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REFLECTED BLAST MEASUREMENTS AT SMALL SCALED DISTANCES FOR M26E1 PROPELLANT

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This project was accomplished as part of the US Army's Manufacturing Methods and Technology Program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques, and equipment for use in production of Army materiel.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

MMT-Blast Measurements	Reflected pressure
Propellant, M26E1	Reflected impulse
Explosives	Reflected time of arrival

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

This report describes an experimental program conducted in support of the US Army Modernization Program. Normal and oblique reflected blast parameters, including peak pressure and impulse, were measured to characterize the explosive output of multiperforated M26E1 propellant. Three sizes of spherical propellant charges were fired over a reflecting surface on which an array of pressure transducers was used to obtain pressure-time histories at scaled

20. ABSTRACT (Continued)

distances of 3 $ft/lb_m^{1/3}$ (1.2 $m/kg^{1/3}$) and smaller. A series of Pentolite tests was also conducted at similar scaled distances to establish a baseline for comparing the reflected blast parameters measured in the propellant experiments. The blast pressure and impulse data obtained showed that at the scaled distances tested the maximum explosive output of M26E1 propellant is comparable to Pentolite. Furthermore, the data curves presented in the report can be used to aid in better design of protective structures to resist blast effects from accidental explosions of M26E1 propellant.

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I. INTRODUCTION

As part of the U. S. Army Production Base Modernization Program, air blast parameters such as pressure and impulse have been experimentally determined for a variety of explosives, propellants and pyrotechnics. The side-on pressures and impulses from these mostly surface burst tests are used in the design of structures and protective walls to withstand the effects of accidental explosions in ammunition plants. By using blast data from a specific propellant being processed, more cost effective yet safe structures can be designed and built.

Of particular interest to design and safety engineers, are the reflected peak pressures and impulses loading a wall or other structural configuration from an explosion occurring in close proximity. Consequently, an experimental program was performed by SwRI for the Manufacturing Technology Division of ARRADCOM to obtain normal and oblique reflected pressure and impulse data from explosions of M26El propellant spheres at scaled distances of less than 3 $ft/lb_m^{1/3}$ (1.2 $m/kg^{1/3}$).

In a previous program conducted by SwRI [1] reflected blast data at small distances were obtained by using a steel table in which electromechanical transducers were used to obtain normal and oblique pressure-time histories from air detonations of small scale Composition C-4 and Pentolite charges. In addition, normal and oblique impulses were obtained from cinematography of free-flying plugs initially mounted in the steel table. This same technique was not practical for making the reflected blast measurements from the multiperforated M26El propellant. In tests conducted by Swatosh, et al [2] using surface bursts of several geometries of this same propellant, it was evident that M26El propellant has a relatively large critical size to obtain a complete reaction even when Composition C-4 boosters are used. Therefore, the size of the table required to obtain the normal and oblique blast data would have made the table excessively expensive and impractical, particularly since tests of at least two different scales were desired. Consequently, the normal and oblique measurements were made by imbedding pressure transducers in a linear array

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1. J. J. Kulesz, E. D. Esparza and A. B. Wenzel, "Blast Measurements at Close Standoff Distances for Various Explosive Geometries," Final Report, Contract DAAA21-76-C-0219, Phase I, U. S. ARRADCOM, Southwest Research Institute, San Antonio, Texas, In Publication.

2. J. J. Swatosh, Jr., J. R. Cook, and P. Price, "Blast Parameters of M26El Propellant," Picatinny Arsenal, Technical Report No. 4901, Dover, New Jersey, Dec 1976.

along a flat ground surface. The propellant spheres were then suspended above the center transducers at the desired standoff distance, and initiated with double conical boosters and exploding bridgewire detonators. Peak pressure and time-of-arrival data were obtained directly from the transducer output while the impulse data were obtained by integrating the pressure-time history recorded.

The program was begun with a series of preliminary experiments to determine the minimum quantity of essentially unconfined M26E1 propellant in a spherical configuration that would generate a blast wave similar in strength to those reported in Reference 2. A total of 17 preliminary tests were conducted using several propellant weights, and single and double conical high-explosive boosters of different sizes. The main test program, consisting of 26 tests, was then conducted using three different size propellant charges and one size Pentolite spheres. The scaling of parameters for these experiments was accomplished as prescribed by the replica modeling law previously derived [1] which states that length, time and impulse are related by the scale factor λ^3 and pressure remains invariant. From the pi-terms formed in deriving this model law, functional relationships for pressure, scaled impulse and time-of-arrival can be obtained to design the experiments as well as interpret the data. Thus, for energy sources having the same geometry, with all dimensions and position properly scaled, and of larger size than their effective explosive limit for detonation, pressure, scaled impulse, and scaled time-of-arrival are functions of two independent quantities, the scaled distance (Z) and the angle of obliquity from the normal at which location these parameters are being measured.

In this report, the experimental program conducted will be covered. A complete summary of the tests fired will be presented along with a description of the experimental apparatus, the instrumentation used, and the data reduction process. Examples of the pressure-time traces recorded will be shown and the results of the entire program will be presented in tabular and graphical form. Conclusions and recommendations are made and tables of all the test data from which the data graphs are derived are included as an Appendix.

II. EXPERIMENTAL PROGRAM

Summary of Tests Conducted

To achieve the objectives of this experimental program two types of tests were conducted. First, an extensive set of 17 preliminary tests was required to determine the minimum quantity of unconfined M26E1 propellant that produced blast pressures comparable to those reported in Reference 2. Propellant charges in an approximate spherical geometry were initiated with Composition C-4 boosters and exploding bridgewire (EBW) detonators. The charges were suspended and fired above ground level at a height to minimize cratering of the ground thus reducing preparation between tests. The M26E1 propellant was furnished by the government and was shipped to SwRI in standard 160 lb cylindrical shipping drums from the Indiana Army Ammunition Plant. Side-on pressure transducers were used down range close to the ground level to measure the blast pressure produced by each charge. Two to three measurements were made at locations corresponding to scaled distances in most cases of 6 and 9.5 $ft/lb_m^{1/3}$ (2.4 and 3.8 $m/kg^{1/3}$). Because at these distances the transducers were located in the Mach stem of the blast wave, the pressures measured were the same as if the charge had been fired on the ground. The data recorded could then be compared with air blast data in the literature [2,3] to determine if the propellant was in effect detonating. Even though the data in Reference 2 were for a cylindrical charge, the scaled distances were large enough that geometry effects were not significant, and thus over-pressures from propellant cylinders and spheres could be compared.

Second, the main set of experiments conducted consisted of 26 tests. Six of these experiments were conducted with Pentolite spheres at three scaled distances from the normal transducer location of 3.0, 1.5 and 1.0 $ft/lb_m^{1/3}$ (1.2, 0.6 and 0.4 $m/kg^{1/3}$). These tests were done to provide a check on the instrumentation system as well as a comparison baseline for the propellant tests. Fourteen of these experiments were conducted with spheres of M26E1 propellant boostered with two conical Composition C-4 charges totaling 10% of the propellant weight. Three different propellant weights were used: 16, 30 and 54 lb (7.3, 13.6, and 24.5 kg). These propellant charges were positioned at distances from the normal transducer location corresponding to the same three scaled distances used with the Pentolite spheres. Finally, six tests were done firing pairs of C-4 boosters of the same size as used on the 16 lb

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3. C. N. Kingery, "Air Blast Parameters Versus Distance for Hemispherical TNT Surface Bursts," BRL Report No. 1344, Aberdeen Proving Ground, Maryland, September 1966.

(7.3 kg) propellant spheres and positioned at the same standoff distances as these propellant spheres. A summary of the tests conducted on this program is presented in Table 1.

TABLE 1. TEST PROGRAM

Test Type	Normal Scaled Distance, $ft/lb_m^{1/3}$ ($m/kg^{1/3}$)			
	3.0 (1.2)	1.5 (0.6)	1.0 (0.4)	Other
	Number of Tests			
Preliminary				17
Pentolite Spheres 1+ lb_m (0.47 kg)	2	1	3	
M26E1 Spheres 16 lb_m (7.3 kg)	2	3	2	
M26E1 Spheres 30 lb_m (13.6 kg)	1	2		
M26E1 Spheres 54 lb_m (24.5 kg)	3	1		
Boosters Alone 1.6 lb_m (0.73 kg)				6

Test Facility

All the experiments in this study were conducted by Southwest Research Institute in the Camp Bullis Facility just north of San Antonio, Texas. This is a U. S. Army facility controlled by Fort Sam Houston, Texas. SwRI has a working arrangement with Camp Bullis for its use on government-sponsored projects requiring firing of large quantities of explosives. This facility is 15 miles from the SwRI campus and all data acquisition equipment is brought from SwRI and housed in mobile trailers or temporary buildings.

For the preliminary tests, the propellant charges were suspended above the ground to minimize cratering and thus eliminate ground preparation between tests by just moving the horizontal location of the charge slightly. Figure 1 shows a sketch of how these tests were set up. Aerodynamically-shaped, side-on pressure transducers were used primarily at two positions corresponding to scaled distances of Z = 6 and 9.5 $ft/lb_m^{1/3}$ (2.4 and 3.8 $m/kg^{1/3}$). The propellant spheres were formed by taping together spherical sections of a thin polyethylene plastic sheet as shown in Figure 2. The plastic

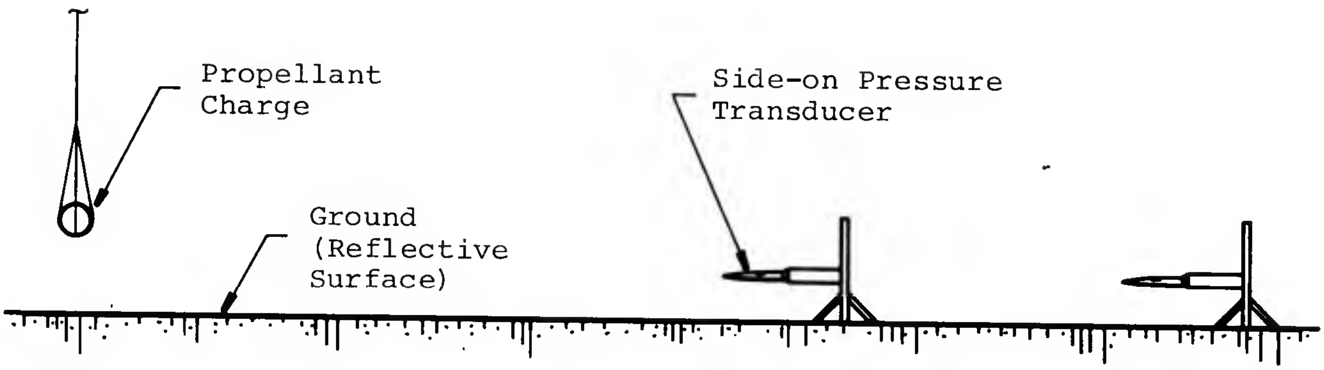


Figure 1. Layout for Preliminary Tests

Figure 2. M26E1 Propellant Sphere

sphere was just strong enough to contain the weight of propellant and consequently offered negligible confinement to the charge. In the preliminary tests, single and double boosters of several sizes were tried with propellant charges weighing from 8 to 100 lb (3.6 to 45.4 kg). The single conical boosters were placed with their base resting on top of the propellant sphere and were initiated at the apex of the booster with an EBW detonator of comparable strength to a Type II, MIL-C-14003 blasting cap. However, the EBW detonators are significantly safer to store, handle, and connect to the firing lines than blasting caps because they do not contain any primary explosives. The double conical boosters were positioned 180° apart along the horizontal diameter of the sphere. The use of EBW detonators provided simultaneous detonation of the boosters within 0.2 μsec. This degree of simultaneity is not possible with conventional blasting caps.

To conduct the main test program, a reflective surface capable of withstanding the loads expected from the M26E1 propellant charges was required. The use of a steel table similar to that used in Phase I of this project [1] was considered and quickly eliminated. Because the minimum propellant charge sizes were quite large, a steel table would have been prohibitively expensive and very impractical. Therefore, it was decided to use the ground as the reflective surface. A test bed was prepared by building up and leveling a 30 x 40 ft (9.1 x 12.2 m) area. An array of eleven protective pressure transducer canisters were laid out as shown in Figure 3. The canisters were buried in the ground so that the surface plates and the pressure transducers were flush with the ground surface. The charges were suspended from two stands as shown in Figure 4 over the center canister such that the double boosters were oriented 90° from the transducer line. The canisters on either side of the center one were symmetrically located. For any one test, a total of seven measurements were made. Each canister had provisions for removing the surface plate and the transducer without taking the canister out of the ground. Depending on the particular test setup, the transducers were mounted on a given set of seven canisters to cover about the same angles of obliquity. Figure 5 shows a 16 lb (7.3 kg) propellant charge being fired.

Instrumentation

Several different transducers were used in this project to obtain the pressure-time data. Each transducer was selected depending on the peak pressure expected at each measurement location on a given test. On the preliminary tests, Celesco Model LC-33 and Susquehanna Model ST-7A "pencil" transducers were used to measure the side-on overpressures. On the main test program, Susquehanna Models ST-2 and ST-4, and PCB Piezotronics Model 102A03 and 109A02 pressure transducers were used to measure the normal and oblique reflected pressures.

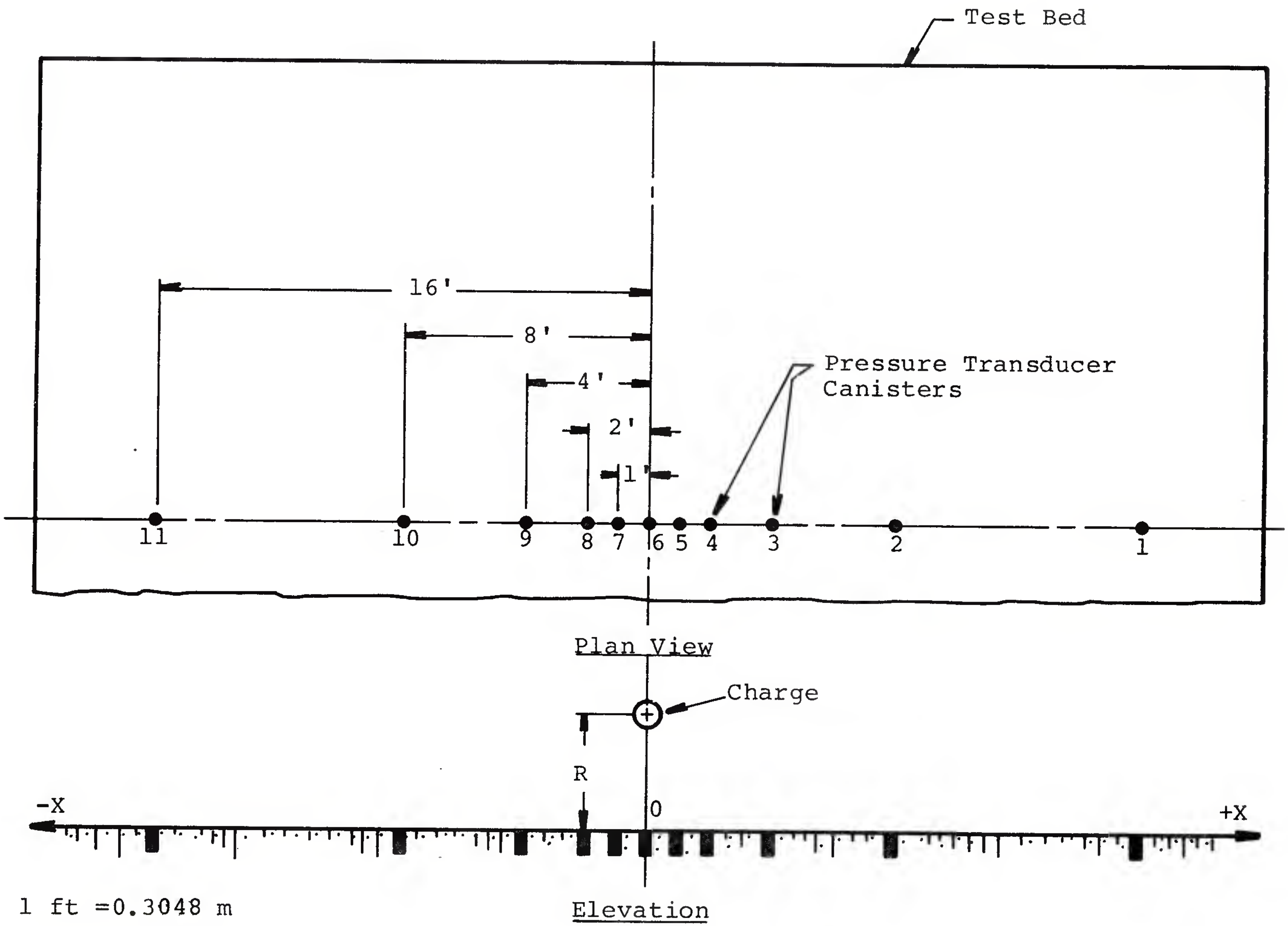


Figure 3. Field Layout of Transducer Canisters

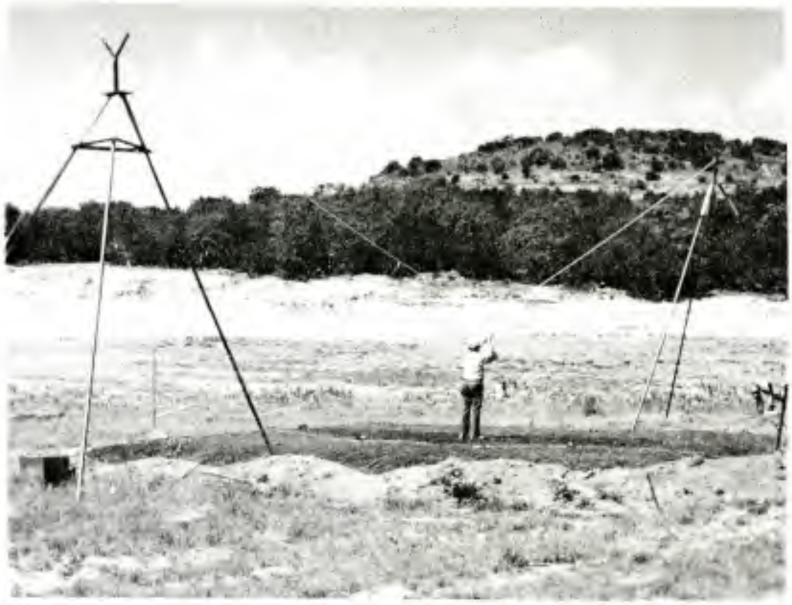


Figure 4. Suspension of Propellant Charge

Figure 5. Firing of Propellant Charge

All these transducers were individually calibrated prior to each test series and after any test in which a transducer may have indicated damage from the blast loading. Any transducers found damaged were replaced before testing was continued.

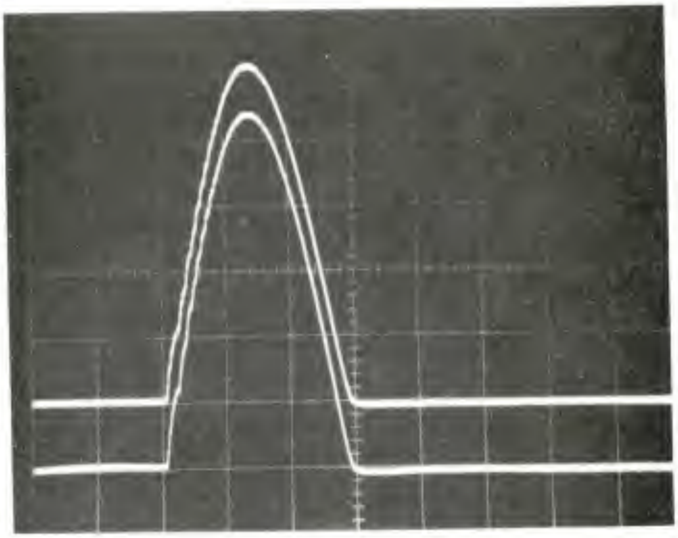
Calibration was accomplished with a dynamic hydraulic calibrator consisting of a triangular chamber filled with oil. Two symmetric ports are provided for flush mounting a reference and a test transducer. The pressure pulse is generated by dropping a weight down a guide tube onto a piston which extends through the top of the chamber. This device produces a half-sine, positive pressure pulse with peak amplitudes from 100 psi (0.7 MPa) to more than 10,000 psi (70 MPa), and rise times of 1 to 2 msec. Different weights and drop heights are used to vary the peak amplitudes. Figure 6 shows a sample of a typical calibration pulse from the hydraulic calibrator. The reference transducer used was first calibrated using a dead-weight hydraulic tester. It in turn was used to determine the pressure input to the test transducer.

For those transducers which were expected to encounter peak pressures lower than 100 psi (0.7 MPa) a second calibration was also performed with a pneumatic calibrator. This unit generates a known step-function increase in pressure for dynamic calibration over a pressure range of 0-150 psig (0-1034 kPa). The rise time is from 3-5 msec. The reference transducer is a precision, 12-inch, bourdon tube gage. The manifold is symmetric such that two transducers can be calibrated simultaneously. Figure 7 is an example of the voltage-time output from two transducers exposed to a 30 psig (207 kPa) pulse. Dividing the output voltage by this pressure provides the sensitivity of each transducer for this pressure level.

In the field tests, the transducers were connected to an underground coaxial cable system which tied into the power and conditioning electronics contained in an instrumentation building approximately 300 ft (91.4 m) from the test area. All data signals for the main test program were recorded on magnetic tape using an Ampex FR-1900 tape recorder with Wideband II, FM electronics. The data were recorded at 120 ips (3.05 m/s) over a frequency range of 0-500 kHz. The data were played back with a speed reduction ratio of 64 into a CEC Model 5-164 oscillograph recorder with 1 kHz upper frequency response galvonometers. The resulting playback frequency range was then 0-64 kHz. For the preliminary tests, the output of the transducers was recorded on Biomation Model 802 transient digital recorders with a frequency response of at least 0-50 kHz and photographed on Polaroid film from a cathode ray display.

Data Reduction

The pressure-time data obtained in the experiments were processed to obtain engineering plots of the pressure and impulse traces. The oscillograph records were reduced by



Upper Trace - Reference Transducer

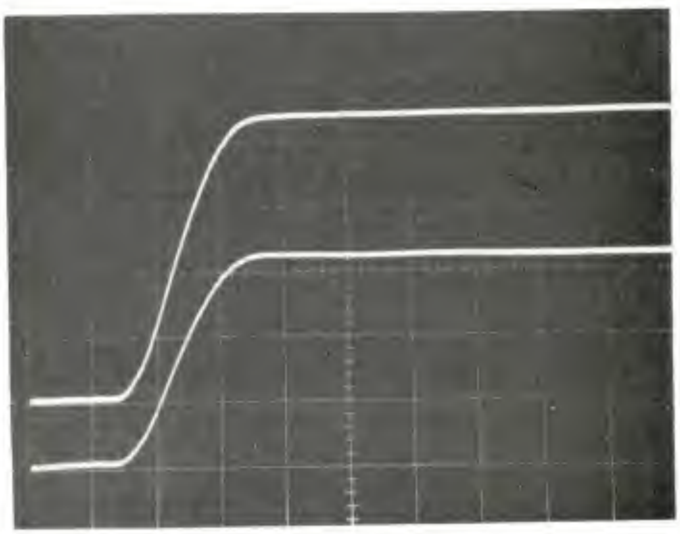
Peak Pressure = 1,016 psig (7,005 kPa)

Lower Trace - Test Transducer

Gain = 0.1 v/div

Sweep = 2 ms/div

Figure 6. Pulse from Hydraulic Calibrator



Gain = 100 mv/div

Sweep = 5 ms/div

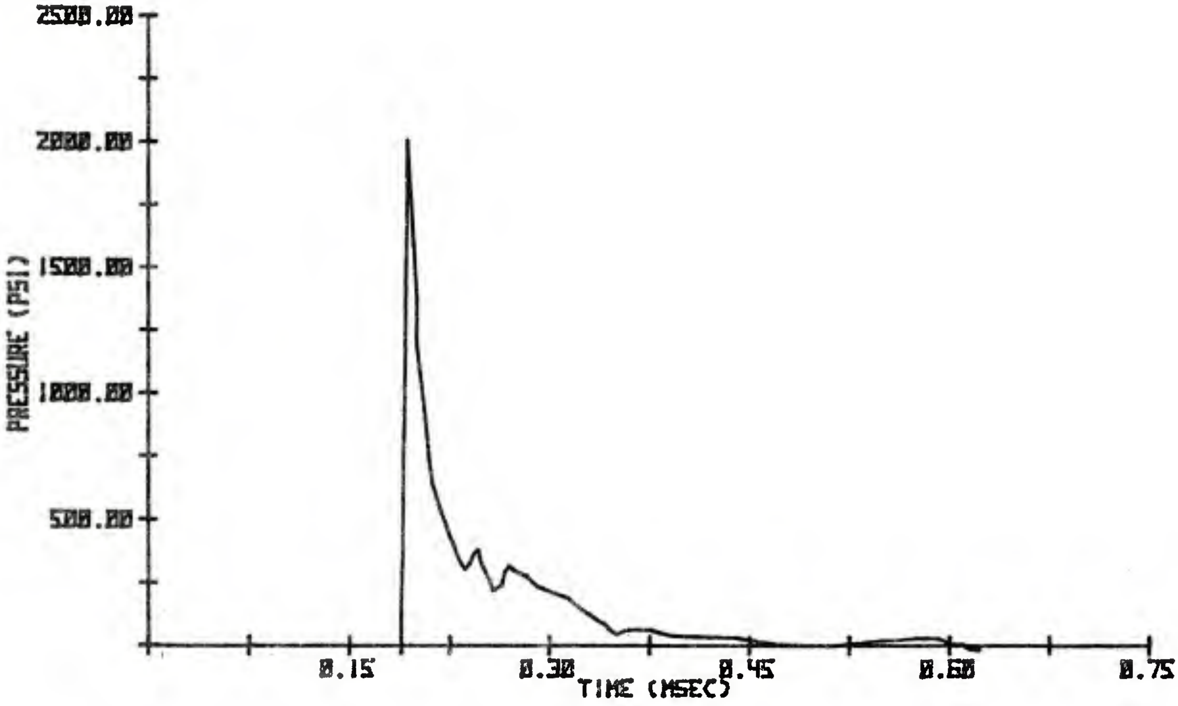
Input Pressure = 30 psig (206.9 kPa)

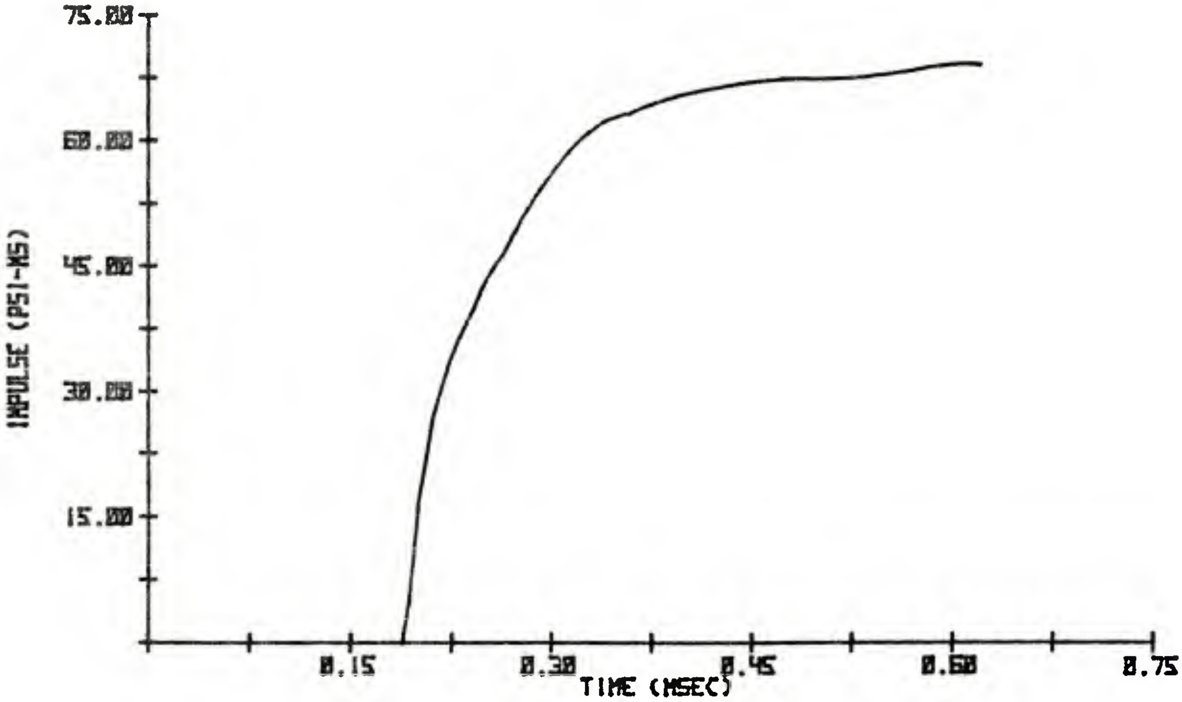
Upper Trace - Test Transducer #1

Lower Trace - Test Transducer #2

Figure 7. Step from Pneumatic Calibrator

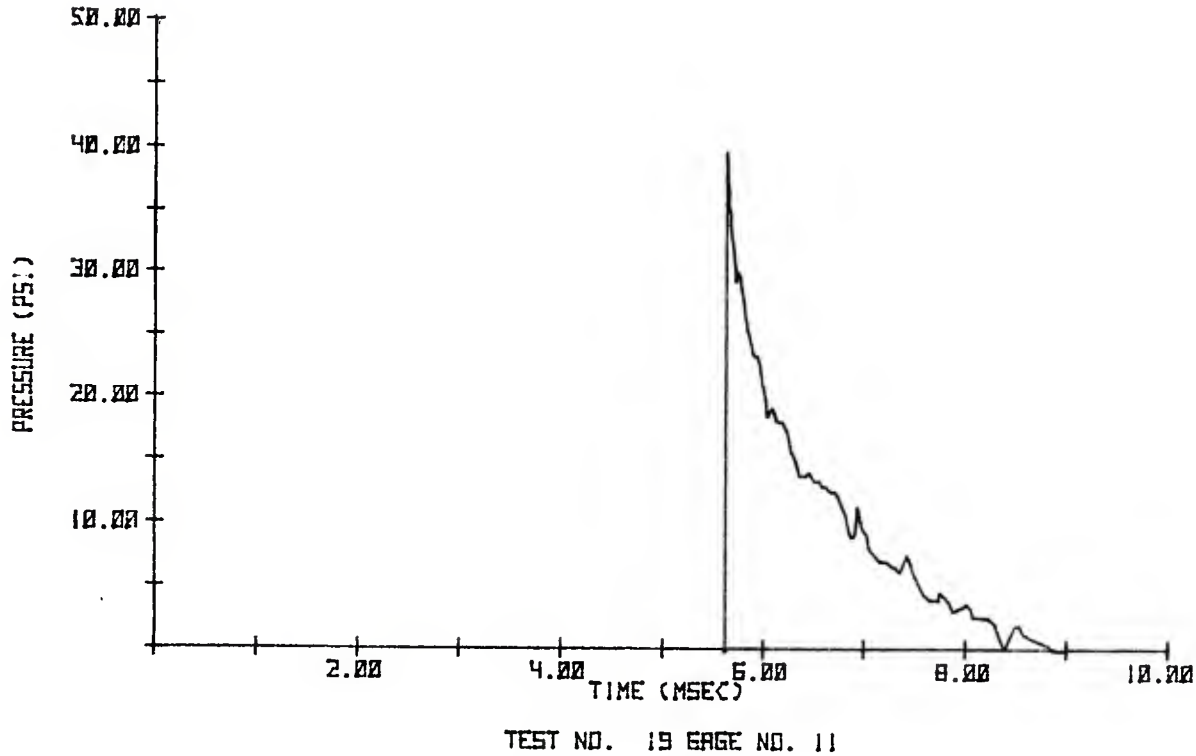
manually digitizing them into a Hewlett-Packard Model 9830 microprocessor system. The BASIC program used to digitize the pressure-time histories also integrated the histories to obtain the specific impulse, properly scaled each parameter, and printed out the peak values. A Model 9862A plotter was used to obtain permanent copies of the data with engineering units for analysis. Figures 8 and 9 show examples of these types of data plots.

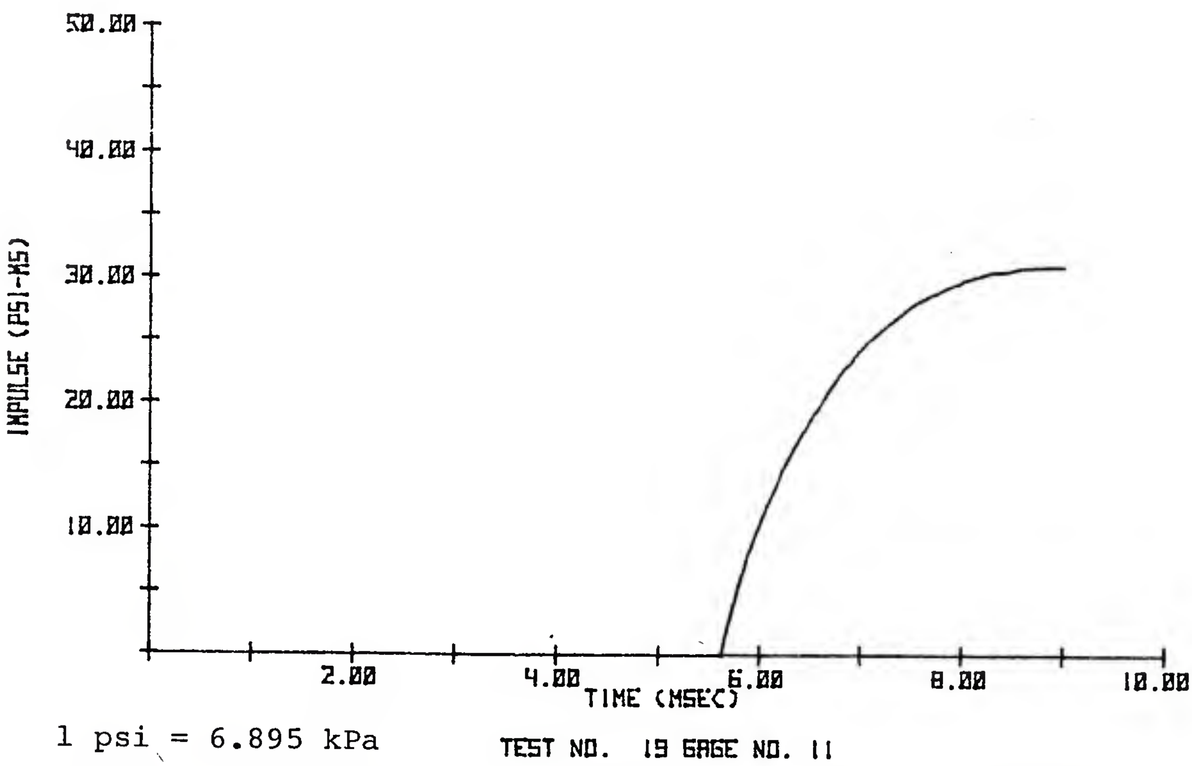




1 psi = 6.895 kPa TEST NO. 12 GAGE NO. 7

Figure 8. Data Plots from Pentolite Test at Z = 1.5 ft/$lb_m^{1/3}$ (0.6 m/$kg^{1/3}$) and X/R = 0.66.





1 psi = 6.895 kPa

Figure 9. Data Plots from M26E1 Test at $Z = 3.0\ ft/lb_m^{1/3}$ ($1.2\ m/kg^{1/3}$) and $X/R = 1.72$.

III. EXPERIMENTAL RESULTS

Preliminary Tests

A series of 17 preliminary tests was conducted primarily to determine the minimum quantity of unconfined M26E1 propellant in a spherical configuration that would detonate and thus establish the size of the smaller charges to be used in the main test program that followed. Several combinations of charge and booster sizes were used. The basis for deciding whether a given propellant charge was "detonating" was to measure side-on overpressures from essentially surface bursts and to compare the results with those in the literature [2,3].

In Reference 2, experimental data from tests using M26E1 shipping drums are presented. This charge geometry is different enough from a sphere that at small scaled distances, overpressures would be significantly different. Consequently, in the preliminary tests the measurements were made at scaled distances large enough that geometry effects were minimal. The scaled distances used were in most cases 6 and 9.5 $ft/lb_m^{1/3}$ (2.4 and 3.8 $m/kg^{1/3}$). A few measurements were also made at a scaled distance of 15 $ft/lb_m^{1/3}$ (6 $m/kg^{1/3}$). The Reference 2 results indicate that in a shipping drum configuration M26E1 propellant would generate a peak overpressure of 42, 10 and 3.9 psi (290, 69 and 27 kPa) at these three scaled distances. From Reference 3, if the propellant is assumed to be as energetic as TNT, the corresponding overpressures for the same three scaled distances are 28, 10.5 and 4.7 psi (193, 72 and 32 kPa). Thus, the measured pressures were compared to these two sets of overpressures and if the measured ones were of similar magnitudes, then the particular propellant-booster charge was assumed to have detonated. The peak pressures measured are presented in Table 2.

The results indicated that to "detonate" M26E1 propellant, a relatively large charge size or substantial boostering is required. Because at least two different size charges were to be used in the main test program, it was very desirable to use the smallest possible charge size to keep the actual test bed size and height of the charge within reasonable and workable limits. Therefore, a 16 lb (7.26 kg) propellant sphere was selected as the smallest charge and a 54 lb (24.5 kg) sphere as the largest scale (1.5 larger) charge. An intermediate weight of 30 lb (13.6 kg) was selected for a few tests.

Main Tests

The main test program consisted of experiments using M26E1 propellant spheres of three different sizes, Pentolite spheres of one size, and double conical Composition C-4 boosters of one size. The Pentolite experiments were conducted primarily to check the instrumentation system for proper

TABLE 2. PEAK PRESSURES FOR PRELIMINARY TESTS

Test No.	Propellant Weight (lb)[a]	No. of Boosters	Total Booster Weight (%)	Measured Peak Pressures (psi)[c]		
				6 $(ft/lb_m^{1/3})$[b]	9.5 $(ft/lb_m^{1/3})$	15 $(ft/lb_m^{1/3})$
PL 1	16.0	1	1.0	10.1	3.0	
PL 2	16.0	1	2.0	10.1	2.9	1.5
PL 3	30.0	1	2.0	23.3	7.7	3.3
PL 4	30.0	1	2.0	25.5	6.8	3.5
PL 5	100.0	1	2.0		9.0	
PL 6	30.0	1	2.0	28.0	4.5	
PL 7	30.0	1	4.0	25.1	9.3	3.0
PL 8	64.0	1	2.0	29.1	9.5	4.1
PL 9	64.0	1	4.0	36.5		2.8
PL10	64.0	1	4.0	45.0		
PL11	8.0	2	5.5	19.0		
PL12	16.0	2	5.5	24.0	8.5	
PL13	16.0	1	5.5	31.0	10.7	
PL14	1.0[d]	-	--	26.0	10.7	
PL15	1.0[d]	-	--	28.7	9.5	
PL16	1.0[d]	-	--	28.5	12.0	
PL17	16.0	2	10.0	32.8	12.0	

[a] 1 lb = 0.4536 kg

[b] $1\ ft/lb_m^{1/3} = 0.3967\ m/kg^{1/3}$

[c] 1 psi = 6.895 kPa

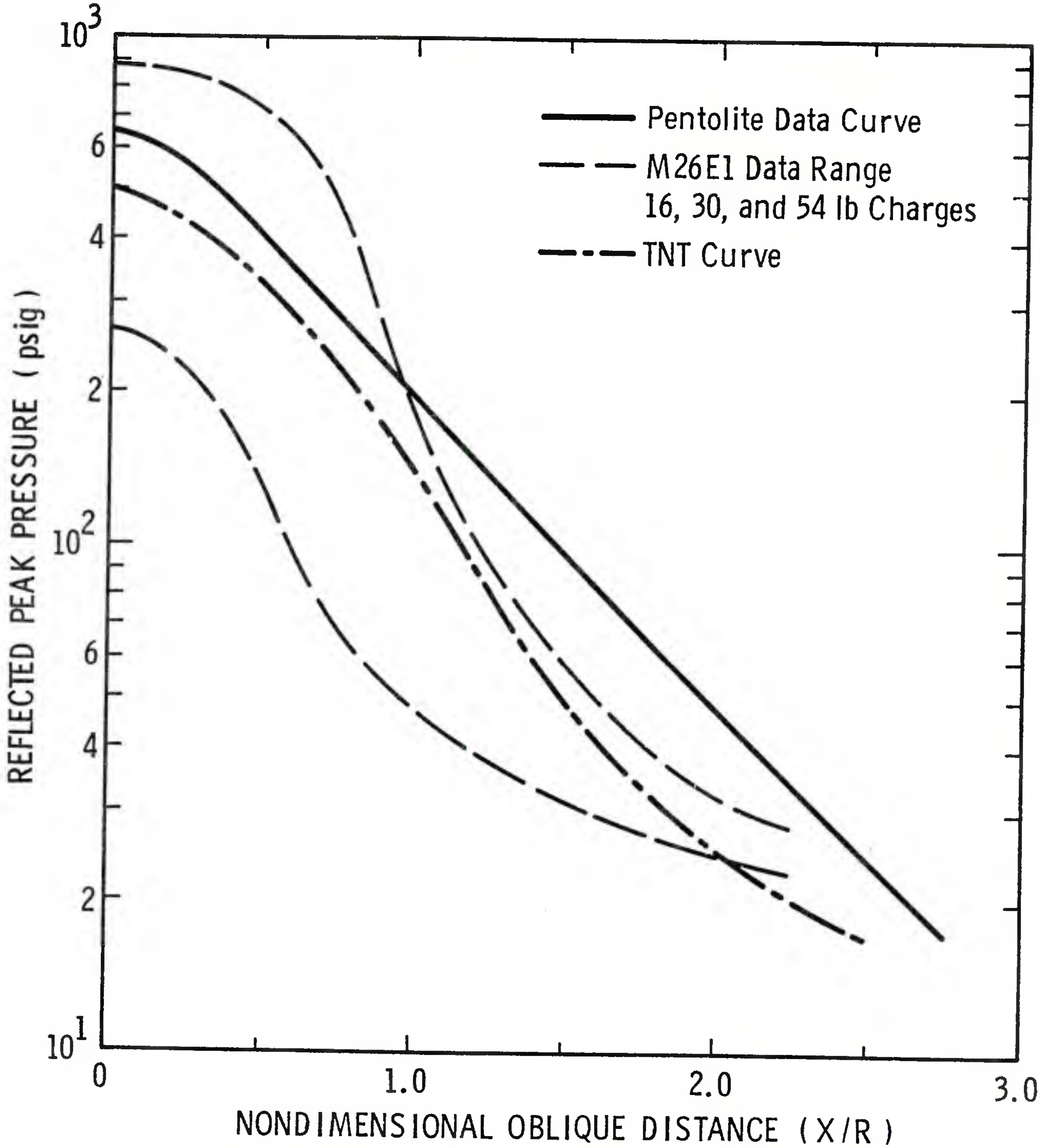
[d] Pentolite Sphere

operation and to provide a comparison baseline for the propellant data. The booster experiments were done to confirm that simultaneous detonations were taking place consistently on each pair of boosters and to show that the contribution of the boosters was essentially the same from test to test of the same propellant weight.

As shown in Table 1, tests were conducted at three scaled distances as measured from the center of the charge to the normal reflected pressure transducer in the array. Transducers were mounted on either side to make oblique reflected measurements with angles of obliquity as large as 70.5° from the normal. For convenience in presenting the data, the obliquity angle will be represented on the figures and discussions that follow by the ratio of the horizontal component (X) to the vertical component (R). This ratio or nondimensional oblique distance (X/R) then ranged from 0, the normal reflected location, to about 2.82, which is the tangent of 70.5°, the largest angle of obliquity. Seven measurements were usually attempted on each test. The center transducer was always the normal measurement and the other six formed pairs of oblique measurements on either side of center.

The pressure data, and later the impulse and time-of-arrival data, are grouped together by scaled distance (Z) and are plotted versus the nondimensional oblique distance. Even though the preliminary experiments showed that a 16 lb (7.26 kg) sphere was detonating as indicated by the side-on measurements, closer-in measurements made in the main tests showed that even with a 10% double booster, the M26E1 propellant had a variable explosive energy output depending on charge size which resulted in appreciable scatter, particularly in the pressure data. Consequently, the propellant data will be presented as envelopes of the range of all the data measured. All the individual data points are included in the Appendix.

Figure 10 presents the range of the propellant data from 16, 30, and 54 lb (7.3, 13.6 and 24.5 kg) spherical M26E1 propellant charges for a scaled distance of 3 $ft/lb_m^{1/3}$ (1.2 $m/kg^{1/3}$). In computing this distance note that even though the boosters added 10% to the propellant charge weight, the error in computing scaled quantities such as the scaled distance is only about 3% (on the conservative side) if the weight of the boosters is neglected. Because of the large variation in output explosive energy of the propellant, the scatter in the data is such that this small error would make an insignificant difference in the data graphs presented. For comparison purposes, a solid line representing an eye-fit curve through the Pentolite data points obtained in this program is shown. In addition, a TNT curve, derived from Reference 4



1 psi = 6.895 kPa
1 lb_m = 0.454 kg

Figure 10. Normal and Oblique Reflected Pressures for $Z = 3.0\ ft/lb_m^{1/3}$ ($1.2\ m/kg^{1/3}$).

by Kot, et al [4] and Figure 4-5 of TM5-1300 [5] is also shown to compare with the Pentolite and propellant data curves. The figure from Reference 4 provides a reflected pressure amplification coefficient for any angle of incidence and was synthesized by Kot, et al [4] from Figure 4-6 of TM5-1300 [5] and more recent data from Carpenter and Brode [6]. The latter information was used primarily for obliquity angles greater than 40°. Because at large obliquity angles an explosion in the vicinity of a large flat surface appears more like a surface burst, Kot, et al [4] makes the reflected pressure approach a value of 150% the side-on overpressure. This is a more accurate assumption than the one in Reference 5 which says that at an obliquity angle of 90° the reflected pressure is the same as the overpressure from a free air explosion. The procedure for deriving the TNT pressure and impulse (shown later) curves is given in Reference 5 and basically consists of computing slant distances from the charge to the points of interest and obtaining the side-on overpressures at the corresponding scaled distances. Each set of side-on overpressure and incidence angle is then used to obtain the reflected pressure coefficient which allows computation of the corresponding reflected pressure. With the reflected pressure determined, a fictitious scaled distance is obtained from the normally reflected pressure versus scaled distance TNT graph in Reference 5 and used to find the corresponding scaled positive reflected impulse. However, the TNT time-of-arrival curves shown later were obtained by simply finding the scaled times for a range of slant scaled distances of interest from the free air TNT graph (Figure 4-5 of the TM5-1300 [5]).

Similar plots for the other two scaled distances, 1.5 $ft/lb_m^{1/3}$ (0.5 $m/kg^{1/3}$) and 1.0 $ft/lb_m^{1/3}$ (0.4 $m/kg^{1/3}$) are shown in Figures 11 and 12. These curves show that in most cases the maximum peak pressures measured for the propellant tests at the three scaled distances are comparable to those from Pentolite over the entire range of scaled oblique distances (X/R) tested. Furthermore, the TNT curve falls within the range of the propellant data. This implies that M26E1 propellant which has been boostered significantly can generate peak pressures at small scaled distances which are about the same magnitude

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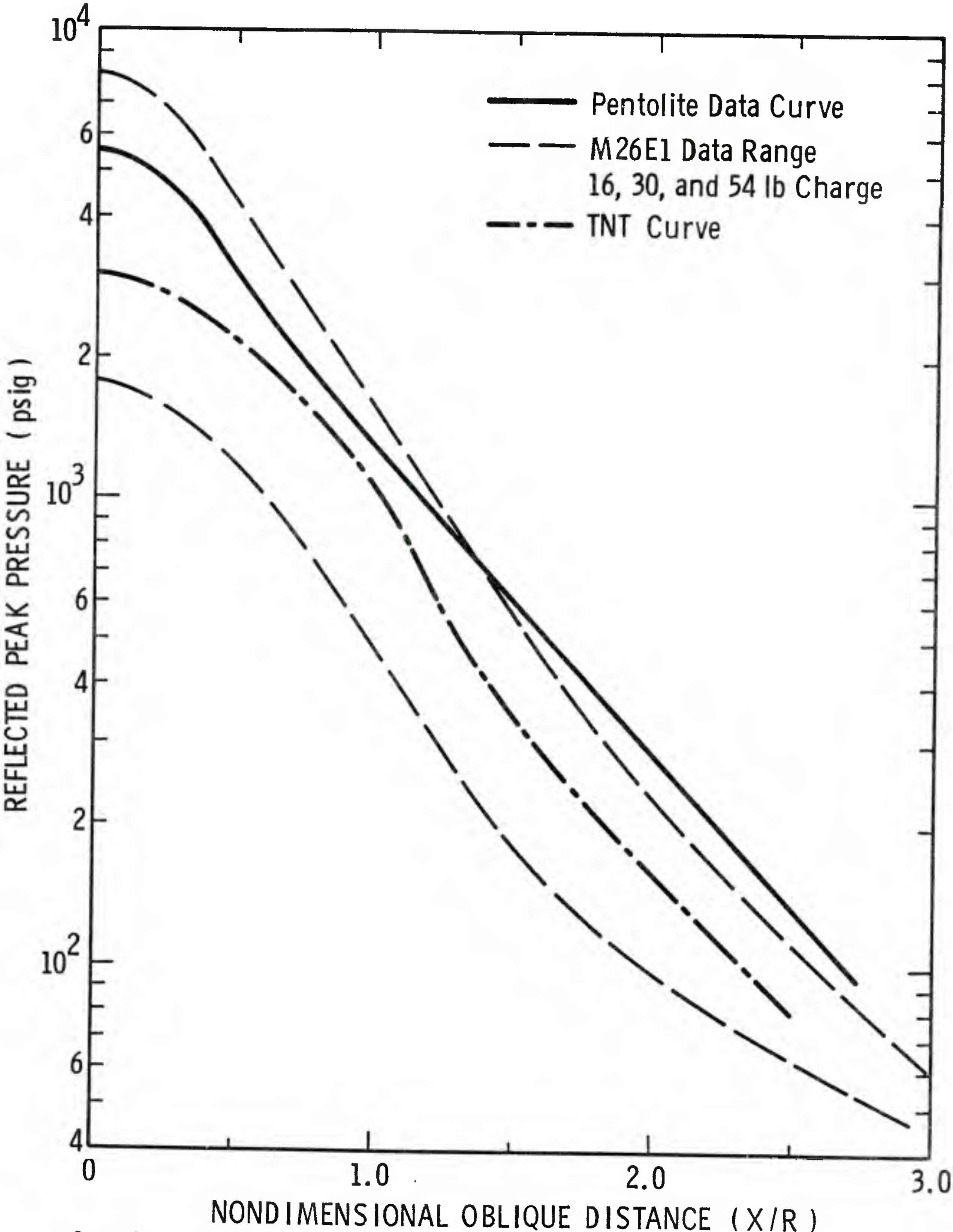
4. C. A. Kot, R. A. Valentin, D. A. McLennan and P. Turula, "Effects of Air Blast on Power Plant Structures and Components," U. S. Nuclear Regulatory Commission CR-0442, Argonne National Laboratory, Argonne, Illinois, October 1978.

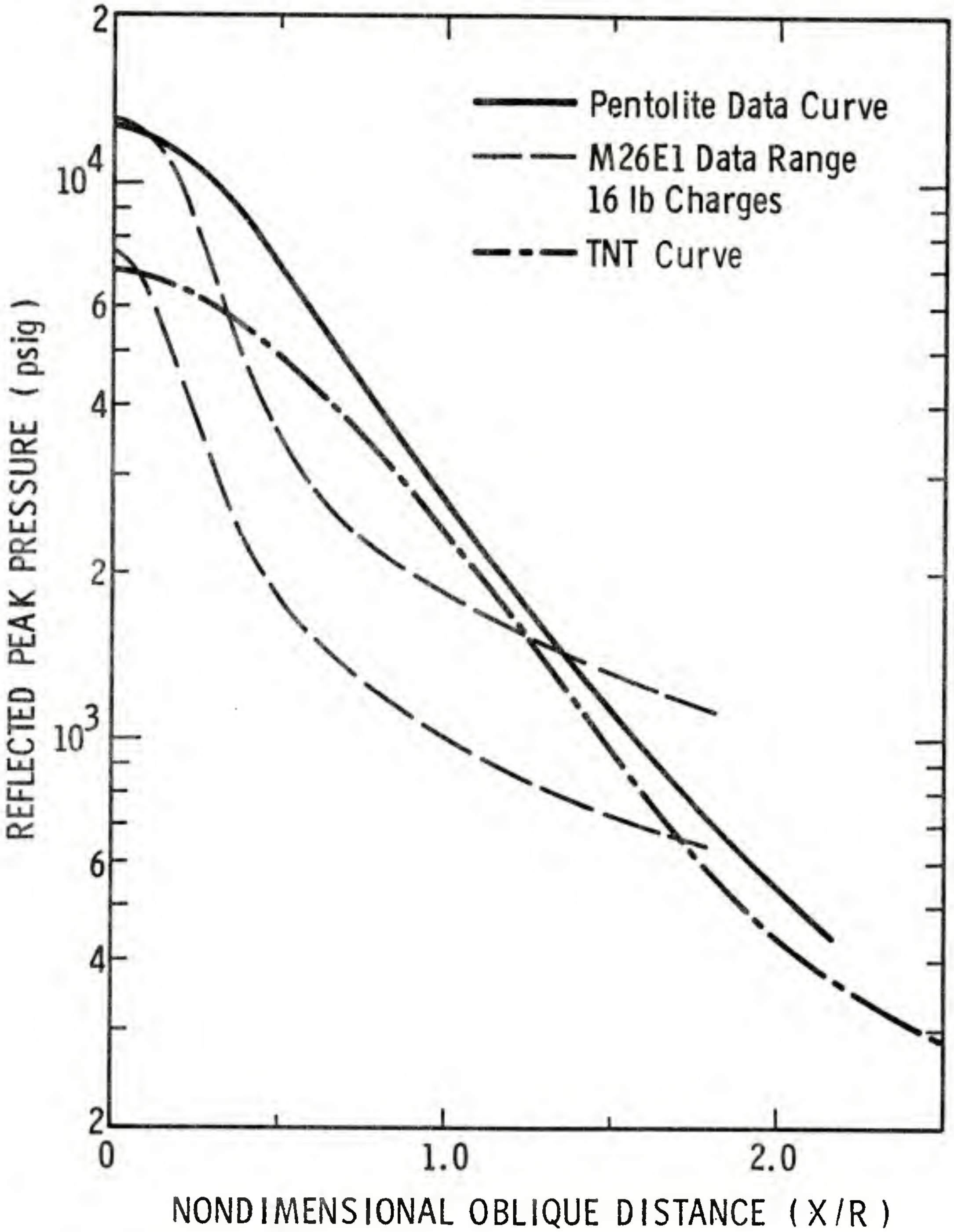
5. "Structures to Resist the Effects of Accidental Explosions," U. S. Army TM5-1300, Washington, D.C., June 1969.

6. H. J. Carpenter and H. L. Brode, "Height of Burst Blast at High Overpressures," R & D Associates, Santa Monica, California, 1975.



1 psi = 6.895 kPa
1 lb_m = 0.454 kg

Figure 11. Normal and Oblique Reflected Pressures for $Z = 1.5\ ft/lb_m^{1/3}$ ($0.6\ m/kg^{1/3}$).



1 psi = 6.895 kPa
1 lb_m = 0.454 kg

Figure 12. Normal and Oblique Reflected Pressures for Z = 1.0 $ft/lb_m^{1/3}$ (0.4 $m/kg^{1/3}$)

as Pentolite. For designing of protective walls or other structures, the use of the maximum pressure line would result in a conservative design.

The scaled impulse data are presented in similar fashion in Figures 13 through 15. These figures show a narrower band of scatter in the propellant impulse data than for the peak pressures. However, the values measured for the M26E1 propelland are again about the same magnitude as the eye-fit line for the Pentolite data. On the other hand, all the experimental data from this program fall below the TNT impulse curve. Thus, a structure designed using TNT impulse data would be conservative when protecting against accidental M26E1 explosions.

Finally, the range of the scaled time-of-arrival data is presented in Figures 16 through 18 and compared to the eye-fit curve through the Pentolite data points. The scatter of these data, especially for the two closer scaled distances, is less than for the pressure data. Figure 16 shows that the maximum arrival times measured on the propellant tests are almost the same as those measured on the Pentolite tests. However, in Figures 17 and 18, the Pentolite curve falls in between the maximum and minimum values measured on the propellant tests. Furthermore, when comparing to the TNT curve obtained from Reference 5, the experimental data from Pentolite tests show similar arrival times of the shock wave as the TNT curve would predict. In some cases (Figure 16) the propellant arrival times are shorter than for the Pentolite and TNT explosives. However, the slope (shock velocity) of the range of the propellant data is about the same or steeper than the explosives curves which indicates shock waves of comparable or lesser strength for the propellant test over the distances on which time of arrival measurements were made. A similar phenomena on tests using pressurized bursting gas spheres [7] has been observed in which arrival times were comparable to those of Pentolite but on which overpressures were of much lower amplitude. This type of behavior may be characteristic of finite-sized energy sources which are not as compact as high explosives.

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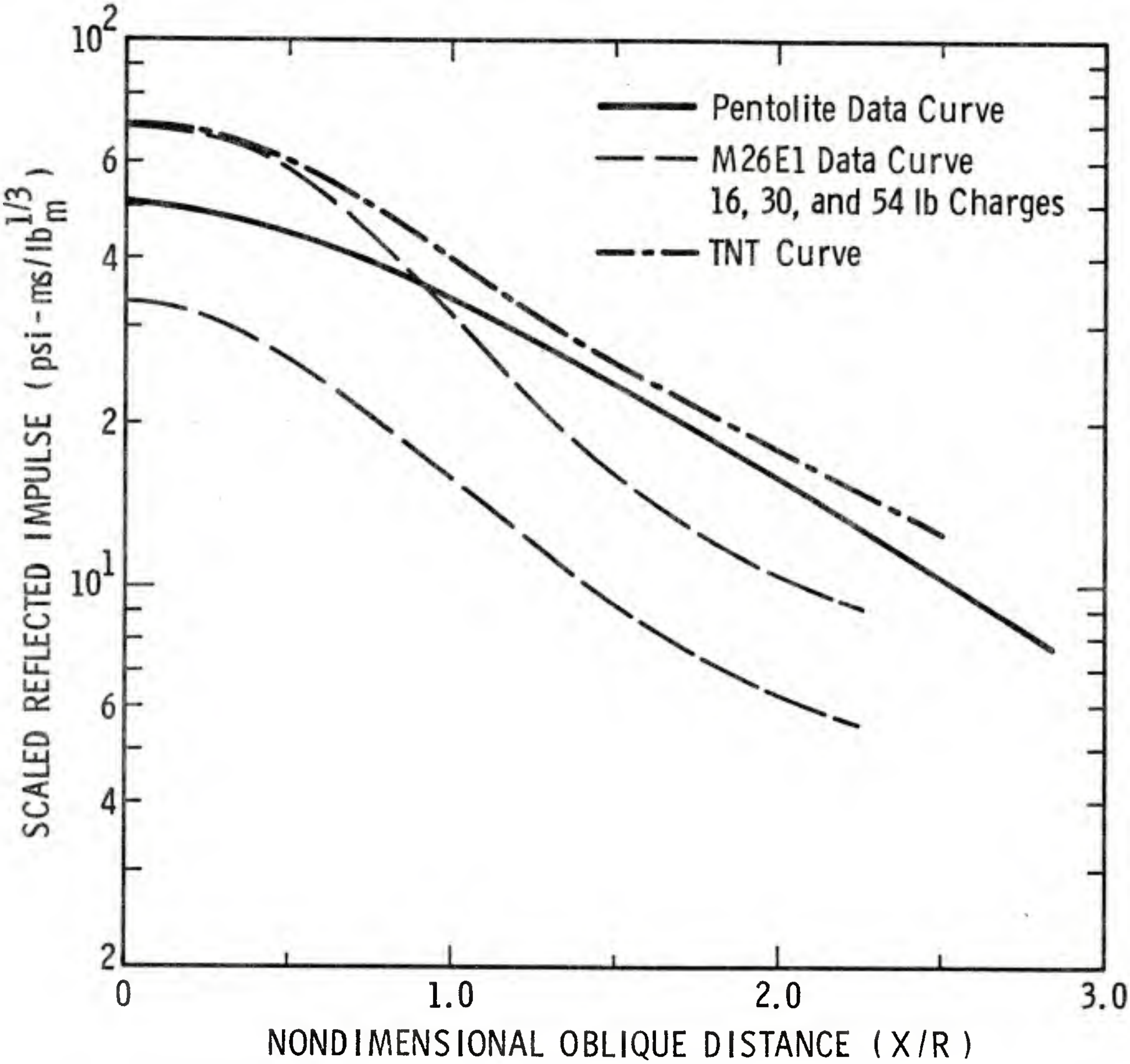
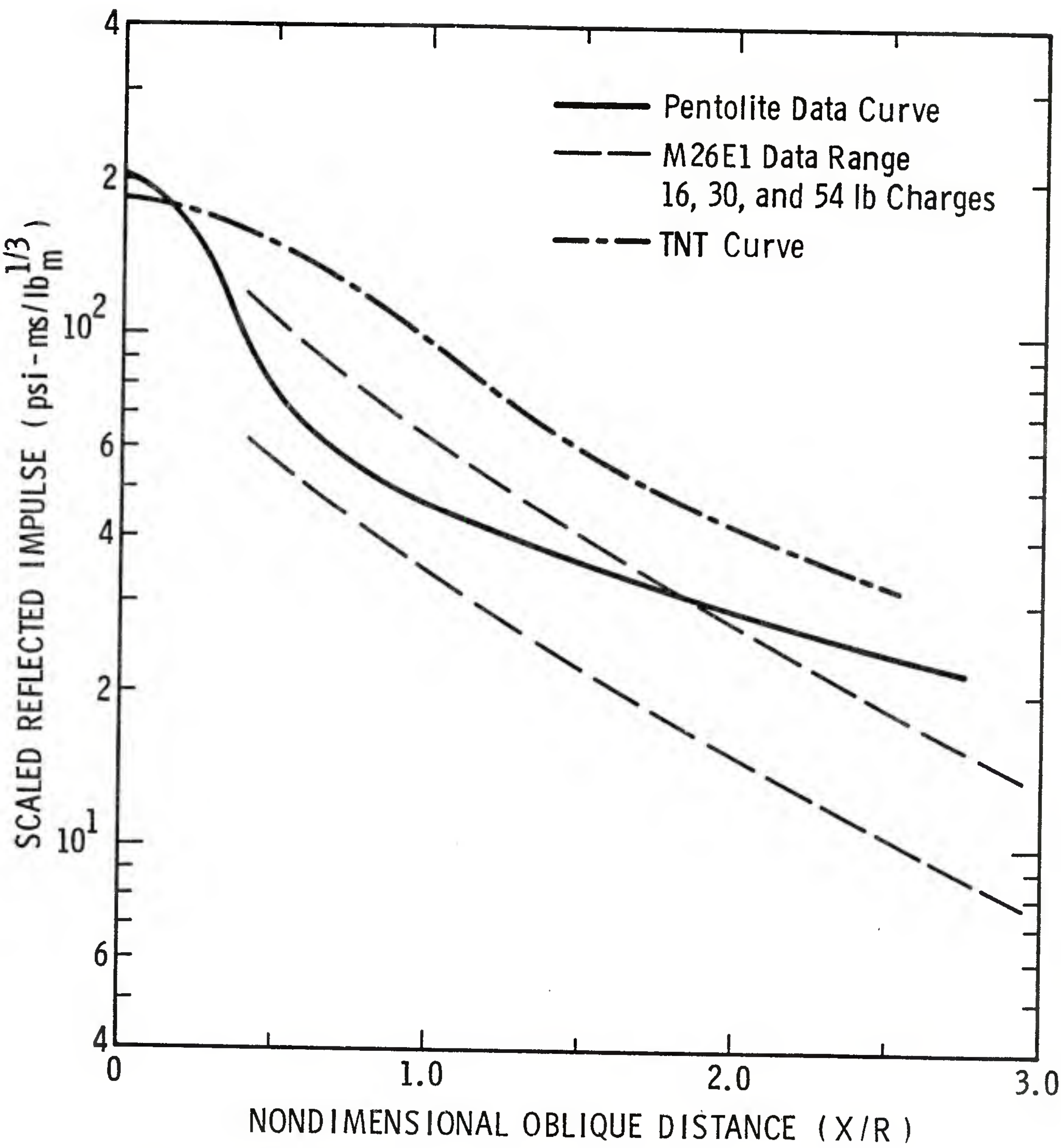
7. E. D.Esparza and W. E. Baker, " Measurement of Blast Waves from Bursting Pressurized Frangible Spheres," NASA Contractor Report No. CR-2843, Washington, D.C., May 1977.



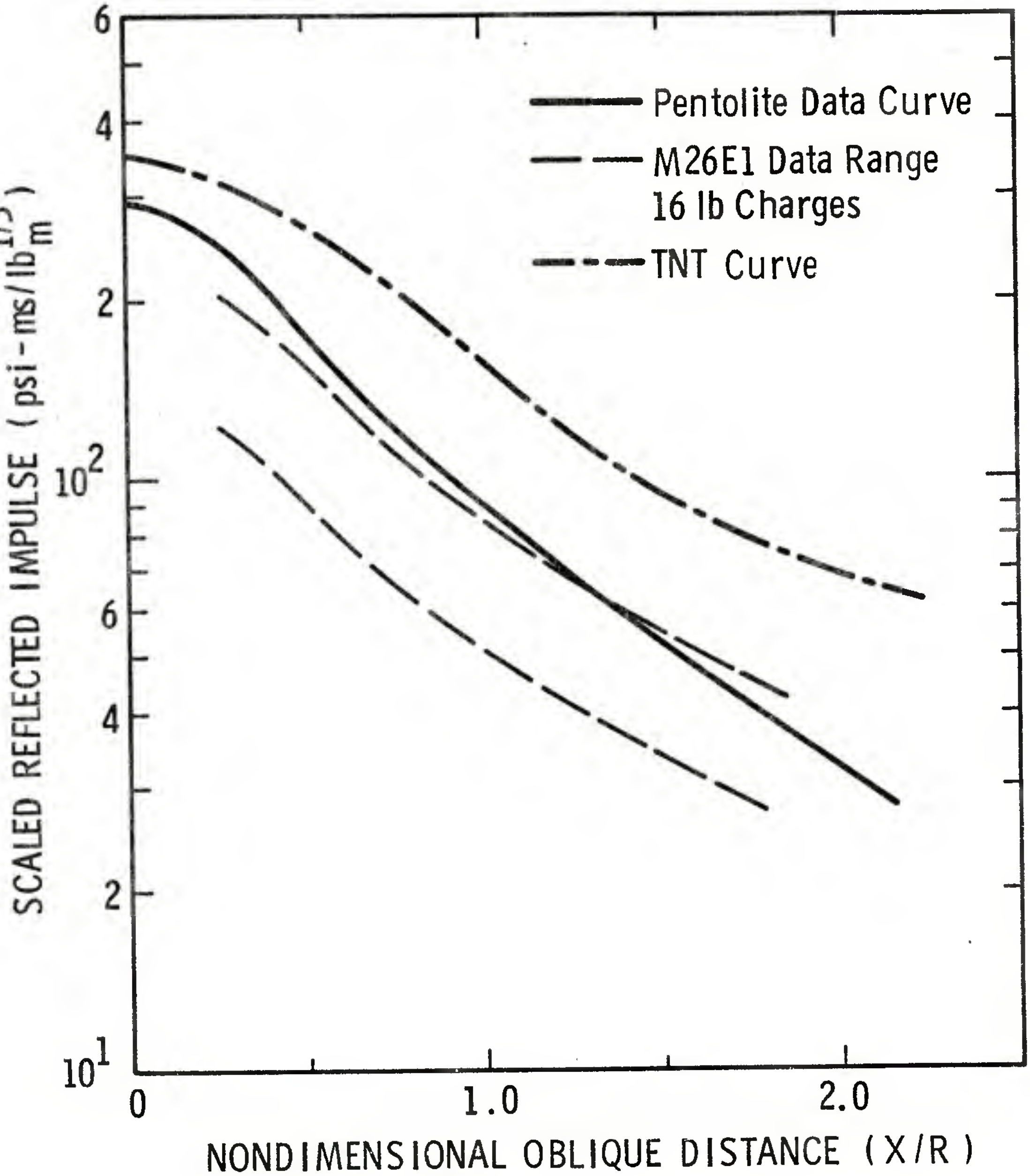
1 psi = 6.895 kPa
1 lb_m = 0.454 kg

Figure 13. Normal and Oblique Reflected Impulses for $Z = 3.0\ ft/lb_m^{1/3}$ ($1.2\ m/kg^{1/3}$).



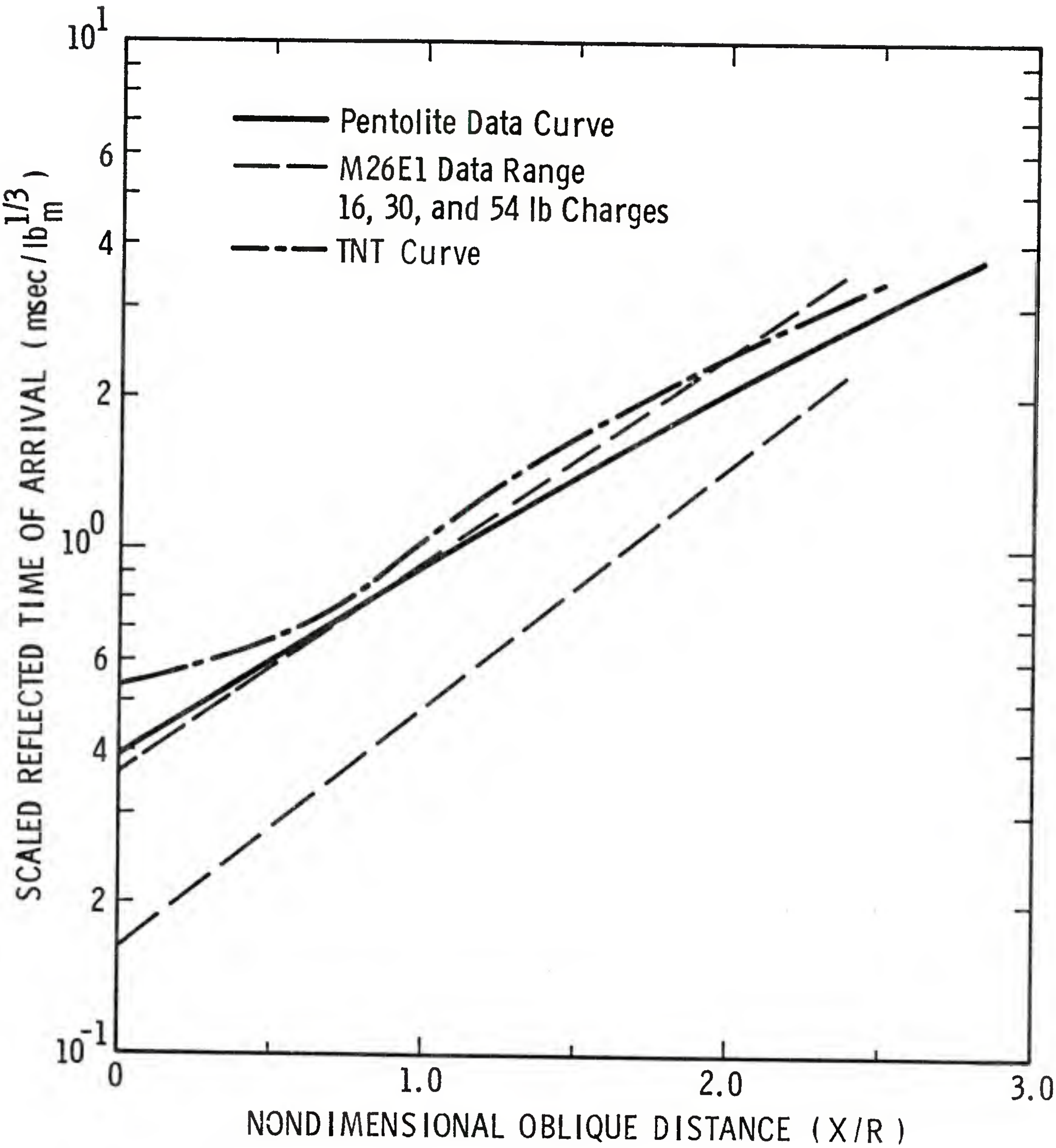
1 psi = 6.895 kPa
1 lb_m = 0.454 kg

Figure 14. Normal and Oblique Reflected Impulses for $Z = 1.5\ ft/lb_m^{1/3}$ ($0.6\ m/kg^{1/3}$).



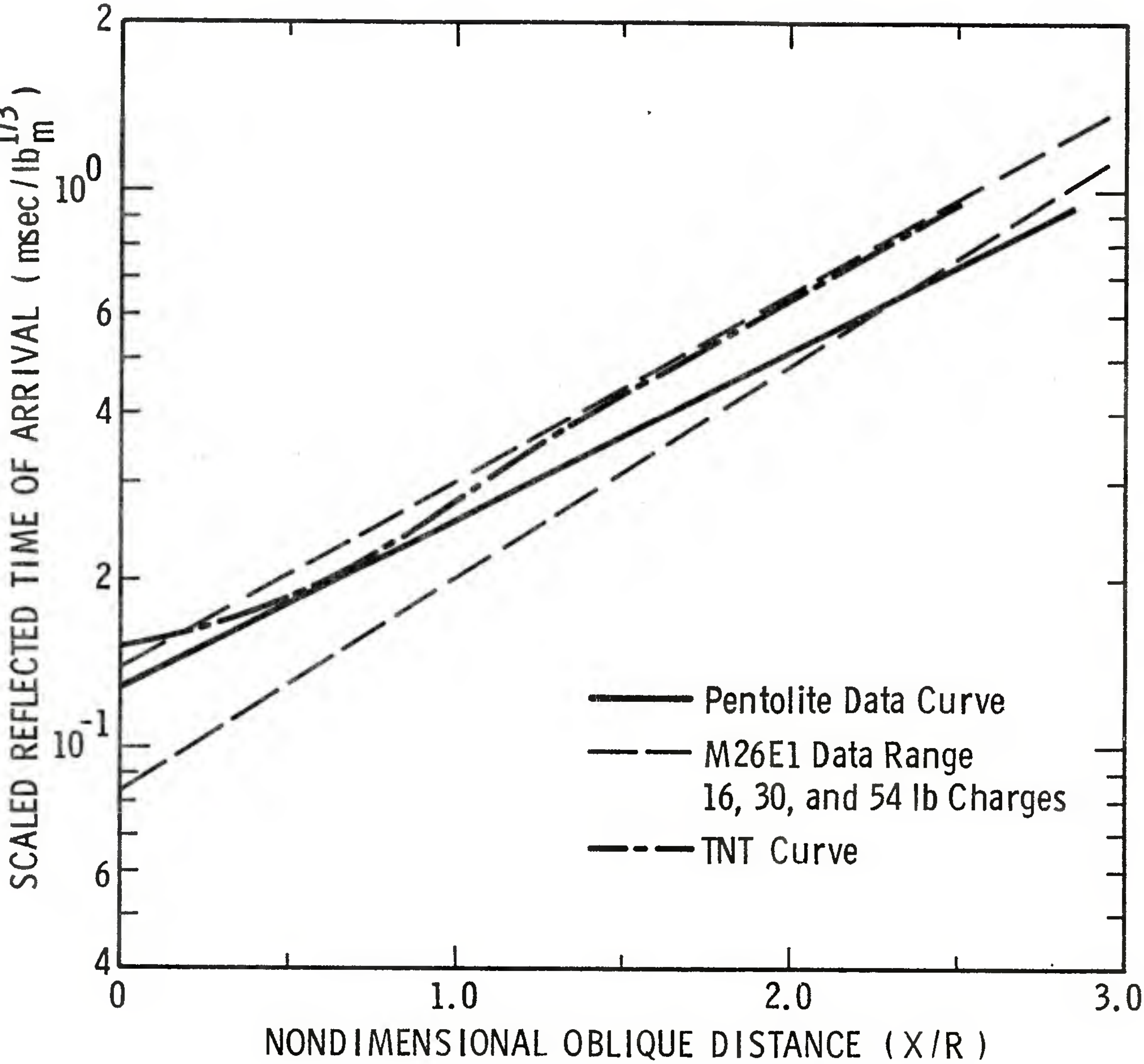
1 psi = 6.895 kPa
1 lb_m = 0.454 kg

Figure 15. Normal and Oblique Reflected Impulses for $Z = 1.0$ ft/$lb_m^{1/3}$ (0.4 m/$kg^{1/3}$).



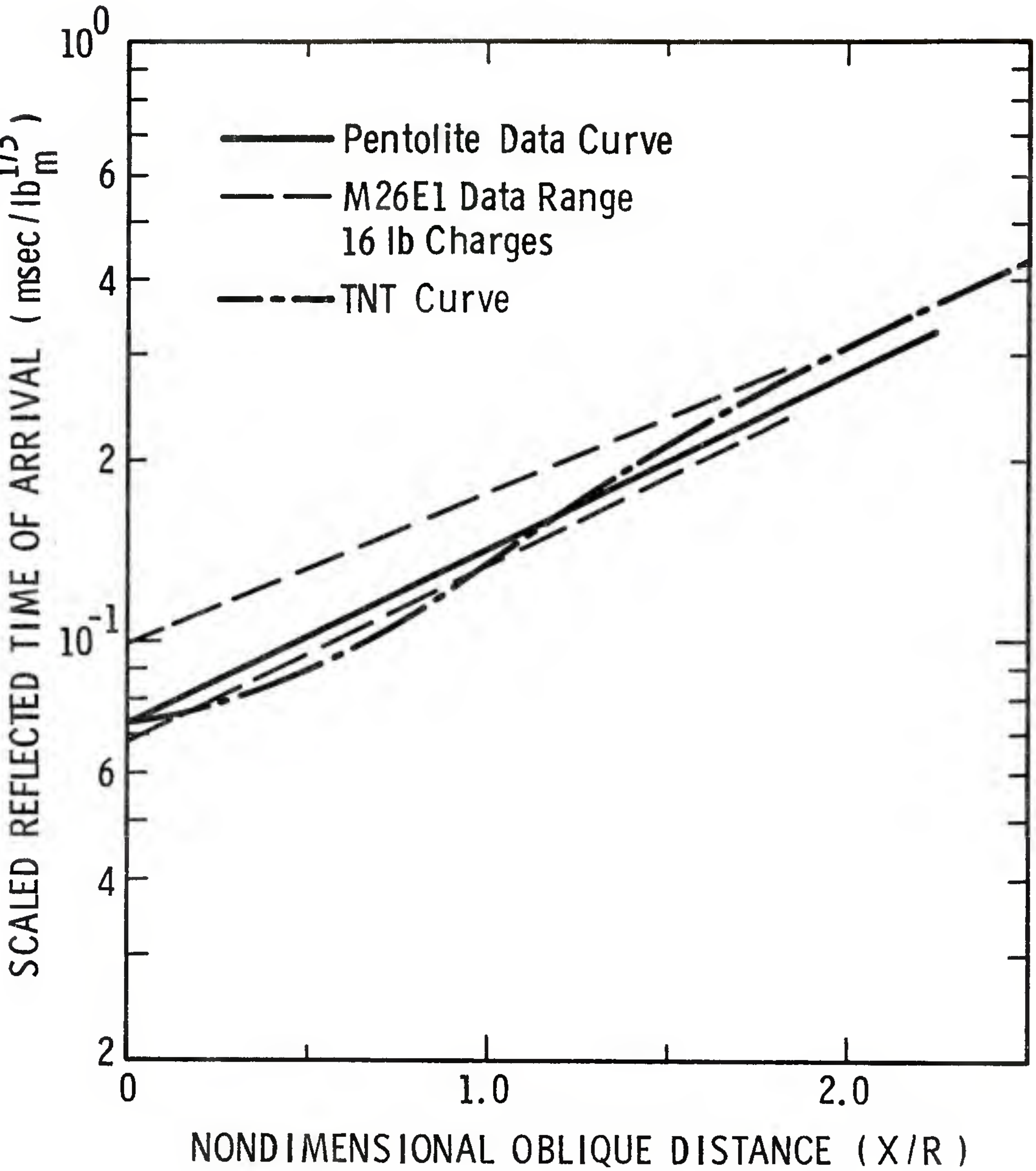
1 lb_m = 0.454 kg

Figure 16. Normal and Oblique Reflected Times of Arrival for $Z = 3.0\ ft/lb_m^{1/3}\ (1.2\ m/kg^{1/3})$.



1 lb_m = 0.454 kg

Figure 17. Normal and Oblique Reflected Times of Arrival for $Z = 1.5\ ft/lb_m^{1/3}$ $(0.6\ m/kg^{1/3})$.



1 lb_m = 0.454 kg

Figure 18. Normal and Oblique Reflected Times of Arrival for Z = 1.0 ft/$lb_m^{1/3}$ (0.4 m/$kg^{1/3}$).

IV. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this exploratory program a number of conclusions and observations were made. These are as follows:

(1) M26E1 multiperforated propellant is a very difficult material to detonate in a relatively unconfined state and in quantities of about 16 lb (7.3 kg). Substantial boostering with a high explosive is required to react the entire charge.

(2) The explosive output of M26E1 even with substantial boostering varies considerably at small scaled distances and as a maximum is slightly more energetic than Pentolite as indicated by reflected pressure, impulse, and time-of-arrival data.

(3) Because this propellant is difficult to detonate in small quantities, experiments to obtain reflected blast parameters require large charges to verify that pressure and impulse do scale with the cube root of the charge weight as indicated by the replica scaling law.

(4) The time-of-arrival data for tests conducted at a scaled distance of 3.0 $ft/lb_m^{1/3}$ (1.2 $m/kg^{1/3}$) showed that the arrival times on the propellant tests were shorter than for the Pentolite tests. However, the slope of the time-distance propellant data was the same or steeper than that of the Pentolite data. This indicates that the shock velocity from the propellant tests was actually the same or lower than the shock velocity for Pentolite over the range of oblique distances tested.

(5) The use of piezoelectric pressure transducers to obtain reflected peak pressures at small scaled distances is more than adequate in small scale experiments. Physical damage and drift problems from the fireball were minimal. However, as the charge weight is increased in size but keeping the scaled distance constant, damage to the transducers from the impulse becomes more common. Even though pressure remains invariant regardless of scale, impulse increases proportionally with the scale factor. Consequently, the probability of damaging a transducer used to obtain the entire pressure-time history increases as the scale of the experiment gets larger. At a scaled distance of 3.0 $ft/lb_m^{1/3}$ (1.2 $m/kg^{1/3}$) obtaining impulse from relatively large propellant charges using pressure transducers is probably not a problem. At closer distances it will become more difficult. Therefore, it is impractical to use pressure transducers any closer than 1.5 $ft/lb_m^{1/3}$ (1.2 $m/kg^{1/3}$) to obtain reflected blast data from propellants whose minimum detonating mass is large.

(6) Some reflected pressure and impulse data at small scaled distances from unconfined, spherical, M26E1 propellant charges were obtained and can be used as a preliminary guide to predict loads for designing barricades, walls or other protective structures near stored or in-process M26E1 propellant.

Based on the work performed in this experimental program and the above observations and conclusions, the following recommendations are made:

(1) Because only a limited number of experiments were performed in this program, additional tests using similar size propellant charges should be conducted to improve the confidence level in the data collected. Measurements should be concentrated at the normal location and angles of obliquity up to 45°.

(2) Large M26E1 propellant tests should be conducted using similar test techniques at scaled distances of 3.0 and 1.5 $ft/lb_m^{1/3}$ (1.2 and 0.6 $m/kg^{1/3}$) to better verify the scaling law. Charge weights used should be in the 100 lb (45.4 kg) range and should be boostered in a similar manner. The use of the larger charges will also determine if the variable explosive output of the propellant found in this program is characteristic of smaller charges only. If it is, smaller boosters should also be used to determine whether the output of the large charges changes enough to be measurable.

(3) In the conduct of these large propellant tests, some effort should be included for developing a different method for obtaining impulse at small scaled distances. This new method should be mechanical or hydraulic in principal, and should not require cinematography which is difficult to accomplish because of the fireball and explosive products.

(4) For efficient design of protective structures adjacent to a propellant production line, the blast output of the particular type of propellant being processed should be known. Consequently, similar experiments such as those conducted for the M26E1 propellant should be performed for other propellants whose blast output has not been experimentally determined.

APPENDIX. DATA TABLES

Conversion Factors:

1 lb = 0.4536 kg
1 ft = 0.3048 m
1 psi = 6.895 kPa
$1\ ft/lb_m^{1/3} = 0.3967\ m/kg^{1/3}$

TEST NO. 1.0
CHARGE WEIGHT 1.08 LB
BOOSTER WT. 0.00 LB

STANDOFF DISTANCE 3.04 FT
SC. DISTANCE 3.0 FT/LB**.33
CHARGE PENTOLITE

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
2	2.63	20	8.4	3.28	8.2	3.20
3	1.32	140	33.9	1.25	33.1	1.22
4	0.66	397	37.4	0.68	36.5	0.66
6	0.00	560	0.0	0.35	0.0	0.34
9	-1.32	101	29.9	1.34	29.1	1.31
10	-2.63	22	10.0	3.49	9.8	3.40

TEST NO. 1.1
CHARGE WEIGHT 1.05 LB
BOOSTER WT. 0.00 LB

STANDOFF DISTANCE 3.04 FT
SC. DISTANCE 3.0 FT/LB**.33
CHARGE PENTOLITE

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
2	2.63	17	10.0	3.41	9.8	3.36
3	1.32	135	28.1	1.35	27.6	1.33
4	0.66	351	34.5	0.72	33.9	0.71
6	0.00	737	51.9	0.44	51.1	0.43
8	-0.66	248	35.5	0.63	34.9	0.62
9	-1.32	117	31.6	1.23	31.1	1.21
10	-2.63	22	10.5	3.22	10.3	3.17

TEST NO. 2
CHARGE WEIGHT 16.00 LB
BOOSTER WT. 1.60 LB

STANDOFF DISTANCE 7.56 FT
SC. DISTANCE 3.0 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
1	2.12	24	16.2	4.31	6.4	1.71
2	1.06	152	37.5	1.86	14.9	0.74
3	0.53	157	63.3	1.03	25.1	0.41
6	0.00	276	83.6	0.80	33.2	0.32
9	-0.53	0	0.0	1.06	0.0	0.42
10	-1.06	155	42.9	1.84	17.0	0.73
11	-2.12	30	14.8	4.25	5.9	1.69

TEST NO. 3
CHARGE WEIGHT 54.00 LB
BOOSTER WT. 5.40 LB

STANDOFF DISTANCE 11.34 FT
SC. DISTANCE 3.0 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
1	1.41	70	43.8	3.35	11.6	0.89
2	0.71	356	84.2	1.56	22.3	0.41
3	0.35	700	137.2	0.98	36.3	0.26
6	0.00	866	154.6	0.74	40.9	0.20
9	-0.35	834	131.5	0.91	34.8	0.24
10	-0.71	387	114.8	1.32	30.4	0.35
11	-1.41	67	38.1	3.19	10.1	0.84

TEST NO. 4
CHARGE WEIGHT 54.00 LB
BOOSTER WT. 5.40 LB

STANDOFF DISTANCE 11.34 FT
SC. DISTANCE 3.0 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
1	1.41	68	68.0	4.64	16.0	1.23
2	0.71	350	138.1	1.92	36.5	0.51
3	0.35	344	176.9	1.20	46.8	0.32
6	0.00	478	150.7	1.09	39.9	0.29
9	-0.35	293	156.7	1.49	41.5	0.39
10	-0.71	422	144.0	2.29	38.1	0.61
11	-1.41	62	56.8	4.83	15.0	1.28

TEST NO. 5
CHARGE WEIGHT 16.00 LB
BOOSTER WT. 1.60 LB

STANDOFF DISTANCE 7.56 FT
SC. DISTANCE 3.0 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
1	2.12	25	21.0	6.05	8.3	2.40
2	1.06	102	69.4	2.32	27.5	0.92
3	0.53	120	72.9	1.14	28.9	0.45
6	0.00	290	114.0	0.87	45.3	0.34
9	-0.53	0	0.0	1.06	0.0	0.42
10	-1.06	137	72.9	2.54	28.9	1.01
11	-2.12	26	24.4	6.33	9.7	2.51

TEST NO. 6
CHARGE WEIGHT 1.60 LB
BOOSTER WT. 0.00 LB

STANDOFF DISTANCE 7.56 FT
SC. DISTANCE 6.5 FT/LB**.33
CHARGE C-4

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
1	2.12	11	6.7	9.00	5.7	7.69
2	1.06	45	19.3	4.35	16.5	3.72
3	0.53	60	22.6	2.75	19.3	2.35
9	-0.53	54	17.1	2.84	14.7	2.43
10	-1.06	43	21.5	4.42	18.4	3.78
11	-2.12	12	7.4	9.26	6.4	7.91

TEST NO. 7
CHARGE WEIGHT 1.60 LB
BOOSTER WT. 0.00 LB

STANDOFF DISTANCE 7.56 FT
SC. DISTANCE 6.5 FT/LB**.33
CHARGE C-4

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
1	2.12	3	3.3	10.31	2.9	8.82
2	1.06	16	11.9	4.98	10.2	4.26
3	0.53	25	11.1	3.17	9.5	2.71
6	0.00	89	36.0	2.74	30.7	2.34
10	-1.06	13	7.4	5.43	6.3	4.64
11	-2.12	5	5.0	10.94	4.3	9.35

TEST NO. 8
CHARGE WEIGHT 1.60 LB
BOOSTER WT. 0.00 LB

STANDOFF DISTANCE 2.52 FT
SC. DISTANCE 2.2 FT/LB**.33
CHARGE C-4

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
3	1.59	146	27.6	0.84	23.6	0.71
4	0.79	393	46.0	0.45	39.3	0.38
5	0.40	1577	86.7	0.33	74.1	0.28
6	0.00	1230	84.0	0.23	71.8	0.19
7	-0.40	1422	70.3	0.36	60.1	0.31
8	-0.79	451	58.0	0.51	49.6	0.43
9	-1.59	141	28.2	0.98	24.1	0.84

TEST NO. 9
CHARGE WEIGHT 1.60 LB
BOOSTER WT. 0.00 LB

STANDOFF DISTANCE 2.52 FT
SC. DISTANCE 2.2 FT/LB**.33
CHARGE C-4

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
3	1.59	153	25.1	0.93	21.4	0.80
4	0.79	510	47.7	0.48	40.8	0.41
6	0.00	998	97.2	0.28	83.1	0.24
8	-0.79	606	54.2	0.49	46.4	0.42
9	-1.59	171	32.2	0.92	27.5	0.79

TEST NO. 10
CHARGE WEIGHT 1.04 LB
BOOSTER WT. 0.00 LB

STANDOFF DISTANCE 1.01 FT
SC. DISTANCE 1.0 FT/LB**.33
CHARGE PENTOLITE

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
6	0.00	9904	0.0	0.07	0.0	0.07
7	-0.99	2223	67.8	0.13	66.9	0.13
8	-1.98	670	33.1	0.30	32.7	0.30

TEST NO. 11
CHARGE WEIGHT 16.00 LB
BOOSTER WT. 1.60 LB

STANDOFF DISTANCE 2.52 FT
SC. DISTANCE 1.0 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
3	1.59	704	79.6	0.50	31.6	0.20
5	0.40	4849	326.9	0.23	129.7	0.09
8	-0.79	2205	174.2	0.29	69.1	0.12
9	-1.59	880	93.4	0.50	37.1	0.20

TEST NO. 12
CHARGE WEIGHT 1.04 LB
BOOSTER WT. 0.00 LB

STANDOFF DISTANCE 1.52 FT
SC. DISTANCE 1.5 FT/LB**.33
CHARGE PENTOLITE

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
3	2.63	121	25.0	0.85	24.7	0.84
4	1.32	902	41.7	0.32	41.1	0.32
5	0.66	2385	54.4	0.18	53.7	0.18
6	0.00	5519	205.1	0.14	202.4	0.14
7	-0.66	2009	69.2	0.19	68.3	0.19
9	-2.63	101	21.7	0.91	21.4	0.90

TEST NO. 13
CHARGE WEIGHT 16.00 LB
BOOSTER WT. 1.60 LB

STANDOFF DISTANCE 3.78 FT
SC. DISTANCE 1.5 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
3	1.06	1055	84.5	0.81	33.5	0.32
4	0.53	1607	153.8	0.52	61.0	0.21
8	-0.53	1415	183.1	0.53	72.7	0.21
9	-1.06	791	92.4	0.77	36.7	0.31

TEST NO. 14
CHARGE WEIGHT 16.00 LB
BOOSTER WT. 1.60 LB

STANDOFF DISTANCE 3.78 FT
SC. DISTANCE 1.5 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
2	2.12	123	50.3	1.66	20.0	0.66
3	1.06	643	115.7	0.71	45.9	0.28
4	0.53	1378	151.3	0.42	60.0	0.17
9	-1.06	478	87.6	0.72	34.8	0.29
10	-2.12	126	49.8	1.69	19.8	0.67

TEST NO. 15
CHARGE WEIGHT 1.60 LB
BOOSTER WT. 0.00 LB

STANDOFF DISTANCE 3.78 FT
SC. DISTANCE 3.2 FT/LB**.33
CHARGE C-4

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
2	2.12	32	15.3	3.03	13.1	2.59
3	1.06	202	30.7	1.28	26.2	1.09
4	0.53	246	37.3	0.81	31.9	0.69
6	0.00	1350	102.1	0.57	87.3	0.48
8	-0.53	350	52.4	0.84	44.8	0.71
9	-1.06	214	35.2	1.33	30.1	1.14
10	-2.12	38	17.8	3.10	15.2	2.65

TEST NO. 16
CHARGE WEIGHT 1.60 LB
BOOSTER WT. 0.00 LB

STANDOFF DISTANCE 3.78 FT
SC. DISTANCE 3.2 FT/LB**.33
CHARGE C-4

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
2	2.12	30	13.8	3.04	11.8	2.60
3	1.06	164	29.2	1.36	25.0	1.16
4	0.53	318	35.5	0.85	30.4	0.73
6	0.00	1274	123.1	0.58	105.2	0.50
8	-0.53	384	55.0	0.82	47.0	0.70
9	-1.06	197	32.1	1.29	27.5	1.10
10	-2.12	36	17.4	2.92	14.9	2.49

TEST NO. 17
CHARGE WEIGHT 30.00 LB
BOOSTER WT. 3.00 LB

STANDOFF DISTANCE 4.66 FT
SC. DISTANCE 1.5 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
2	1.72	352	73.2	1.22	23.6	0.39
3	0.86	1432	141.6	0.66	45.6	0.21
6	0.00	8044	0.0	0.37	0.0	0.12
9	-0.86	2020	172.4	0.55	55.5	0.18
10	-1.72	364	89.1	1.26	28.7	0.40

TEST NO. 18
CHARGE WEIGHT 16.00 LB
BOOSTER WT. 1.60 LB

STANDOFF DISTANCE 3.78 FT
SC. DISTANCE 1.5 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
2	2.12	93	35.4	1.66	14.0	0.66
3	1.06	852	118.0	0.73	46.8	0.29
4	0.53	1591	264.2	0.41	104.9	0.16
6	0.00	7298	0.0	0.35	0.0	0.14
8	-0.53	1128	167.5	0.48	66.5	0.19
9	-1.06	430	92.9	0.73	36.9	0.29
10	-2.12	142	63.2	1.75	25.1	0.69

TEST NO. 19
CHARGE WEIGHT 30.00 LB
BOOSTER WT. 3.00 LB

STANDOFF DISTANCE 9.32 FT
SC. DISTANCE 3.0 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
1	1.72	34	30.2	5.77	9.7	1.86
2	0.86	208	83.0	2.28	26.7	0.73
3	0.43	382	143.7	1.35	46.2	0.43
6	0.00	268	154.5	1.13	49.7	0.36
9	-0.43	571	127.0	1.41	40.9	0.45
10	-0.86	188	74.9	2.19	24.1	0.70
11	-1.72	40	31.0	5.63	10.0	1.81

TEST NO. 20
CHARGE WEIGHT 54.00 LB
BOOSTER WT. 5.40 LB

STANDOFF DISTANCE 11.34 FT
SC. DISTANCE 3.0 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
1	1.41	58	41.7	5.05	11.0	1.33
2	0.71	286	133.2	2.49	35.3	0.66
3	0.35	793	250.8	1.79	66.4	0.47
6	0.00	673	225.5	1.25	59.7	0.33
10	-0.71	390	174.5	2.71	46.2	0.72
11	-1.41	68	43.3	5.21	11.5	1.38

TEST NO. 21
CHARGE WEIGHT 1.04 LB
BOOSTER WT. 0.00 LB

STANDOFF DISTANCE 1.01 FT
SC. DISTANCE 1.0 FT/LB**.33
CHARGE PENTOLITE

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
4	1.98	548	37.3	0.28	36.8	0.28
5	0.99	2893	115.2	0.14	113.7	0.14
6	0.00	15304	294.6	0.09	290.8	0.08
7	-0.99	2957	104.8	0.14	103.5	0.14
8	-1.98	402	32.0	0.29	31.6	0.28

TEST NO. 22
CHARGE WEIGHT 1.05 LB
BOOSTER WT. 0.00 LB

STANDOFF DISTANCE 1.01 FT
SC. DISTANCE 1.0 FT/LB**.33
CHARGE PENTOLITE

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
4	1.98	458	31.4	0.28	30.9	0.27
5	0.99	3011	0.0	0.14	0.0	0.14
7	-0.99	2568	0.0	0.14	0.0	0.14
8	-1.98	666	32.1	0.28	31.6	0.28

TEST NO. 23
CHARGE WEIGHT 16.00 LB
BOOSTER WT. 1.60 LB

STANDOFF DISTANCE 2.52 FT
SC. DISTANCE 1.0 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
3	1.59	999	126.5	0.56	50.2	0.22
6	0.00	12806	0.0	0.25	0.0	0.10
7	-0.40	2262	0.0	0.26	0.0	0.10
8	-0.79	1499	160.4	0.35	63.7	0.14
9	-1.59	1268	129.4	0.62	51.4	0.25

TEST NO. 24
CHARGE WEIGHT 54.00 LB
BOOSTER WT. 5.40 LB

STANDOFF DISTANCE 5.67 FT
SC. DISTANCE 1.5 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
1	2.82	67	44.9	3.83	11.9	1.01
2	1.41	311	130.6	1.35	34.5	0.36
3	0.71	899	288.7	0.62	76.4	0.17
6	0.00	5168	0.0	0.44	0.0	0.12
9	-0.71	844	174.0	0.64	46.0	0.17
10	-1.41	209	98.1	1.21	26.0	0.32
11	-2.82	75	51.2	3.82	13.5	1.01

TEST NO. 25
CHARGE WEIGHT 30.00 LB
BOOSTER WT. 3.00 LB

STANDOFF DISTANCE 4.66 FT
SC. DISTANCE 1.5 FT/LB**.33
CHARGE M26E1

GAGE	X/R	PEAK PRESSURE (PSI)	IMPULSE (PSI-MS)	ARRIVAL TIME (MS)	SCALED IMPULSE (PSI-MS/LB**.33)	SC. ARRIVAL TIME (MS/LB**.33)
3	0.86	1388	140.1	0.65	45.1	0.21
9	-0.86	1896	229.4	0.60	73.8	0.19

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