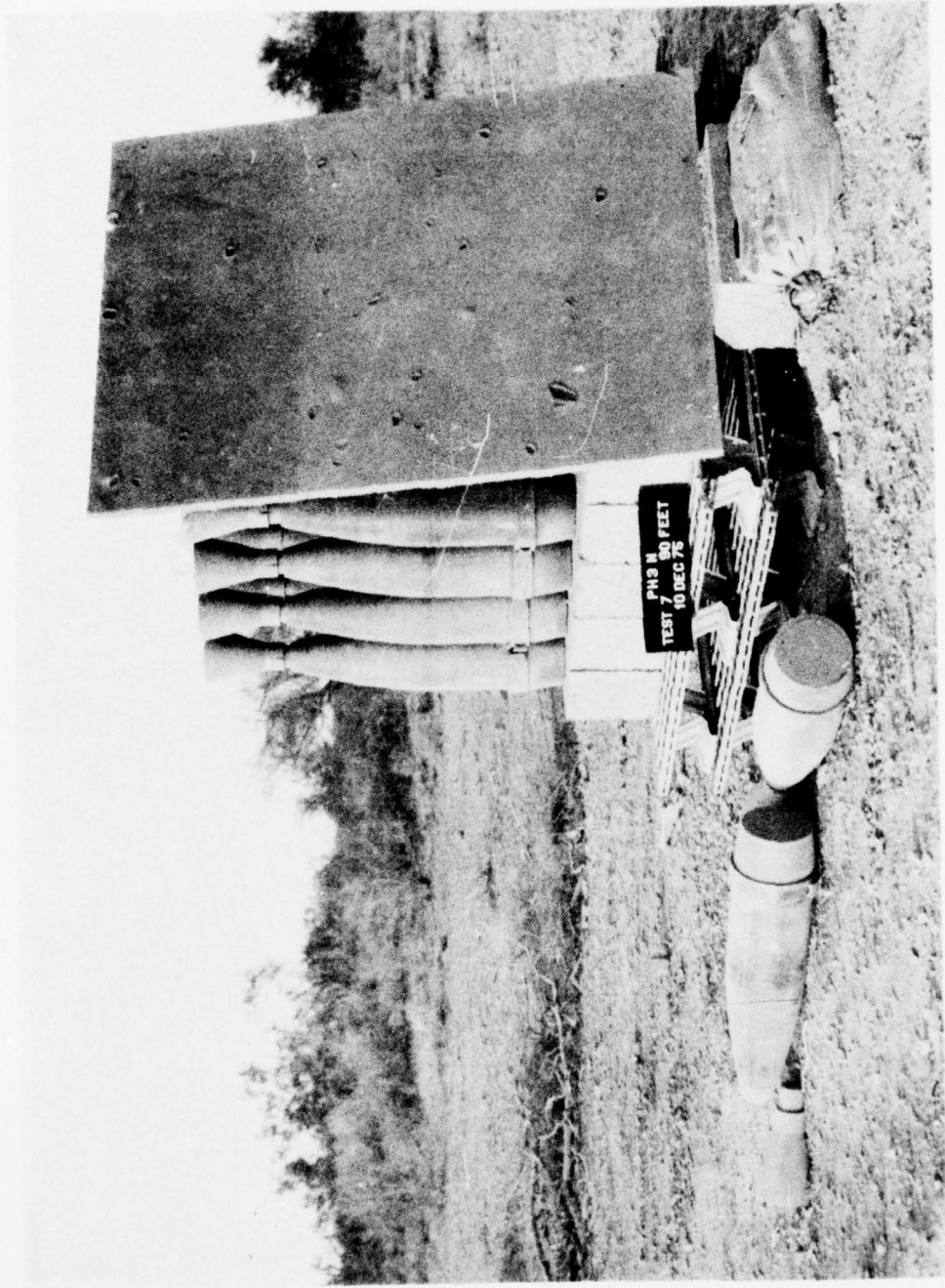


Fig 9 Typical test results--Test No. 63

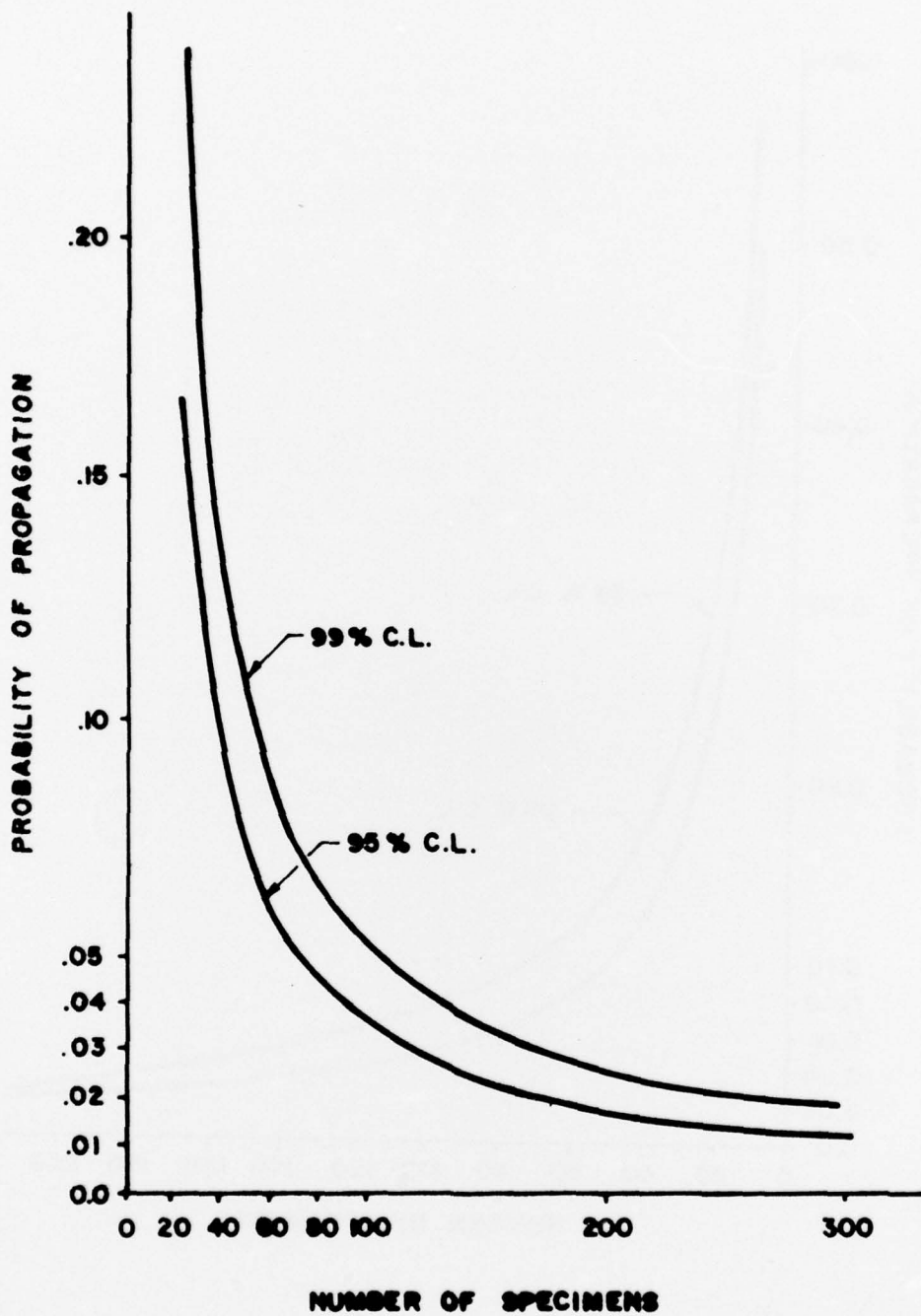


Fig 10 Maximum probability of propagation vs. number of specimens at a given confidence level for no observations of propagation

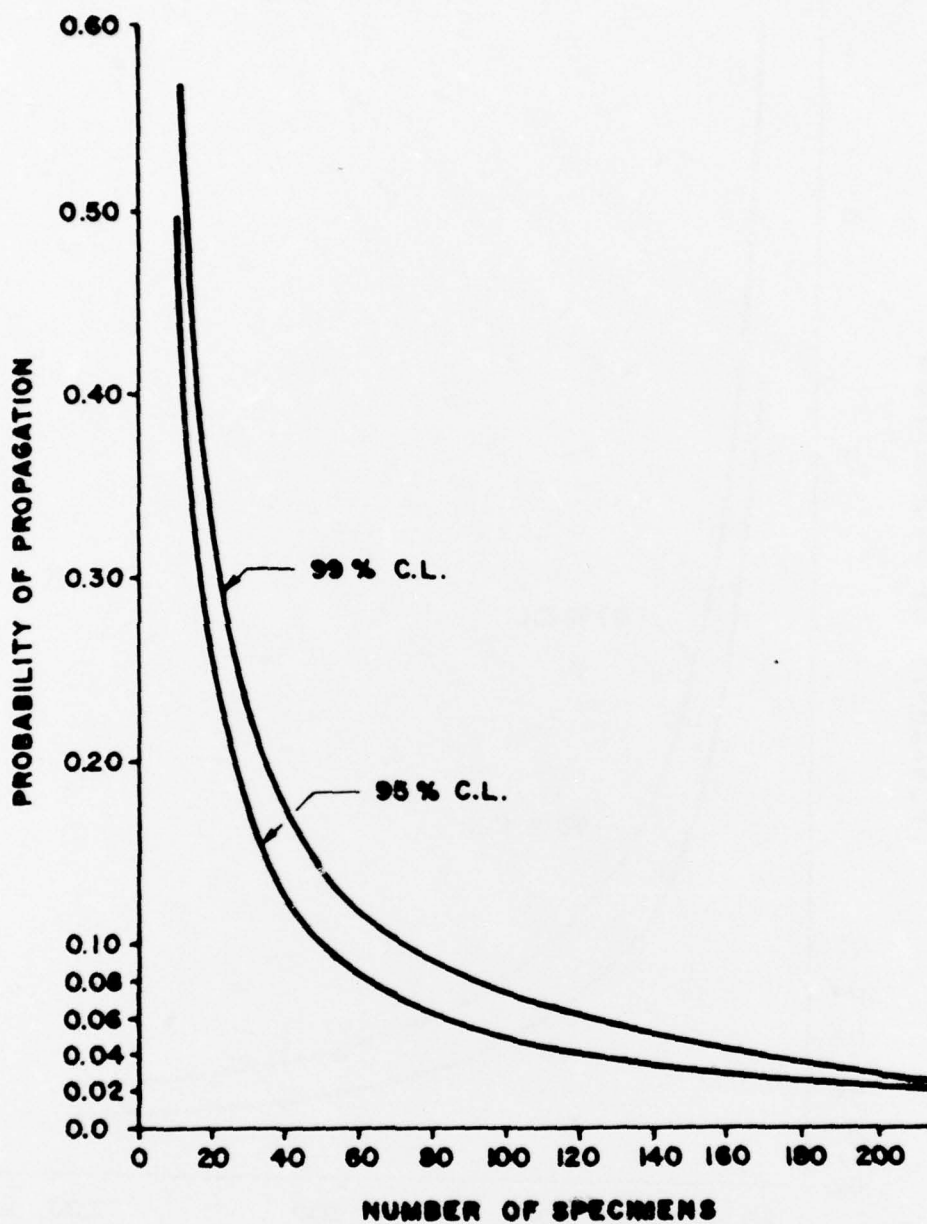


Fig 11 Maximum probability of propagation vs. number of specimens at a given confidence level for one observation of propagation

DISTRIBUTION LIST

	<u>Copy No.</u>
Commander Picatinny Arsenal ATTN: SARPA-CO	1
SARPA-MT-C	2
SARPA-MT-S	3-17
SARPA-S	18
SARPA-TS-S	19-23
Dover, N. J. 07801	
Chairman	24-25
Department of Defense Explosive Safety Board Forrestal Bldg., GB-270 Washington, D. C. 20314	
Administrator	26-37
Defense Documentation Center ATTN: Accessions Division Cameron Station Alexandria, Va. 22314	
Commander	38
Department of the Army Office, Chief Research, Development and Acquisition ATTN: DAMA-CSM-P Washington, D. C. 20301	
Office, Chief of Engineers	39
ATTN: DAEN-MCZ Washington, D. C. 20314	
Director	40-41
DARCOM Field Activity ATTN: DRXOS Charlestown, Indiana 47111	
Commander	
U. S. Army Materiel Development & Readiness Command	
ATTN: DRCSF	42
DRCRD	43
DRCRP	44
DRCIS	45
Eisenhower Avenue Alexandria, Va. 22333	

	<u>Copy No.</u>
Commander DARCOM Installations & Services Agency ATTN: DRCIS-RI-1 Rock Island, Il. 61201	46
Director Industrial Base Engineering Activity ATTN: DRXIB-MT Rock Island, Il. 61201	47
Project Manager for Munition Production Base Modernization and Expansion ATTN: DRCPM-PBM DRCPM-PBM-S DRCPM-PBM-L DRCPM-PBM-E Dover, N. J. 07801	48 49 50-51 52-53
Commander U. S. Army Armament Command ATTN: DRSAR-SF DRSAR-SC DRSAR-EN DRSAR-PPI DRSAR-PPI-C DRSAR-RDP DRSAR-IS Rock Island, Il. 61201	54-56 57 58 59 60 61 62
Commander Edgewood Arsenal ATTN: SAREA-TD SAREA-MTD Aberdeen Proving Ground, Md. 21010	63 64
Commander Frankford Arsenal ATTN: SARFA-T Philadelphia, Pa. 19137	65
Commander U. S. Army Engineer Division ATTN: HNDED P. O. Box 1600-West Station Huntsville, Al. 35809	66

	<u>Copy No.</u>
Commander Radford Army Ammunition Plant Radford, Va. 24141	67
Commander Badger Army Ammunition Plant Baraboo, Wisconsin 53913	68
Commander Indiana Army Ammunition Plant Charlestown, Indiana 47111	69
Commander Lone Star Army Ammunition Plant Texarkana, Texas 75501	70
Commander Milan Army Ammunition Plant Milan, Tn. 38358	71
Commander Iowa Army Ammunition Plant Burlington, Ia. 52601	72
Commander Joliet Army Ammunition Plant Joliet, Il. 60436	73
Commander Longhorn Army Ammunition Plant Marshall, Tx. 75670	74
Commander Louisiana Army Ammunition Plant Shreveport, La. 71130	75-76
District Engineer U. S. Army Engineering District, Ft. Worth Corps of Engineers P. O. Box 17300 Ft. Worth, Tx. 76102	77
Commander Kansas Army Ammunition Plant Parsons, Ks. 67357	78-79

	<u>Copy No.</u>
District Engineer U. S. Army Engineering District, Mobile Corps of Engineers P. O. Box 2288 Mobile, Al. 36628	80
District Engineer U. S. Army Engineering District, Omaha Corps of Engineers, 6014 U. S. P. O. & Courthouse 215 N. 17th Street Omaha, Nb. 68102	81
District Engineer U. S. Army Engineering District, Baltimore Corps of Engineers P. O. Box 1715 Baltimore, Md. 21203	82

