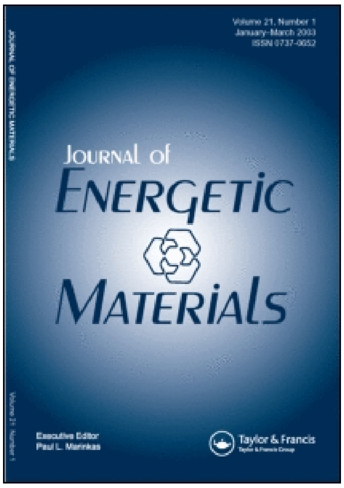

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A RAPID METHOD FOR THE ASSESSMENT OF THE AXIAL OUTPUT PERFORMANCE OF BOOSTER CHARGES

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ABSTRACT

An experimental method involving the determination of the shock induced in PMMA by a test explosive is described which allows an assessment of the relative output performance of a booster composition in a geometry and size which could be reasonably expected to appear in a weapon design. By applying the same analytical treatment of the experimental results to data generated by the 2-D Eulerian Hydrodynamic Code, HULL, estimates of the detonation pressure and the adiabatic exponent, γ, are obtained. The results indicate that the ordering of performance determined experimentally by this method agrees well with that deduced from velocity of detonation data using a simple γ-law equation of state and with a subsequent experimental verification where the run distance to detonation in a main charge explosive is observed when the booster is separated from the acceptor by a standard attenuator. Further, it is deduced that in the geometry considered

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using the initiation system described, the booster charges have probably reached steady-state detonation in 25mm lengths.

INTRODUCTION

Many methods have been devised for comparing the performance of explosive charges. These vary from uninstrumented firings involving the determination of the depth of dent produced in a standard witness block (the plate dent test[1]) to the sophisticated manganin pressure transducer technique which measures the Chapman-Jouget pressure directly[2]. Whereas the former technique is generally qualitative, the latter allows not only for comparisons, but for accurate measurement of an important detonation parameter. In common with the manganin gauge method, other techniques such as the determination of detonation pressure by the measurement of free surface velocities of different thicknesses of plates in contact with the explosive and extrapolating to zero plate thickness[3,4] and the measurement of particle velocity by means of embedded particle-velocity gauges[5], together with velocity of detonation data and a simple γ-law equation of state to give detonation pressures, are time-consuming and require great attention to experimental detail if they are to provide correct results. It would, of course, be ideal if such quantitative methods could be applied regularly to the determination of performance of explosives, but frequently a qualitative result must be accepted since, where new compositions are being investigated, it is common for there to be insufficient material available for elaborate testing in the early stages of development.

Detonation pressure measurements are usually made on large samples since, for secondary explosives, steady-state detonation frequently requires a value for the charge length to diameter ratio in excess of four[6]. For main charge explosives, which in any warhead constitute the major part of the explosive content, detonation is to be expected when the system functions and a performance comparison based on P_{CJ} is acceptable. However, for booster explosives the situation is different since they are not only more shock sensitive than main charge explosives but are present in much smaller quantities. The question therefore arises as to whether the use of P_{CJ} values is valid when comparing their output in geometries where they may not be fully detonating. A practical approach has therefore been adopted which acknowledges this fact and compares the performance from the end of a booster charge of dimensions which could reasonably be expected to be employed in a munition or which err on the small side. From one experiment, the shock velocity in an inert attenuator placed in contact with the sample is measured and, by means of impedance matching techniques, the pressure in the explosive at the interface is determined. However, in order to extend the present test to produce useful, quantitative information concerning the detonation pressure of the explosive, a computer simulation using known explosive donor materials was performed and allows the comparative experimental data to be converted into detonation pressures through a correction factor. In order to confirm the results of the experiments which examined the axial output performance of the boosters, a series of firings was carried out in which the distance to break-out of detonation was monitored in a main charge explosive composed of TATB/Kel-F 800 95/5 separated from a 25mm diameter x 25mm long booster charge by a 3mm thick aluminium alloy disc representing the end portion of a booster housing. The results obtained are in line with those expected from the shock velocity measurements. Ijsselstein[7] has recently described another simple comparative test and its application to a comparison of the output of blasting caps based upon the shock-induced polarisation of PMMA, but this method has not been applied to this study of booster explosives.

This work has been carried out as part of a programme to assess the suitability for service of several new booster compositions. Since no more than 400g of some compositions were available for a study involving safety testing, thermal stability and performance assessment, only a limited number of firings were possible. It is realised that in several cases further experimental verification is required, but the experimental method presented here is a good example of a performance screening test which can be applied with confidence where only small quantities of test material are available.

EXPLOSIVE MATERIALS AND EXPERIMENTAL METHODS

As part of the UK programme to replace tetryl [N-methyl-N-

(2,4,6-trinitro-phenyl)-nitramine] in lead and booster applications, a number of alternative materials have been examined. These are:

(a) Debrix 2 [nominally RDX 95%, Wax 8 5%]

(b) LX-15 [HNS(hexanitrostilbene) 95%, Kel-F 800 5%]

(c) BX compositions comprising

BX1 TATB 60%, Nitramine 35% [shock sensitive RDX 95%, HMX 5%], Kel-F 800 5%

BX3 TATB 60%, Nitramine 35% [shock sensitive RDX 90%, HMX 10%], Kel-F 800 5%

BX4 TATB 60%, Nitramine 35% [shock sensitive RDX 90%, HMX 10%], PTFE 5%

(d) AFX 521 [PYX (2,6-bis-(picrylamino)-3,5-dinitropyridine) 95%, Kel-F 800 5%]

(e) Although not as shock sensitive as the above compositions, the US and UK versions of PBX 9503 [TATB 80%, HMX 15%, Kel-F800 5%] were also examined.

Velocity of Detonation Determination

The velocity of detonation of each sample in 12.7mm diameter geometry was determined using a Cordin Model 132A streak camera running at 8mm μs^{-1}. A stack of ten 12.7mm long pellets of pressed explosive was used and for all compositions except tetryl and Debrix 2. A cigarette paper flasher was attached to the streaked surface. Two firings of each composition were performed and that part of the record representing the last two pellets was analysed on a Kontron MOP digitising system, a least squares fitting routine being applied to determine the detonation velocity. Insufficient material was available for the detonation velocity of certain compositions to be determined at 25mm diameter and consequently for the analysis presented later, the experimental values at 12.7mm are used. As shown by James[8] and Gibbs and Popolato[9], the percentage increase between the unconfined velocity of detonation of compositions measured at the same density at 12.7mm and 25.4mm diameters is not, in general, more than 1% provided they are not near to failure. This is considered to be applicable to these booster compositions whose failure diameters are considerably less than 10mm. Results of these experimental firings are given in Table 1.

TABLE 1 Velocity of Detonation Results in 12.7mm Diameter Geometry

EXPLOSIVE	DENSITY/ $Mg\ m^{-3}$	VELOCITY OF DETONATION/ kms^{-1}
Tetryl	1.50	7.10 +/- 0.05
Debrix 2	1.65	8.17 +/- 0.09
LX-15	1.57	6.74 +/- 0.05
AFX 521	1.53	6.76 +/- 0.05
BX1	1.83	7.78 +/- 0.08
BX3	1.81	7.79 +/- 0.09
BX4	1.80	7.78 +/- 0.09
PBX 9503(UK)	1.86	7.73 +/- 0.08
PBX 9503(US)	1.80	7.34 +/- 0.06

Shock Velocity Measurements

Figure 1 illustrates the experimental assembly used to measure the velocity of the shock transmitted to PMMA by the test explosive. The stack of five 50mm diameter PMMA discs consists of four whose thickness is 1.3mm - 1.5mm, measured accurately to 5μm, and a base disc 2mm thick. A small hole 0.8mm in diameter is drilled to a depth of approximately 0.3mm in each of the four top discs such that when placed together, a line of four holes extending over a distance of no more than ±4mm from the centre is formed. The flash gaps are assembled so that they emit light when the air entrapped in them is compressed and shocked by the front hitting the next disc rather than upon initial contact with the shock front. This mechanism of light emission was deduced from an initial series of experiments to determine the optimum flash gap dimensions, in which the discs were assembled so that the shock front impinged upon the open end of the flash gap first. These produced a visual streak record when the shock reached the base of the gap, (see Fig. 2a), and consequently irregular transit times were observed because the depth of the flash gaps was not accurately controlled.

A 25mm diameter plane wave shaper, manufactured from two RDX-based plastic bonded explosives[10], having an output planarity better than 50ns over the central 20mm, was initiated by an exploding bridgewire detonator in conjunction with a small RDX pellet and used to detonate the 25mm diameter by 25mm long booster explosive under test. The whole explosive assembly was clamped between two aluminium alloy plates and positioned so that the line of flash gaps was along the slit of the Cordin Model 132A streak camera.

A writing speed of 18mm μs^{-1} was used. The streak records (Fig.2) show that the arrival time of the detonation front over the whole of the output end of the booster charge is ca. 170ns and over the central 8mm is planar within 20ns. The shock transit times for each flash gap were measured on the Kontron MOP system and are accurate to <5ns.

Break-out Distance Measurements

A final series of experiments utilised the Cordin Model 132A streak camera operating at 8mm μs^{-1} and a Beckman & Whitley Model 189 framing camera recording at an interframe time of 1μs to determine the distance to break-out of detonation in a 71mm long by 36mm diameter cylinder of TATB/Kel-F 800 95/5, double-end die-pressed to a density of 1.87Mg m^{-3}. A booster charge of similar dimensions to that used above was the donor, initiated by an exploding bridegwire detonator and a single 12.7mm diameter by 12.7mm long pellet of the same material (except for PBX 9503(US) where an extra 12.7mm x 12.7mm tetryl pellet was employed beneath the detonator) and separated from the TATB/Kel-F 800 charge by a 3mm thick, 100mm diameter disc of HE 30 TF aluminium alloy. The break-out distance was read from the streak record and the framing record was useful in determining the velocity of the shock transmitted through the TATB/Kel-F 800 charge when detonation did not occur. Both argon flash and available light techniques were used for the framing records. Figure 3 shows the streak results of four firings.

RESULTS AND DISCUSSION

Analysis of Shock Velocity Measurements

The attenuation of a shock as it travels through an inert medium in contact with a detonating explosive is governed by the rate at which the pressure exerted by the donor on the inert material decreases and, if the detonation reaction zone is thin, this will be controlled by the expansion of the products behind the CJ plane. In the region monitored, side rarefactions play no part in the time-scale of the experiment. To determine the detonation pressure in the explosive at the explosive/inert monitor interface, the initial velocity of the shock transmitted to the inert by the explosive is first calculated from the distance (x) - time (t) data which are fitted to a curve and the value of dx/dt at t = 0 derived. From the known Hugoniot for the inert, the particle velocity at essentially zero thickness of inert is deduced, thereby allowing the detonation pressure of the explosive to be determined by the acoustic approximation method[3]. This method assumes that the CJ state is unaffected by the reflected wave from the interface into the reaction products and, in the case of military explosives in contact with PMMA, the impedance match is adequate for this assumption to be made[11].

Using an aquarium technique, Rigdon and Akst[12] carried out a series of experiments to determine detonation pressure and monitored the velocity of the shock transmitted into water at the water/explosive interface using a streak camera. They showed that the value of dx/dt at t = 0, determined by a straight line graphical fit to the first few millimetres of streak record on a 40x photographic enlargement, generally gave good results and the method was recommended for a quick evaluation. However, they found the most expedient method, which also produced the best results, was a least squares fitting of a straight line over the first few millimetres of shock travel. This method was preferred to polynomial regression fits of varying degrees because, in their view, there was no obvious or reliable criterion for selecting the degree of polynomial which would yield the best result. In a similar series of experiments on low density PETN, using PMMA as the inert monitor, Hornig et al[13] chose to fit their x - t data to a quadratic of the form $t = a + bx + cx^2$. In this present work, the x - t data are shown to lie close to a straight line with a little curvature occurring at distances greater than 6mm from the explosive. Consequently, a least squares fitting of a straight line was employed as the best estimate of the average shock velocity, $\overline{U}_s$, over the region of interest in the PMMA. The results of these shock velocity measurements are given in Table 2 and Figure 4 shows some experimental data used in their acquisition, together with the x - t data generated from the computer simulation discussed below.

From the measured shock velocity data, the particle velocity, U_p, in the PMMA at the explosive/PMMA junction is computed via the Hugoniot for PMMA[14], $U_s = 2.561 + 1.595U_p$. The pressure in the

TABLE 2 Results of Shock Velocity Measurements and Detonation Pressure Determinations

EXPLOSIVE	SHOCK VELOCITY IN PMMA, $\overline{U}_s$,/ mm μs^{-1}	P_{HE}/ GPa	CORRECTED PRESSURE(CJ)/ GPa	P_{calc}/ GPa	$P_{Kamlet/Jacobs}$/GPa	γ
Tetryl	5.526 +/- 0.078	16.0+/-0.5	19.0 +/- 0.7	18.9+/-0.2	19.2	2.9(8)
Debrix 2	6.082 +/- 0.033	22.8+/-0.3	27.1 +/- 1.0	27.5+/-0.6	27.3	3.0(6)
LX-15	5.196 +/- 0.182	13.8+/-1.1	16.4 +/- 0.6	17.8+/-0.2	19.1	3.3(4)
AFX 521	5.198 +/- 0.081	13.6+/-0.5	16.2 +/- 0.7	17.5+/-0.3	17.7	3.3(2)
BX1	6.053 +/- 0.119	23.5+/-1.0	27.9 +/- 1.0	27.7+/-0.6	27.9	2.9(7)
BX3	5.947 +/- 0.205	22.5+/-1.6	26.7 +/- 1.0	27.5+/-0.5	27.4	3.1(1)
BX4	5.867 +/- 0.086	21.7+/-0.7	25.8 +/- 1.0	27.3+/-0.6	27.1	3.2(2)
PBX9503/UK	5.960 +/- 0.132	22.8+/-1.1	27.1 +/- 1.0	27.8+/-0.6	26.9	3.1(0)
PBX9503/US	5.769 +/- 0.074	20.2+/-0.6	24.0 +/- 0.9	24.3+/-0.4	25.2	3.0(4)

explosive at the interface with the PMMA is then calculated from the acoustic approximation equation

$$P_{HE} = P_{PMMA}\left\{\frac{\rho_o\bar{U}_s + \rho_{HE}D}{2\rho_o\bar{U}_s}\right\}$$

where P_{HE} = pressure in explosive

P_{PMMA} = pressure in PMMA at interface from $\rho_o\bar{U}_s\bar{U}_p$

ρ_o = initial density of PMMA, 1.186Mg m^{-3}

ρ_{HE} = initial density of the explosive

$\bar{U}_s$ = average shock velocity in the PMMA

D = detonation velocity

which is formulated on the assumption that

$(\rho_{\text{detonation products}} \times U_{s\ \text{detonation products}}) = \rho_{HE}D$

which, as shown by Wilkins[6], is very nearly exact for a CJ detonation. Coleburn[15] suggests this equation produces results to within 3% of the CJ pressure. The output performance of the test explosive can, therefore, readily be compared with tetryl. The results are given in Table 4.

Computer Simulation

The geometry shown in Fig. 1 was used for a simulation of the experimental tests, (a) to examine the planarity of the shock wave by monitoring stations placed in the PMMA representing the flash gaps and (b) by using two explosives with known JWL equations of state [Octol (HMX 77.5%, TNT 22.5%) and Comp B (RDX 64%, TNT 36%)], determine the value of $\bar{U}_s$ for each explosive and relate the determined value of P_{HE} to the known P_{CJ} figure. With the aid of the 2-D Eulerian Hydrodynamic Code, HULL, the problem was run with the donor explosive reaching a steady-state detonation at the monitor interface. The results indicate that the shock enters the PMMA in a planar fashion over the central 19mm of the PMMA discs and intersects the flash gap stations without deviation from planarity within the limits of the mesh dimensions (0.5mm), thereby reinforcing the experimental results on the wave planarity. The x - t data for the transmission of the shock through PMMA are given in Fig. 4 and the computed values of $\overline{U}_s$ and P_{HE} are presented in Table 3.

TABLE 3 Shock Velocity and Detonation Pressure Data from HULL Calculations

EXPLOSIVE	SHOCK VELOCITY IN PMMA, $\overline{U}_s$,/ kms^{-1}	P_{HE}/ GPa	$\frac{P_{CJ}}{P_{HE}} = F$
Comp B	6.246 +/- 0.136	24.96 +/- 1.10	1.18(2)
Octol	6.508 +/- 0.081	28.65 +/- 0.71	1.19(4)

P_{HE} is, as expected, smaller than the actual CJ value because the true value of the initial shock velocity (and initial particle velocity) is not known. However, by comparing the value of the known CJ pressures with the measured P_{HE} (simulation), an experimental correction factor, F, can be obtained. For Octol, F = 1.194 $\pm$ 0.030 and for Comp B, F = 1.182 $\pm$ 0.054. By comparison, the data of Jameson and Hawkins[11] allow for values of F for TNT-Plexiglass (1.12), Octol-Plexiglass (1.18), PBX 9404-Plexiglass

(1.11) and Pentolite-Plexiglass (1.14) to be determined. These lower values are explained by the fact that these data have not been extrapolated back to the CJ plane, whereas for the HULL results the CJ condition is known.

Therefore, by using the average value of F from the Octol and Comp B data, the magnitude of the experimentally determined P_{HE} term for the booster explosives can be corrected to give an estimate of the CJ pressure. These values appear in Table 2 under the heading Corrected Pressure (CJ). The detonation pressures of the explosives have also been calculated using the expression $P_{calc} = \frac{1}{1+\gamma}\rho_{HE}D^2$ assuming a value of 3 for γ and taking the measured velocities of detonation. Further, it is possible to estimate the adiabatic exponent, γ, from this equation by using the Corrected Pressure (CJ) value. Results of these calculations, together with estimates of the CJ pressure determined by the method of Kamlet and Jacobs[16], are included in Table 2.

Booster Output Comparisons

The results of the output performance of the various boosters obtained by the above methods have been compared with that of tetryl (Table 4). Several comparative values based on the Explosive Performance Potential, X_{pp}, of Mohan and Tang[17] have also been included. The X_{pp} figures are somewhat variable and the reason for the low values for the TATB-based compositions is not clear. In the main, the comparisons between the experimentally derived performance data andthose calculated is good and offers support to

TABLE 4 A Comparison of Booster Performance

EXPLOSIVE	CORRECTED PRESSURE (CJ) Method/%	P_{calc} Method/%	$P_{Kamlet/Jacobs}$ Method/%	X_{pp}/%
Tetryl	100	100	100	100
Debrix 2	143	146	142	144
LX-15	86	94	99	86
AFX 521	85	93	92	-
BX1	147	147	145	-
BX3	141	146	143	-
BX4	136	144	141	127
PBX 9503(UK)	143	147	140	-
PBX 9503(US)	126	129	131	119

the viability of the method. As a practical test of the results, the detonation break-out distance in a charge of TATB/Kel-F 800 95/5 was observed when a 25mm diameter by 25mm long booster pellet, separated by a 3mm thick disc of HE 30 TF aluminium alloy, was detonated. The results are given in Table 5. Detonation in the TATB/Kel-F 800 charges was observed with Debrix 2 (2 out of 2 firings), BX4 (2 out of 2 firings), PBX 9503(US) (1 firing) and tetryl (1 out of 2 firings) donor charges and failure with tetryl (1 out of 2 firings) and LX-15 (1 firing). The break-out distances produced by the first four explosives reflect the relative performances well. The results for tetryl show that the situation is marginal for this booster.

TABLE 5 Results from Distance to Break-out of Detonation Experiments with Booster Charge and TATB/Kel-F 800 95/5 Cylinders

EXPLOSIVE	NUMBER OF FIRINGS	RESULT ON WITNESS PLATE	BREAK-OUT DISTANCE /mm	EXPERIMENTAL DETONATION TIME(t*)/ μs	CALCULATED DETONATION TIME(t)/μs	$\frac{t}{t^*}$	COMMENTS
Debrix 2	2	Take over	6.1	7.54	8.51	1.13	
		Take over	7.0	7.53	8.39	1.11	
BX4	2	Take over	6.8	7.69	8.42	1.09	
		Take over	-	-	-	-	No camera record
PBX9503/US	1	Take over	9.0	7.52	8.13	1.08	
Tetryl	2	Take over	16.3	6.17	7.17	1.16	
		Failure	-	-	-	-	Deflagration in TATB charge. Little explosive remains.
LX-15	1	Failure	-	-	-	-	Little, if any, of TATB charge consumed

From these firings, the velocity of detonation in the TATB/Kel-F 800 95/5 charge was determined as 7.627 $\pm$ 0.050mm μs^{-1} using a least squares solution of the curve $x = D(t^2 + 2kt)^{\frac{1}{2}}$, which represents a streak record for short charges[18]. Using this figure, the theoretical time for the charge to detonate through a distance [charge length — break-out distance] was calculated and compared with the values measured from the streak records. These times are given in Table 5 under Calculated Detonation Time (t) and Experimental Detonation Time (t*) respectively. Ideally, the ratio of these two times should be unity, but the former figure is larger because of the effect that the experimental geometry has upon the streak record which causes the initial part of the record to appear to have almost infinite velocity[18]. However, if the donor charges produce break-out of detonation in the TATB/Kel-F 800 cylinders where the first visible light is recorded on the streak photograph and, with TATB charges, this is most likely since it is well known that they do not give out much visible light even when fully detonating, then the ratio t/t* should be constant. This is shown to be true within experimental error.

In the cases of the two rounds where failure occurred, the framing camera records were used to determine the velocity of the shock transmitted to the TATB/Kel-F 800 charge. Figure 5 shows the x - t data for these firings together with an earlier result where a 3mm pad of felt was placed beneath a Debrix 2 donor pellet, thereby causing failure[19]. The lower value of the shock velocity induced by LX-15 is consistent with its lower comparative performance. As it is clear that the shock donated by tetryl is marginal for the initiation of TATB/Kel-F 800 in this geometry, the measurement of the transmitted shock velocity can be used to estimate a minimum shock initiation pressure. Using the value of $\overline{U}_s = 4.6\ \mathrm{kms^{-1}}$ for the shock velocity in the acceptor charge, derived from the first four measured points, together with the Hugoniot for TATB/Kel-F 800 92.5/7.5 (LX-17)[20], $U_s = 2.33 + 2.32U_p$, a pressure of 8.4GPa is obtained. Table 6 summarises this and other experimental data which have been used to determine the shock initiation threshold of TATB/Kel-F 800 95/5.

TABLE 6 Calculation and Experimental Results of the Shock Initiation Threshold for TATB/Kel-F 800 95/5

TEST	CONFINEMENT	CHARGE DIAMETER mm	P_{PMMA}/GPa	P_{TATB}/GPa
1. LSGT	confined	36.2	8.7 (measured)	11.5
2. LASI[21]	unconfined	50.0	10.8 (measured)	14.4
3. GAP TEST[22]	unconfined	25.4	-	13.8 (measured)
4. This work	unconfined	36.2	-	>8.4 (measured)

The values of P_{TATB} for tests 1 and 2 have been determined by impedance matching techniques using the Hugoniots given above for PMMA and LX-17. The figure of 8.4GPa determined here is low compared with the other results because it is both deduced from a failure mode experiment and the framing record was taken with available light only, the early (and most important) part of the shock transit consequently not being recorded.

The method presented, whereby the average shock velocity transmitted to PMMA by a booster charge used in conjunction with a computer simulation to estimate the CJ pressure of the explosive, is found to provide a good agreement with the CJ values estimated theoretically. For tetryl, the value of the detonation pressure determined by this method compares well with the experimental measurements of Coleburn[15], whose data, corrected for density to 1.50Mg m^{-3} according to the method of Deal[4], give 19.0Gpa at 50mm diameter, those of Edwards et al[23] who give 19.1GPa at a density of 1.51Mg m^{-3} and 50.8mm diameter, and Jacobs and Edwards[24] who find 19.0GPa at a density of 1.51Mg m^{-3} and 50.8mm diameter, assuming $\gamma = 3$. These data, in conjunction with the results from the break-out distance experiments which show that t/t* is constant, strongly suggest that using the initiation system described here to detonate the booster charges, culminates in the booster reaching full order detonation within 25mm travel. To test this hypothesis, an experiment was performed in which the shock velocity in PMMA was determined using 2 x 25mm long Debrix 2 pellets. The resulting P_{HE} value, 23.8 $\pm$ 0.9GPa, does not differ significantly from that determined from a charge 25mm long as the results overlap at the 2σ level. Indeed, for PBX 9407 (94% RDX, 6% Exon) pressed to a density of 1.60Mg m^{-3}, Lindstrom[25] shows that full detonation is achieved from an initial planar input shock of 0.2GPa in around 15mm travel in a wedge machined from a cylinder 50.8mm in diameter with a 13^{o} toe angle, and therefore initiation via a more substantial input source will almost certainly lead to the CJ condition being achieved in under 25mm travel.

CONCLUSIONS

The work described in this paper shows that a relatively simple test, which measures the average shock velocity delivered to a PMMA monitor by a booster charge 25mm diameter x 25mm long, can be used to provide a comparative determination of the performance of the explosives and, when used in conjunction with a computer simulation of the test, produces reasonable estimates of the detonation pressure. By separate determination of the velocity of detonation at the same density, estimates of the adiabatic exponent γ are possible. Further experiments indicate that all the booster compositions examined, when initiated by a 25mm diameter RDX-based plane wave shaper, are probably fully detonating at the end of their 25mm length. Studies on the hazard potential of certain booster explosives in fuel fires suggest that, to suppress cook-off, these compositions are required to be of relatively small dimensions and this present work supports the claim that large booster components in weapon systems are, on the whole, unnecessary. In a practical situation, where air gaps, felt pads and other design features alter the pressure/time profiles of the booster output, the 25mm diameter x 25mm long pellet may not be entirely sufficient

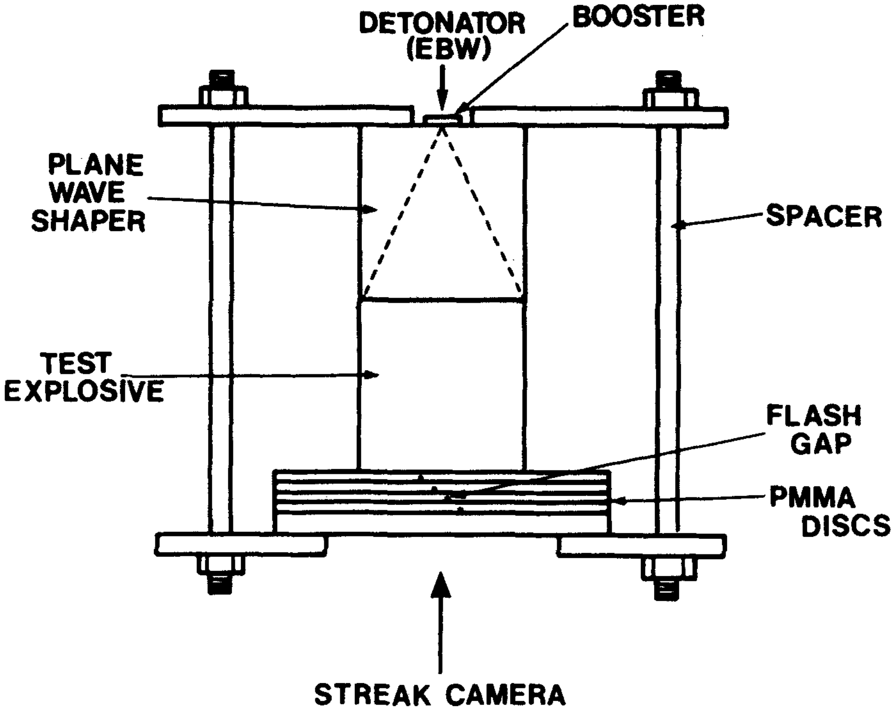

FIGURE 1

Diagrammatic representation of the experimental arrangement used to measure the shock velocity in PMMA delivered from a 25mm long by 25mm diameter cylindrical test explosive.

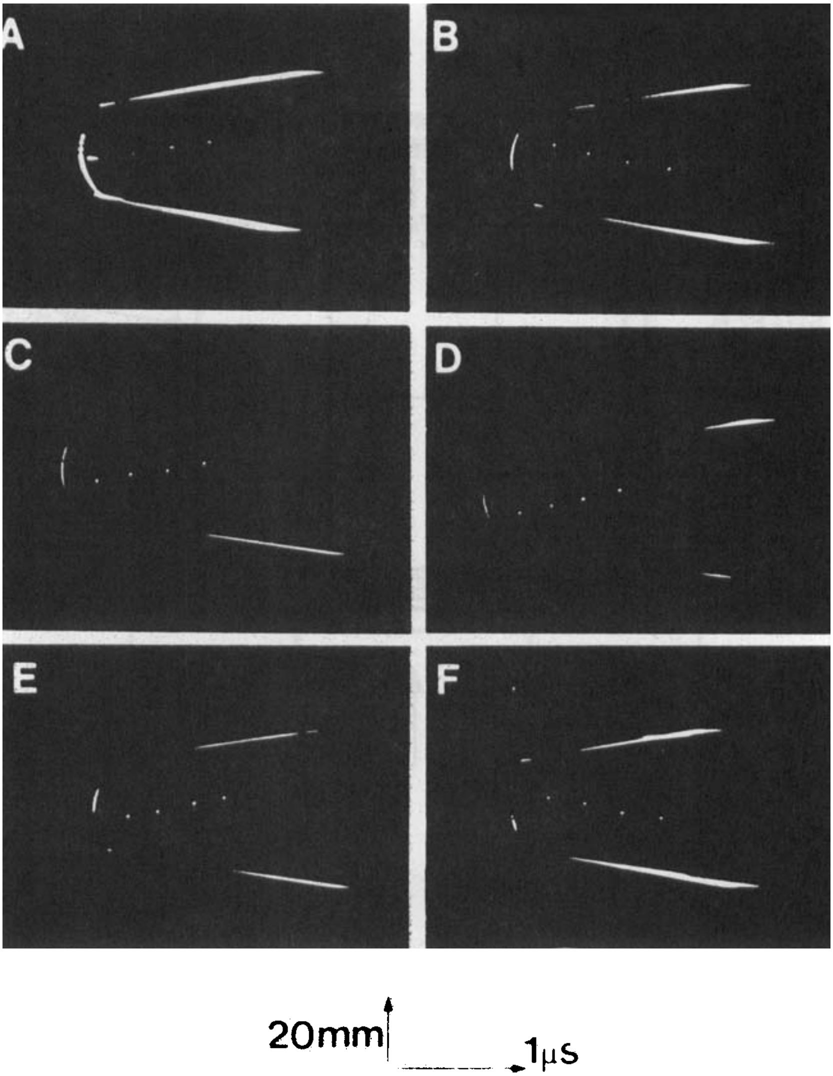

FIGURE 2

Streak records used for the measurement of the average shock velocity in PMMA showing the pin points of light produced from the flash gaps. A. Test experiment using Comp A5 showing the effect produced when the flash gaps are arranged such that the shock hits the open end of the gap first. There is a distinct time lag between the shock front hitting the PMMA and the light output. B. AFX 521, C. PBX 9503(US), D. PBX 9503(UK), E. BX4, F. Tetryl.

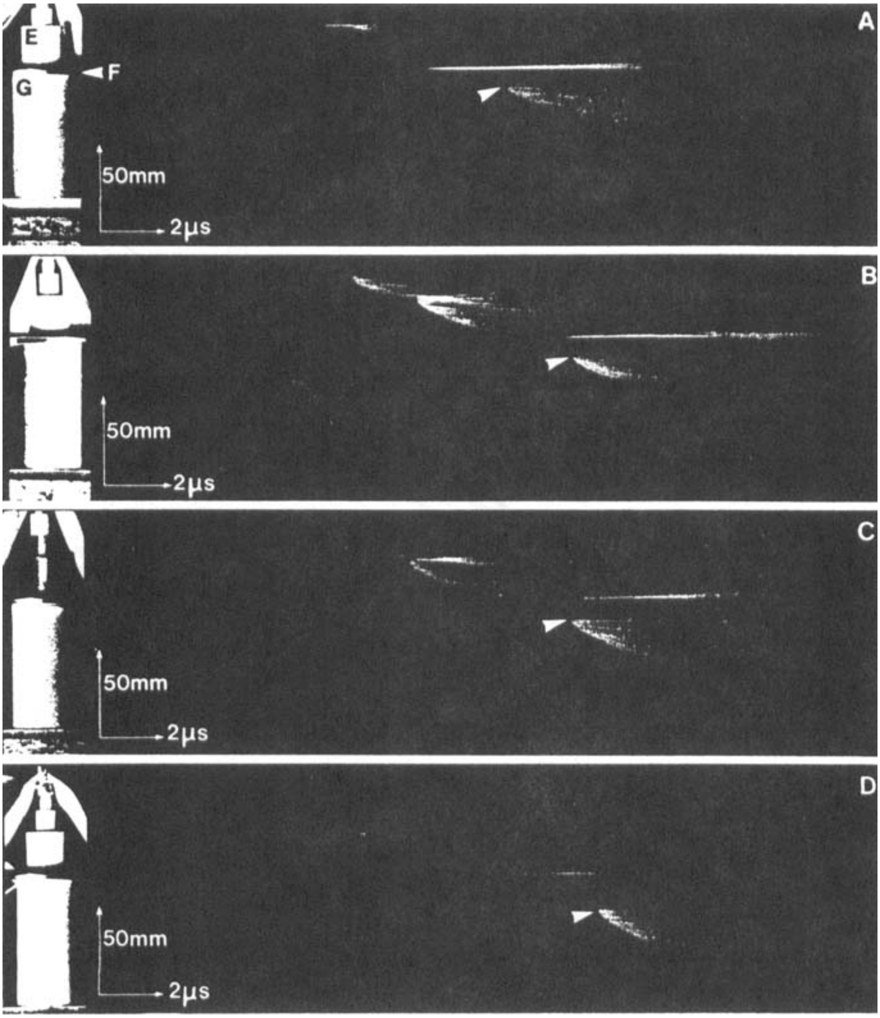

FIGURE 3

Streak records of the experiments to determine the distance to break-out of detonation in a TATB/Kel-F 800 95/5 charge.
E. Booster explosive pellet, 25mm long x 25mm diameter. F. 3mm thick HE 30 TF aluminium alloy disc. G. TATB/Kel-F 800 95/5 acceptor charge. A. Record from a Debrix 2 donor, B. Record from a BX4 donor, C. Record from a PBX 9503(US) donor, D. Record from a Tetryl donor. Arrows indicate break-out of detonation.

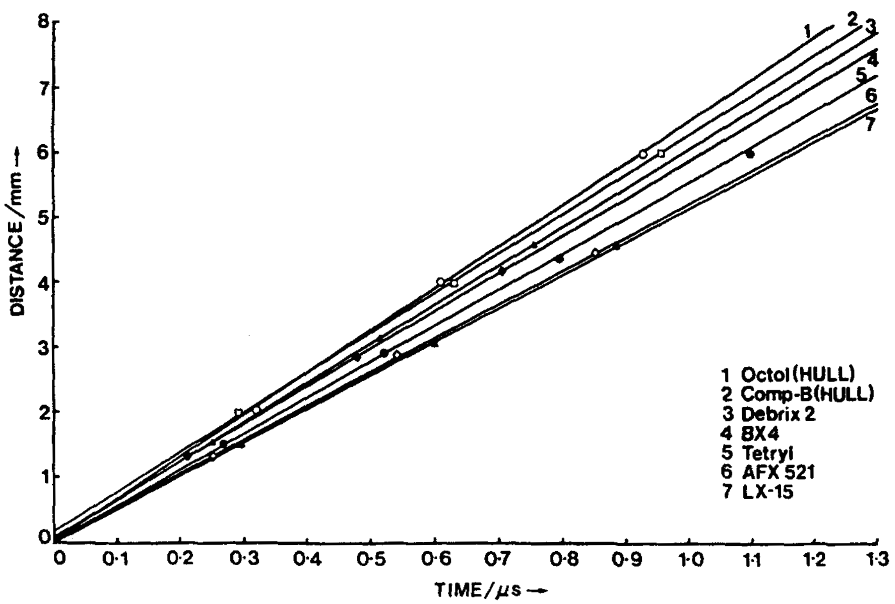

FIGURE 4

Results of the x - t data acquired from the streak records shown in Figure 2 and the HULL computer simulations. Measurement errors are contained within the symbol size. For values of $\overline{U}_S$, see Table 2.

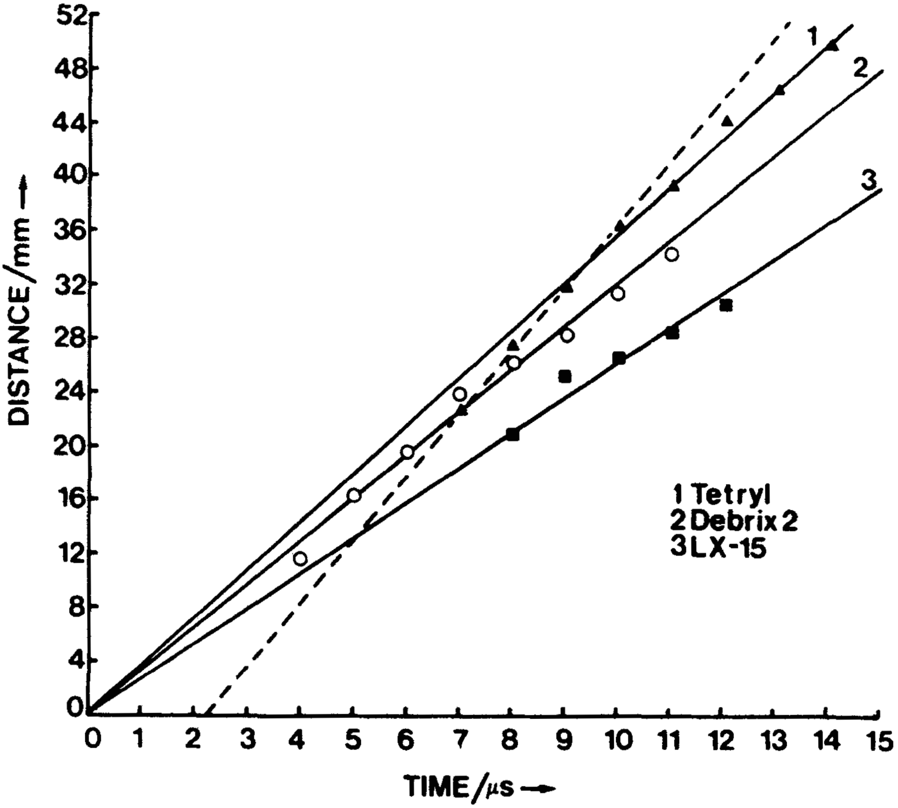

FIGURE 5

x - t data taken from three framing camera records of experiments where the booster donor was separated from a TATB/Kel-F 800 95/5 charge by 3mm aluminium alloy (and 3mm felt in the case of Debrix 2) resulting in failure of the TATB/Kel-F 800 to detonate. The continuous lines are drawn to show the trend in average shock velocity only. The dotted line is taken as the value of U_s for the first four pictures of the framing record for tetryl for the calculation of the shock initiation threshold of TATB/Kel-F 800.

to provide a reliable source of initiation, but adequate experimentation with real systems should show that booster dimensions need not exceed those examined in this paper by excessive amounts in order to achieve the required pressure/time profile for initiation of the main charge explosive. To confirm the findings presented here, CJ pressure measurements using manganin pressure transducers are planned. This work will allow the peak pressure as a function of distance in the booster to be monitored, thereby producing valuable data whereby booster design may be optimised.

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REFERENCES

1. L C Smith, Explosivstoffe, 5, 106; 6,130 (1967)
2. H Vantine, J Chan, L Erickson, R Weingart and R Lee, Rev. Sci. Instrum., 51, (1), 116 (1980)
3. R E Duff and E Houston, J. Chem. Phys., 23, (7), 1268 (1955)
4. W E Deal, J. Chem. Phys., 27, (3), 796 (1957)
5. B Hayes, Rev. Sci. Instrum., 52, (4), 594 (1981)
6. M L Wilkins, 4th Symposium (International) on Detonation, White Oak, 1965, p. 519
7. R R Ijsselstein, Proc. 12th Symposium on Explosives and Pyrotechnics, San Diego, 1984, p. 3.89
8. E James, 2nd ONR Symposium on Detonation, Washington, 1955, p. 1

9. T R Gibbs and A Popolato, "LASL Explosives Property Data", Univ-Calif. Press, Berkeley, 1980

10. M A van Gool, ICT Jahrestagung, Karlsruhe, 1981, p. 333

11. R L Jameson and A Hawkins, 5th Symposium (International) on Detonation, Pasadena, 1970, p. 23

12. J K Rigdon and I B Akst, 5th Symposium (International) on Detonation, Pasadena, 1970, p. 59

13. H C Hornig, E L Lee, M Finger and J E Kurrle, 5th Symposium (International) on Detonation, Pasadena, 1970, p. 503

14. J O Erkman, D J Edwards, A R Clairmont and D Price, NOL-TR 73-15, 1973

15. N L Coleburn, NOL-TR 64-58, 1964

16. M J Kamlet and S J Jacobs, J. Chem. Phys., 48, (1), 23 (1968)

17. V Krishna Mohan and T B Tang, Prop. Expl. Pyro., 9, 30 (1984)

18. A R Clairmont and I Jaffe, SPIE Journal, 5, 18 (1966)

19. C D Hutchinson, 16th International Congress on High Speed Photography, Strasbourg, 1984

20. R K Jackson et al, 6th Symposium (International) on Detonation, Coronado, 1976, p. 755

21. D G Tasker, 7th Symposium (International) on Detonation, Annapolis, 1981, p. 285

22. G C W Foan and G D Coley, 7th Symposium (International) on Detonation, Annapolis, 1981, p. 228

23. D J Edwards, J O Erkman and D Price, NOL-TR 72-83, 1972

24. S J Jacobs and D J Edwards, 5th Symposium (International) on Detonation, Pasadena, 1970, p. 413

25. I E Lindstrom, J. Appl. Phys., 37, (13), 4873 (1966)