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TECHNICAL REPORT ARLCD-TR-78004

DETERMINATION OF MINIMUM NON-PROPAGATION DISTANCE OF M42 AND M46 GRENADES WITHOUT FUZE

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FEBRUARY 1978

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DOVER, NEW JERSEY

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Technical Report ARLCD-TR-78004

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): DETERMINATION OF MINIMUM NON-PROPAGATION DISTANCE OF M42 AND M46 GRENADES WITHOUT FUZE

5. TYPE OF REPORT & PERIOD COVERED: Final technical rept.

6. PERFORMING ORG. REPORT NUMBER

7. [redacted]
William M. Stirrat, Project Engineer, ARRADCOM
Richard M. Rindner, Project Leader, ARRADCOM

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Manufacturing Technology Division
LCWSL, ARRADCOM
Dover, NJ 07801

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
ARRADCOM
ATTN: DRDAR-TSS
Dover, NJ 07801

12. REPORT DATE: Feb [redacted] 78

13. [redacted]: 47 (45p.)

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
ARRADCOM
LCWSL
Dover, 07801

15. SECURITY CLASS. (of [redacted])
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT [redacted]

Approved for public release; distribution unlimited.

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)
Minimum non-propagation distance
M42, M46 grenades
High order detonation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A series of tests were conducted with M42 grenades to establish the minimum non-propagation distances for three LAP configurations currently being used at Milan Army Ammunition Plant, Tennessee. The test results indicate that the minimum non-propagation distances are 5.1 cm (2 in.), 2.14 m (7 ft) and 12.2 m (40 ft) respectively, for single grenades positioned vertically on a conveyor, trays of 64 grenades placed on a conveyor, and

DD FORM 1473, 1 JAN 73 — EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued)

carriers of 12 trays suspended from a pendant type conveyor within a covered ramp. The tests also demonstrated that the initiation of a detonation of one grenade results in high order detonation of the remaining grenades within the same carriage unit.

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to the following individuals for their participation, guidance and cooperation during the performance of the Safe Separation Distance Test Program: Messrs. James I. Jensen and Kenneth O. Rhea of Tooele Army Depot, Utah, and Robert S. Kukuvka of ARRADCOM, Dover, New Jersey.

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SUMMARY

The tests described in this report were requested by the ARRADCOM Safety Office, specifically for the Milan Army Ammunition Plant, Tennessee. The plant is utilized to manufacture M42 and M46 grenades loaded with A5 Composition. The tests are to determine a safe separation distance for three different loading, assembly and packout (LAP) production line configurations. The three configurations are: (1) a series of single grenades set vertically (shaped charge facing down) on a conveyor; (2) a series of single trays which contain 64 grenades arranged in an 8 x 8 matrix set on a conveyor; and (3) a series of carriers containing 12 trays with 64 grenades in each tray, suspended from a pendant type conveyor within a covered ramp. The tests were performed from April 1976 to July 1977 at Tooele Army Depot, Utah, and limited to M42 grenades only. The design and explosive contents of M42 and M46 are similar; hence, the testing of M46 grenades becomes unnecessary and uneconomical.

The tests were conducted in three test series corresponding to three LAP configurations. Each series consists of two phases: an exploratory phase during which the probable minimum safe separation distance was determined by trial and error and a confimatory phase where sufficient tests were performed to statistically establish the probability of propagation of an explosive incident at the safe separation distance established during the exploratory phase.

The first series established the minimum safe spacing between single M42 grenades positioned vertically in a conveyor belt as 5.1 centimeters (2 inches) with an upper limit of 6.6 percent probability of propagation at a 95 percent confidence level. The second series established the minimum safe spacing between adjacent trays set on a conveyor belt as 2.14 metres (7 feet) with an upper limit of 7.1 percent probability of propagation at a 95 percent confidence level. The third series established the minimum safe spacing between carriers suspended from a pendant type conveyor within a covered ramp of 12.2 metres (40 feet) with an upper limit of 8.8 percent probability of propagation at a 95 percent confidence level.

INTRODUCTION

Background

The determination of the minimum non-propagation distances of M42 and M46 grenades is part of an Army-wide program presently under way to upgrade existing installations and to develop design criteria for new explosive manufacturing and LAP (Load, Assemble and Pack) facilities. This effort will enable the U.S. Army to achieve increased production cost effectiveness with improved safety, as well as to provide design data for manufacturing facilities for new weaponry. As an integral part of this overall program, the Manufacturing Technology Division, Large Caliber Weapon Systems Laboratory, ARRADCOM, Dover, New Jersey, is engaged in the development of safety criteria as an activity entitled "Safety Engineering in Support of Ammunition Plants" which includes safe separation distance studies of munitions end items and in-process explosive materials. These criteria will be utilized as part of the basis for the design of all explosive production installations due for modernization and expansion, including Government-owned, contractor-operated (GOCO) ammunition plants.

The tests described in this report were undertaken at the request of the ARRADCOM Safety Office for Milan Army Ammunition Plant, Tennessee. Currently, the plant is utilizing three LAP configurations to handle M42 and M46 grenades loaded with A5 Composition. The design and explosive content of M46 grenades are similar to those of the M42 grenades; hence, the tests were conducted for M42 grenades only to achieve cost saving.

The three configurations were:

1. Single grenades set vertically on the conveyor belt.

2. Trays of 64 grenades arranged in an 8 x 8 matrix set on a conveyor belt.

3. Carriers containing 12 trays with 64 grenades in each tray suspended from a pendant type overhead conveyor within a covered ramp.

The grenades used in the tests were fully assembled and loaded with the exception that the M223 general purpose fuze was removed.

Purpose and Objective

The purpose of this Safe Separation Distance Program is to provide existing and future loading plants with viable safe separation distance criteria for the set-up of LAP operations on M42 and M46 grenades.

The objective of the program was to determine experimentally the minimum safe (non-propagative) spacing for all three LAP configurations being used at the Milan Army Ammunition Plant. The program may be considered as consisting of two phases. The first phase involved exploratory testing for the purpose of establishing the necessary clear spacing between adjacent transport carriages of grenades. The second phase consisted of confirmatory testing as required to establish statistical confidence in the results.

Criteria for Tests

The testing was conducted in such a manner as to accurately simulate the actual loading configurations. The only acceptable criterion for determining the safe clear separation distances for each configuration was the non-propagation of a detonation from the donor unit to the acceptor units. Note that the clear distances are measured edge-to-edge, not center-to-center, on the adjacent grenades.

TEST CONFIGURATIONS

General

The safe separation distance testing of the M42 grenades in all three LAP configurations was performed from April 1976 to July 1977 at Tooele Army Depot in Utah. Two phases of testing, exploratory and confirmatory, were accomplished for each of the three LAP configurations in order to establish the minimum non-propagation distances between the various M42 grenade carriers. The program may be considered as consisting of three separate test series, corresponding to three LAP hardware configurations.

In the analysis of the test data, it will be noted that the various test series and phases were not conducted in either chronological or series order. Because of the long time period and the large number of tests involved, individual tests were conducted whenever the coordination of manpower, test materials and test site could be effected. In fact, several test configurations and test series were intermingled within a particular day's test activity. However, in all test series, the exploratory test phase was always fully completed and its data reviewed and analyzed prior to the inception of the confirmatory phase.

Test Specimens

Each of the test series utilized the same basic test specimen, the M42 grenade without the M223 general purpose fuze (Figure 1). The grenade's basic dimensions are 6.25 centimeters (2.46 inches) in length with a maximum diameter of 3.89 centimeters (1.53 inches). Each grenade contains a minimum of 30 grams of A5 Composition contained in a shaped charge configuration.

Test Arrangements

The first test series utilized only the basic M42 grenades equally placed on a pine board of 2.54 centimeters (1 inch) by 15.24 centimeters (6 inches) by 2.44 metres (8 feet) and supported by cinder blocks at both ends at a distance of approximately 76.2 centimeters (30 inches) from the ground. Figure 2 is representative of the test arrangement for this series. The center grenade acted as donor, while grenades at both sides acted as acceptors. It was initially planned to conduct 7 exploratory tests followed by 25 confirmatory tests; however, in order to establish an accurate safe separation distance, a total of 52 exploratory tests were performed.

The second test series utilized polypropylene trays containing 64 grenades arranged in an 8 x 8 matrix (Figure 3). The grenades were oriented in a vertical position (shaped charge down) in the slotted compartments in the tray. Three loaded trays were placed on a simulated conveyor made of a 2.54-centimeter (1.0-inch) by 30.48-centimeter (12.0-inch) by 2.44-metre (8.0-foot) pine board supported at each end at a distance of approximately 76.2 centimeters (30 inches) from the ground. The two-acceptor/one-donor technique, with the high order initiation of the donor, was utilized. The center tray acted as donor while the others acted as acceptors. Figure 4 illustrates a typical set-up for the second test series. A total of four exploratory tests and 25 confirmatory tests were conducted.

For the third and final series of tests as shown in Figure 5, the middle carriage acted as donor while the other two carriages acted as acceptors. Each carrier consisted of 6 aluminum shelves, 40.64 centimeters (16 inches) by 81.28 centimeters (32 inches), each shelf containing two trays of 64 grenades in each tray and spaced vertically 11.43 centimeters (4.5 inches) apart (see Figure 6). The carriers were suspended from the ceiling to simulate the pendant type conveyor in an aluminum-sided and roofed conveyor tunnel. In this series, a total of three exploratory tests were conducted to establish the non-propagative distance between two carriers. The number of confirmatory tests were limited to 20 tests due to the high costs and the complexity of the tests.

TEST RESULTS

General

As previously mentioned, the safe separation distance tests of the M42 grenades had been grouped into three test series according to the LAP manufacturing processes; i.e., single grenades, a tray of 64 grenades and a carrier of 12 trays. The results of each test series are presented in Tables 1, 2 and 3, respectively. In addition, a summary of the number of high order detonations corresponding to the various separation distances for the three test series are compiled as Table 4.

Results of Individual Test Series

Test Series 1 - Single Grenades

The separation distances utilized in the exploratory testing phase of this test series ranged from a minimum of zero spacing (grenades touching each other) to a maximum of 38.1 centimeters (15 inches), measured edge-to-edge on the grenades. The only detonation that occurred was at zero spacing.

Confirmatory testing on the single M42 grenades was originally conducted at a safe separation distance of 22.8 centimeters (9 inches). However, during discussions with loading plant personnel, it was noted that this much spacing would necessitate excessively high and unrealistic conveyor speeds in order to meet desired production rates.

A second series of M42 grenade exploratory tests were initiated which eventually led to a series of confirmatory tests at a safe separation distance of 10.2 centimeters (4 inches) (see Tests 32 through 52 of Table 1). Low order detonations in some tests were observed for the acceptors next to the donor.

Finally, a third series of single M42 grenade confirmatory tests were conducted at a safe separation spacing of 5.1 centimeters (2 inches). Twenty-five tests (Tests 53 through 77 of Table 1), each with 5 grenades in a line (Figure 2) were conducted. The result indicated that random low order propagations (12 total) to the nearest acceptors (Numbers 2 and 4 of Figure 2) occurred.

Figure 7 shows the layout of a confirmatory test for the single grenade tests. The center grenade was armed with a detonator to set it off as a high order detonation. Figure 8 is the post test result in which there was no propagation of the detonation of the donor to any of the acceptors, except for fragment damage to the inner acceptors. Figure 9 is another post test result of the single grenade confirmatory tests; there was a low order detonation of the inner acceptor on the left side. However, since the propagation of the detonation was not carried any further, the result was considered to be acceptable.

Test Series 2 - Tray of 64 Grenades

In the exploratory phase of this second series of M42 grenade tests, the separation distances tested ranged from 2.14 metres (7 feet) down to 0.15 metre (6 inches), measured edge-to-edge on the grenade trays. High order detonations of acceptor trays were observed at a separation distance up to 1.53 metres (5 feet). While there were no detonations of acceptor trays observed at the separation distance of 1.83 metres (6 feet), the damage caused by donor tray fragments was evident. Therefore, a non-propagation distance of 2.14 metres (7 feet) was established.

A total of 25 confirmatory tests were performed for the safe separation distance of 2.14 metres (7 feet). The results show no propagation of the donor's high order explosion to the acceptor trays (Table 2, Tests 5 through 29). Figure 10 shows the post test results of a donor detonation at a safe separation distance of 2.14 metres (7 feet). Note that some of the outside grenades and portion of tray were damaged by donor fragments.

Test Series 3 - Carrier with 12 Trays

The total number of tests conducted for this test series was severely curtailed due to the complexity of the test set-up and the high costs associated with construction of the necessary simulated tunnel structures. Therefore, only three tests were conducted during the exploratory phase of the program, with separation distances ranging from 15.3 meters (50 feet) down to 6.9 metres (20 feet). Based on the results of the tests, the separation distance of 12.2 metres (40 feet) was accepted as the distance for confirmatory tests.

A total of 20 confirmatory tests were conducted. It was observed that only some of the grenades in acceptor carriers were being spilled out of trays.

Figure 11 is an end view of the simulated tunnel for the carrier test. The carriers were supported to the proper heights by metal ammunition boxes in lieu of an overhead suspension system in order to reduce program costs. Figure 12 is the post test results of the donor detonation at a separation distance of 12.2 metres (40 feet). Note that the acceptor carriers landed upright; however, some of the grenades were spilled from the individual trays.

Summary of Test Results

While a few high order detonations of acceptor specimens were observed in two of the three test series, the confirmatory test results clearly showed that no propagation of detonations occurred at the established safe clear separation distances. The established safe clear separation distances are 5.1 cm (2 in) for single grenades; 2.14 m (7 ft) for a tray with 64 grenades; and 12.2 m (40 ft) for a carrier with 12 trays.

The results of the program also demonstrated conclusively that when the M42 grenades were placed in close proximity to each other, the detonation of one grenade would result in high order detonation of adjoining grenades. This was observed in the case in which one detonated grenade would initiate the whole 8 x 8 matrix tray and/or the whole carrier of 12 trays to a high order detonation.

Analysis of Test Results

Variations in manufacturing tolerances, materials, wear, etc. require that statistical reasoning be employed in the comparative interpretation of the test data. The probability of the propagation of an explosive incident is a function of the number of propagation occurrences in the individual test series and the number of tests conducted (see Appendix for statistical theory). The results as shown in Table 4 indicate that high order detonations occurred in two of the three test series conducted. However, no propagations were observed during any of the confirmatory tests.

In Test Series 1, single M42 grenades spaced at 5.1 cm (2 in) apart, a total of 54 acceptor specimens were tested. Therefore, from Figure 13, the probability of a detonation of an acceptor by a donor initiation is 6.6 percent at the 95 percent confidence level.

In Test Series 2, 64 grenades per tray arranged in an 8 x 8 matrix, a total of 50 acceptor specimens were tested. This results in a probability of detonation of an acceptor by a donor initiation of 7.1 percent at a confidence level of 95 percent.

In the third test series, 12 trays of 64 grenades per carrier, a total of 40 acceptor carrier specimens were tested. This produces a probability of detonation of an acceptor by a donor initiation of 8.8 percent at the 95 percent confidence level.

These values are equivalent to stating that in a large number of tests, 95 out of 100 times, the probability of the propagation in an explosive event will be less than or equal to the stated values. These values indicate the quality of the tests and the reliance that can be placed upon the conclusions drawn from the testing.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The minimum safe clear spacing for single M42 grenades positioned vertically on a conveyor belt was established at 5.1 centimeters (2 inches) as a result of an upper limit of 6.6 percent probability of propagation at the 95 percent confidence level for 54 test specimens.

2. The minimum safe spacing for trays of 64 grenades arranged in an 8 x 8 matrix was established at 2.14 metres (7 feet) as a result of an upper limit of 7.1 percent probability of propagation at the 95 percent confidence level for 50 test specimens.

3. The minimum safe spacing for carriers of 12 trays of 64 grenades suspended from a pendant type conveyor within a covered ramp was established at 12.2 metres (40 feet) as a result of an upper limit of 8.8 percent probability of propagation at the 95 percent confidence level for 40 test specimens.

4. Separate testing of the M46 grenades was unnecessary as they are similar in design and explosive content to the M42 grenades, and parallel testing of M46 grenades would only escalate the program costs.

5. The initiation of a single grenade within either the tray of 64 grenades or the carrier of 12 trays would result in a high order detonation of all the grenades within the group.

Recommendations

The following safe clear separation distances are recommended:

1. 5.1 centimeters (2 inches) between adjacent single grenades.

2. 2.14 metres (7 feet) between adjacent trays of 64 grenades.

3. 12.2 metres (40 feet) between adjacent carriers of 12 trays.

Table 1

Test data summary,
single M42 grenade without fuze

Test No.	Separation cm	(in)	No. of grenades[1]	Results[2]
1	30.5/25.4	(12/10)	3	NDP, minor dents
2	22.8	(9)	3	NDP, minor dents
3	17.8/20.3	(7/8)	3	LOD one side
4	0	0	3	LOD both sides
5	22.8	(9)	3	NDP, major dents, no penetrations
6	22.8	(9)	3	NDP, minor dents
7	22.8	(9)	3	NDP, minor dents
8	22.8	(9)	3	NDP, minor penetration
9	22.8	(9)	3	NDP, minor dents
10	22.8	(9)	3	NDP, minor penetration
11	22.8	(9)	3	NDP, minor dents
12	22.8	(9)	3	NDP, minor penetration
13	22.8	(9)	3	NPD, minor dents
14	22.8	(9)	3	NDP, minor penetration
15	22.8	(9)	3	NDP, minor dents
16	22.8	(9)	3	NDP, minor dents
17	22.8	(9)	3	NDP, minor penetration

1 In a line with center grenade being donor

2 NDP - No detonation propagation
LOD - Low order detonation
HOD - High order detonation

Table 1
(continued)

Test No.	Separation cm	(in)	No. of grenades[1]	Results[2]
18	22.8	(9)	3	LOD one side
19	22.8	(9)	3	LOD one side
20	22.8	(9)	3	NDP, minor penetration
21	22.8	(9)	3	NDP, minor penetration
22	22.8	(9)	3	NDP, minor penetration
23	30.5	(12)	3	NDP, minor penetration
24	30.5	(12)	3	LOD one side
25	38.1	(15)	3	NDP, minor dents
26	38.1	(15)	3	NDP, minor dents
27	38.1	(15)	3	NDP, minor dents
28	38.1	(15)	3	NDP, minor dents
29	38.1	(15)	3	NDP, minor penetration
30	38.1	(15)	3	NDP, minor dents
31	38.1	(15)	3	NDP, minor penetration
32	0	0	11	HOD all grenades
33	5.1	(2)	11	LOD, one acceptor
34	5.1	(2)	7	LOD, one acceptor
35	7.6	(2)	5	NDP, minor dents
36	10.2	(4)	5	NDP

[1] In a line with center grenade being donor

[2] NDP - No detonation propagation
LOD - Low order detonation
HOD - High order detonation

Table [illegible]
(continued)

Test No.	Separation cm	(in)	No. of grenades[1]	Results[2]
37	10.2	(4)	5	NDP, minor dents
38	10.2	(4)	5	LOD, one acceptor
39	10.2	(4)	5	NDP
40	10.2	(4)	5	NDP
41	10.2	(4)	5	NDP
42	10.2	(4)	5	LOD, one acceptor
43	10.2	(4)	5	NDP
44	10.2	(4)	5	NDP
45	10.2	(4)	5	LOD, two acceptors
46	10.2	(4)	7	NDP
47	10.2	(4)	7	NDP
48	10.2	(4)	7	NDP
49	10.2	(4)	7	LOD, one acceptor
50	10.2	(4)	7	NDP
51	10.2	(4)	7	LOD, one acceptor
52	10.2	(4)	7	NDP
53	5.1	(2)	5	LOD, one inner acceptor
54	5.1	(2)	5	NDP, minor penetrations

1 In a line with center grenade being donor

2 NDP - No detonation propagation
LOD - Low order detonation
HOD - High order detonation

Table 1
(concluded)

Test No.	Separation cm	(in))	No. of grenades[1]	Results[2]
73	5.1	(2)	5	NDP
74	5.1	(2)	5	LOD, one inner acceptor
75	5.1	(2)	5	LOD, one inner acceptor
76	5.1	(2)	5	LOD, one inner acceptor
77	5.1	(2)	5	NDP

[1] In a line with center grenade being donor

[2] NDP - No detonation propagation
LOD - Low order detonation
HOD - High order detonation

Table 1
(concluded)

Test No.	Separation cm	(in)	No. of grenades[1]	Results[2]
73	5.1	(2)	5	NDP
74	5.1	(2)	5	LOD, one inner acceptor
75	5.1	(2)	5	LOD, one inner acceptor
76	5.1	(2)	5	LOD, one inner acceptor
77	5.1	(2)	5	NDP

[1] In a line with center grenade being donor

[2] NDP - No detonation propagation
LOD - Low order detonation
HOD - High order detonation

Table 2

Test data summary,
trays with 64 grenades

Test	Separation		
No.	m	(ft)	Results[1]
1	0.61	(2)	NDP, minor penetration
	1.22	(4)	NDP, minor penetration
2	0.30	(1)	HOD
	1.22	(4)	NDP, minor penetration
3	0.15	(.5)	HOD
	0.30	(1)	HOD
4	1.22	(4)	HOD
	1.53	(5)	NDP, minor dents
5	1.83	(6)	NDP, minor dents
	2.14	(7)	NDP
6	1.83	(6)	NDP, minor dents
	2.14	(7)	NDP
7	2.14	(7)	NDP
	2.14	(7)	NDP
8	2.14	(7)	NDP, minor penetration
	2.14	(7)	NDP
9	2.14	(7)	NDP
	2.14	(7)	NDP
10	2.14	(7)	NPD
	2.14	(7)	NDP
11	2.14	(7)	NDP
	2.14	(7)	NDP
12	2.14	(7)	NDP
	2.14	(7)	NDP

[1] NDP - No detonation propagation
HOD - High order detonation

Table 2
(continued)

Test No.	Separation m	(ft)	Results[1]
13	2.14	(7)	NDP
	2.14	(7)	NDP
14	2.14	(7)	NDP
	2.14	(7)	NDP
15	2.14	(7)	NDP
	2.14	(7)	NDP
16	2.14	(7)	NDP
	2.14	(7)	NDP
17	2.14	(7)	NDP
	2.14	(7)	NDP
18	2.14	(7)	NDP
	2.14	(7)	NDP
19	2.14	(7)	NDP
	2.14	(7)	NDP
20	2.14	(7)	NDP
	2.14	(7)	NDP
21	2.14	(7)	NDP
	2.14	(7)	NDP
22	2.14	(7)	NDP
	2.14	(7)	NDP
23	2.14	(7)	NDP
	2.14	(7)	NDP
24	2.14	(7)	NDP
	2.14	(7)	NDP
25	2.14	(7)	NDP
	2.14	(7)	NDP

[1] NDP - No detonation propagation
HOD - High order detonation

Table 2
(concluded)

Test No.	Separation m	(ft)	Results[1]
26	2.14	(7)	NDP
	2.14	(7)	NDP
27	2.14	(7)	NDP
	2.14	(7)	NDP
28	2.14	(7)	NDP
	2.14	(7)	NDP
29	2.14	(7)	NDP
	2.14	(7)	NDP

[1] NDP - No detonation propagation
HOD - High order detonation

Table 3

Carriers with 12 trays

Test No.	Separation m	(ft)	Results[1]
1	12.12	(40)	NDP
	15.3	(50)	NDP
2	6.1	(20)	NDP, damaged grenades
	9.2	(30)	NDP, damaged grenades
3	9.2	(30)	NDP, minor penetrations
	9.2	(30)	NDP, minor penetrations
4	12.2	(40)	NDP
	12.2	(40)	NDP
5	12.2	(40)	NDP
	12.2	(40)	NDP
6	12.2	(40)	NDP
	12.2	(40)	NDP
7	12.2	(40)	NDP
	12.2	(40)	NDP
8	12.2	(40)	NDP
	12.2	(40)	NDP
9	12.2	(40)	NDP
	12.2	(40)	NDP
10	12.2	(40)	NDP
	12.2	(40)	NDP
11	12.2	(40)	NDP
	12.2	(40)	NDP
12	12.2	(40)	NDP
	12.2	(40)	NDP
13	12.2	(40)	NDP
	12.2	(40)	NDP

[1] NDP - No detonation propagation

Table 3
(concluded)

Test No.	Separation m	(ft)	Results[1]
14	12.2	(40)	NDP
	12.2	(40)	NDP
15	12.2	(40)	NDP
	12.2	(40)	NDP
16	12.2	(40)	NDP
	12.2	(40)	NDP
17	12.2	(40)	NDP
	12.2	(40)	NDP
18	12.2	(40)	NDP
	12.2	(40)	NDP
19	12.2	(40)	NDP
	12.2	(40)	NDP
20	12.2	(40)	NDP
	12.2	(40)	NDP
21	12.2	(40)	NDP
	12.2	(40)	NDP
22	12.2	(40)	NDP
	12.2	(40)	NDP
23	12.2	(40)	NDP
	12.2	(40)	NDP

[1] NDP - No detonation propagation

Table 4

Summary of high order detonations

Separation Distance		No. of Acceptors	Test Configuration	High Order Detonations
38.1 cm	(15 in)	14	Single	0
30.5 cm	(12 in)	5	Single	1*
25.4 cm	(10 in)	1	Single	0
22.8 cm	(9 in)	38	Single	2*
20.3 cm	(8 in)	1	Single	0
17.8 cm	(7 in)	1	Single	1*
10.2 cm	(4 in)	34	Single	0
7.6 cm	(3 in)	2	Single	0
5.1 cm	(2 in)	54	Single	0
0 cm	(0 in)	4	Single	4
2.14 m	(7 ft)	48	64/tray	0
1.83 m	(6 ft)	2	64/tray	0
1.53 m	(5 ft)	1	64/tray	1
1.22 m	(4 ft)	3	64/tray	2
0.61 m	(2 ft)	1	64/tray	0
0.30 m	(1 ft)	2	64/tray	2
0.15 m	(6 in)	1	64/tray	1
15.3 m	(50 ft)	1	12 tray/carrier	0
12.2 m	(40 ft)	40	12 tray/carrier	0
9.2 m	(30 ft)	3	12 tray/carrier	0
6.1 m	(20 ft)	1	12 tray/carrier	0

* Unconfirmed; could have been low order.

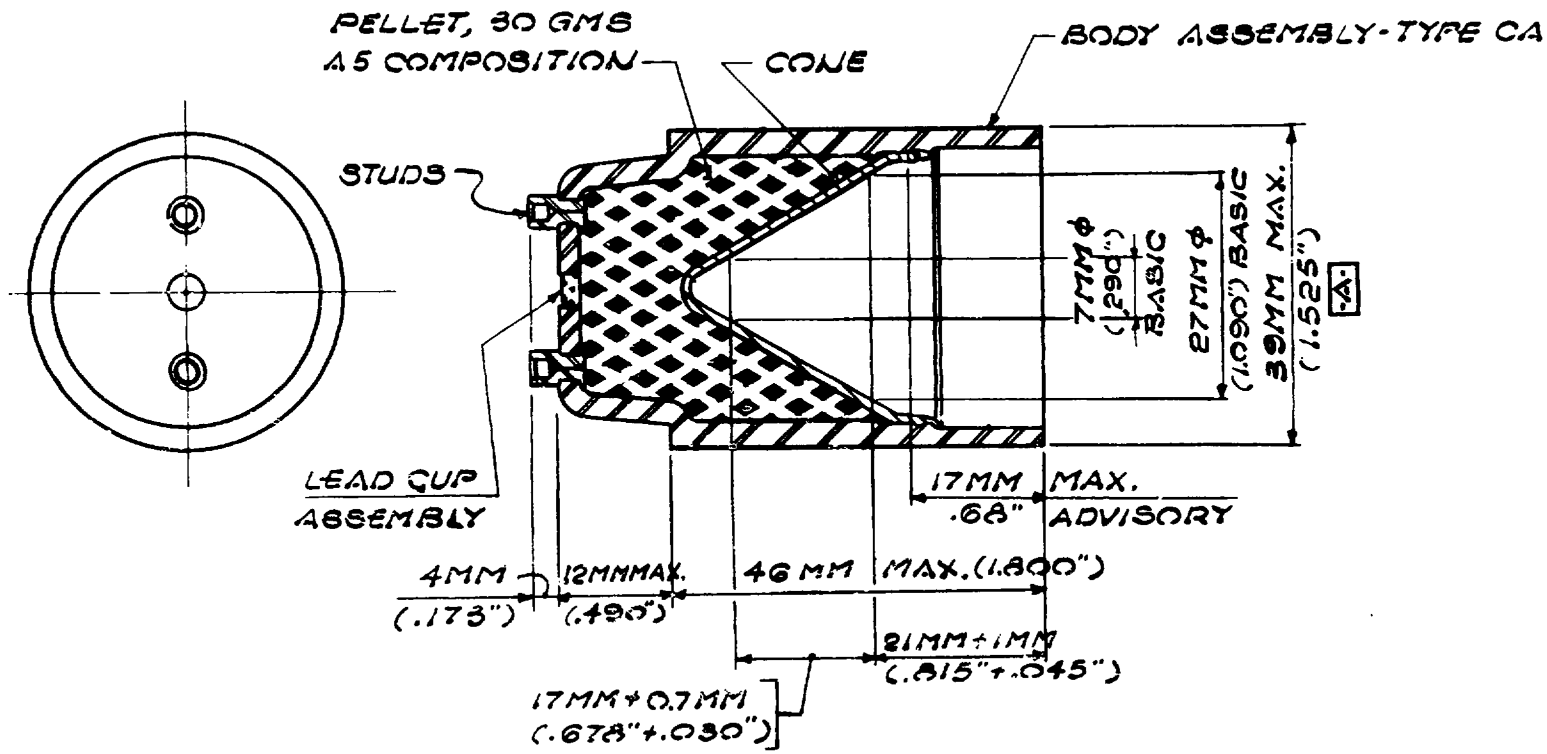

Fig 1 M42 grenade loading assembly

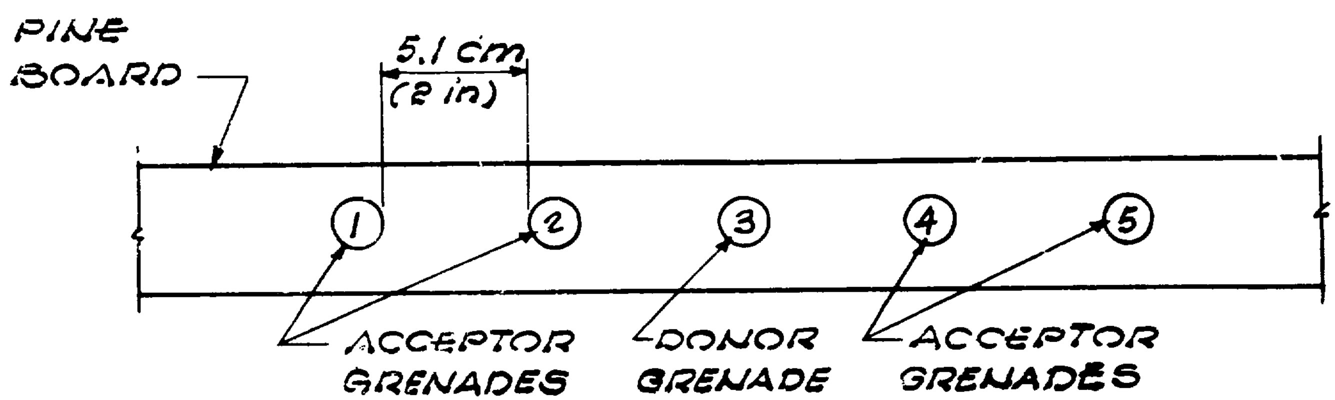

Fig 2 - Typical test set-up for single grenades

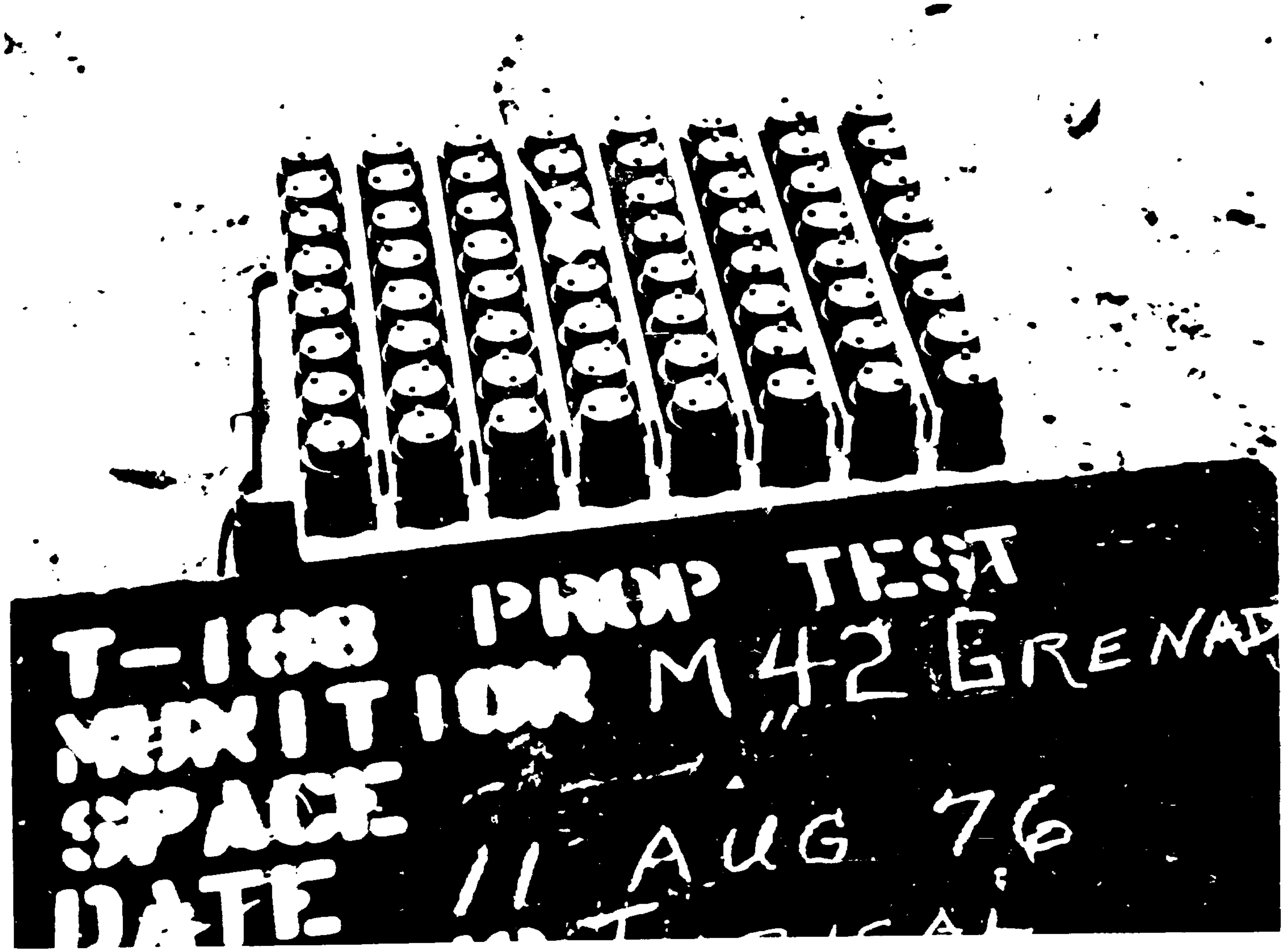

Fig 3 - Tray with 64 M42 grenades with detonator

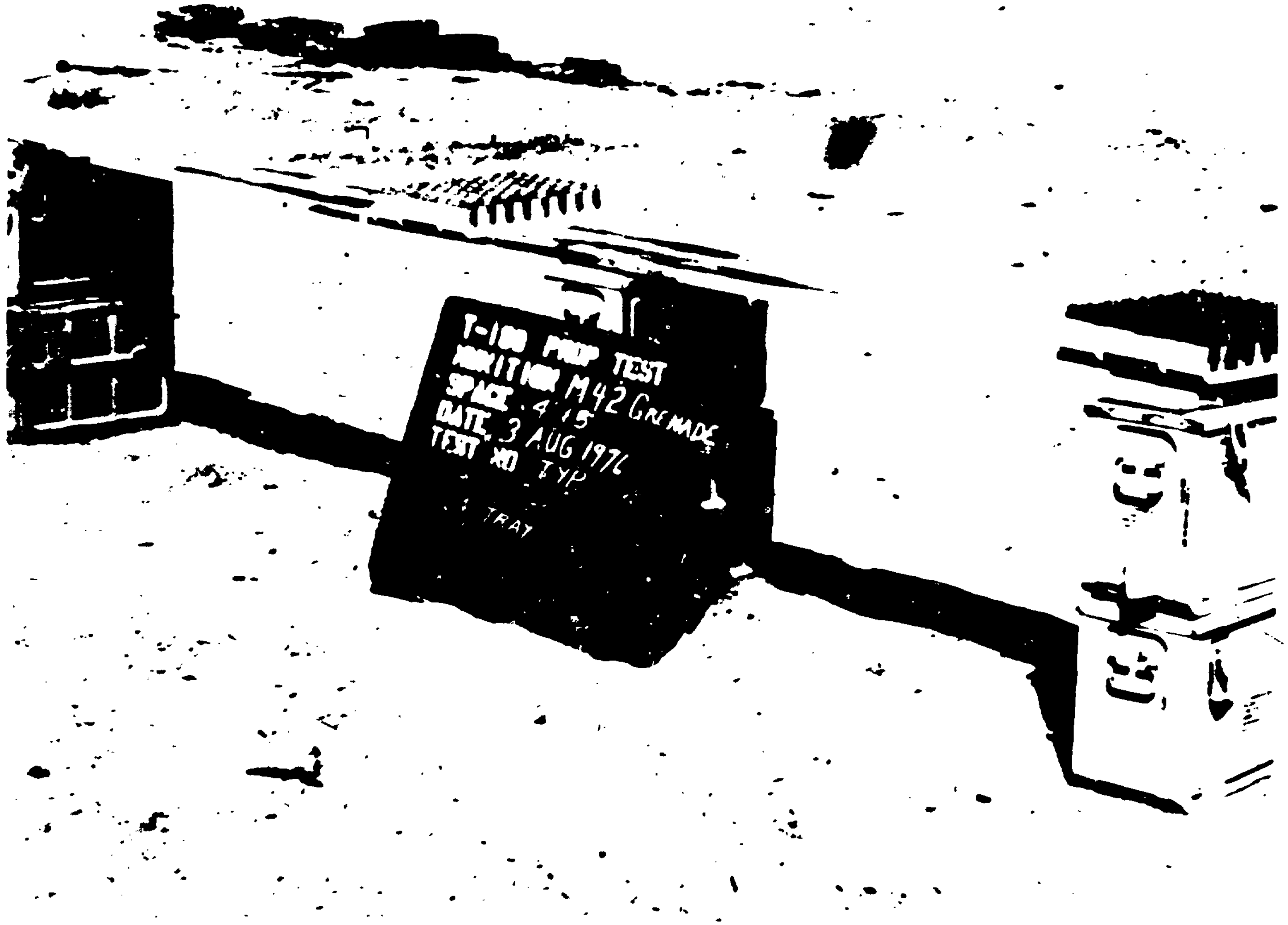

Fig 4 - Typical test set-up for single trays

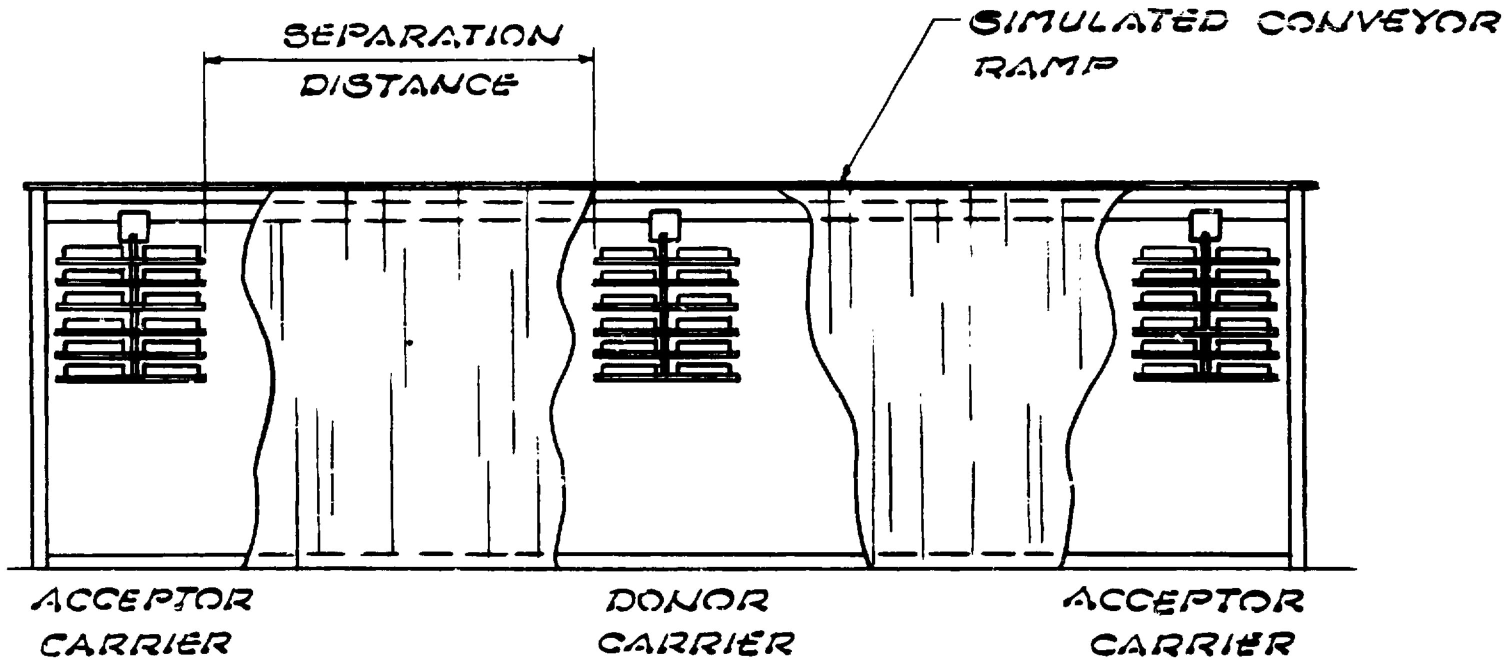

Fig 5 - Test set-up for carriers with 12 trays

Fig 6 - Carriers with 12 trays

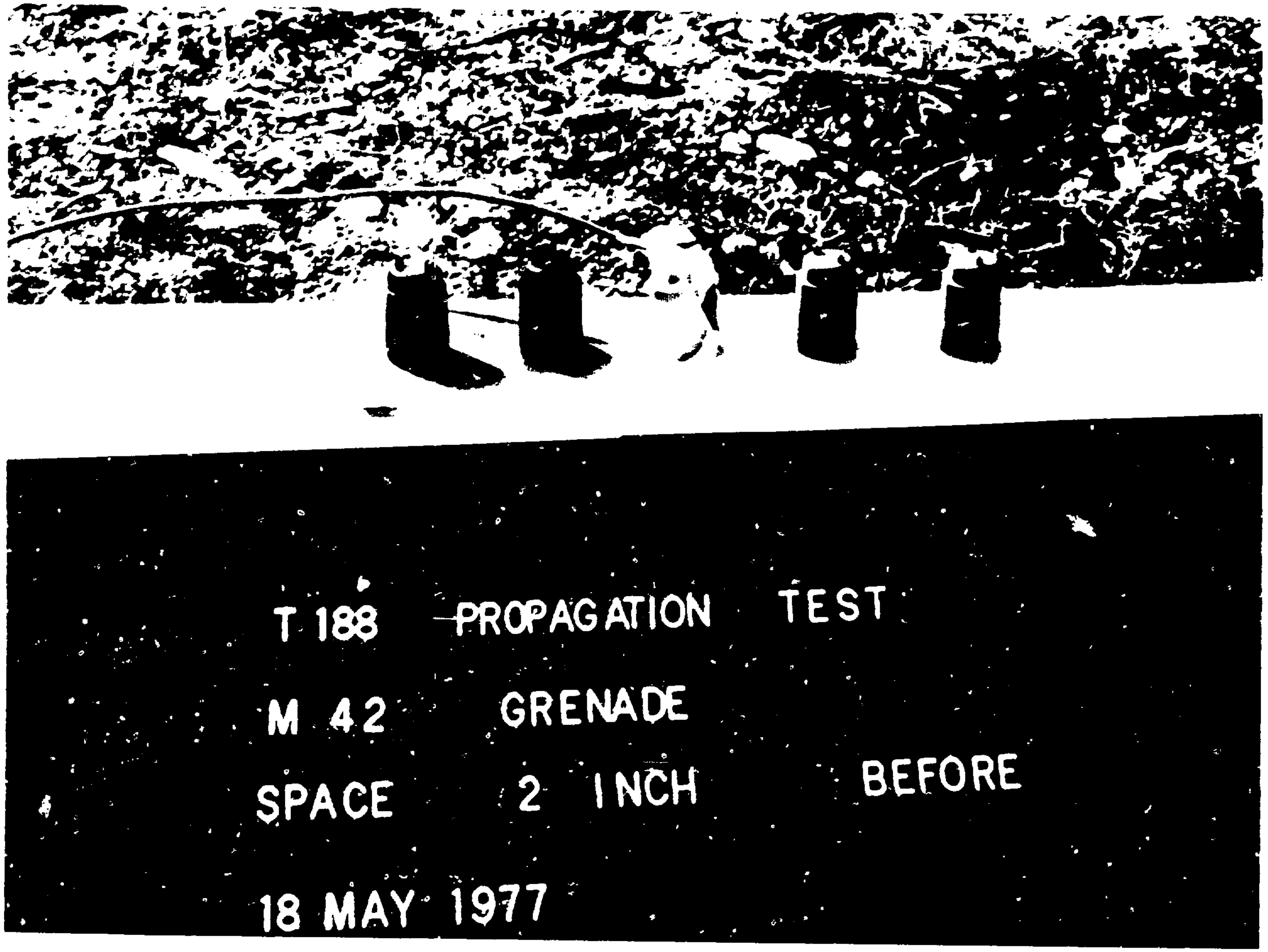

Fig 7 Test set-up for single M42 grenade

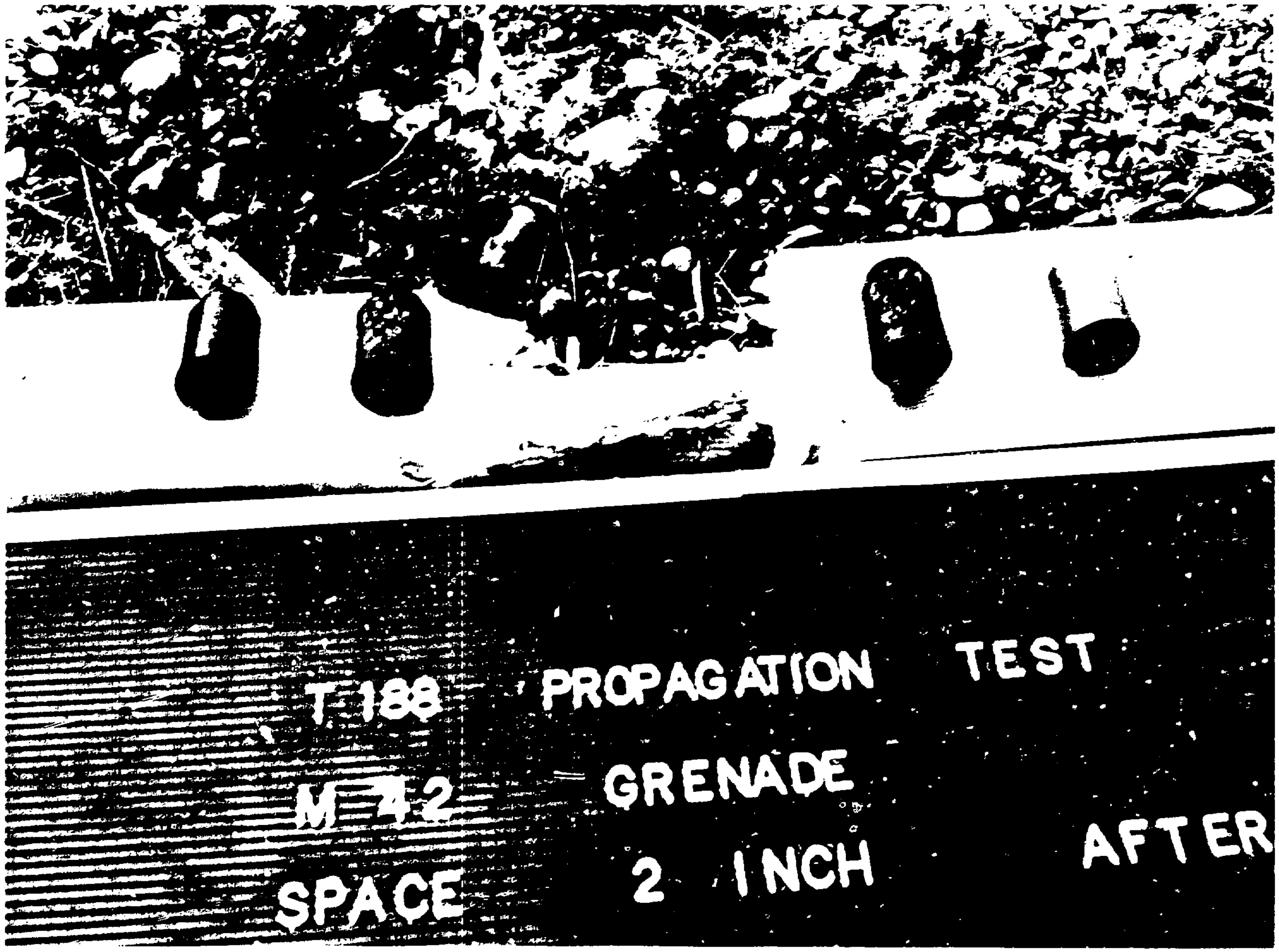

Fig 8 - Test results of single M42 grenade, no detonation propagation

Fig 9 - Test results of single M42 grenade, #2 grenade was low order detonation

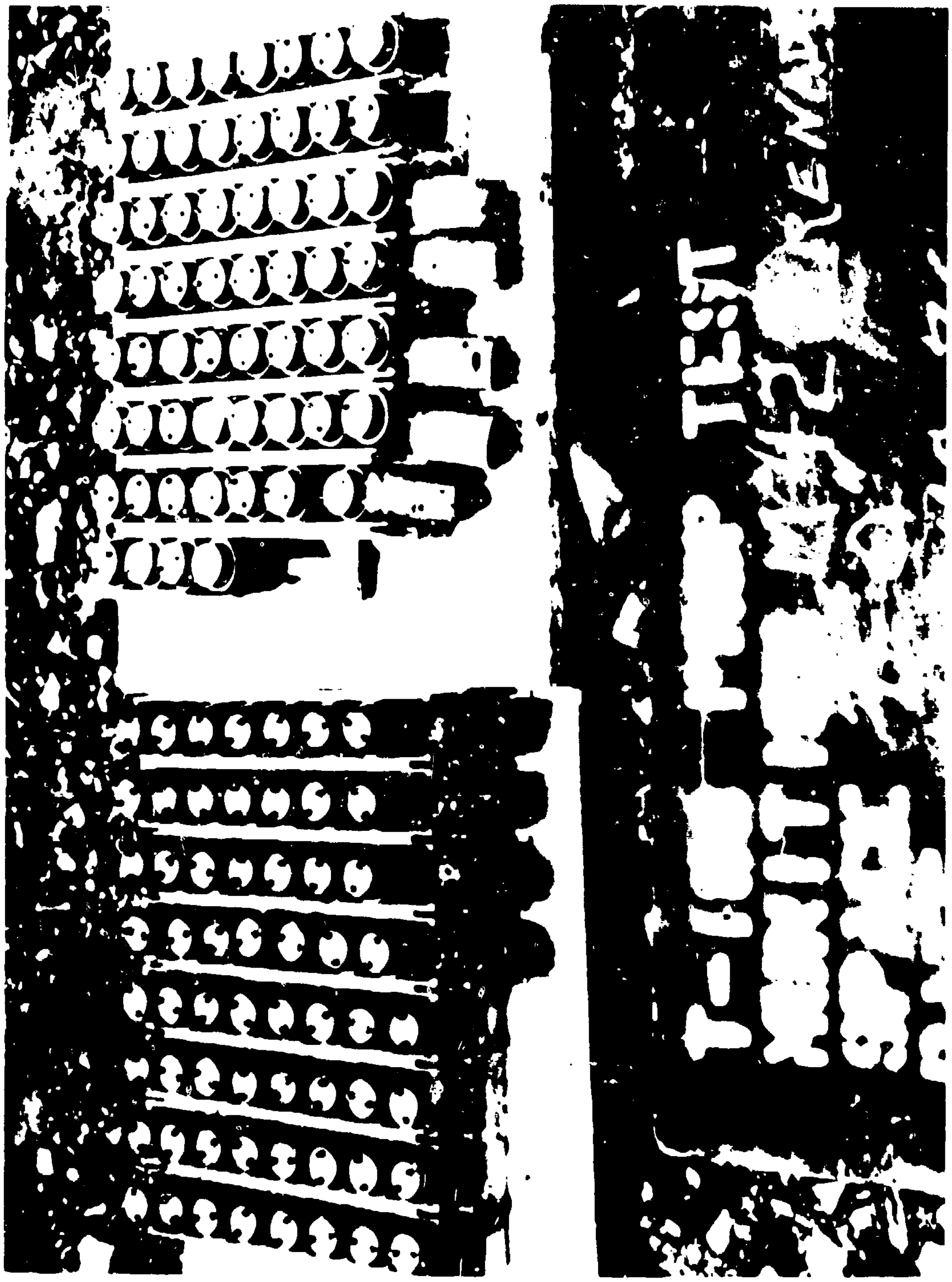

Fig 10 - Test results for single trays

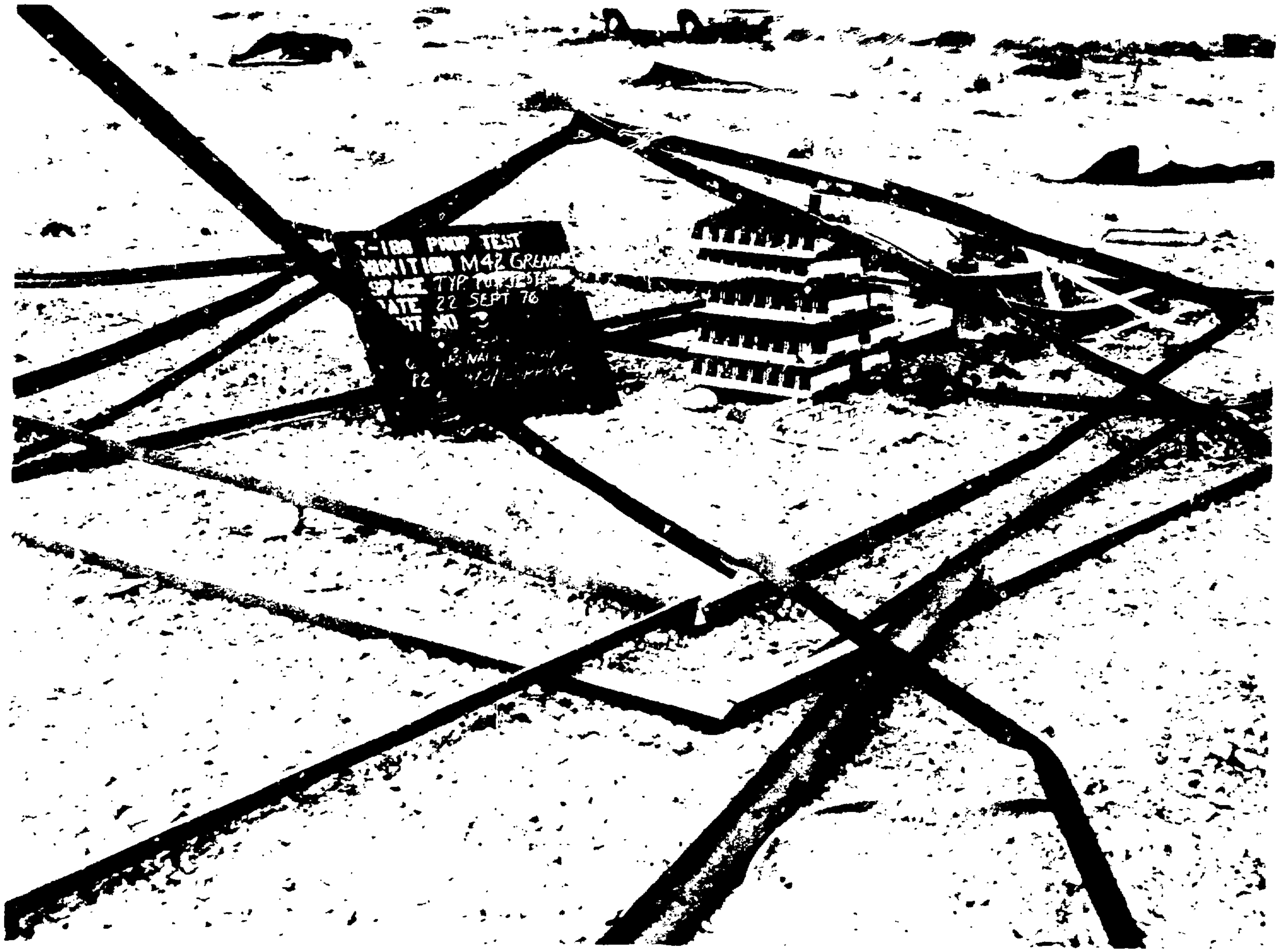

Fig 12 - Test results of carriers

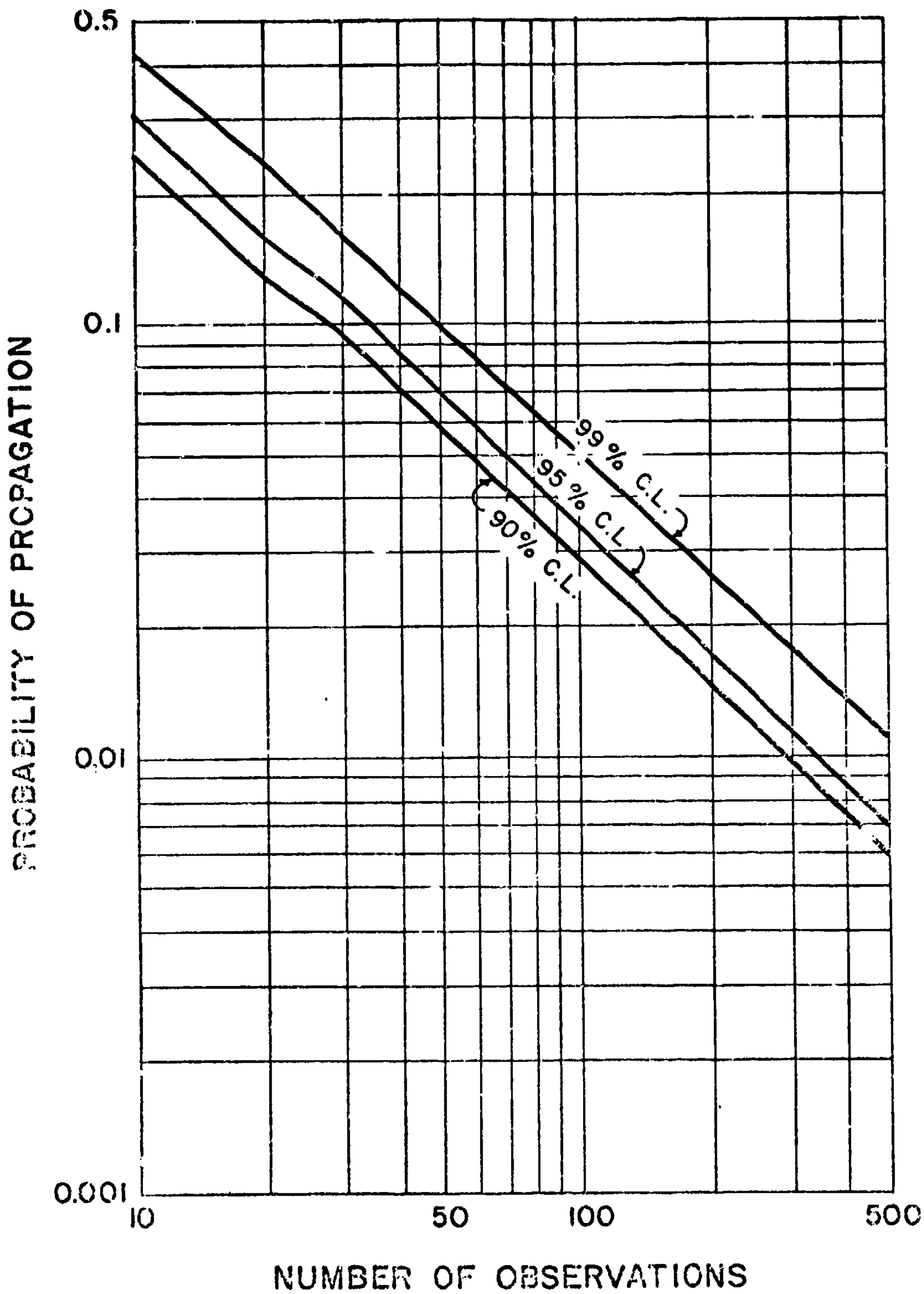

Fig 13 - Variation of propagation probability versus number of observations as a function of confidence level

APPENDIX

STATISTICAL EVALUATION OF EXPLOSION PROPAGATION

APPENDIX

STATISTICAL EVALUATION OF EXPLOSION PROPAGATION

Statistical Theory

An attempt was made in the main body of this report to evaluate the possibility of the occurrence of explosion propagation based upon a statistical analysis of the test results. This section of the report is devoted to mathematical means by which the statistical analysis was performed.

The probability of the occurrence of an explosion propagation is dependent upon the degree of certainty or confidence level involved and has upper and lower limits. The lower limit for all confidence levels is zero; whereas the upper limit is a function of the number of observations or, in this particular case, the number of acceptor items tested. Since each observation is independent of the others and each observation has a constant probability of a reaction occurrence (explosion propagation), the number of reactions (x) in a given number of observations (n) will have a binomial distribution. Therefore, the estimate of the probability (p) of a reaction occurrence can be represented mathematically by:

$$p = x/n \qquad \text{Eq. 1}$$

and, therefore, the expected value of (x) is given by:

$$E(x) = np \qquad \text{Eq. 2}$$

Each confidence level will have a specific upper limit (p_2) depending upon the number of observations involved. The upper probability limit for a given confidence level α, when a reaction is not observed, is expressed as:

$$(1 - p_2)^n = \varepsilon \qquad \text{Eq. 3}$$

where $\varepsilon = (1 - \alpha)/2$ and $\alpha < 1.0$ Eq. 4

Use of Equation 3 is illustrated in the following example:

Example

Determine the upper probability limit of the occurrence of an explosion propagation for a confidence level of 95 percent based upon 30 observations without a reaction occurrence.

Given

Number of Observations (n) = 30
Confidence level (α) = 95 percent

Solution

1. Substitute the given value of (α) into Equation 4 and solve for ε:

   $$\varepsilon = (1 - \alpha)/2 = (1 - 0.95)/2 = 0.025$$

2. Substitute the given value of (n) and value of (ε) into Equation 3 and solve for p_2:

   $$\varepsilon = 0.025 = (1 - p_2)^{30}$$

   or

   $$p_2 = 0.116 \text{ (11.6 percent)}$$

Conclusions

For a 95 percent confidence level and 30 observations, the true value of the probability of explosion propagation will fall between zero and 0.116; or statistically, it can be interpreted that in 30 observations, a maximum of 3.48 (0.116 x 30) observations could result in a reaction for a 95 percent confidence level.

Probability Table

Table A-1 shows the probability limits and the range of the expected value E(x) for different numbers of observations. Three confidence limits, 90, 95 and 99 percent, are used to derive the probabilities.

TABLE A-1

Probabilities of Propagation for Various Confidence Limits

Number of Observations n	90 percent p_2	C.L. E(x)	95 percent p_2	C.L. E(x)	99 percent p_2	C.L. E(x)
10	0.259	2.59	0.308	3.08	0.411	4.11
20	0.131	2.62	0.168	3.36	0.233	4.66
30	0.095	2.85	0.116	3.48	0.162	4.86
40	0.072	2.88	0.088	3.52	0.124	4.96
50	0.058	2.9	0.071	3.55	0.101	5.05
60	0.049	2.92	0.060	3.6	0.085	5.10
80	0.037	2.96	0.045	3.6	0.064	5.12
100	0.030	3.0	0.036	3.6	0.052	5.2
200	0.015	3.0	0.018	3.6	0.026	5.2
300	0.010	3.0	0.012	3.6	0.018	5.4
500	0.006	3.0	0.007	3.5	0.011	5.5

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