Research paper

Airblast equivalent weights of several industrial explosives and propellants

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Abstract

Equivalent Weight data for conventional industrial explosives and propellants are compared with those for conventional explosives. The data upon which the Equivalent Weight determinations were made were obtained from surface and free-air detonations. Values of Equivalent Weight based upon both peak pressure and impulse are provided. Details of the test and evaluation procedures are given.

The information presented is significant for conducting safety studies of existing operations and for the safe design of manufacturing and storage facilities.

Keywords: Airblast, Experimental, Equivalent weight, Industrial Explosives, Propellants

1. Introduction

The comparative equivalent weight (*EW*) of a particular explosive is determined by actual field tests. The two types of *EW* for an explosive as compared to a standard explosive (e.g. TNT) detonated under the same physical conditions are generally based on the two most significant airblast wave parameters: 1) Peak Pressure and 2) Impulse. The *EW* for a particular explosive is not single valued over the range of the data. As a result, average values of *EW* are usually provided and used for most safety and design considerations. The designer can select either the Peak Pressure or Impulse Equivalent Weights for his analysis.

In this work *EW* data are presented for some commercial explosives and detonators as well as for a conventional propellant material.

2. Theoretical

The theory of *EW* determinations is based on the analysis of airblast measurements. Field tests are conducted to measure the peak pressure and impulse of the blast wave in air as a function of distance. These tests are often made using different weights, *W*, of explosive. The measured airblast parameters: Distance, *R*, Peak pressure, *P* and Impulse, *I* are scaled using Hopkinson scaling[1]. Using this well known and proven technique, the data from tests with a wide range of weights can be plotted (logarithmic coordinates) on the same graph and then used for conducting the *EW* analysis.

For determining the peak pressure equivalent weight ($EW_{P(CONST)}$) of a particular test explosive, a curve of the peak pressure of the airblast wave, (*P*) as a function of scaled distance (distance divided by the cube root of the weight, ($R\ W^{-1/3}$)) is compared to a similar curve for the standard explosive. The value of the "Peak Pressure *EW*" (a dimensionless value) at a particular pressure level is determined using the equation:

$$EW_{P(CONST)} = [(R\ W^{-1/3})_{TEST}]^3\ [(R\ W^{-1/3})_{STANDARD}]^{-3} \quad [1]$$

If the *P* versus ($R\ W^{-1/3}$) curves on logarithmic coordinates for the test explosive and for the standard explosive run parallel, then there is a single value for the "peak pressure *EW*". In general the curves are not parallel and for convenience, an average value of *EW* is usually used. For impulse, the method of determining the *EW* is somewhat more complex. Similar to the procedure for peak pressure data above, curves of the scaled impulse versus scaled distance for the test and standard explosives are plotted on logarithmic coordinates.

Since both the impulses and the distances are scaled using the Hopkinson [1] cube root scaling method, the scaled distances ($R\ W^{-1/3}$) selected for this analysis are taken along a slope of the logarithmic cycle scale. The equation for "Impulse *EW*" is written similar to equation [1]:

$$EW_{IMPULSE} = [(R\ W^{-1/3})_{TEST}]^3\ [(R\ W^{-1/3})_{STANDARD}]^{-3} \quad [2]$$

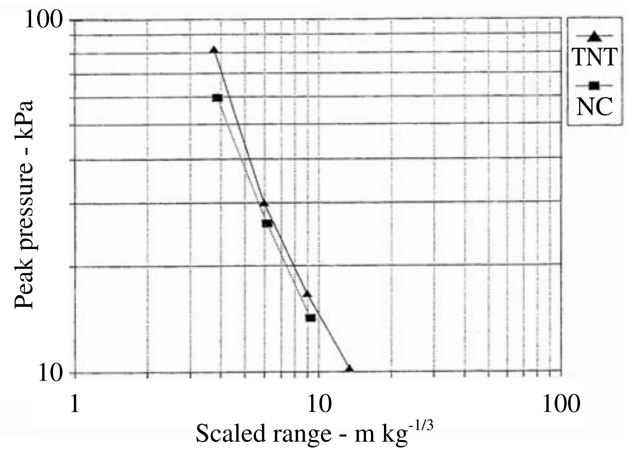

Fig. 1 Peak pressure versus scaled range for cellulose nitrate and cast TNT.

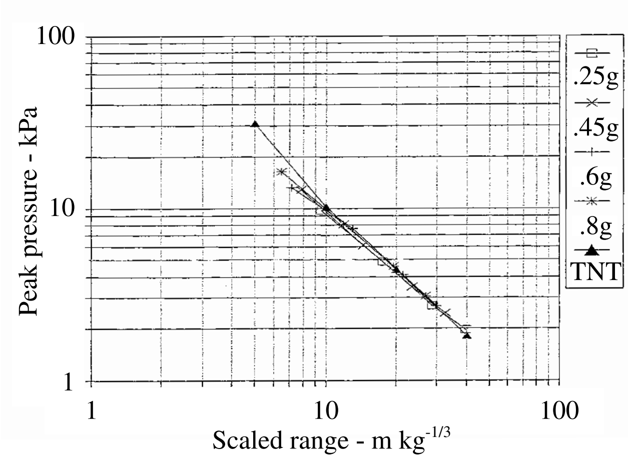

Fig. 2 Peak pressure versus scaled range in free air for detonators with various PETN base charges and for cast TNT.

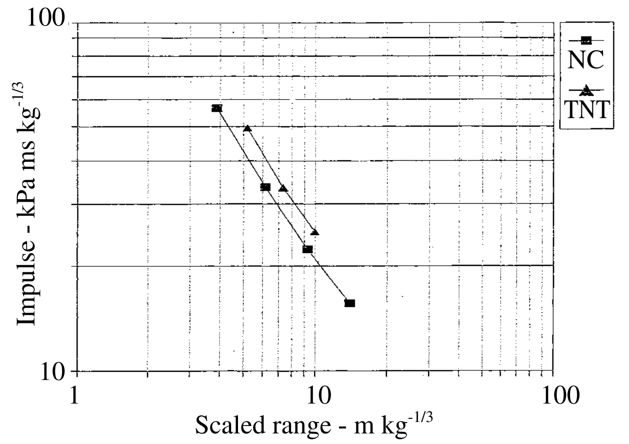

Fig. 3 Scaled impulse versus scaled range for cellulose nitrate and cast TNT.

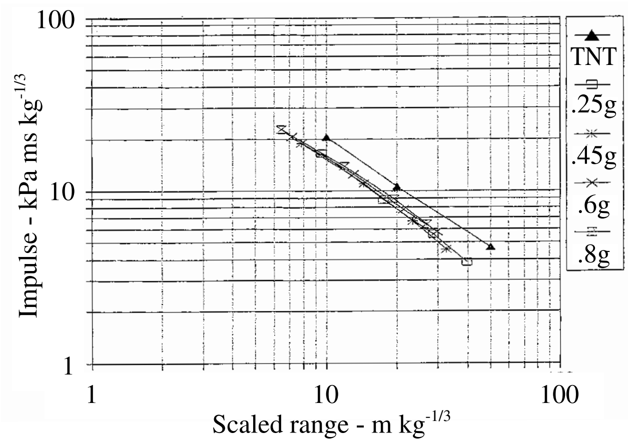

Fig. 4 Scaled impulse versus scaled range in free air for detonators with various PETN base charges and for cast TNT.

3. Experimental

3.1 Energetic materials:

The data in this work are for the following explosives, explosive devices and propellants: AN-FO, (94.5-5.5 Ammonium Nitrate-Fuel Oil), Chen-Ammon, a slurry explosive (also used in the underwater explosion tests conducted in the Dead Sea [2)]), Dry Cellulose nitrate, the primary constituent of single base propellants, Electrical detonators with various PETN base charge weights.

The AN/FO had a density of 0.85 g cm^{-3} and weight of between 1 and 4 kg, Chen-Ammon had a density of 1.3 g cm^{-3} and weight of 1 kg and Cellulose nitrate had a density of 0.8 g cm^{-3} and weighed 1 kg.

3.2 Method for obtaining the data

The experimental method used for obtaining data for the EW analyses involved the following test arrangement: An array of piezoelectric pressure gages (The pressure gages were Model 137 Free Field Blast Pressure Probes manufactured by PCB Piezotronics.) was deployed at several distances from each explosion. For the detonators suspended in air, the gages were suspended at the same height and oriented along the detonator axis. The low impedance electrical signals from these gages were fed over coaxial cables to a suitable recording system.

In this work, a hardened field computer with eight channels of A-D data was used. The sampling rate for each data channel was 62,500 samples per second (providing a reading on each channel every 16 μs). This was sufficient to "capture" the short rise-time shock waves and to follow their exponential decay of pressure with time. The peak pressures were subsequently read directly from the pressure-time (P-T) curves generated from the recorded data with the aid of Excel based, SEC developed, proprietary software. The impulses for each distance were determined by computer integration of the P-T data between the time of arrival of the shock wave (TOA) and the time when the pressure decays to ambient level. At least three replicates were conducted for each explosive tested. The reference standard explosive was cast TNT. The explosives and propellant charges were detonated on the surface. The detonators were detonated in "Free Air".

Table 1 Peak pressure and impulse equivalent weights (average) of energetic materials relative to cast TNT.

Energetic material	Peak pressure *EW (ave)*	Impulse *EW (ave)*
AN-FO	0.83	0.72
Chen-Ammon	0.57	0.74
Cellulose nitrate	0.76	0.79
800 mg PETN detonator	0.91	0.60
600 mg PETN detonator	0.9	0.58
450 mg PETN detonator	0.87	0.57
250 mg PETN detonator	0.84	0.55

4. Results and discussion

Figure 1 is a logarithmic presentation of peak pressure, *P* versus the scaled range, $R\ W^{-1/3}$ for the propellant Cellulose nitrate and for the standard of comparison: cast TNT. Both energetic materials were tested as surface bursts at the same firing site. Note that the curves are not entirely parallel. Therefore, as is quite common, the true equivalent weight varies with pressure level. This is a familiar phenomenon and is typical behavior among all explosives. Plots similar to these were used for all of the energetic materials evaluated and reported in this work.

The base data for the various detonators were obtained during a cooperative study with detonators supplied by Davey Bickford of France. Figure 2 shows the Peak Pressure versus Scaled Range data for these detonators. The airblast measurements in free air were performed on detonators with PETN base charges. The raw data (published “un-scaled” without doing a “conventional” *EW* relative to TNT analysis) are from reference 4. For the present work, Hopkinson [1] scaling was applied using the PETN weights and the results are compared with scaled TNT data in free air from the literature [5]. Figure 3 is a logarithmic plot of scaled Impulse versus scaled Range for Cellulose nitrate and for TNT. All of the Impulse *EW* analyses in this work were done using similar graphs to Fig. 3. Figure 4 contains the Scaled Impulse versus Scaled Range data for the detonators. The standard of comparison TNT “Free Air” data are from reference 5.

The following table provides the average values of equivalent weight for the energetic materials considered in this work. These averages were determined based on several calculations of *EW* along the curves of the parameters of Peak Pressure and of scaled Impulse versus scaled Range.

The values of *EW* presented for small AN-FO charges confirm earlier work done by the author for multi-ton explosions and described in reference 3.

At scaled ranges greater than 10 m $kg^{-1/3}$, the scaled detonator Peak Pressure versus Scaled Range data seem to be very close to the data for TNT. The overall average $EW_{PRESSURE}$ values are all less than 1.0 relative to TNT. Airblast data for small charges do not always correspond with heat of explosion comparisons.

The $EW_{IMPULSE}$ analyses for the detonators show consistently low average values relative to cast TNT. Cellulose nitrate has similar values of $EW_{IMPULSE}$ and $EW_{PRESSURE}$. In contrast, the Impulse *EW* of the detonators was found to be considerably lower than the Peak Pressure performance.

5. Summary

Conducting Equivalent Weight studies on explosives using airblast measurements provides a powerful tool for evaluating the output of different explosives.

When considering the safety aspects involved in designing explosives production facilities, the design team must use such data as are presented here. Airblast testing is not complex and can be performed with a minimum of difficulty.

Chen-Ammon, is a slurry type commercial explosive and used extensively for quarrying. Due to its high bulk density, it was selected for the underwater explosion tests described in reference 2. In terms of airblast behavior, in contrast to its underwater performance, it was found to be considerably weaker than TNT.

Energetic materials such as dry Cellulose nitrate are normally categorized as propellants. However, from the observations of its typical airblast behavior, it definitely should be considered as an explosive. As was found in the early work on AN-FO [3], it is entirely possible that the *EW* values for large charges of this material could approach those of TNT. This topic warrants future work.

Similarly, the airblast behavior from multiple detonators may be different than that which was observed from the individual detonators.

References

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