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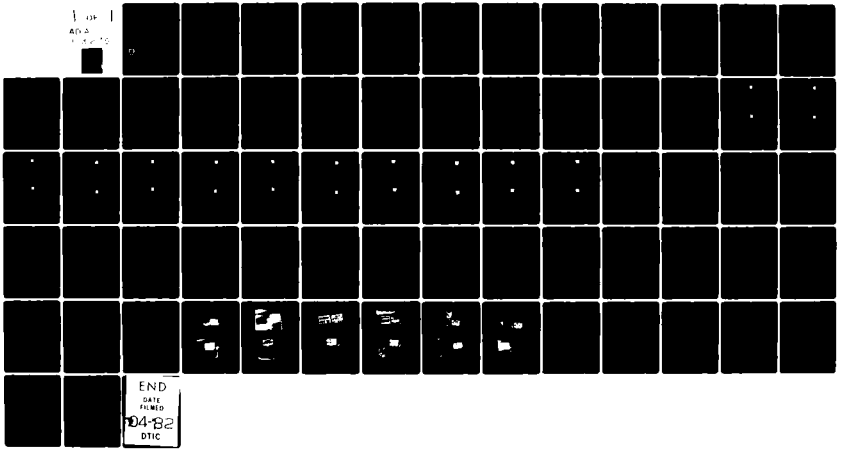

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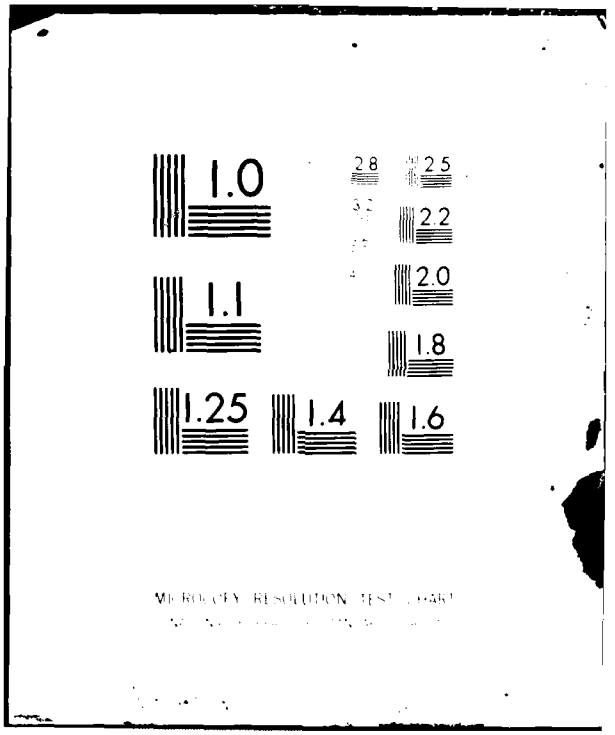
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TNT EQUIVALENCY OF CYCLOTOL 70/30

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Peak side-on blast overpressure and scaled positive impulse were measured for Cyclotol 70/30 using configurations that simulate in-plant processing and shipping containers. The equivalency testing addressed the hopper configuration at the end of the casting belt, transfer box, and shipping container, typical in a manufacturing facility. High explosive equivalency values for each test series were obtained as a function of scaled distance by comparison to known pressure and impulse characteristics for TNT surface bursts.		

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SUMMARY

Cyclotol 70/30, a high explosive with a nominal composition of 70 percent RDX and 30 percent TNT, was detonated in configurations representative of the hopper configuration at the end of the casting belt, the transfer box, and shipping container typical in a manufacturing facility. Blast output parameters were measured. The airblast overpressure and impulse data were compared with a standard hemispherical TNT curve to determine equivalency. The results of these tests are presented in the table below.

The pressure equivalencies were greater than 100 percent at the near-field scaled distances $\leq$ 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) for all configurations, and varied above and below 100 percent at the far-field scaled distances $\geq$7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$). Impulse equivalencies varied for each test series and were greater than 100 percent for all configurations at scaled distances $<$ 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) and varied above and below 100 percent at scaled distances $\geq$ 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$). Test results indicated that pressure and impulse values were dependent on geometry and scaled according to the cube root of the charge weight.

Configuration	TNT Equivalency (Percent) at Scaled Distance											
	1.19 m/kg$^{1/3}$ (3.0 ft/lb$^{1/3}$)		1.59 m/kg$^{1/3}$ (4.0 ft/lb$^{1/3}$)		2.14 m/kg$^{1/3}$ 5.4 ft/lb$^{1/3}$		3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$)		7.14 m/kg$^{1/3}$ (18.0 ft lb$^{1/3}$)		15.87 m kg$^{1/3}$ (40.0 ft lb$^{1/3}$)	
	P	I	P	I	P	I	P	I	P	I	P	I
Shipping Container 13.61 kg (30 lb.)	353	327	391	210	290	203	159	92	98	111	[illegible]	[illegible]
Shipping Container 27.22 kg (60 lb.)	564	356	430	197	279	185	151	116	93	[illegible]	[illegible]	[illegible]
Transfer Box 45.36 kg (100 lb.)	445	248	365	189	319	186	165	105	136	81	136	[illegible]
Transfer Box 68.04 kg (150 lb.)	563	295	642	246	342	183	179	91	111	[illegible]	161	126
Wood Hopper 45.36 kg (100 lb.)	657	356	874	466	585	395	216	133	168	[illegible]	[illegible]	[illegible]
Wood Hopper 68.04 kg (150 lb.)	630	362	904	298	588	324	231	141	154	71	[illegible]	112

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TABLES

FIGURES

INTRODUCTION

Tests were conducted under Project No. 5794285 TNT Equivalency as an engineering effort to provide TNT equivalency data in support of Project 5863000B(RDX Special Products Facility).

Cyclotol 70/30 is a high explosive with a nominal composition of 70 percent RDX and 30 percent TNT. The TNT equivalency tests covered those configurations which are encountered at sensitive locations of the explosive manufacturer's facility. These configurations are the hopper configuration at the end of the casting belt, the transfer box, and the shipping container, typical of a manufacturing facility. The amounts of Cyclotol 70/30 in these configurations are 113.4 kg (250 lb), 635.03 kg (1400 lb), and 27.22 kg. (60 lb), respectively. The large weight contained in the hopper configuration and the transfer box configuration was scaled down for these tests. The explosive is found in the manufacturer's plant in both wet and dry conditions. Since the dry condition is more sensitive than the wet, only the dry condition was tested.

The objective of this work was to determine the maximum output from the detonation of Cyclotol 70/30 explosive in terms of the peak airblast overpressure and positive impulse. The measured pressure and impulse data were compared with known TNT test data (curves), to determine the equivalency of Cyclotol 70/30 in relation to TNT.

EXPERIMENTAL METHODS

MATERIALS

The test material was Cyclotol 70/30 Type II, Class A, Lot Number HOL 79G 795-003, Batch numbers 46, 47, 48 and 49. The explosive was received from Holston Army Ammunition Plant in standard shipping containers of 27.22 kg (60 lb) net weight.

TEST PLAN

Airblast output was evaluated for weights and configurations of Cyclotol 70/30 representing bulk Cyclotol in a shipping box, transfer box and a hopper configuration. Physical characteristics of the test items are as follows:

(1) The orthorhombic shipping container was tested with a linear dimensional scaling factor of 0.79 and in the full-scale linear dimension. The boxes were fabricated and filled with 13.61 kg (30 lb) and 27.22 kg (60 lb) of Cyclotol 70/30 respectively. These containers are represented in figures 1a and 1b.

(2) The fiberboard transfer box was tested with linear dimensional scaling factors of 0.41 and 0.47. The boxes were fabricated and filled with 45.36 kg (100 lb) and 68.04 kg (150 lb) respectively. These containers are represented in figures 1c and 1d.

(3) The simulated wood hopper was tested with linear dimensional scaling factors of 0.73 and 0.84. The simulated wood hoppers were fabricated from plywood and filled with 45.36 kg (100 lb) and 68.04 kg (150 lb) respectively. These containers are represented in figures 1e and 1f.

A composition C4 conically shaped booster (aspect ratio 1:2 L/D) was centered on top of the shipping container and transfer box test charges. Boosters for the simulated wood hopper had an aspect ratio of 1:4 L/D and were similarly placed. The size of the booster was 2 percent of the charge weight. The booster was initiated with an engineers special J2 blasting cap inserted at the apex and embedded to the center of the cone.

The test charges in each configuration were placed on a 1010 carbon steel witness plate 1.27 cm (0.5 in.) thick with the dimensions being at least 5.08 cm (2 in.) larger than the base of the test configuration dimension.

INSTRUMENTATION

Twelve PCB Piezotronics side-on pressure transducers were mounted flush to the surface in each of two sand-filled arrays within the test area shown in figure 2. Distances from the charge to the transducer corresponded to scaled distances from 1.19 to 15.87 $m/kg^{1/3}$ (3 to 40 $ft/lb^{1/3}$). The transducers were individually calibrated prior to the beginning of each test series with pressure pulses from a standard solenoid-actuated air pressure calibration fixture, adjusted to correspond to expected blast pressure based on an assumed TNT equivalency of 100 percent. Signal line continuity and channelization were checked prior to each test along with a daily electrical calibration of the recording system. Details of distances between charge and transducers, calibration pressure, and expected peak blast pressure at each distance are shown in table 1.

Photographic coverage was restricted to two tests of each configuration (figure 2). Motion picture coverage included a Mitchell camera Model 11516-E4 operating at 500 frames per second (fps) and one Mitchell camera (same model) operating at 24 fps. Before and after color still photographs were taken of each test showing typical setup and results. Standard meteorological data were recorded for each test.

RESULTS

DATA ANALYSIS

Peak blast overpressure and positive impulse information were obtained in digital form. The mean and standard deviation were then obtained and all data which fell outside two standard deviations were excluded from the TNT equivalency calculations. The data were then compared to data from TNT hemispheres.[1] A computer program was employed which utilizes an iterative process that factors out the contribution of the booster charge weight and calculates the pressure and impulse equivalencies.[2] The calculated TNT equivalencies were arranged in tabular form and also plotted as functions of sample scaled distance. The standard curve for TNT hemisphere reference data is shown in Figure 3.

TEST RESULTS

Data sheets for all tests with pertinent measured parameters are given in Appendix A. Selected pretest and posttest still photographs are given in Appendix B. Test numbers shown are for local reference only and provide access to original range data files.

Mean pressure, scaled positive impulse, and TNT equivalency data are summarized by test configuration in Tables 2 through 7. Figures 4, 6, 8, 10, 12, and 14 show the plots of peak pressure and scaled positive impulse versus scaled distance. Figures 5, 7, 9, 11, 13, and 15 show the plots of TNT equivalency versus scaled distance for peak pressure and scaled positive impulse by test configuration. The deviation from cube root scaling is shown in Figure 16. Fireball diameter and duration, as measured from the high speed motion pictures, are given in Table 8.

DISCUSSION

Plots of peak pressure and scaled positive impulse for the scaled shipping container are shown in Figure 4. The plots of TNT equivalencies for pressure and scaled impulse are shown in Figure 5. Pressure values were greater than expected, except at the scaled distance of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). Pressure equivalencies were greater than 100 percent, except at the scaled distance of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) where the value was 98 percent. At a near-field value of 1.59 $m/kg^{1/3}$ (4.0 $ft/lb^{1/3}$), the pressure equivalency was 391 percent for the highest value, ranging to a low of 98 percent at the far-field value of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and increasing to 197 percent at the scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). Scaled impulse values were greater than expected, except at the scaled distance of 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). Scaled impulse equivalencies were greater than 100 percent, except at the scaled distance of 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$) where the value was 92 percent. At a near-field value of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$), the impulse equivalency was 327 percent for the highest value, ranging to a low of 92 percent at the scaled distance of 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$ and increasing to a value of 119 percent at a scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$).

Plots of peak pressure and scaled positive impulse for the original shipping container are shown in figure 6. The plots of TNT equivalencies for pressure and scaled impulse are shown in Figure 7. Pressure values were greater than expected, except at the far-field scaled distance of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). Pressure equivalency values were greater than 100 percent, except at the scaled distance of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) where the value was 93 percent. At a near-field value of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$) the pressure equivalency value was 564 percent for the highest value, ranging to a low of 93 percent at a far-field scaled distance of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). Scaled impulse values were greater than expected at all scaled distances. Impulse equivalency values were greater than 100 percent at all scaled distances. At a near-field value of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$), the impulse equivalency was 356 percent for the highest value, ranging to a low of 116 percent at a scaled distance of 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$) and increasing to a value of 173 percent at a scaled distance of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$).

The plots of peak pressure and scaled positive impulse for the 13.61 kg (30 lb) charge and the 27.22 kg (60 lb) charge show the same general trend. The plots of TNT equivalency values for pressure and scaled positive impulse show the same general trend. At the close-in scaled distance of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$), the pressure values for the 27.22 kg (60 lb) charge was significantly higher than for the 13.61 kg (30 lb) charge. This is consistent with high explosives where the pressure differences are greater close to the charge and diminish as the distance increases.

Plots of peak pressure and scaled positive impulse for the scaled fiberboard transfer box for a charge weight of 45.36 kg (100 lb) are shown in Figure 8. The plots of TNT equivalencies for pressure and scaled impulse are shown in Figure 9. Pressure values were greater than expected at all scaled distances. Pressure equivalency values were greater than 100 percent at all scaled distances. At a near-field value of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$), the pressure equivalency was 445 percent for the highest value, ranging to a low of 136 percent at the far-field scaled distances of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). Scaled impulse values were greater than expected, except at the far-field scaled distances of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). Impulse equivalency values were greater than 100 percent, except at the scaled distances of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$) where the values were 81 percent and 97 percent. At a near-field value of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$), the impulse equivalency was 248 percent for the highest value, ranging to a low of 81 percent at the far-field value of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$).

Plots of peak pressure and scaled positive impulse for the scaled fiberboard transfer box for a charge weight of 68.04 kg (150 lb) are shown in Figure 10. The plots of TNT equivalencies for pressure and scaled positive impulse are shown in Figure 11. Pressure values were greater than expected at all scaled distances. Pressure equivalency values were greater than 100 percent at all scaled distances. At a near-field value of 1.59 $m/kg^{1/3}$ (4.0 $ft/lb^{1/3}$), the pressure equivalency was 642 percent for the highest value, ranging to a low of 111 percent at a far-field scaled distance of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and increasing to a value of 161 percent at a far-field scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). Scaled impulse values were greater than expected, except at the scaled distances of 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$) and 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$ where the values were 91 percent and 77 percent. At a near-field value of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$), the impulse equivalency was 295 percent

for the highest value, ranging to a low of 77 percent at the far-field scaled distance of 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) and increasing to a value of 126 percent at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$).

The plots of peak pressure and scaled positive impulse versus scaled distance for the 45.36 kg (100 lb) and 68.04 kg (150 lb) charges show the same general trend. The plots of TNT equivalency values for pressure and scaled positive impulse show the same general trend. At the close-in scaled distances of 1.19 m/kg$^{1/3}$ (3.0 ft/lb$^{1/3}$) and 1.59 m/kg$^{1/3}$ (4.0 ft/lb$^{1/3}$), the pressure values for the 68.04 kg (150 lb) charge were greater than for the 45.36 kg (100 lb) charge. This is consistent with high explosives where the pressure differences are greater close to the charge and diminish as the distance increases.

Plots of peak pressure and scaled positive impulse for the simulated wood hopper for a charge weight of 45.36 kg (100 lb) are shown in Figure 12. The plots of TNT equivalencies for pressure and scaled impulse are shown in Figure 13. Pressure values were greater than expected, except at a far-field scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). Pressure equivalency values were greater than 100 percent, except at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$) where the value was 94 percent. At a close-in scaled distance of 1.59 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$), the pressure equivalency was 874 percent for the highest value, ranging to a low of 94 percent at a far-field scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). Scaled impulse values were greater than expected, except at a scaled distance of 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$). Impulse equivalency values were greater than 100 percent, except at the far-field scaled distance of 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) where the value was 57 percent. At a close-in scaled distance of 1.59 m/kg$^{1/3}$ (4.0 ft/lb$^{1/3}$), the impulse equivalency was 466 percent for the highest value, ranging to a low of 57 percent at a far-field scaled distance of 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$), and then increasing to a value of 147 percent at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$).

Plots of peak pressure and scaled positive impulse for the simulated wood hopper for a charge weight of 68.04 kg (150 lb) are shown in Figure 14. The plots of TNT equivalencies for pressure and scaled impulse are shown in Figure 15. Pressure values were greater than expected, except at a far-field scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). Pressure equivalency values were greater than 100 percent, except at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$) where the value was 94 percent. At a close-in scaled distance of 1.59 m/kg$^{1/3}$ (4.0 ft/lb$^{1/3}$), the pressure equivalency was 904 percent for the highest value, ranging to a low of 94 percent at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). The scaled impulse values were greater than expected, except at a scaled distance of 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$). Impulse equivalency values were greater than 100 percent at the far-field scaled distance of 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) where the value was 71 percent. At a close-in scaled distance of 1.19 m/kg$^{1/3}$ (3.0 ft/lb$^{1/3}$), the impulse equivalency was 362 percent for the highest value, ranging to a low of 71 percent at a scaled distance of 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) and increasing to a value of 112 percent at the far-field scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$).

The plots of peak pressure and scaled positive impulse versus scaled distance for the 45.36 kg (100 lb) charge and 68.04 kg (150 lb) charge in a simulated wood hopper show the same general trend. The plots of TNT equivalency values for pressure and scaled positive impulse show the same

general trend. Peak pressure and scaled positive impulse were greater in the direction normal to the long side of the hopper, but not enough of a significant difference existed to separate them into an odd gage/even gage relationship. The high equivalency values are consistent with tests performed on Octol 75/25[3] in the same hopper configuration.

Figure 16 shows the deviation from cube root scaling as a function of the charge weight. Theoretically, a given output will occur at a distance from an explosion that is proportional to the cube root of the energy yield (known as cube root scaling or Hopkinson's Scaling).[4] With the aid of such a law, it is possible to present data for a large range of weights in a single form, and by the use of scaled distances, one is able to calculate properties of an explosion of any given energy if those for another energy are known. By the use of cube root scaling, one can determine if output is increasing or decreasing with charge weight. To what degree the output is increasing or decreasing can be determined by performing a least squares linear regression analysis which is designed to minimize the sum of the squares of the deviations of the actual data points from the straight line of best fit. A slope of 1.00 for this line would indicate, by definition, that the data scales. An increase in output with increasing charge weight would be indicated by a positive slope. A decrease in output with increasing charge weight would be indicated by a negative slope. Equal rise or fall in the slope of the line indicates equal percentage changes. For Cyclotol 70/30 explosive, the slopes of the line for deviation from "cube root scaling" for peak pressure at each scaled distance, as a function of charge weight, ranged from a negative slope of 0.9979 to a positive slope of 1.0043. The slopes of the line for deviation from "cube root scaling" for scaled positive impulse at each scaled distance, as a function of charge weight, ranged from a negative slope of 0.9966 to a positive slope of 1.0018.

All of the information presented in this report is based on experimental data. As with any result based on experimental data, there is an inherent scatter involved; that is, the curves and tables presented represent the "best fit" or average values of the data, with some associated error band.

CONCLUSIONS

1. Cyclotol 70/30, when detonated, can generate peak pressure and positive impulse values which are greater than those produced from an equivalent weight of TNT.

2. The blast output from Cyclotol 70/30 is dependent upon the configuration from which it detonates.

3. TNT equivalency values were determined for Cyclotol 70/30 in three configurations that simulate in-plant processing and shipping containers.

4. To within experimental limits, blast pressure and impulse scale as a cube root function of the charge weight.

RECOMMENDATIONS

1. In order to design meaningful experiments and for the resulting data to be intelligently applied, it is important that the many factors and parameters that affect the airblast be recognized and the data be used in the context in which they were derived.

2. The TNT equivalency of pressure and impulse values determined by this test series should be used in the structural design of protective facilities.

3. The high equivalency values obtained for the simulated wood hopper indicate the need for **further testing of different hopper configurations for improved safety.**

4. Flaked TNT should be tested in configurations that simulate in-plant processing and shipping containers to establish a standard for the explosives of a flake-type physical characteristic.

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2. Gary L. McKown, Darl E. Westover, "TNT Equivalency of R284 Tracer Composition, I559 Igniter Mix, and I560 Subigniter Mix," Technical Report ARLCD-TR-79026, ARRADCOM, Dover, NJ, August 1979.

3. Larry Mars, Darl E. Westover, "TNT Equivalency of Octol 75/25," ARRADCOM Contractor Report, in press.

4. B. Hopkinson, 1915 British Ordnance Board Minutes 13565.

Table 1. Transducer calibration and placement for Cyclotol 70/30 equivalency testing

Channel number	Scaled distance $m/kg^{1/3}$ ($ft/lb^{1/3}$)	Full-Scale calibration pressure kPa (psi)	Expected pressure kPa (psi)	R_1 distance in meters (ft) from charge			
				Charge weight 13.61 kg (30 lb)	Charge weight 27.22 kg (60 lb)	Charge weight 45.36 kg (100 lb)	Charge weight 68.04 kg (150 lb)
1	1.19	2068.5	922	2.84	3.58	4.24	4.86
2	(3.0)	(300.0)	(133.71)	(9.32)	(11.745)	(13.92)	(15.94)
3	1.59	1034.3	479.8	3.79	4.77	5.66	6.48
4	(4.0)	(150.0)	(69.58)	(12.43)	(15.66)	(18.57)	(21.25)
5	2.14	517.2	242.5	5.12	6.44	7.64	8.75
6	(5.4)	(75.0)	(35.17)	(16.78)	(21.14)	(25.06)	(28.69)
7	3.57	103.4	81.5	8.53	10.74	12.73	14.58
8	(9.0)	(15.0)	(11.82)	(27.97)	(35.234)	(41.77)	(47.82)
9	7.14	34.5	24.07	17.05	21.48	25.47	29.15
10	(18.0)	(5.0)	(3.49)	(55.93)	(70.468)	(83.55)	(95.64)
11	15.9	13.8	8.14	37.89	47.73	56.59	64.79
12	(40.0)	(2.0)	(1.18)	(124.29)	(156.595)	(185.66)	(212.53)

Table 2. Summary of test results 13.61 kg (30 lb) charge Cyclotol 70/30 fiberboard shipping container

Radius Meters (ft)	Scaled Distance $M/kg^{1/3}$ ($ft/lb^{1/3}$)	Peak Pressure kPa (psi)	Scaled Positive Impulse $kPa.ms/kg^{1/3}$ ($psi\ ms/lb^{1/3}$)	Pressure TNT Equivalency %	Impulse TNT Equivalency %
2.84 (9.32)	1.19 (3.0)	2298.3 (333.33)	349.5 (38.05)	353	327
3.79 (12.43)	1.59 (4.0)	1312.2 (190.29)	210.2 (23.42)	391	210
5.12 (16.78)	2.14 (5.4)	543.0 (78.74)	161.0 (17.94)	290	203
8.53 (27.97)	3.57 (9.0)	113.2 (16.42)	65.8 (7.33)	159	92
17.05 (55.93)	7.14 (18.0)	23.7 (3.43)	40.1 (4.47	98	111
37.89 (124.29)	15.87 (40.0)	10.8 (1.57	19.5 (2.17)	197	119

Table 3. Summary of test results 27.22 kg (60 lb) charge Cyclotol 70/30 fiberboard shipping container

Radius Meters (ft)	Scaled Distance $M/kg^{1/3}$ ($ft/lb^{1/3}$)	Peak Pressure kPa (psi)	Scaled Positive Impulse $kPa.ms/kg^{1/3}$ ($psi\ ms/lb^{1/3}$)	Pressure TNT Equivalency %	Impulse TNT Equivalency %
3.58 (11.745)	1.19 (3.0)	3240.1 (469.87)	369.0 (41.11)	564	356
4.77 (15.66)	1.59 (4.0)	1398.9 (202.87)	202.9 (22.61)	430	197
6.44 (21.14)	2.14 (5.4)	519.8 (75.38)	154.0 (17.16)	279	185
10.74 (35.234)	3.57 (9.0)	108.5 (15.74)	73.9 (8.24)	151	116
21.48 (70.468)	7.14 (18.0)	22.4 (3.25)	52.0 (5.80)	93	173
47.73 (156.595)	15.87 (40.0)	12.3 (1.78)	20.3 (2.26)	248	128

Table 4. Summary of test results 45.36 kg (100 lb) charge Cyclotol 70/30 fiberboard transfer box

Radius Meters (ft)	Scaled Distance $M/kg^{1/3}$ ($ft/lb^{1/3}$)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa.ms/$kg^{1/3}$ (psi ms/$lb^{1/3}$)	Pressure TNT Equivalency %	Impulse TNT Equivalency %
4.24 (13.92)	1.19 (3.0)	2737.6 (397.00)	298.0 (33.21)	445	248
5.66 (18.57)	1.59 (4.0)	1249.5 (181.20)	199.6 (22.24)	335	189
7.64 (25.06)	2.14 (5.4)	581.9 (84.39)	154.6 (17.23)	319	186
12.73 (41.77)	3.57 (9.0)	116.7 (16.92)	72.0 (8.02)	165	105
25.47 (83.55)	7.14 (18.0)	28.4 (4.12)	32.8 (3.66)	136	81
56.59 (185.66)	15.87 (40.0)	9.4 (1.37)	17.1 (1.91)	136	97

Table 5. Summary of test results 68.04 kg (150 lb) charge Cyclotol 70/30 fiberboard transfer box

Radius Meters (ft)	Scaled Distance $M/kg^{1/3}$ ($ft/lb^{1/3}$)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa.ms/$kg^{1/3}$ (psi ms/$lb^{1/3}$)	Pressure TNT Equivalency %	Impulse TNT Equivalency %
4.86 (15.94)	1.19 (3.0)	3255.9 (472.17)	327.6 (36.50)	563	295
6.48 (21.25)	1.59 (4.0)	1883.2 (273.10)	234.7 (26.15)	642	246
8.75 (28.69)	2.14 (5.4)	606.5 (87.96)	150.9 (16.81)	342	183
14.58 (47.82)	3.57 (9.0)	123.2 (17.87)	66.1 (7.36)	179	91
29.15 (95.64)	7.14 (18.0)	25.3 (3.67)	31.8 (3.54)	111	77
64.79 (212.53)	15.87 (40.0)	10.1 (1.46)	20.3 (2.26)	161	126

Table 6. Summary of test results 45.36 kg (100 lb) charge Cyclotol 70/30 simulated wood hopper

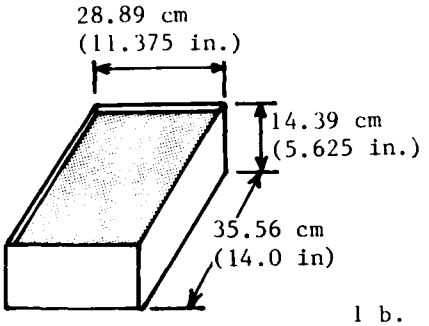
Radius Meters (ft)	Scaled Distance $M/kg^{1/3}$ ($ft/lb^{1/3}$)	Peak Pressure kPa (psi)	Scaled Positive Impulse $kPa.ms/kg^{1/3}$ ($psi\ ms/lb^{1/3}$)	Pressure TNT Equivalency %	Impulse TNT Equivalency %
4.24 (13.92)	1.19 (3.0)	3647.8 (529.00)	367.3 (40.92)	657	356
5.66 (18.57)	1.59 (4.0)	2353.9 (341.36)	343.8 (38.31)	874	466
7.64 (25.06)	2.14 (5.4)	910.3 (132.01)	243.5 (27.13)	585	395
12.73 (41.77)	3.57 (9.0)	141.4 (20.51)	81.3 (9.06)	216	133
25.47 (83.55)	7.14 (18.0)	32.0 (4.64)	26.1 (2.91)	168	57
56.59 (185.66)	15.87 (40.0)	8.0 (1.16)	22.3 (2.48)	94	147

Table 7. Summary of test results 68.04 kg (150 lb) charge Cyclotol 70/30 simulated wood hopper

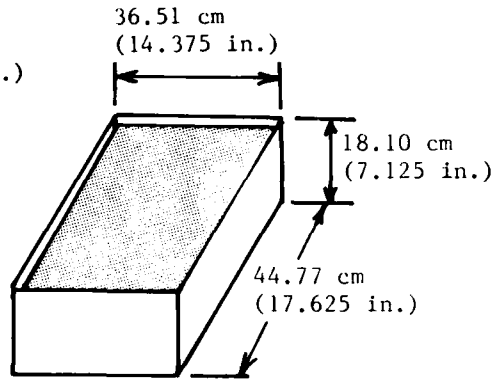
Radius Meters (ft)	Scaled Distance $M/kg^{1/3}$ ($ft/lb^{1/3}$)	Peak Pressure kPa (psi)	Scaled Positive Impulse $kPa.ms/kg^{1/3}$ ($psi\ ms/lb^{1/3}$)	Pressure TNT Equivalency %	Impulse TNT Equivalency %
4.86 (15.94)	1.19 (3.0)	3723.7 (540.00)	367.6 (40.96)	680	362
6.48 (21.25)	1.59 (4.0)	2437.4 (353.46)	264.0 (29.41)	904	298
8.75 (28.69)	2.14 (5.4)	909.2 (131.85)	216.6 (24.13)	588	324
14.58 (47.82)	3.57 (9.0)	151.0 (21.90)	81.0 (9.02)	237	131
29.15 (95.64)	7.14 (18.0)	30.4 (4.41)	29.7 (3.31)	154	71
64.79 (212.53)	15.87 (40.0)	8.0 (1.16)	18.7 (2.08)	94	112

Table 8. Fireball diameter and duration

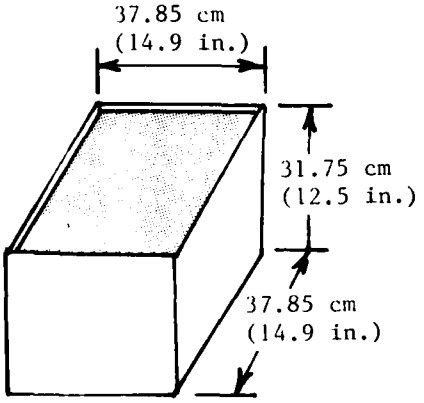
Charge weight kg (lb)	Maximum fireball diameter meters (ft)	Fireball duration msec
13.61 kg (30 lb) Shipping container	12.2 (40)	110
27.22 kg (60 lb) Shipping container	15.2 (50)	120
45.36 kg (100 lb) Transfer box	19.8 (65)	150
68.04 kg (150 lb) Transfer box	24.4 (80)	130
45.36 kg (100 lb) Wood hopper	18.3 (60)	150
68.04 kg (150 lb) Wood hopper	22.9 (75)	140



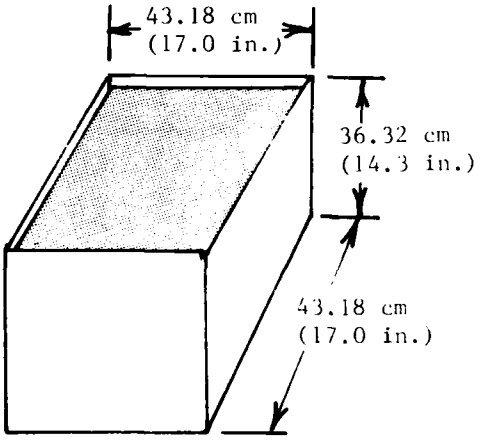
1 a. SCALED SHIPPING CONTAINER (13.61 kg; 30 lb.)



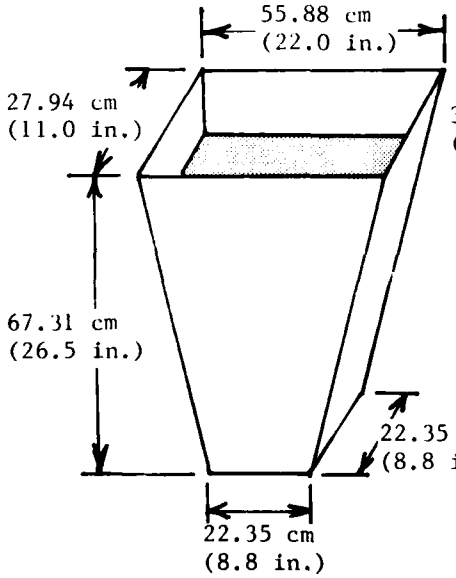
1 b. STANDARD SHIPPING CONTAINER (27.22 kg; 60 lb.)



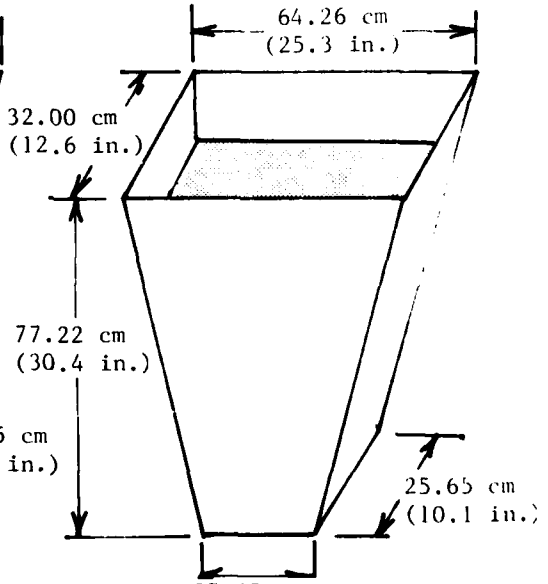
1 c. SCALED FIBERBOARD TRANSFER BOX
(45.36 kg; 100 lb.)



1 d. SCALED FIBERBOARD TRANSFER BOX
(68.04 kg; 150 lb.)



1 e. SCALED SIMULATED WOOD HOPPER
(45.36 kg; 100 lb.)



1 f. SCALED SIMULATED WOOD HOPPER
(68.04 kg; 150 lb.)

Figure 1. Test container configuration

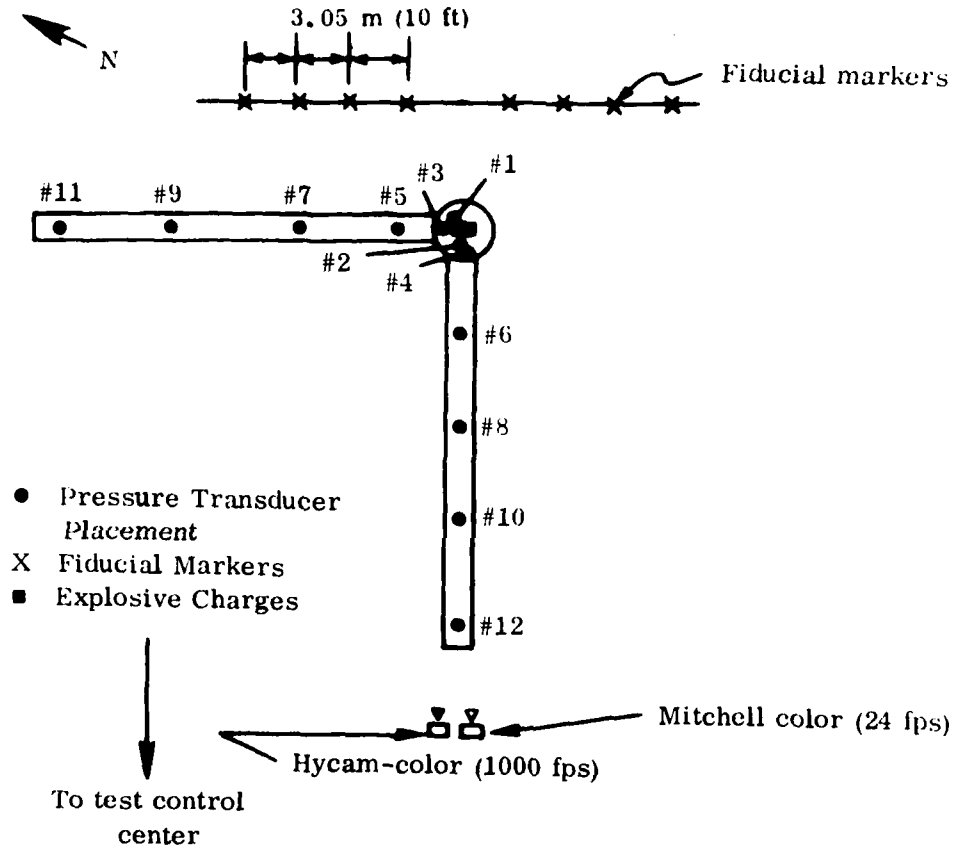


Figure 2. Test area showing charge placement, transducer placement and camera placement

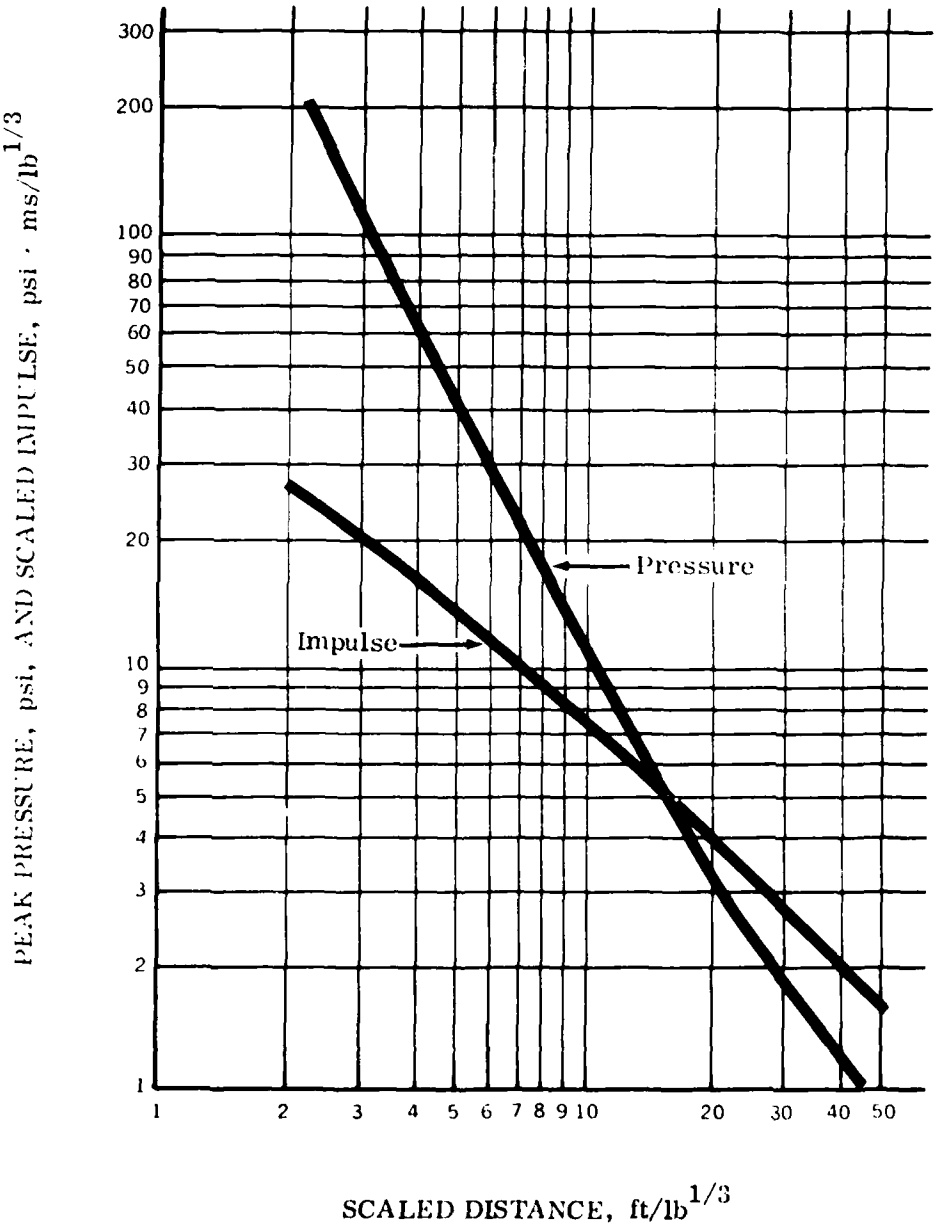


Figure 3. TNT hemisphere reference data

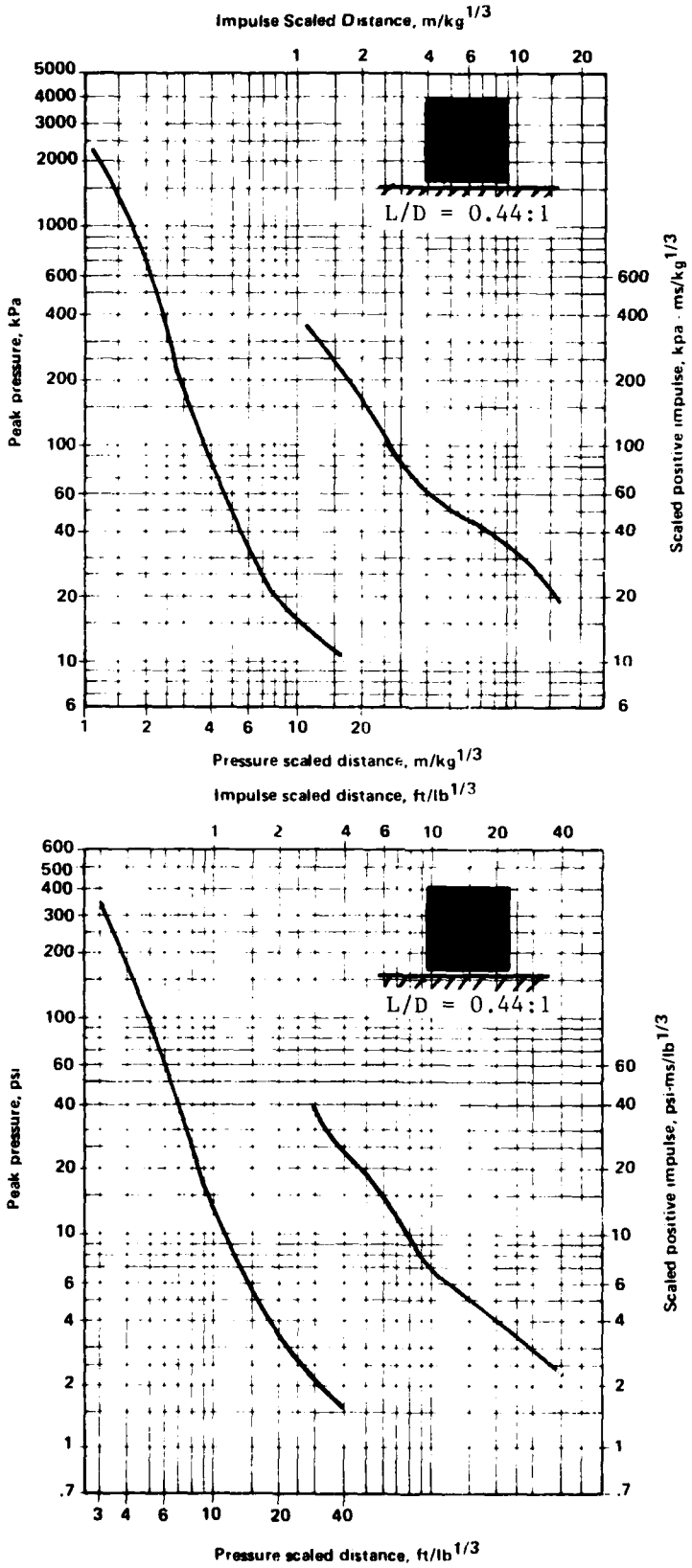
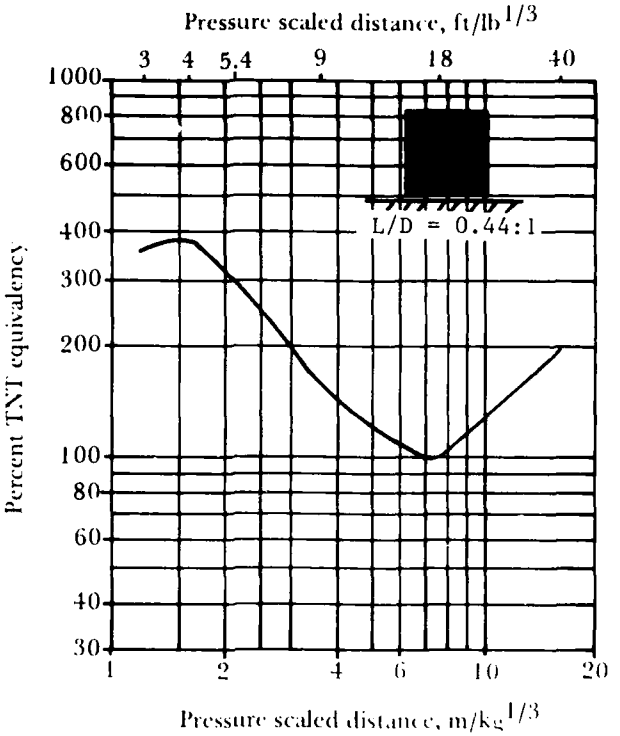


Figure 4. Pressure and impulse versus scaled distance for Cyclotol 70/30, 13.61 kg (30 lb) charge in fiberboard shipping container



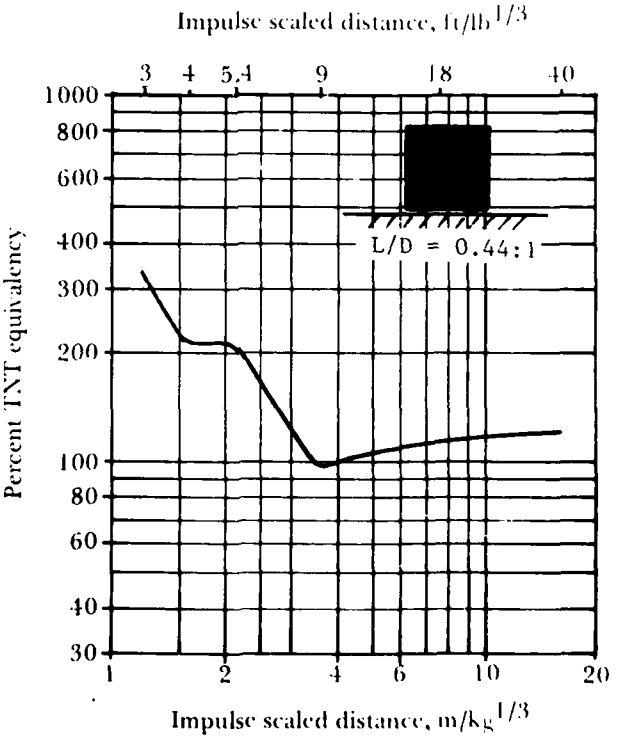


Figure 5. Pressure and impulse TNT equivalency for 13.61 kg (30 lb) fiberboard shipping container

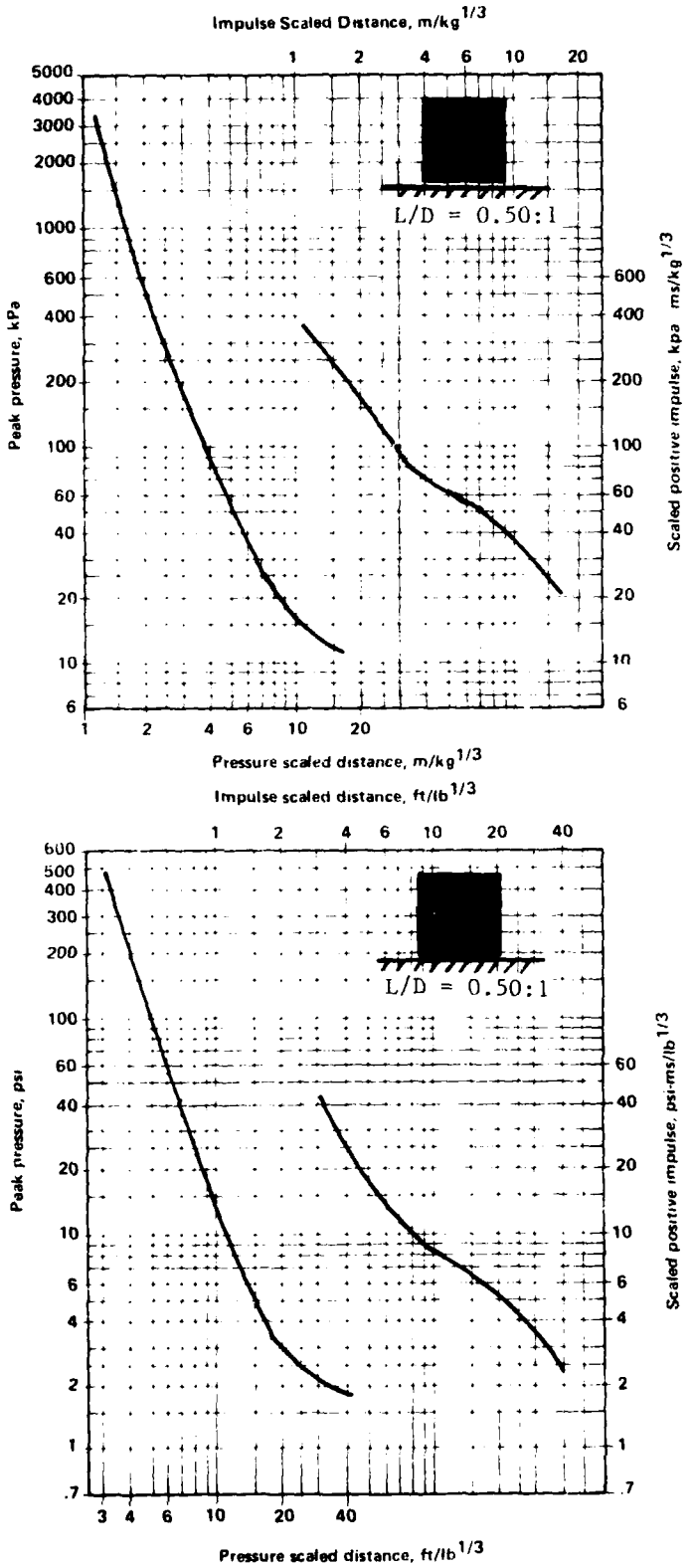
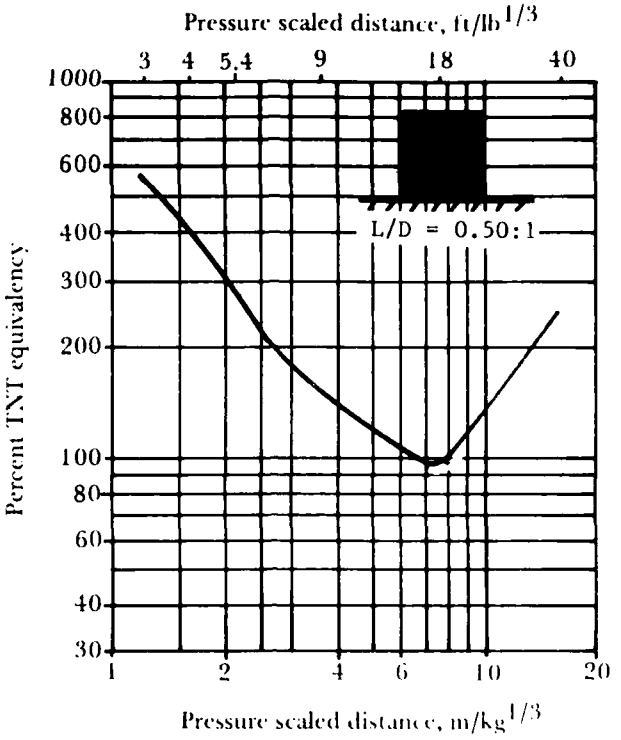


Figure 6. Pressure and impulse versus scaled distance for Cyclotol 70/30, 27.22 kg (60 lb) charge in fiberboard shipping container



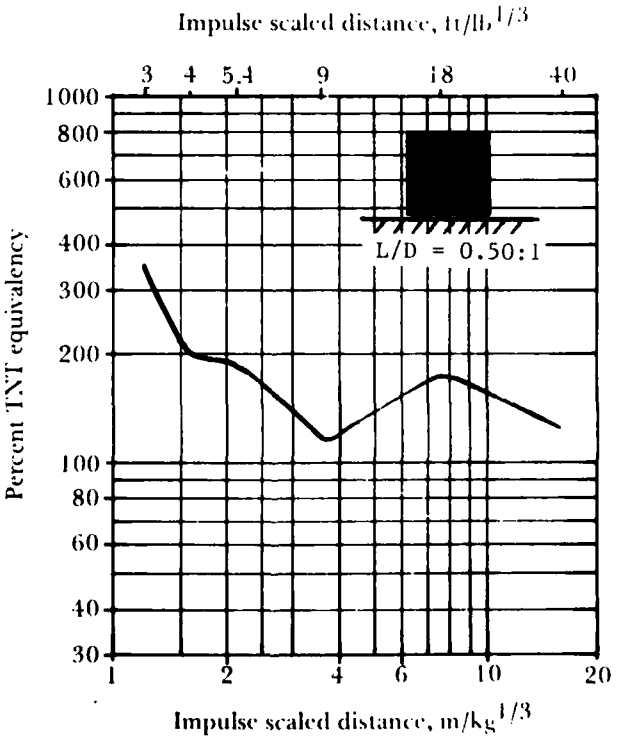


Figure 7. Pressure and impulse TNT equivalency for 27.22 kg (60 lb) fiberboard shipping container

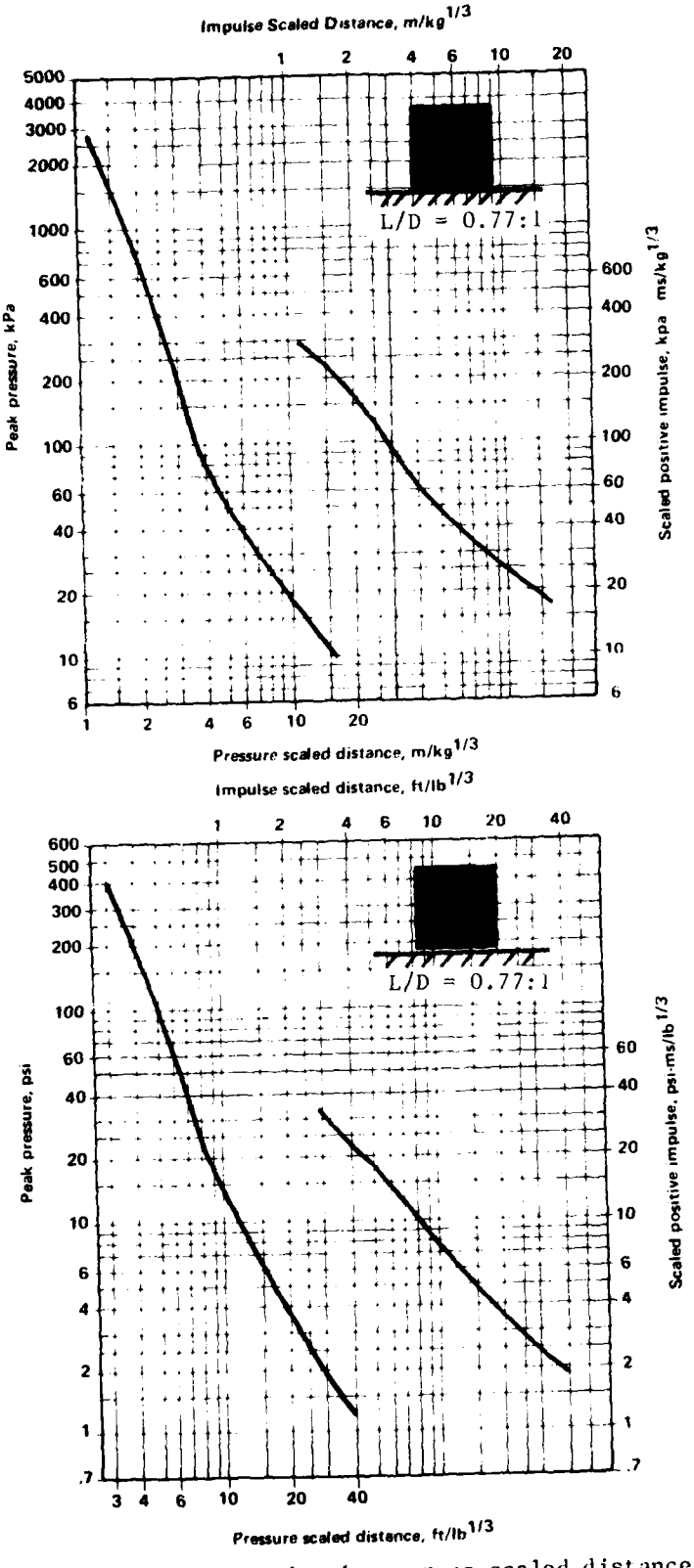


Figure 8. Pressure impulse versus scaled distance for Cyclotol 70/30, 45.36 kg (100 lb) charge in fiberboard transfer box

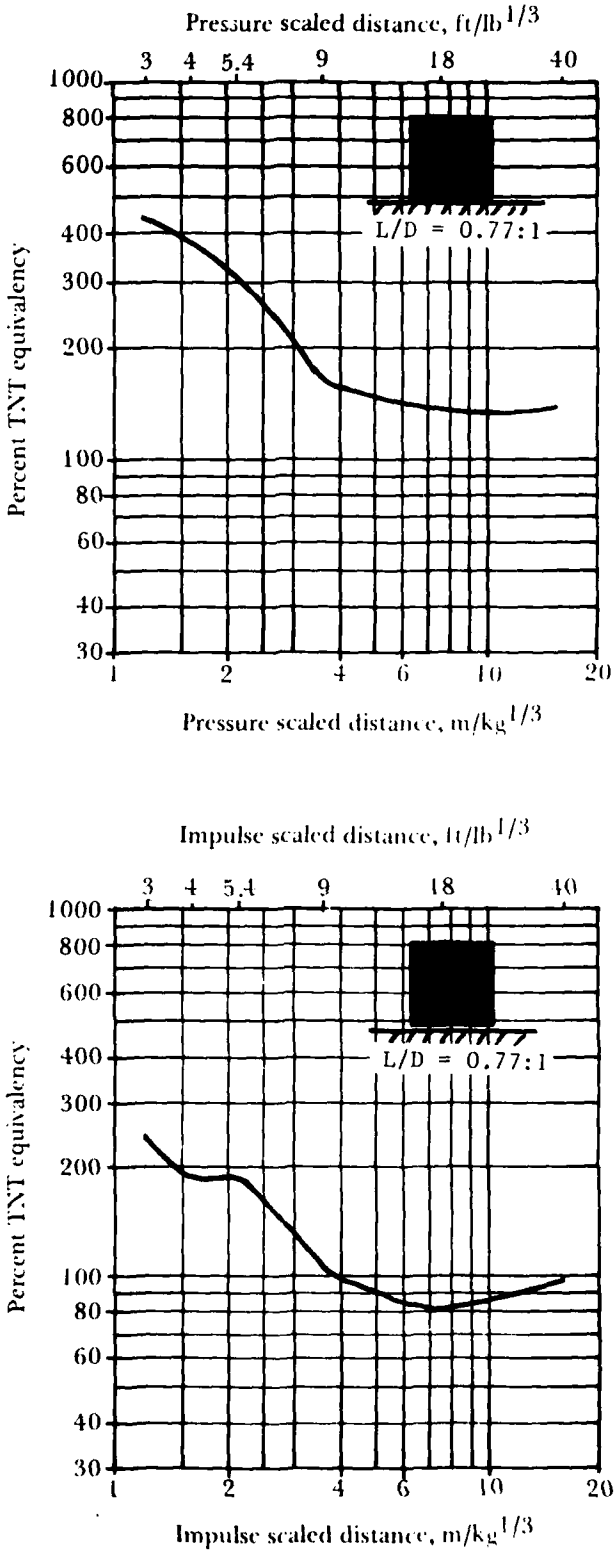


Figure 9. Pressure and impulse TNT equivalency for 45.36 kg (100 lb) fiberboard transfer box

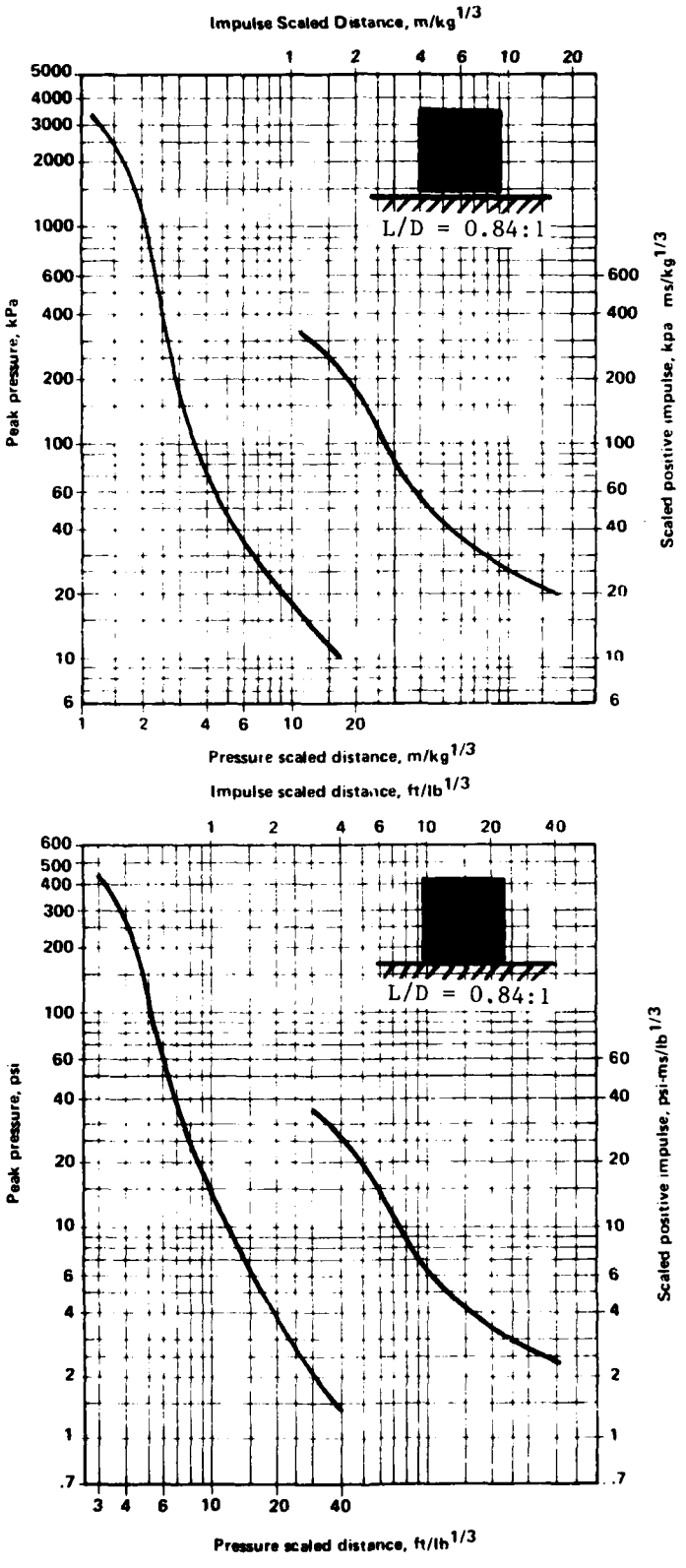
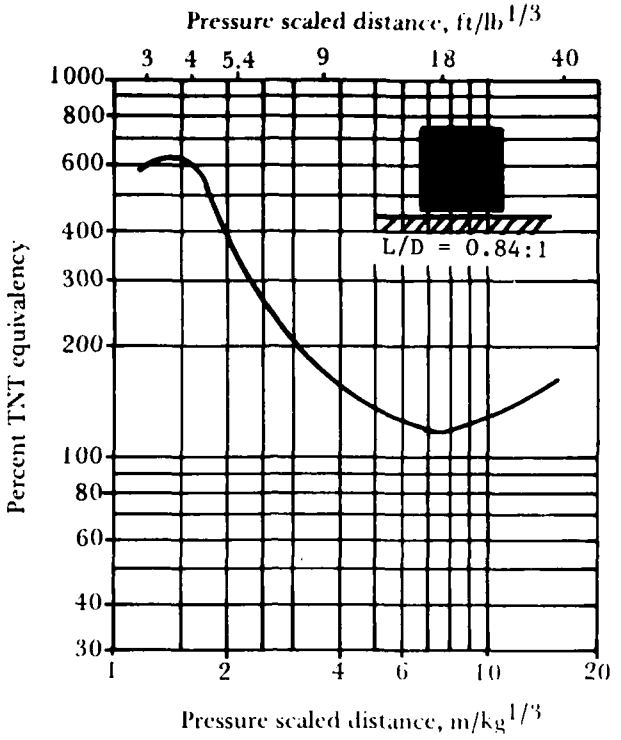


Figure 10. Pressure and impulse versus scaled distance for Cyclotol 70/30, 68.04 kg (150 lb) charge in fiberboard transfer box



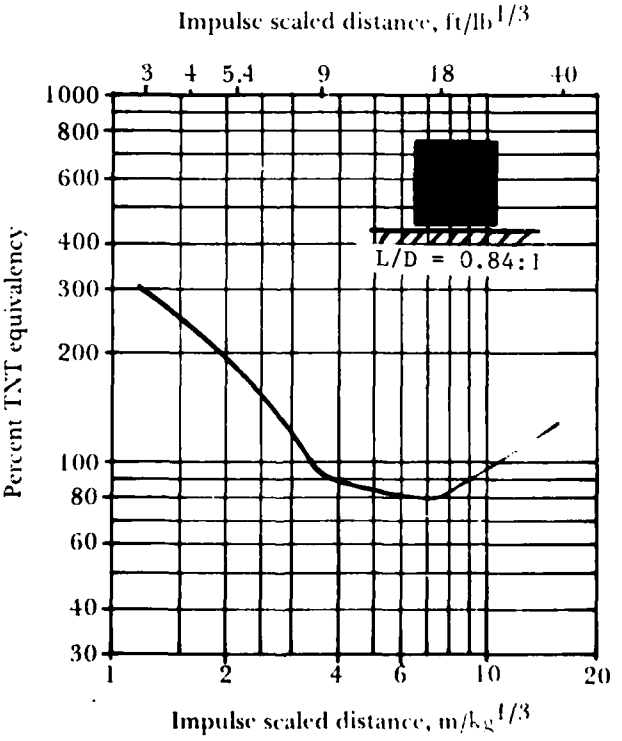


Figure 11. Pressure and impulse TNT equivalency for 68.04 kg (150 lb) fiberboard transfer box

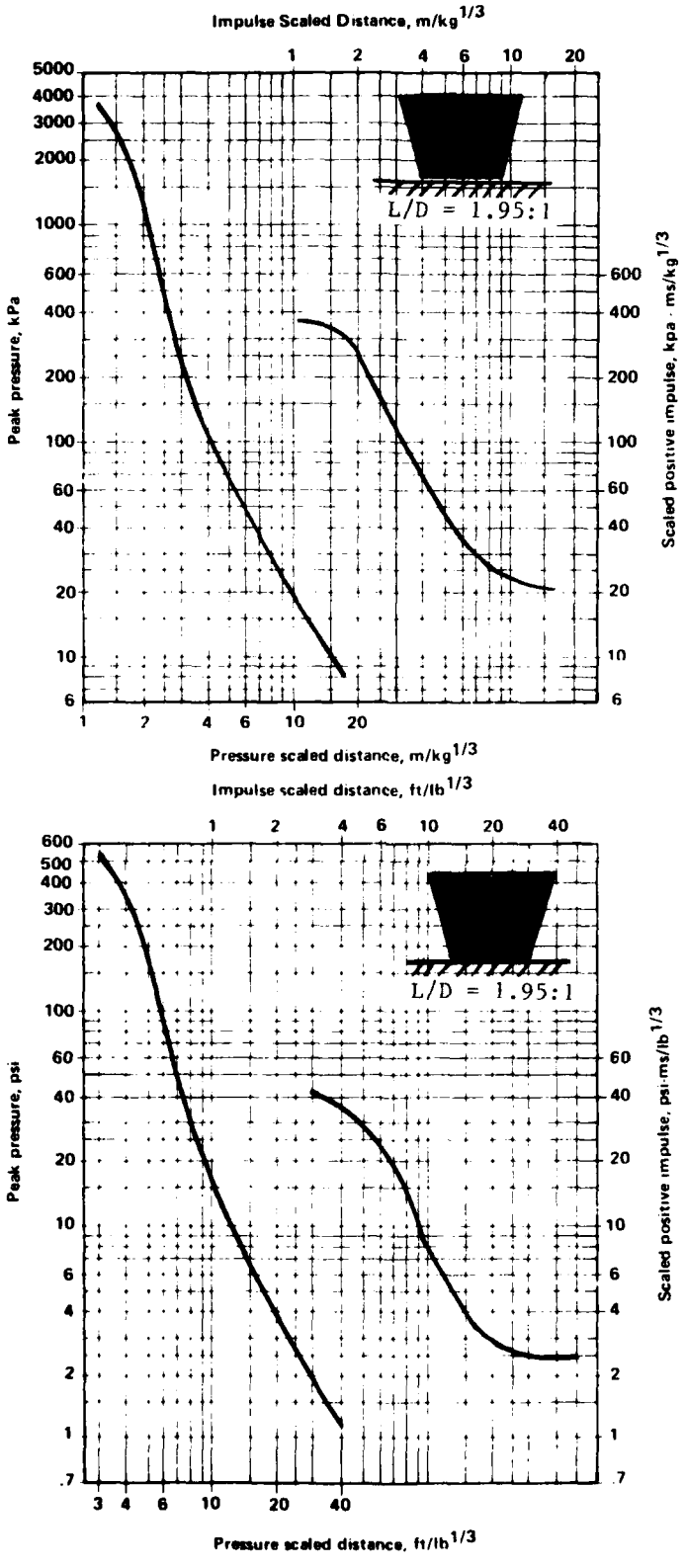
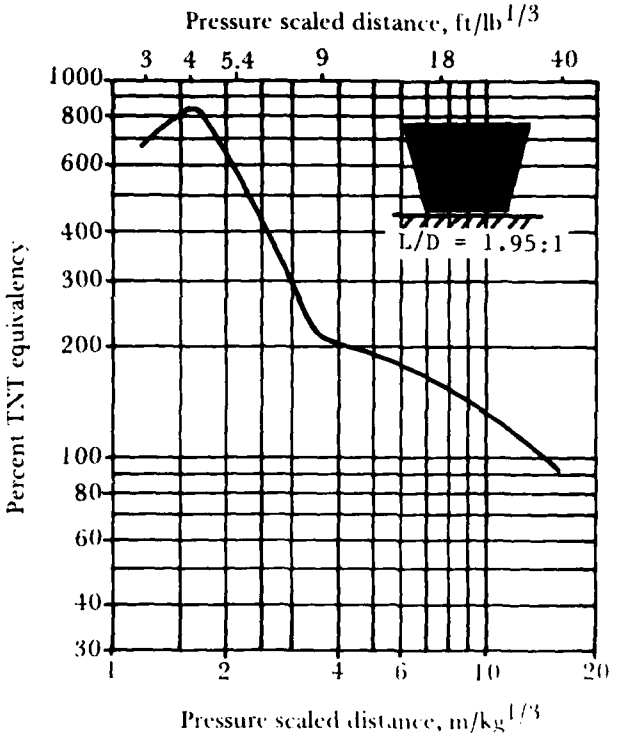


Figure 12. Pressure and impulse versus scaled distance for Cyclotol 70/30, 45.36 kg (100 lb) charge in simulated wood hopper



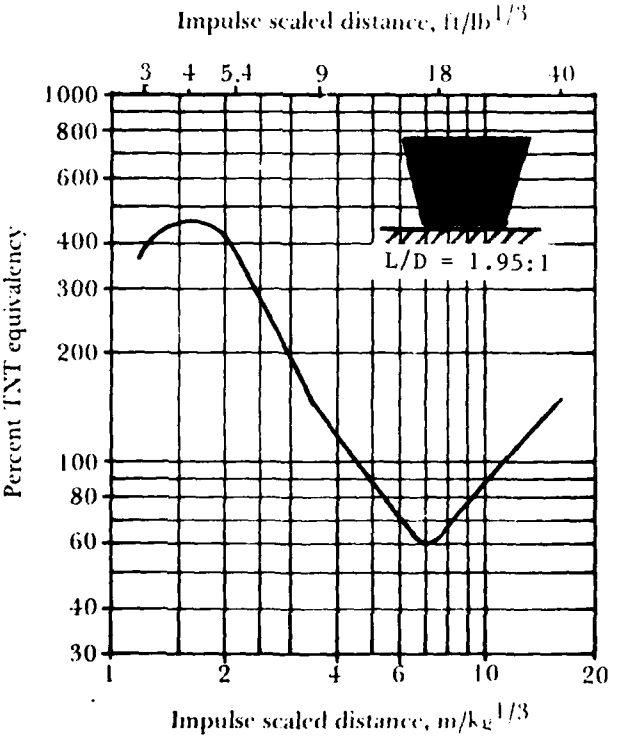


Figure 13. Pressure and impulse TNT equivalency for 45.36 kg (100 lb) simulated wood hopper

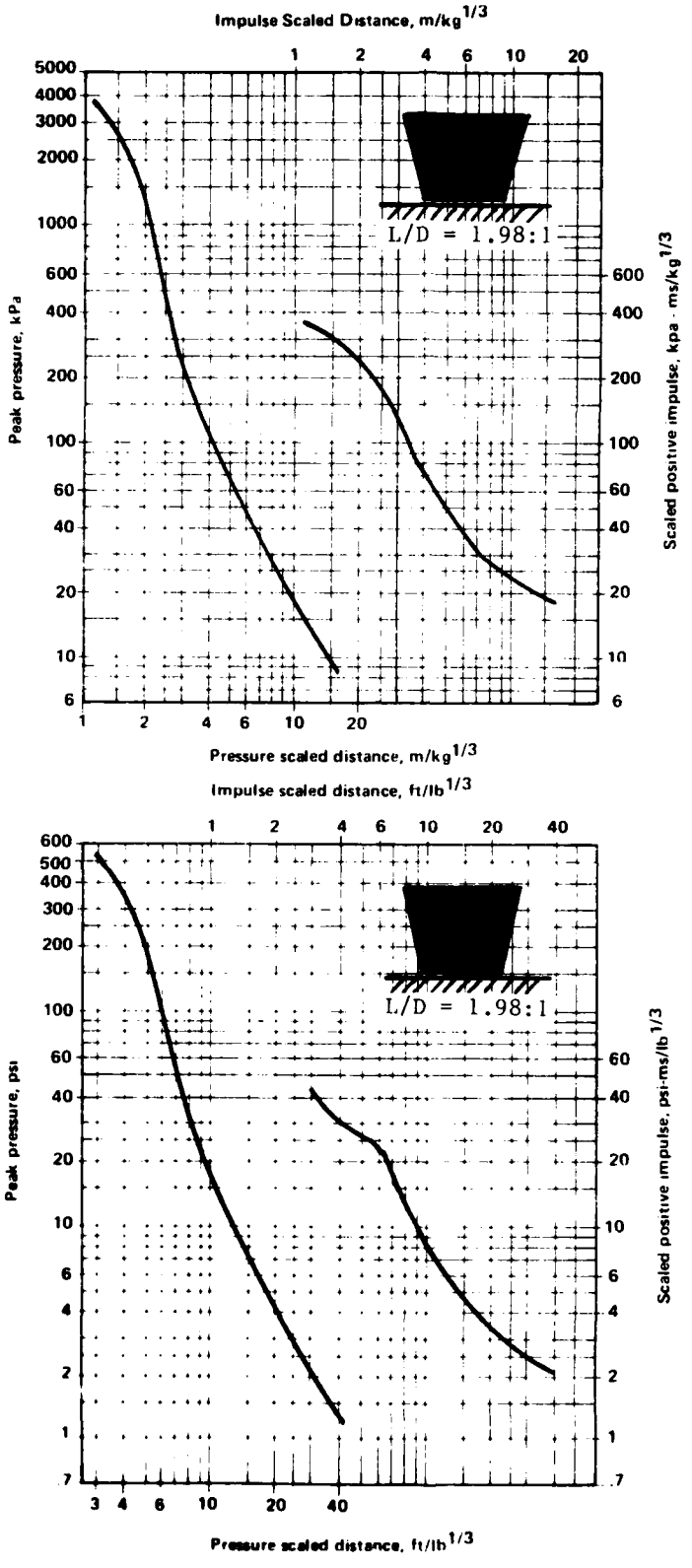
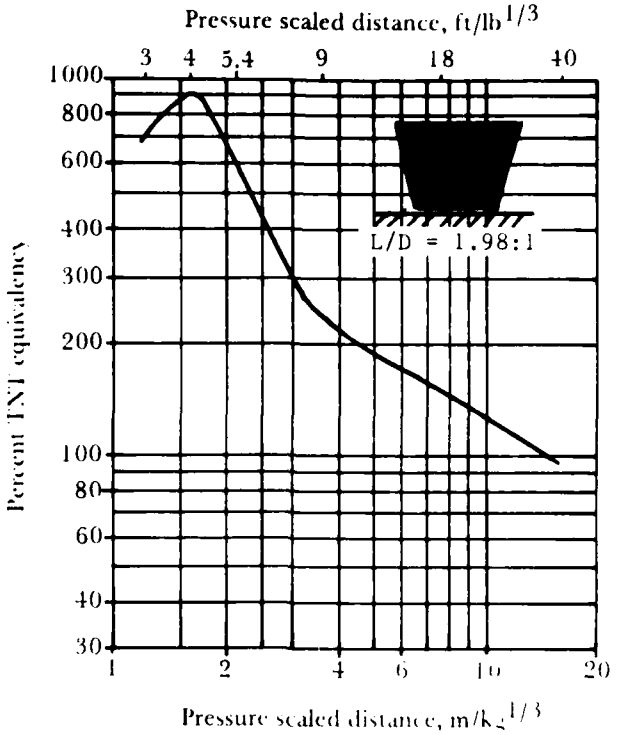


Figure 14. Pressure and impulse versus scaled distance for Cyclotol 70/30, 68.04 kg (150 lb) charge in simulated wood hopper



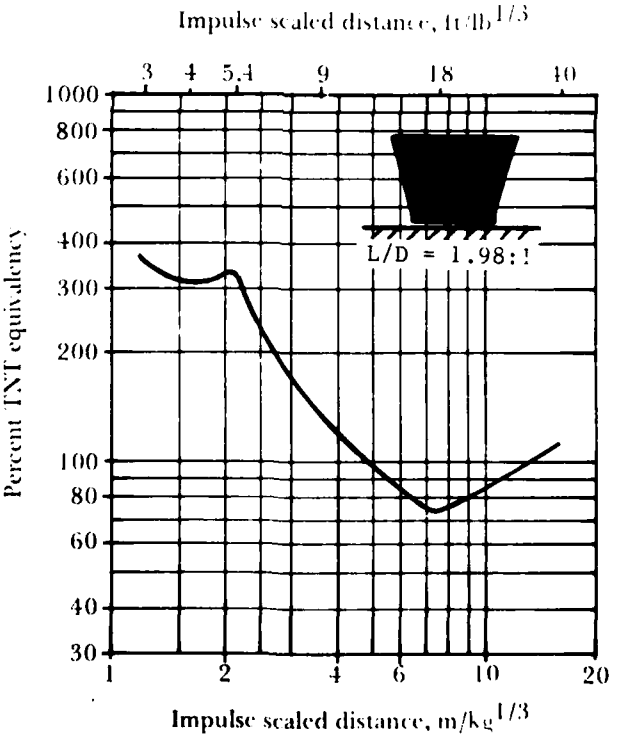


Figure 15. Pressure and impulse TNT equivalency for 68.04 kg (150 lb) simulated wood hopper

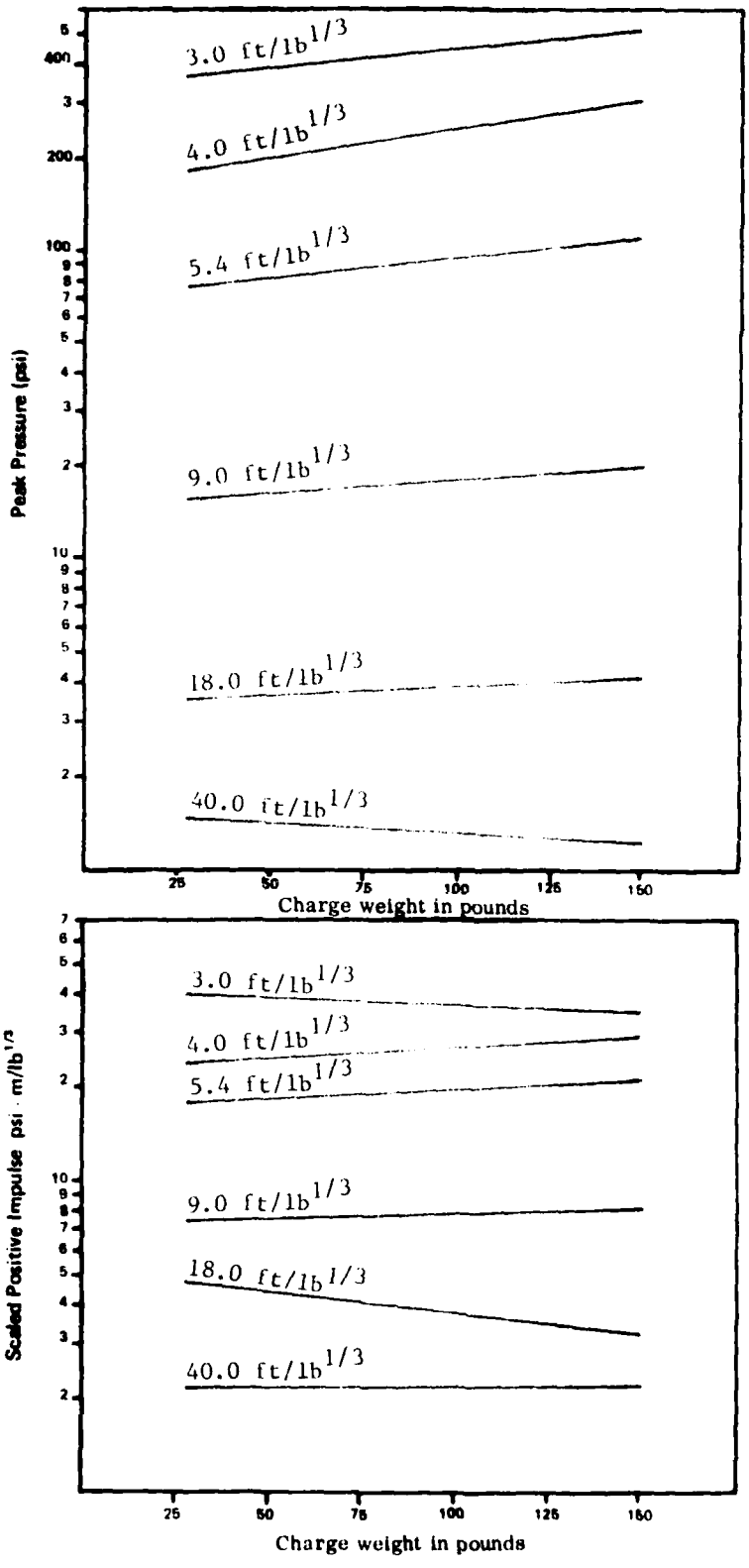


Figure 16. Deviation from cube root scaling

APPENDIX A

TEST DATA SHEETS

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 13.6 kg (30 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 0.27 Kg (0.60lb)

TEST NO. 8-81-03

CONTRACT NO. NAS13-50

DATE 24 Feb 1981

TIME 1005

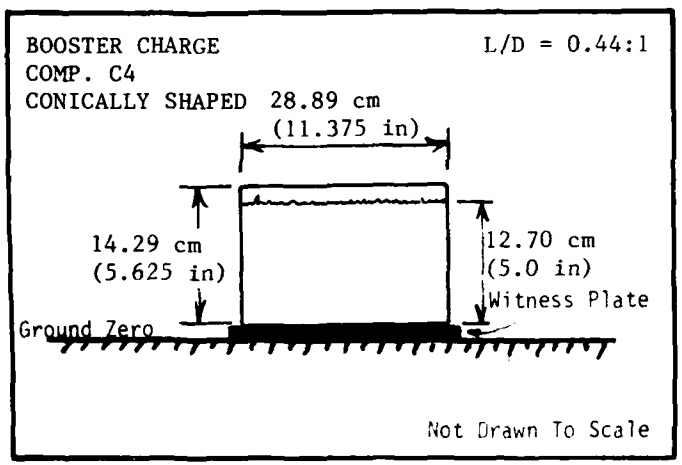
TEMP. 57°F

HUMIDITY 54%

BAR. PRESS. 30.06

WIND DIR. 300°

WIND VEL. 2K



FIELD EVALUATION: Detonation occurred, crater size 0.61 m (2 ft) x 2.1 m (7 Ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	2.84 (9.32)	1379.1 (200.00)	242.0 (26.97)	2.0
2		2715.2 (393.75)	420.3 (46.83)	2.2
3	3.79 (12.43)	827.1 (119.95)	173.7 (19.35)	2.8
4		1237.5 (179.46)	191.8 (21.37)	2.9
5	5.12 (16.78)	384.8 (55.81)	126.6 (14.11)	4.3
6		593.1 (86.01)	133.5 (14.88)	4.5
7	8.53 (27.97)	106.3 (15.41)	55.6 (6.20)	10.5
8		119.2 (17.28)	63.4 (7.06)	10.2
9	17.05 (55.93)	20.8 (3.02)	39.7 (4.42)	31.2
10		26.9 (3.90)	44.5 (4.96)	31.1
11	37.89 (124.29)	13.3 (1.93)	-	84.8
12		9.9 (1.44)	22.2 (2.47)	84.8

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 13.6 kg (30 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 0.27 kg (0.60 lb)

TEST NO. 8-81-04

CONTRACT NO. NAS13-50

DATE 24 Feb 1981

TIME 1048

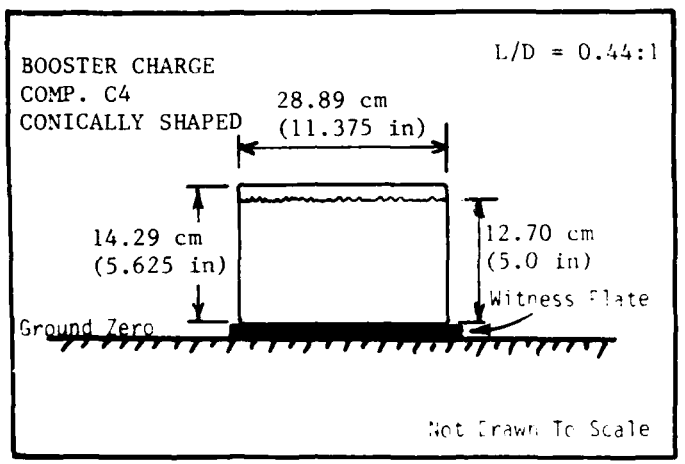
TEMP. 60°F

HUMIDITY 34%

BAR. PRESS. 30.06

WIND DIR. 305°

WIND VEL. 4K



FIELD EVALUATION: Detonation occurred, crater size

0.5 m (1.5 ft) x 2.4 m (8 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse (kPa-msec/kg$^{1/3}$) (psi-sec/lb$^{1/3}$)	Time of Arrival (msec)
1	2.84 (9.32)	2370.4 (343.75)	403.7 (44.98)	1.1
2		2370.4 (343.75)	324.9 (36.20)	1.2
3	3.79 (12.43)	1378.6 (199.92)	173.9 (19.38)	1.7
4		1521.5 (220.65)	294.6 (32.82)	1.7
5	5.12 (16.78)	553.2 (80.22)	173.6 (19.34)	3.1
6		567.9 (82.35)	129.9 (14.48)	3.1
7	8.53 (27.97)	113.6 (16.48)	59.5 (6.63)	9.2
8		123.6 (17.92)	89.2 (9.94)	9.1
9	17.05 (55.93)	27.3 (3.96)	35.5 (3.96)	30.2
10		24.8 (3.59)	38.4 (4.28)	29.7
11	37.89 (124.29)	13.0 (1.89)	-	84.2
12		7.6 (1.10)	15.9 (1.77)	84.2

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 13.61 kg (30 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 0.27 kg (0.60 lb)

TEST NO. 8-81-05

CONTRACT NO. NAS13-50

DATE 24 Feb 1981

TIME 1119

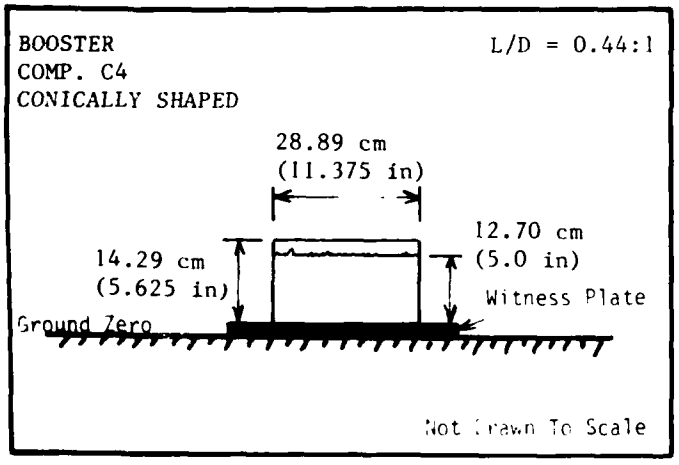
TEMP. 62°F

HUMIDITY 33%

BAR. PRESS. 30.06

WIND DIR. 310°

WIND VEL. 3K



FIELD EVALUATION: Detonation occurred, crater size 0.45 m (1.5 ft) x 2.1 m (6.75 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	2.84 (9.32)	2585.9 (375.00)	412.3 (45.94)	2.6
2		2370.4 (343.75)	294.3 (32.79)	2.6
3	3.79 (12.43)	1447.5 (209.92)	176.9 (19.72)	3.2
4		1460.6 (211.82)	250.4 (27.90)	3.3
5	5.12 (16.78)	553.2 (80.22)	237.0 (26.41)	4.5
6		605.7 (87.84)	165.2 (18.41)	4.6
7	8.53 (27.97)	97.4 (14.12)	60.1 (6.70)	10.2
8		119.2 (17.28)	66.7 (7.43)	10.4
9	17.05 (55.93)	17.9 (2.59)	43.2 (4.81)	30.5
10		24.2 (3.51)	39.6 (4.41)	30.8
11	37.89 (124.29)	12.7 (1.84)	-	85.4
12		8.3 (1.20)	20.6 (2.29)	85.7

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 27.22 kg (60 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 0.54 kg (1.20 lb)

TEST NO. 8-81-06

CONTRACT NO. NAS13-50

DATE 25 Feb 1981

TIME 1005

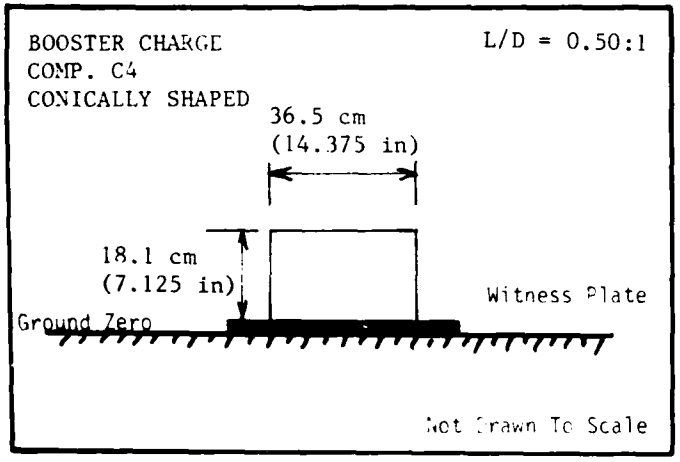
TEMP. 60°F

HUMIDITY 60%

BAR. PRESS. 30.09

WIND DIR. 270°

WIND VEL. 2K



FIELD EVALUATION: Detonation occurred, crater size 0.9 m (3 ft) x 3 m (10 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Impulse (Pa-msec/kg$^{1/3}$) (psi-msec/lb$^{1/3}$)	Time of Arrival (msec)
1	3.58 (11.745)	2482.4 (360.00)	411.6 (45.86)	2.1
2		3640.9 (528.00)	268.4 (29.91)	2.1
3	4.77 (15.66)	1977.4 (286.76)	199.7 (22.25)	2.9
4		1664.6 (241.40)	183.2 (20.41)	2.8
5	6.44 (21.44)	403.8 (58.56)	174.9 (19.49)	4.7
6		841.8 (122.08)	177.5 (19.78)	4.1
7	10.74 (35.234)	87.2 (12.64)	54.5 (6.07)	13.2
8		112.5 (16.32)	121.9 (13.58)	11.7
9	21.48 (70.468)	32.4 (4.70)	65.2 (7.27)	39.7
10		11.0 (1.60)	45.9 (5.12)	39.1
11	47.73 (156.595)	10.9 (1.58)	20.6 (2.30)	108.4
12		14.1 (2.05)	12.8 (1.43)	108.3

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 27.22 kg (60 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 0.54 kg (1.20 lb)

TEST NO. 8-81-07

CONTRACT NO. NAS13-50

DATE 25 Feb 1981

TIME 1120

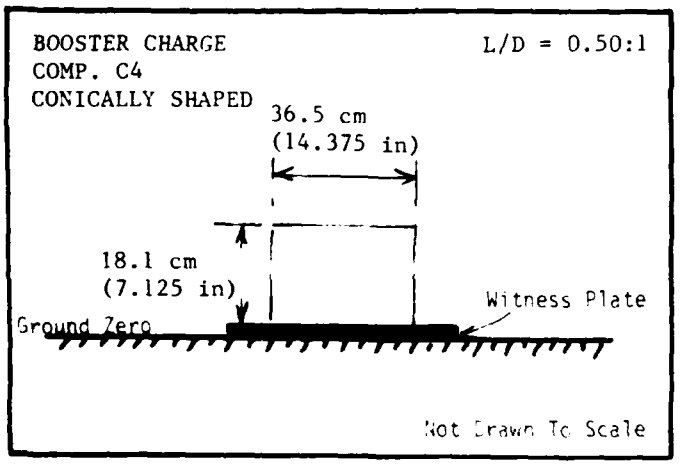
TEMP. 62°F

HUMIDITY 56%

BAR. PRESS. 30.09

WIND DIR. 320°

WIND VEL. 2K



FIELD EVALUATION: Detonation occurred, crater size 0.9 m (3 ft) x 3.4 m (11 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	3.58 (11.745)	4344.3 (630.00)	428.0 (47.69)	1.7
2		2441.1 (354.00)	316.5 (35.27)	1.8
3	4.77 (15.66)	1505.2 (218.28)	174.2 (19.41)	2.3
4		998.8 (144.84)	191.3 (21.31)	2.7
5	6.44 (21.44)	328.1 (47.58)	165.7 (18.46)	4.3
6		589.3 (85.46)	127.4 (14.20)	4.6
7	10.74 (35.234)	109.7 (15.91)	60.0 (6.68)	12.8
8		139.0 (20.16)	74.8 (8.34)	12.3
9	21.48 (70.468)	29.2 (4.23)	72.9 (8.12)	39.3
10		15.4 (2.24)	34.9 (3.89)	38.6
11	47.73 (156.595)	11.9 (1.72)	22.5 (2.51)	107.9
12		12.1 (1.75)	21.10 (2.35)	107.3

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 27.22 kg (60 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 0.54 kg (1.20 lb)

TEST NO. 8-81-08

CONTRACT NO. NAS13-50

DATE 25 Feb 1981

TIME 1313

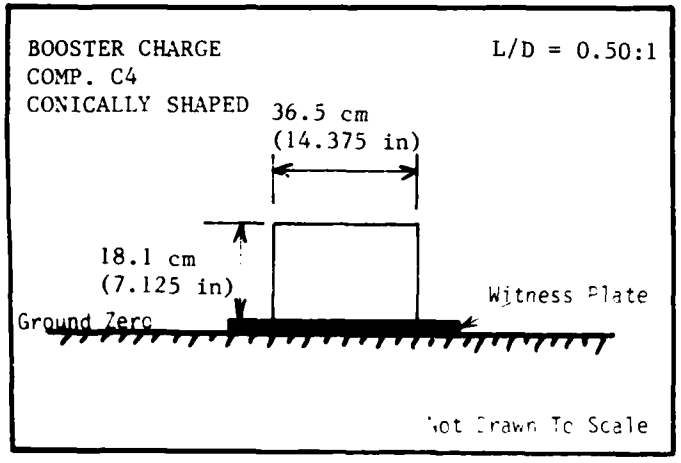
TEMP. 70°F

HUMIDITY 34%

BAR. PRESS. 30.08

WIND DIR. 10°

WIND VEL. 3K



FIELD EVALUATION: Detonation occurred, crater size 0.9 m (3 ft) x 3.4 m (11 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	3.58 (11.745)	3470.1 (503.23)	440.1 (49.04)	2.6
2		3061.7 (444.00)	349.1 (38.90)	2.3
3	4.77 (15.66)	1092.0 (158.36)	172.8 (19.25)	3.5
4		1155.4 (167.56)	296.4 (33.02)	3.2
5	6.44 (21.44)	378.6 (54.90)	152.3 (16.97)	5.6
6		577.2 (83.71)	126.3 (14.07)	5.2
7	10.74 (35.234)	94.7 (13.73)	45.6 (5.08)	13.8
8		108.1 (15.68)	86.8 (9.67)	12.9
9	21.48 (70.468)	29.8 (4.32)	57.6 (6.42)	40.3
10		16.8 (2.43)	35.7 (3.98)	39.3
11	47.73 (156.595)	12.4 (1.80)	17.2 (1.92)	108.5
12		12.1 (1.75)	27.6 (3.07)	107.8

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 45.36 kg (100 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 0.91 kg (2 lb)

TEST NO. 8-81-09

CONTRACT NO. NAS13-50

DATE 26 Feb 1981

TIME 0951

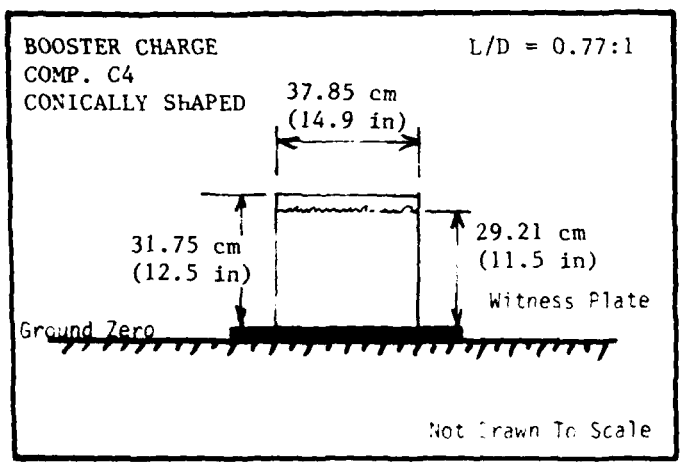
TEMP. 48°F

HUMIDITY 72%

BAR. PRESS. 30.12

WIND DIR. 340°

WIND VEL. 3K



FIELD EVALUATION: Detonation occurred, crater size 0.9 m (3 ft) x 3 m (10 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	4.24 (13.92)	2482.4 (360.00)	296.9 (33.09)	2.4
2		3392.7 (492.00)	342.2 (38.13)	2.5
3	5.66 (18.57)	1389.1 (201.44)	177.7 (19.80)	3.2
4		1118.2 (162.16)	234.9 (26.17)	3.5
5	7.64 (25.06)	443.1 (64.26)	165.7 (18.46)	5.1
6		659.8 (95.68)	135.9 (15.14)	5.8
7	12.73 (41.77)	112.9 (16.37)	70.3 (7.83)	14.4
8		119.3 (17.30)	54.6 (6.08)	14.8
9	25.47 (83.55)	28.8 (4.18)	31.3 (3.49)	45.4
10		29.0 (4.20)	32.6 (3.63)	46.2
11	56.59 (185.66)	8.7 (1.26)	18.5 (2.06)	127.5
12		9.7 (1.41)	17.1 (1.91)	128.3

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 45.36 kg (100 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 0.91 kg (2 lb)

TEST NO. 8-81-10

CONTRACT NO. NAS13-50

DATE 26 Feb 1981

TIME 1032

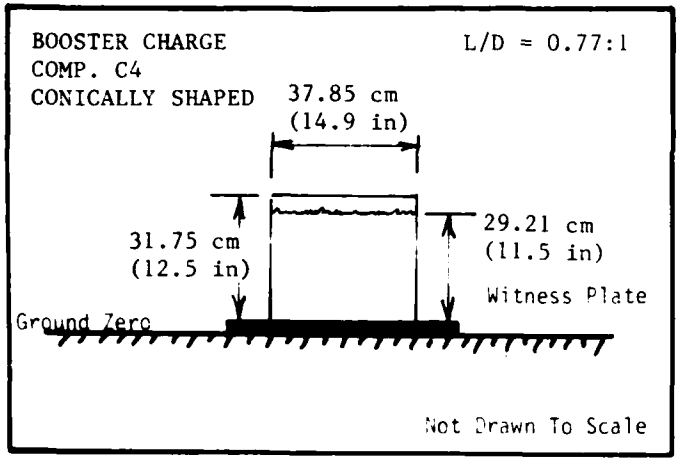
TEMP. 63°F

HUMIDITY 38%

BAR. PRESS. 30.13

WIND DIR. 5°

WIND VEL. 2K



FIELD EVALUATION: Detonation occurred, crater size

0.76 m (2.5 ft) x 3.4 m (11 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	4.24 (13.92)	2896.2 (420.00)	260.0 (28.97)	1.3
2		2978.9 (432.00)	346.4 (38.60)	1.5
3	5.66 (18.57)	1300.4 (188.58)	188.8 (21.04)	1.9
4		1202.0 (174.32)	235.1 (26.20)	2.4
5	7.64 (25.06)	487.5 (70.69)	158.7 (17.68)	4.0
6		672.7 (97.55)	143.6 (16.00)	4.6
7	12.73 (41.77)	116.5 (16.90)	79.3 (8.84)	13.3
8		121.8 (17.67)	79.1 (8.81)	13.6
9	25.47 (83.55)	28.8 (4.18)	31.2 (3.48)	44.3
10		26.6 (3.86)	29.8 (3.32)	44.5
11	56.59 (185.66)	9.9 (1.44)	17.9 (2.00)	125.9
12		9.1 (1.32)	16.5 (1.84)	126.0

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 45.36 kg (100 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 0.91 kg (2 lb)

TEST NO. 8-81-11

CONTRACT NO. NAS13-50

DATE 26 Feb 1981

TIME 1113

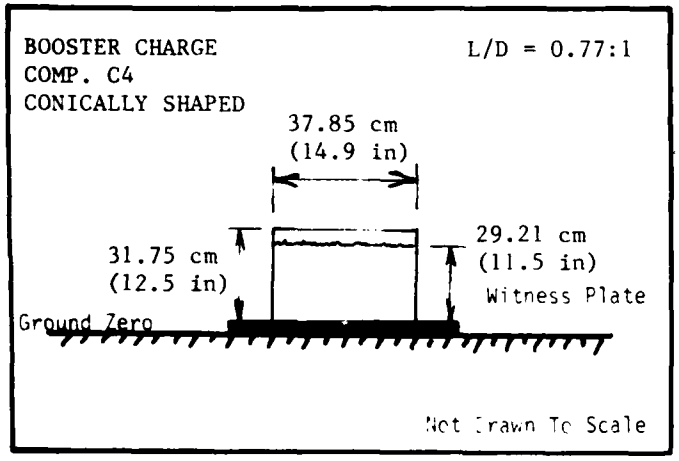
TEMP. 77°F

HUMIDITY 34%

BAR. PRESS. 30.13

WIND DIR. 120°

WIND VEL. 3K



FIELD EVALUATION: Detonation occurred, crater size 0.45 m (1.5 ft) x 3.4 m (11 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	4.24 (13.92)	2399.7 (348.00)	266.6 (29.71)	2.7
2		2275.6 (330.00)	275.9 (30.74)	2.6
3	5.66 (18.57)	1536.8 (222.87)	174.5 (19.44)	3.5
4		950.5 (137.84)	186.8 (20.81)	3.5
5	7.64 (25.06)	517.0 (74.97)	186.8 (20.81)	5.6
6		711.5 (103.18)	137.4 (15.31)	5.7
7	12.73 (41.77)	107.4 (15.58)	79.8 (8.89)	14.7
8		121.8 (17.67)	69.1 (7.70)	15.2
9	25.47 (83.55)	30.4 (4.41)	39.8 (4.44)	45.4
10		26.6 (3.86)	32.2 (3.59)	46.1
11	56.59 (185.66)	9.2 (1.33)	15.9 (1.77)	126.5
12		10.0 (1.45)	16.7 (1.86)	127.8

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 68.04 kg (150 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 1.36 kg (3.0 lb)

TEST NO. 8-81-12

CONTRACT NO. NAS13-50

DATE 27 Feb 1981

TIME 1018

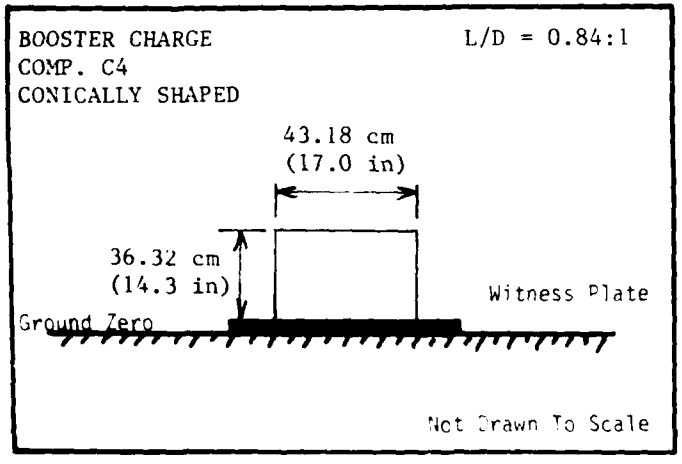
TEMP. 61°F

HUMIDITY 50%

BAR. PRESS. 30.13

WIND DIR. 120°

WIND VEL. 3K



FIELD EVALUATION: Detonation occurred, crater size

1.06 m (3.5 ft) x 3.5 m (11.5 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	4.86 (15.94)	2606.6 (378.00)	210.5 (23.45)	-
2		3663.4 (531.25)	362.4 (40.38)	-
3	6.48 (21.25)	2034.2 (295.00)	224.6 (25.02)	-
4		2334.8 (338.59)	245.1 (27.31)	-
5	8.75 (28.69)	493.5 (71.57)	117.6 (13.10)	-
6		909.00 (131.82)	209.4 (23.33)	-
7	14.58 (47.82)	112.9 (16.37)	60.0 (6.68)	-
8		150.4 (21.81)	77.2 (8.60)	-
9	29.15 (95.64)	25.8 (3.74)	28.0 (3.12)	-
10		21.9 (3.18)	36.4 (4.06)	-
11	64.79 (212.53)	9.7 (1.40)	20.1 (2.24)	-
12		9.0 (1.30)	20.2 (2.25)	-

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 68.04 kg (150 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 1.36 kg (3.0 lb)

TEST NO. 8-81-13

CONTRACT NO. NAS13-50

DATE 27 Feb 1981

TIME 1114

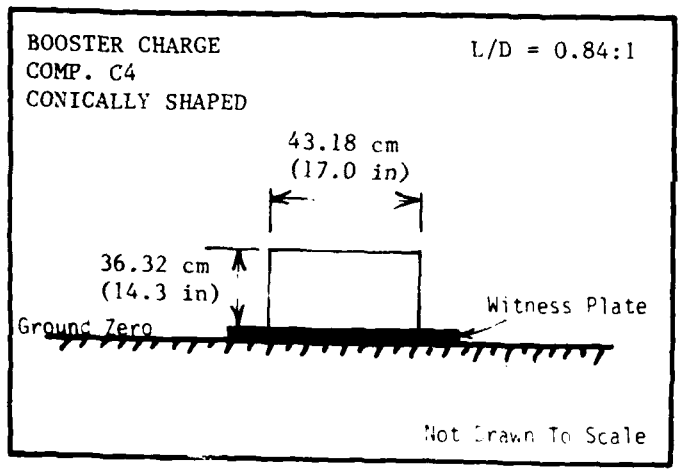
TEMP. 68°F

HUMIDITY 36%

BAR. PRESS. 30.13

WIND DIR. 125°

WIND VEL. 3K



FIELD EVALUATION: Detonation occurred, crater size 0.9 m (3 ft) x 3.5 m (11.5 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	4.86 (15.94)	3227.2 (468.00)	445.9 (49.69)	-
2		3447.8 (500.00)	313.9 (34.68)	-
3	6.48 (21.25)	1896.3 (275.00)	223.9 (24.95)	-
4		1477.7 (214.30)	251.2 (27.99)	-
5	8.75 (28.69)	505.2 (73.27)	175.7 (19.58)	-
6		769.1 (111.54)	174.3 (19.42)	-
7	14.58 (47.82)	112.9 (16.37)	62.3 (6.94)	-
8		132.3 (19.18)	69.5 (7.74)	-
9	29.15 (95.64)	24.4 (3.54)	29.4 (3.28)	-
10		27.0 (3.92)	28.3 (3.15)	-
11	64.79 (212.53)	9.7 (1.40)	18.9 (2.11)	-
12		9.9 (1.44)	20.6 (2.29)	-

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 68.04 kg (150 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 1.36 kg (3.0 lb)

TEST NO. 8-81-14

CONTRACT NO. NAS13-50

DATE 27 Feb 1981

TIME 1309

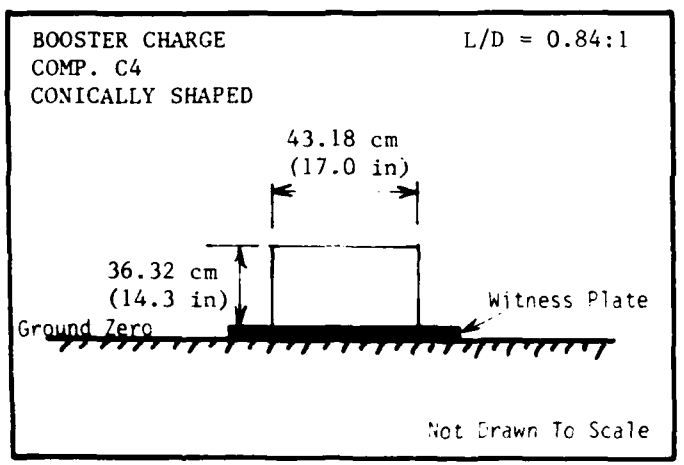
TEMP. 76°F

HUMIDITY 22%

BAR. PRESS. 30.12

WIND DIR. 120°

WIND VEL. 8K



FIELD EVALUATION: Detonation occurred, crater size 0.3 m (1 ft) x 1.2 m (4 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	4.86 (15.94)	3185.8 (462.00)	296.7 (33.06)	-
2		3404.7 (493.75)	338.6 (37.73)	-
3	6.48 (21.25)	2344.5 (340.00)	213.9 (23.84)	-
4		1211.8 (175.73)	249.6 (27.81)	-
5	8.75 (28.69)	528.8 (76.68)	118.8 (13.24)	-
6		433.5 (62.87)	109.7 (12.22)	-
7	14.58 (47.82)	109.2 (15.84)	59.1 (6.59)	-
8		121.8 (17.67)	68.5 (7.63)	-
9	29.15 (95.64)	25.8 (3.74)	36.2 (4.03)	-
10		27.0 (3.92)	32.0 (3.57)	-
11	64.79 (212.53)	12.4 (1.80)	20.7 (2.31)	-
12		9.9 (1.44)	21.0 (2.34)	-

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 45.36 kg (100 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 0.91 kg (2 lb)

TEST NO. 9-81-15

CONTRACT NO. NAS13-50

DATE 2 Mar 1981

TIME 1010

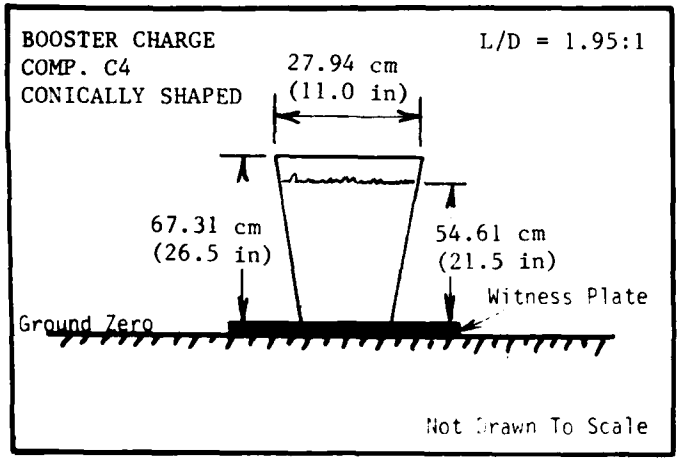
TEMP. 58°F

HUMIDITY 60%

BAR. PRESS. 30.99

WIND DIR. 010°

WIND VEL. 6K



FIELD EVALUATION: Detonation occurred, crater size 0.3 m (1 ft) x 1.4 m (4.5 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	4.24 (13.92)	3434.1 (498.00)	315.9 (35.20)	1.3
2		4178.8 (606.00)	456.4 (50.85)	1.5
3	5.66 (18.57)	1410.9 (204.60)	340.0 (37.88)	2.1
4		1655.1 (240.02)	307.9 (34.31)	2.0
5	7.64 (25.06)	730.2 (105.89)	235.5 (26.24)	3.9
6		970.2 (140.70)	243.9 (27.18)	3.6
7	12.73 (41.77)	138.0 (20.02)	75.7 (8.44)	12.6
8		108.6 (15.75)	40.6 (4.52)	11.4
9	25.47 (83.55)	31.8 (4.61)	29.4 (3.28)	43.3
10		34.8 (5.04)	26.5 (2.95)	41.8
11	56.59 (185.66)	7.7 (1.12)	20.6 (2.29)	126.7
12		6.1 (0.88)	16.8 (1.87)	124.5

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 45.36 kg (100 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 0.91 kg (2 lb)

TEST NO. 9-81-16

CONTRACT NO. NAS13-50

DATE 2 Mar 1981

TIME 1056

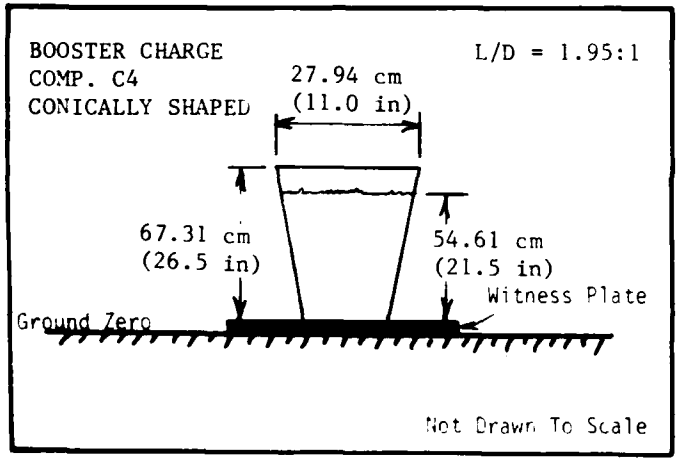
TEMP. 65°F

HUMIDITY 50%

BAR. PRESS. 30.99

WIND DIR. 20°

WIND VEL. 5K



FIELD EVALUATION: Detonation occurred, crater size 0.3 m (1 ft) x 1.2 m (4 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa-msec/kg$^{1/3}$ (psi-msec/lb$^{1/3}$)	Time of Arrival (msec)
1	4.24 (13.92)	2772.0 (402.00)	237.6 (26.47)	2.3
2		3971.9 (576.00)	364.4 (40.60)	2.1
3	5.66 (18.57)	2821.7 (409.20)	426.1 (47.48)	3.4
4		2807.7 (407.17)	302.7 (33.73)	2.7
5	7.64 (25.06)	988.8 (143.39)	300.3 (33.46)	5.3
6		1009.00 (146.33)	220.6 (24.58)	3.9
7	12.73 (41.77)	136.1 (19.74)	77.8 (8.67)	13.3
8		160.5 (23.27)	85.4 (9.52)	11.2
9	25.47 (83.55)	29.8 (4.32)	28.8 (3.21)	43.8
10		30.9 (4.48)	22.3 (2.48)	41.9
11	56.59 (185.66)	8.8 (1.28)	20.2 (2.25)	126.7
12		7.6 (1.10)	26.4 (2.94)	124.3

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 45.36 kg (100 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 0.91 kg (2 lb)

TEST NO. 9-81-17

CONTRACT NO. NAS13-50

DATE 2 Mar 1981

TIME 1142

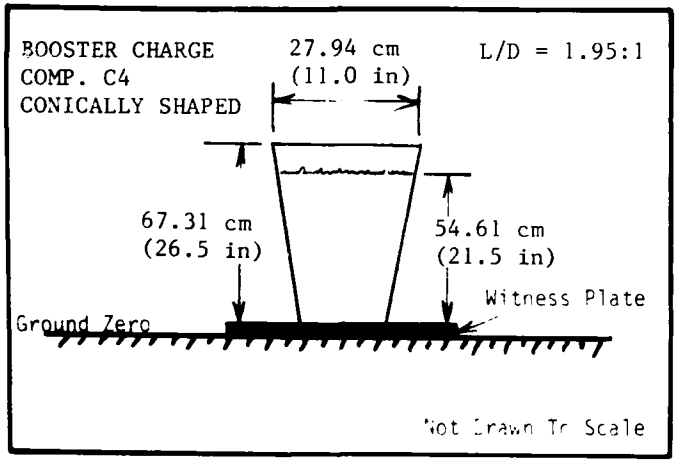
TEMP. 66°F

HUMIDITY 44%

BAR. PRESS. 30.98

WIND DIR. 015°

WIND VEL. 3K



FIELD EVALUATION: Detonation occurred, crater size 0.27 m (0.88 ft) x 1.2 m (4 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	4.24 (13.92)	3599.5 (522.00)	464.1 (51.71)	1.1
2		3930.5 (570.00)	365.4 (40.71)	1.1
3	5.66 (18.57)	2915.8 (422.84)	397.4 (44.28)	2.1
4		2512.2 (364.31)	288.6 (32.16)	1.8
5	7.64 (25.06)	806.2 (116.92)	256.0 (28.52)	3.8
6		957.3 (138.82)	204.5 (22.79)	3.3
7	12.73 (41.77)	139.9 (20.29)	89.8 (10.01)	12.2
8		165.4 (23.99)	118.6 (13.21)	11.1
9	25.47 (83.55)	29.3 (4.25)	26.2 (2.92)	42.7
10		35.3 (5.12)	23.7 (2.64)	41.3
11	56.59 (185.66)	8.6 (1.24)	19.9 (2.22)	125.9
12		9.1 (1.32)	29.8 (3.32)	123.1

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 68.04 kg (150 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 1.36 kg (3.0 lb)

TEST NO. 9-81-18

CONTRACT NO. NAS13-50

DATE 5 Mar 1981

TIME 1043

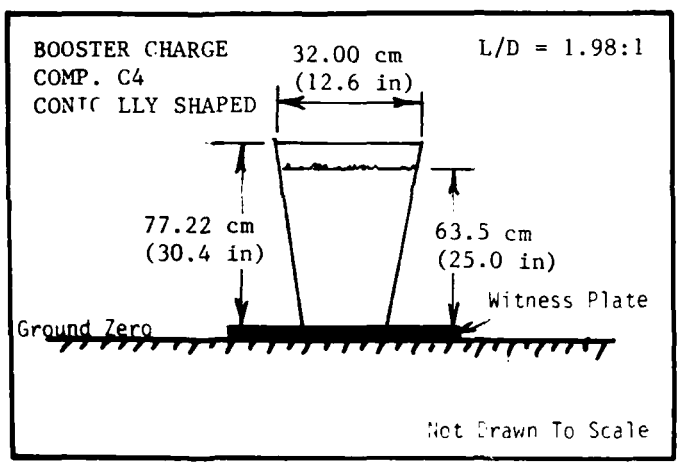
TEMP. 68°F

HUMIDITY 33%

BAR. PRESS. 30.98

WIND DIR. 290°

WIND VEL. 6K



FIELD EVALUATION: Detonation occurred, crater size

0.4 m (1.33 ft) x 2.0 m (6.5 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	4.86 (15.94)	2606.6 (378.00)	309.5 (34.48)	2.5
2		4716.7 (684.00)	417.4 (46.51)	2.8
3	6.48 (21.25)	1943.6 (281.85)	263.0 (29.31)	3.7
4		2470.6 (358.28)	279.2 (31.11)	3.6
5	8.75 (28.69)	841.9 (122.09)	190.3 (21.20)	5.7
6		1009.0 (146.33)	230.1 (25.64)	5.2
7	14.58 (47.82)	131.0 (19.00)	59.0 (6.57)	15.5
8		159.6 (23.14)	87.0 (9.70)	14.2
9	29.15 (95.64)	30.9 (4.48)	23.7 (2.64)	50.5
10		26.2 (3.80)	23.4 (2.61)	48.9
11	64.79 (212.53)	6.3 (0.92)	25.7 (2.86)	145.5
12		9.1 (1.32)	15.3 (1.70)	141.8

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 68.04 kg (150 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 1.36 kg (3.0 lb)

TEST NO. 9-81-19

CONTRACT NO. NAS13-50

DATE 5 Mar 1981

TIME 1123

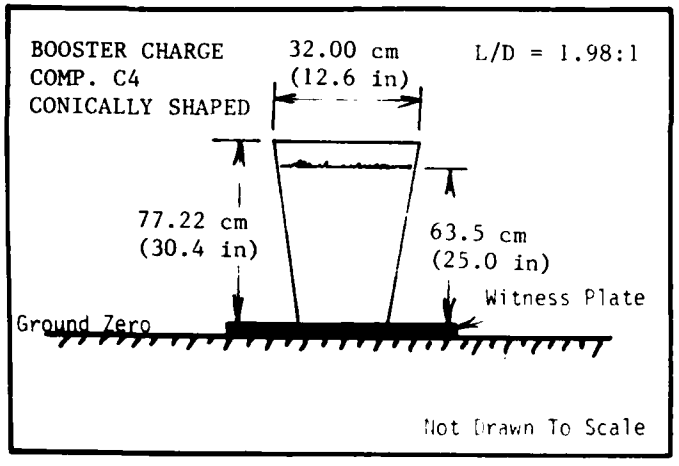
TEMP. 69°F

HUMIDITY 32%

BAR. PRESS. 30.98

WIND DIR. 300°

WIND VEL. 8K



FIELD EVALUATION: Detonation occurred, crater size 0.45 m (1.5 ft) x 1.8 m (6 ft)

Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	4.86 (15.94)	4509.8 (654.00)	280.0 (31.20)	2.7
2		3392.7 (492.00)	314.7 (35.06)	2.7
3	6.48 (21.25)	2821.3 (409.14)	262.9 (29.29)	3.6
4		2671.7 (387.44)	255.7 (28.49)	3.6
5	8.75 (28.69)	709.0 (102.82)	189.7 (21.14)	5.7
6		918.5 (133.20)	247.2 (27.54)	5.5
7	14.58 (47.82)	124.1 (18.00)	59.9 (6.67)	15.7
8		181.9 (26.39)	96.7 (10.77)	14.5
9	29.15 (95.64)	34.7 (5.04)	42.0 (4.68)	50.6
10		30.3 (4.40)	23.6 (2.63)	49.0
11	64.79 (212.53)	8.0 (1.16)	20.1 (2.24)	145.4
12		8.5 (1.23)	16.0 (1.78)	142.4

TEST TITLE TNT Equivalency

TEST SAMPLE Cyclotol 70/30

SAMPLE WEIGHT 68.04 kg (150 lb)

IGN. SOURCE J2 Blasting Cap

BOOSTER WT. 1.36 kg (3.0 lb)

TEST NO. 9-81-20

CONTRACT NO. NAS13-50

DATE 5 Mar 1981

TIME 1317

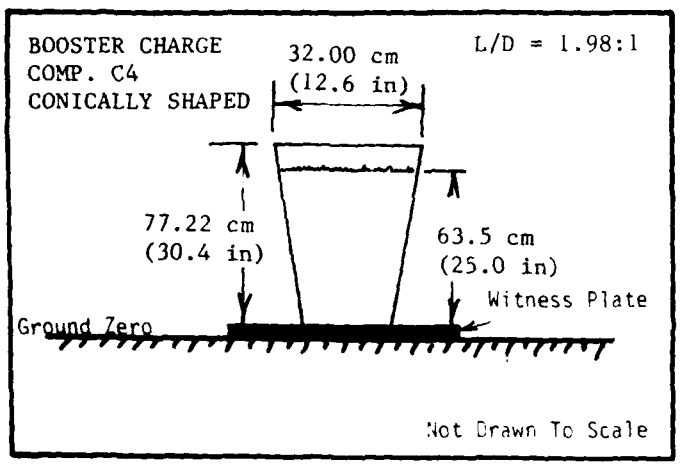
TEMP. 72°F

HUMIDITY 28%

BAR. PRESS. 30.97

WIND DIR. 310°

WIND VEL. 8K

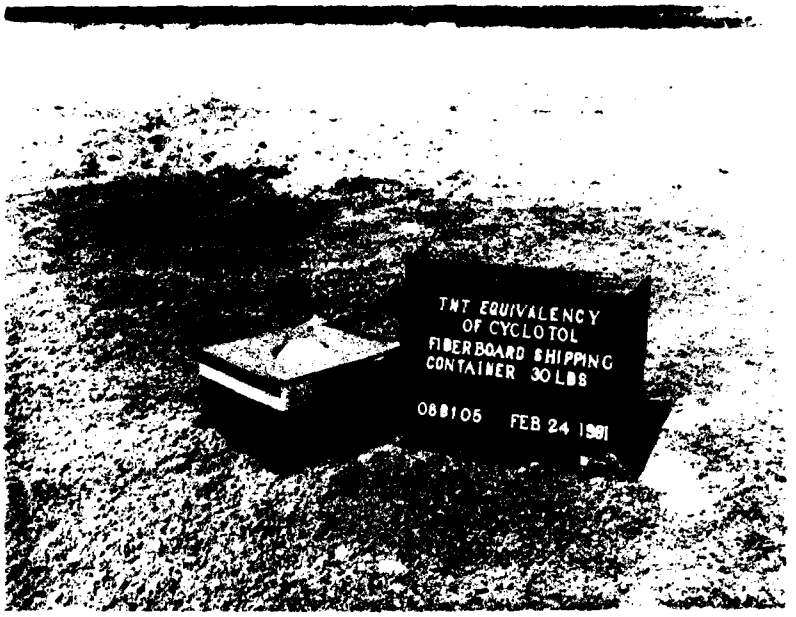


FIELD EVALUATION: Detonation occurred, crater size 0.45 m (1.5 ft) x 1.8 m (6 ft)

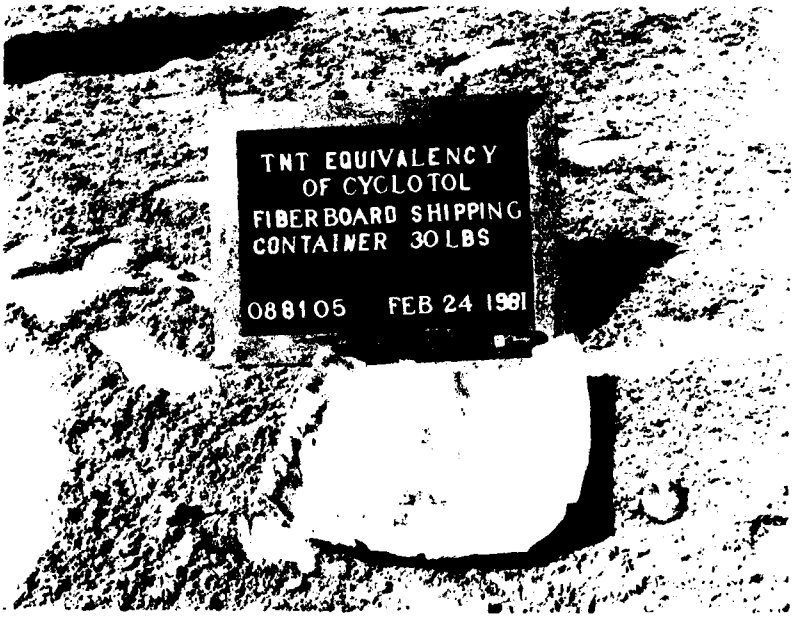
Channel Number	Distance Meters (ft)	Peak Pressure kPa (psi)	Scaled Positive Impulse kPa msec/kg$^{1/3}$ (psi msec/lb$^{1/3}$)	Time of Arrival (msec)
1	4.86 (15.94)	3723.7 (540.00)	571.4 (63.67)	2.2
2		3392.7 (492.00)	312.4 (34.81)	2.3
3	6.48 (21.25)	2131.7 (309.13)	285.2 (31.78)	3.5
4		2585.5 (374.94)	237.5 (26.46)	3.2
5	8.75 (28.69)	709.0 (102.82)	229.6 (25.58)	5.5
6		1267.7 (183.84)	212.8 (23.71)	4.8
7	14.58 (47.82)	127.6 (18.50)	71.3 (7.94)	15.4
8		181.9 (26.39)	111.9 (12.47)	13.5
9	29.15 (95.64)	33.7 (4.88)	33.7 (3.76)	50.3
10		26.6 (3.86)	31.5 (3.51)	48.0
11	64.79 (212.53)	8.3 (1.20)	19.7 (2.20)	145.3
12		7.9 (1.14)	15.2 (1.69)	141.7

APPENDIX B

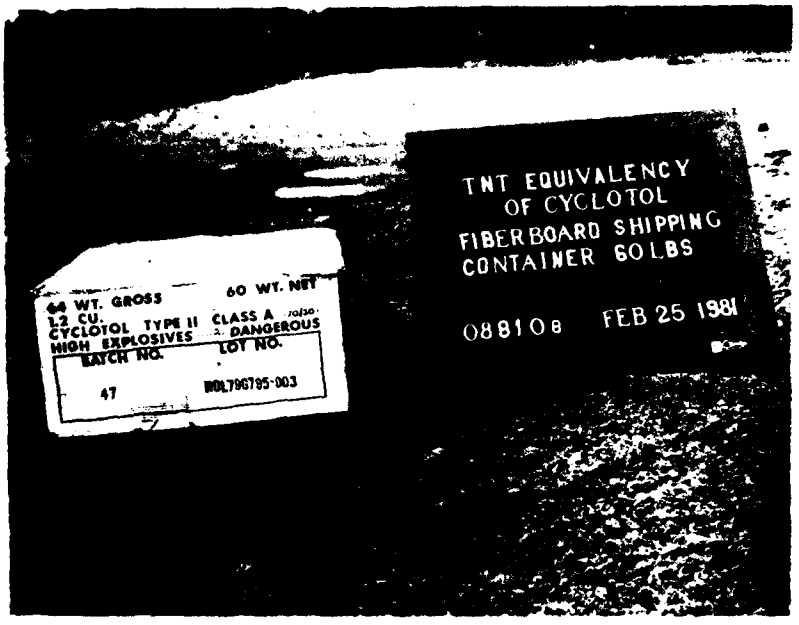
SELECTED PHOTOGRAPHS



Cyclotol 70/30 pretest configuration 13.61 kg (30 lb) fiberboard shipping container



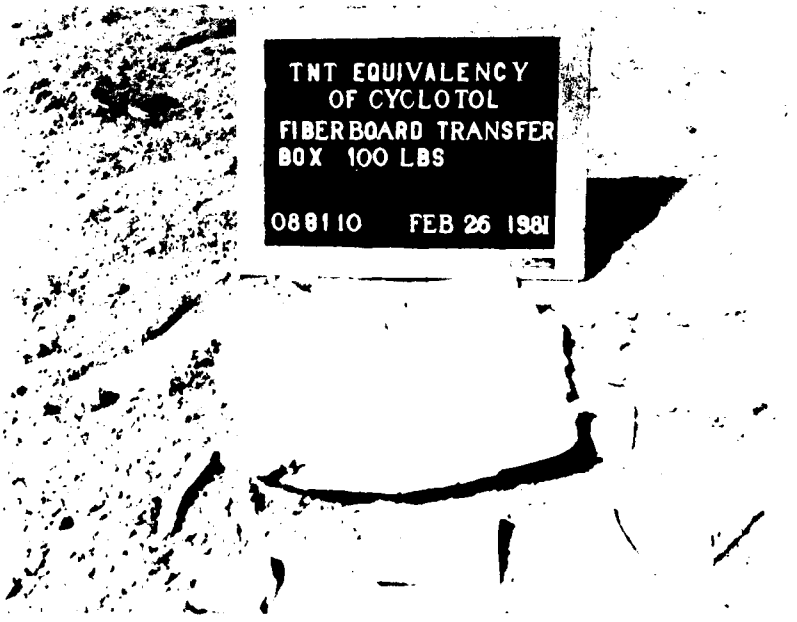
Cyclotol 70/30 posttest configuration 13.61 kg (30 lb) fiberboard shipping container



Cyclotol 70/30 pretest configuration 27.22 kg (60 lb) fiberboard shipping container

Cyclotol 70/30 posttest configuration 27.22 kg (60 lb) fiberboard shipping container

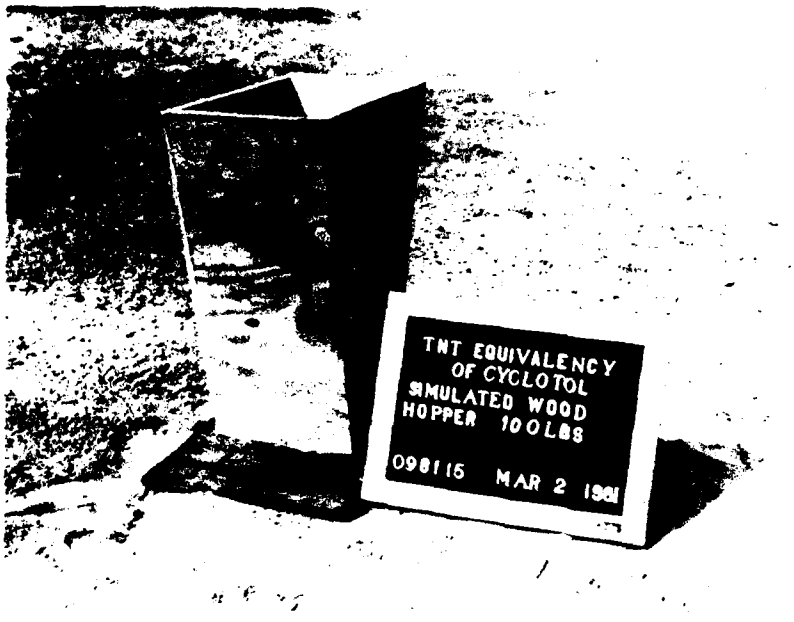
Cyclotol 70/30 pretest configuration 45.36 kg (100 lb) fiberboard transfer box



Cyclotol 70/30 posttest configuration 45.36 kg (100 lb) fiberboard transfer box

Cyclotol 70/30 pretest configuration 68.04 kg (150 lb) fiberboard transfer box

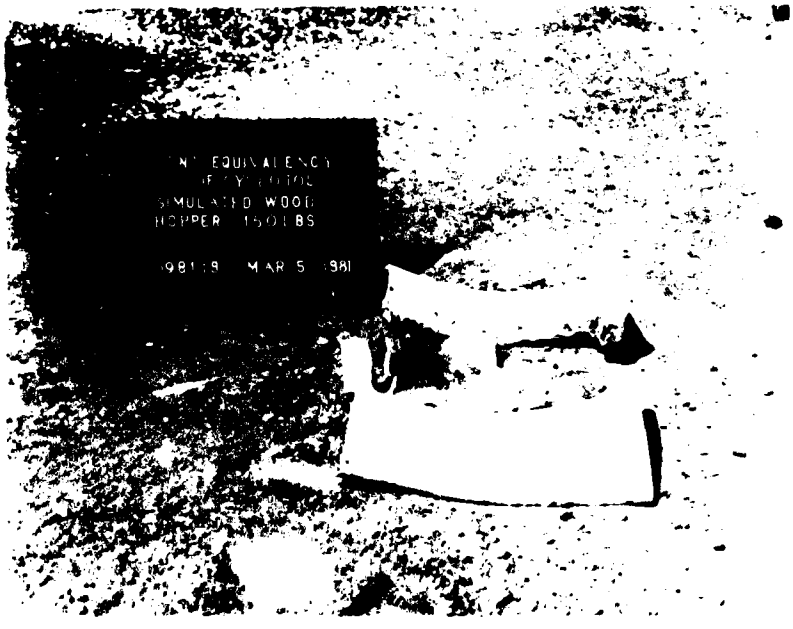
Cyclotol 70/30 posttest configuration 68.04 kg (150 lb) fiberboard transfer box



Cyclotol 70/30 pretest configuration 45.36 kg (100 lb) simulated wood hopper

Cyclotol 70/30 posttest configuration 45.36 (100 lb) simulated wood hopper

Cyclotol 70/30 pretest configuration 68.04 kg (150 lb) simulated wood hopper



Cyclotol 70/30 posttest configuration 68.04 kg (150 lb) simulated wood hopper

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