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Short Communication

PROPAGATION OF BLAST WAVES PRODUCED BY A PYROTECHNIC MIXTURE

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1. Introduction

For producing signals like sound and flash, pyrotechnic devices containing mixtures of aluminium and potassium perchlorate are often used.

These pyrotechnic mixtures consist mostly of 30% aluminium and 70% potassium perchlorate. Few data are available on the blast waves produced by such a mixture. First systematic investigations [1] show that these blast waves are comparable to those produced by high explosives. Hence pyrotechnic devices filled with this mixture may constitute a serious hazard to persons; for example, eye injuries and ear-drum ruptures may occur. It is, therefore, desirable to be able to predict the characteristics of these blast waves. In the following, measurements are described by means of which such predictions become possible.

2. Experimental set up and test procedures

As already mentioned, the experiments were performed with a pyrotechnic sound and flash mixture consisting of 70% $KClO_4$ and 30% Al. The aluminium powder (pyrograde) had a grain size of approximately 0.028 mm. The grain size of the potassium perchlorate was between 0.028 mm and 0.09 mm.

As most pyrotechnic devices normally contain not more than 0.075 kg of the mixture, the investigations were limited to weights between 0.01 kg and 0.075 kg. In order to assure spherical blast waves, the substances were packed into small plastic spheres. The spheres had a diameter of 37.9 mm for weights up to 0.03 kg and a diameter of 62 mm for weights exceeding 0.03 kg. Blast wave pressure—time dependence was measured at distances from 0.5 m to 3 m. The charges were ignited by means of a non-detonating electric match head consisting of approximately 0.035 g lead picrate.

For measuring the pressure—time dependence a piezoelectric quartz gauge was used. The resonant frequency of the quartz was about 500 kHz, the rise-time approximately 1 μs. The diameter of the gauge was 6.33 mm, the length 11.2 mm. The resonant frequency of the charge amplifier, which converted the electric charge produced by the quartz into electric current, was 180 kHz. The signals were recorded by means of a digital oscilloscope. The quartz was built into a speartype housing. The tip had a length of 160 mm and a maximum diameter of 30 mm. The quartz was orientated to the charge in such a manner that the pressure in the free-expanding blast wave could be determined (side-on pressure).

A sketch of the experimental set up can be seen in Fig. 1. A typical pressure—time history is shown in Fig. 2. Due to limited rise-times the real peak overpressure is not recorded by the measuring devices. In order to get the real peak overpressure, the first part of the pressure—time history was fitted to the exponential function $p = p_0 e^{-t/t_0}$ by means of a least squares procedure. By extrapolating to time zero the peak overpressure was obtained [2].

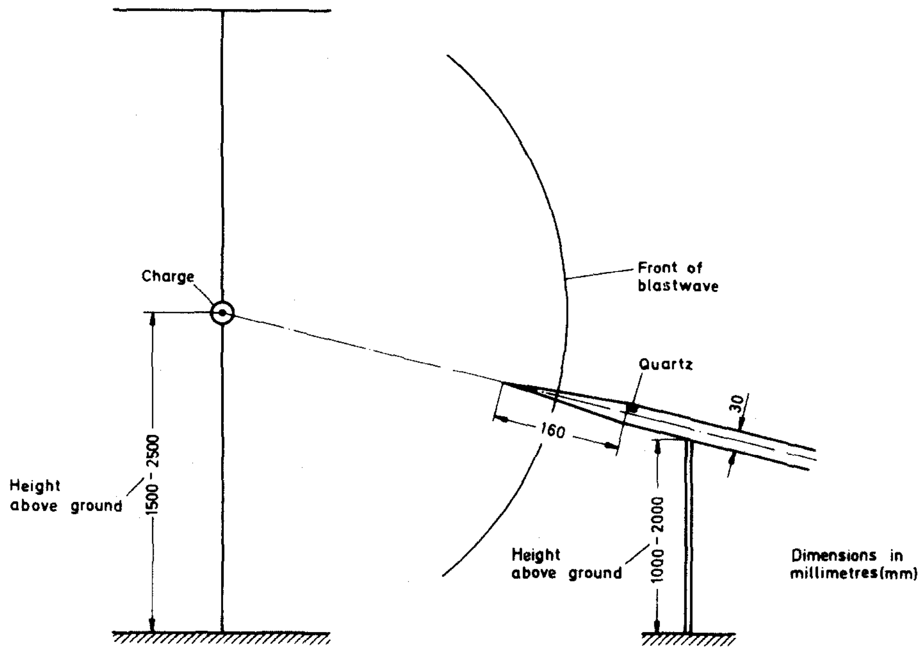

Fig. 1. Experimental set up.

3. Results

A blast wave is normally described by the maximum peak overpressure p_{max} and the specific impulse I_+ of the positive phase $\int_0^{t_+} p dt$. From investigations in the field of high-explosives, it is known that the maximum peak overpressure is a function of the scaled distance $R/W^{1/3}$ (R = distance, W = mass of the charge). The same holds for the scaled specific impulse $I_+/W^{1/3}$. This

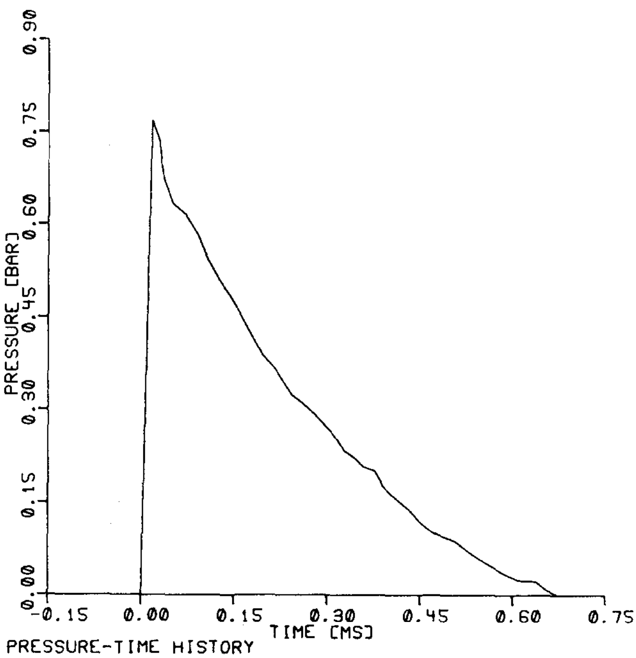

Fig. 2. Pressure—time history in the blast wave.

quantity is also a function of scaled distance. Through this functional dependence it is possible to determine overpressure and/or specific impulse for various distances and charge weights from one function.

In Fig. 3 the measured values for the overpressure p_{max} are plotted as a function of scaled distance and in Fig. 4 the same is done for the scaled specific impulse. For the purpose of comparison some TNT blast wave overpressure data (derived from [2]) are plotted in Fig. 3. As can be seen from these figures, peak overpressure and specific impulse of the blast waves can be represented as a function of scaled distance. By means of a least squares fit the following formulae describing the dependence of both overpressure and specific impulse on scaled distance were obtained:

$$p_{max} = \exp\,[8.54 - 2.16 \ln \bar{R} + 0.2(\ln \bar{R})^2] \tag{1}$$

$$\bar{I}_+ = 1.11\ \bar{R}^{-0.86} \tag{2}$$

with p_{max} = maximum peak overpressure in mbar, $\bar{I}_+$ = scaled specific positive impulse in bar ms^{-1} kg$^{-1/3}$. $\bar{R}$ = scaled distance in m kg$^{-1/3}$. The error in eqn. (1) is about 2.5%, whereas in eqn. (2) the error does not exceed 5%.

4. Summary

Formulae were derived by means of which peak-overpressure and specific-

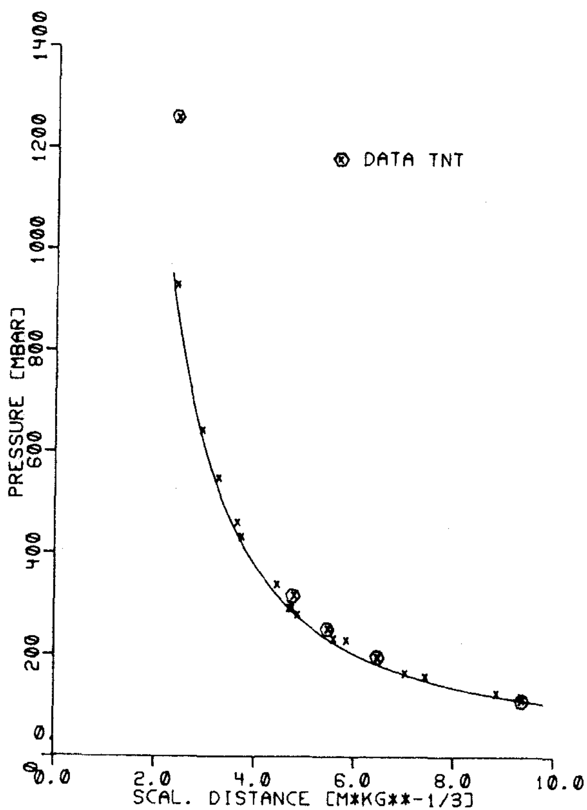

Fig. 3. Maximum peak overpressure versus scaled distance.

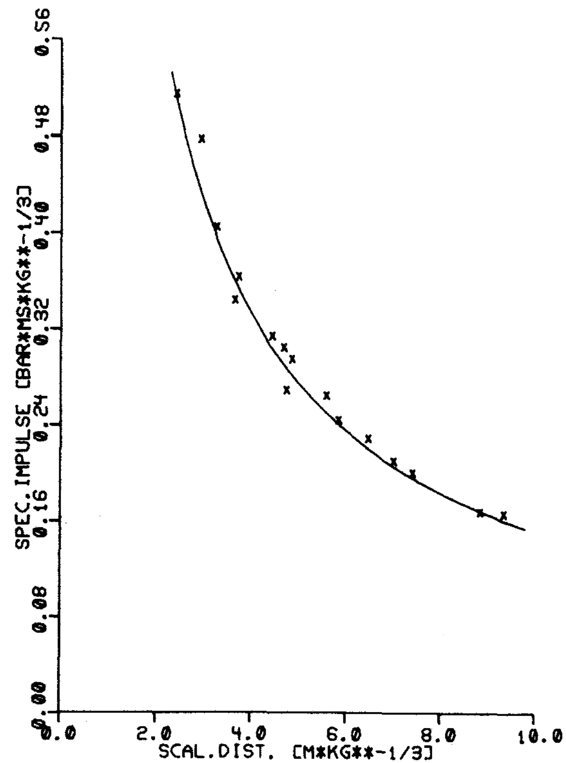

Fig. 4. Scaled specific impulse versus scaled distance.

impulse of a blast wave produced by a pyrotechnic mixture (30% Al, 70% $KClO_4$) can be calculated. Both equations hold, at least for charge weights up to 0.075 kg.

Recent investigations show that the above-mentioned formulae also hold approximately for mixtures containing 25%—40% aluminium, 75%—60% potassium perchlorate respectively. It is now possible to estimate the hazard when using such pyrotechnic devices.

References

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2 W.E. Baker, Explosions in Air, University of Texas Press, Austin and London, 1973.