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THEORETICAL PREDICTION OF THE BLAST FROM DEFA PROJECTILE IN FRE--ETC(U)
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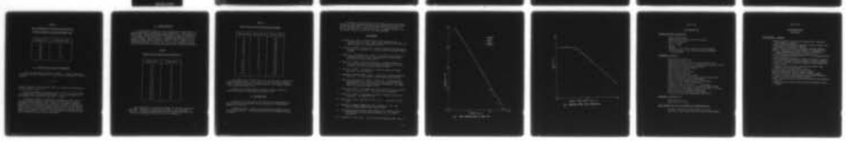

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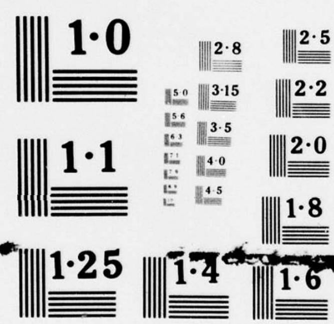
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G.J. Jenks

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G.J. Jenks

ABSTRACT

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CONTENTS

		Page No.
1.	INTRODUCTION	1
2.	THE DEFA ROUND	1
3.	DETONATION PARAMETERS OF EXPLOSIVE COMPOSITIONS	2
4.	PASSAGE OF THE SHOCK FRONT INTO AIR	3
5.	PEAK OVERPRESSURES FROM EXPERIMENTAL DATA	4
6.	DISCUSSION ON PEAK OVERPRESSURE	8
7.	BLAST IMPULSE	9
8.	CONCLUSIONS	10
	REFERENCES	11

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THEORETICAL PREDICTION OF THE BLAST

FROM DEFA PROJECTILE IN FREE AIR

1. INTRODUCTION

The 30 mm DEFA projectile, now in service with the Royal Australian Air Force, is used in an air-to-air role. The reliability and effectiveness of this round and associated gun system against specific targets is currently being evaluated within Australia; this report presents an analysis of the expected peak overpressure as a function of distance from the detonation point of a single projectile in free air.

2. THE DEFA ROUND

The DEFA projectile is filled with seven low-density consolidated pellets of high explosive; each pellet is about 7.3 g in mass giving a total explosive mass of about 51.5 g. The total charge is approximately cylindrical, 25 mm diameter and 65 mm long. The composition is hexal (RDX 80%, aluminium 20%) pressed to an average density of 1.74 Mg/m^3. Possible alternative fillings are torpex (RDX 42%, TNT 40%, aluminium 18%, density 1.72 Mg/m^3), H6 (RDX 43%, TNT 30%, aluminium 22%, wax 5%, density 1.80 Mg/m^3), or Alex 20 (RDX 44%, TNT 36%, aluminium 20%, density 1.78 Mg/m^3).

The ratio of the mass of the explosive charge to the mass of the metallic case in the cylindrical region of the projectile is approximately 0.6. Some of the energy produced in the detonation is dissipated by the fragmentation of the case; only a fraction of the original energy is available for the shock wave. From an empirical expression (1), it may be shown that the encased charge of 51.5 g produces a peak overpressure-distance profile identical with that obtained from a bare charge of 23 g of the same composition. This expression is based primarily on CHNO explosives, and may not be directly applicable to aluminised compositions. In these compositions (such as hexal) the overpressure may increase due to a relatively long burning time of the aluminium particles. This charge of 23 g can be regarded, to a first approximation, as a spherical charge of radius 14.7 mm.

3. DETONATION PARAMETERS OF EXPLOSIVE COMPOSITIONS

The Fortran BKW code (2), developed at the Los Alamos Scientific Laboratory, has been used for predicting the detonation parameters of many condensed high explosives (3). Results relevant to the present study are listed in Table 1.

TABLE 1

FORTRAN BKW RESULTS

High Explosive	Density (Mg/m^3)	Detonation Pressure (GPa)	Detonation Velocity (m/s)
Hexal	1.74	25.8	7170
Torpex	1.72	22.5	7150
Alex 20	1.78	23.7	7280
H6	1.80	23.5	7380
RDX (4)	1.80	34.7	8750
RDX (4)	1.60	26.4	7990
TNT (4)	1.64	20.6	6950
Aust. Comp B	1.65	25.0	7760

The BKW code assumes instantaneous transition from the condensed explosive to the gaseous or solid products formed. This assumption may well be satisfactory for RDX, TNT and similar compositions. Current work (5) suggests that the detonation velocity derived by BKW for aluminised compositions is greater than that obtained experimentally; this discrepancy has been attributed to the relatively long burning time of the aluminium, and is therefore dependent on particle size. Similarly BKW is expected to predict lower detonation pressures than are observed experimentally; the experimental result would arise from the detonation pressure at the shock front together with the pressure caused by the after-burning of the aluminium. The magnitude of the difference between the theoretical and experimental pressures cannot be predicted; an estimate of 25% seems plausible (6). Thus effective detonation pressures of 30 GPa seem reasonable .

4. PASSAGE OF THE SHOCK FRONT INTO AIR

Fortran SIN (7), another computer code developed at Los Alamos Scientific Laboratory for solving one-dimensional hydrodynamic problems, has been used to model the passage of the shock front into the surrounding air. Current work (8) has been limited to spherical uncased charges of Composition B, of radius 127 mm, density 1.65 Mg/m^3 and thus of mass 14.2 kg.

In order to obtain a reliable comparison, the DEFA charge must be assumed spherical and the overpressure from the aluminised charge must be related to that from Composition B. The assumption of a spherical charge seems reasonable at distances greater than about twice the charge radius.

It is, however, more difficult to obtain a reliable correlation between the pressure produced from the aluminised DEFA charge and Composition B of the same geometrical shape, cased or uncased. At overpressures between 30 and 300 kPa, the average ratio of the pressure produced from the detonation of a charge of H6 to the overpressure produced at the same distance from the same weight of Composition B is 1.24 (1), the ratio increasing with increasing overpressure. Outside this range, no information is available. It would be tempting to assume that this ratio increases monotonically over the entire pressure range, particularly as it is generally accepted that at very low pressure (1 kPa or less) the ratio is unity. This assumption should be rejected as the corresponding ratio for the pressure from a pentolite charge to the pressure from a TNT charge oscillates above 300 kPa. Thus, for the purpose of this work, the ratio of the pressure from the DEFA detonation to the pressure from the same mass of Composition B is assumed to be 1.24.

The SIN results on Composition B (8) can now be used to predict the peak overpressure-versus-distance profile for the detonation of a DEFA projectile in free air. From SIN, the distance at which a given overpressure is obtained is proportional to the diameter of the charge; this result is equivalent to the Sachs scaling law (9). Then if P_o is the peak overpressure at a distance d_o from a bare charge of Composition B of mass W_o g, 1.24 P_o is the pressure at a distance d from a DEFA projectile, which has an equivalent bare charge of W g; W, W_o, d and d_o are related (10) by

$$\frac{d}{d_o} = \left(\frac{W}{W_o}\right)^{\frac{1}{3}} \tag{1}$$

In the current example, W is 23 and W_o is 14200. Thus

$$\frac{d}{d_o} = 0.12 \tag{2}$$

The SIN code assumes instantaneous detonation of the high explosive and the consequent generation of a high pressure by the gaseous products formed. Thus SIN predicts a peak overpressure of 11.5 GPa within the volume occupied by Composition B charge. Correspondingly, a peak overpressure of 14.3 GPa would be expected in the DEFA projectile before the shock wave enters the surrounding air. This pressure value assumes a spherical charge within the projectile.

Immediately outside the charge, the peak overpressure falls sharply. At any point, its value cannot be reliably estimated as it is in this region that the assumption of a spherical charge cannot be justified.

At greater distances, SIN predicts a peak overpressure of 29 MPa at 36 mm, 21 MPa at 48 mm and 16 MPa at 60 mm.

5. PEAK OVERPRESSURES FROM EXPERIMENTAL DATA

Further from the detonation point, the scaling law (1) can be applied provided the peak overpressure is known as a function of distance for a given charge. The standard charge is usually taken as 1 lb (450 g) of TNT. The ratio of the pressure from the DEFA detonation to the pressure from the same mass of TNT is assumed to be 1.38 throughout the pressure range (1).

Data are available (1) in graphical and tabular form of the peak overpressure against distance for a 1 lb spherical bare charge of TNT. From the scaling law (1), and from the pressure ratio of 1.38, values of the peak overpressure against distance are given in Table 2.

TABLE 2

PEAK OVERPRESSURE Vs DISTANCE FROM SCALING LAW

FOR DEFA PROJECTILE USING SWISDAK (1)

Distance (cm)	Overpressure (kPa)
1.47	76,000 (d)
1.70	67,000 (d)
2.26	56,000 (d)
3.39	38,000 (d)
4.52	28,500 (d)
5.66	19,000 (d)
7.92	14,300 (d)
11.5	7,600
13.5	5,700
14.9	4,800
16.7	3,800
19.3	2,850
21.1	2,380
23.5	1,900
27.0	1,430
32.6	950
36.0	760
40.7	570
43.8	480
66.4	190
91.8	95
134	48
249	19
425	10

The symbol (d) indicates that this result was obtained from computer prediction and not experiment.

An alternative approach is to use the data reproduced in Baker (10). Results are given in Table 3, when applied to the DEFA projectile. These results are generally in agreement with those of Table 2.

TABLE 3

PEAK OVERPRESSURE Vs DISTANCE FROM SCALING LAW

FOR DEFA PROJECTILE USING BAKER (10)

Distance (cm)	Peak Overpressure (kPa)
43	950
47	760
53	570
56	480
81	190
115	95
180	48
320	19
550	9.5

In these data (10), appreciable scatter has been noted. Overpressures at given distances may vary up to ± 30%, particularly for low pressures. Caution in using these results is thus necessary.

Another method involves using results (11) from the 500 lb G.P. (general purpose) bomb, which produces the same pressure-distance profile as 86 kg of uncased TNT (11). From the standard Sachs (9) scaling law (1),

$$\frac{d}{d_o} = 0.065$$

where d refers to the DEFA detonation and d_o to the 500 lb bomb. Table 4 summarises the data available as applied to the DEFA round.

TABLE 4

BLAST OVERPRESSURE Vs DISTANCE FROM SCALING LAW

FOR DEFA PROJECTILE USING 500 LB BOMB DATA (11)

Distance (cm)	Overpressure (kPa)
24	9,500 (b)
40	1,900 (b)
49	950 (b)
56	760 (b)
58	570 (b)
63	480 (b)
91	190 (b)
125	95 (b)
140	76 (b)
175	48 (b)
315	19

(b) These results should be treated cautiously as the distances involved are comparable with or less than the length of the bomb. Thus the assumption of a spherical burst is therefore suspect at these distances.

Another possibility is the use of nuclear weapon data (13), although the justification of scaling laws between small-calibre DEFA rounds and large nuclear explosions must be regarded as tenuous, particularly at points close to the bomb. Results are listed in Table 5. In this case,

$$\frac{d}{d_o} = 2.8 \times 10^{-3}$$

where the subscript o refers to a one kiloton nuclear burst.

TABLE 5

BLAST OVERPRESSURE Vs DISTANCE FROM SCALING LAW

FOR DEFA PROJECTILE USING NUCLEAR WEAPON DATA

Distance (cm)	Overpressure (kPa)
105	95
130	76
160	57
180	48
300	19
450	9.5

6. DISCUSSION ON PEAK OVERPRESSURE

The results obtained are plotted on Figure 1. It may be seen that the points are almost collinear on a log-log graph, satisfying the empirical relation

$$P = k\, r^{-1.75}$$

k being a constant. This presumably would give reasonable extrapolation at distances greater than 0.5 m.

The results obtained at distances between 1 and 5 cm from the centre of detonation should be regarded cautiously. It is in this region that the assumption of a spherical charge would be invalid.

No systematic attempt has been made to assign error limits to the peak overpressures obtained. Any such attempt would require a careful assessment of each assumption used. However it is probably reasonable to suggest that the actual pressure would be within a factor of two from the curve as drawn. It should be noted that such a blast in free air would be difficult to realise, as there would be reflection or diffraction from the ground or from adjacent structure. Any such reflected or diffracted shock could significantly alter the peak overpressure.

7. BLAST IMPULSE

It is generally accepted (1) that any prediction of blast impulse is less reliable than the prediction of peak overpressure. Table 6 lists the impulse from a spherical aluminised charge based on data (1) obtained for a 1 lb spherical bare charge of TNT. A scaling law similar to (1) can be used for impulse. Recent evidence (1) suggests that the impulse from an aluminised charge differs from that of TNT by a factor of about 1.15 over the pressure range 30 to 500 kPa; this factor is not constant over this range and some caution in interpreting these results is therefore required.

TABLE 6

IMPULSE FOR DEFA PROJECTILE FROM SWISDAK (1)

Distance (cm)	Impulse (Pa s)
14.9	43
16.7	43
19.3	43
21.1	44
23.5	44
27.0	43
32.6	42
36.0	40
40.7	38
43.8	37
66.4	27
91.8	20
134.0	13

Other information is available from Baker (10), and the 500 lb bomb data (11). Results for these are given in Table 7, with the source indicated. No attempt has been made to use the nuclear weapon data (13), in view of the entirely different nature of the explosive.

TABLE 7

IMPULSE FOR DEFA PROJECTILE FROM OTHER SOURCES

Distance (cm)	Impulse (Pa s)	Source of Data
56	35	(10)
67	29	(10)
90	23	(10)
135	17	(10)
170	15	(10)
450	6	(10)
58	39	(11)
72	30	(11)
88	26	(11)
108	20	(11)
150	15	(11)
220	10	(11)
300	7.5	(11)
430	5	(11)

The computer code, Fortran SIN (7), has not been used for predicting impulse from detonations, as many hundreds of time and space increments would be required to produce a reliable estimate; this computer capacity is not readily available to MRL.

Results of the impulse against distance are shown in Figure 2; reliable information is unavailable below about 20 cm.

8. CONCLUSIONS

Estimates of the peak overpressure and positive impulse have been derived from empirical arguments for the detonation of a single DEFA projectile in free air.

Overpressure results, based on data obtained from several sources, are plotted in Figure 1. Corresponding results for the impulse are shown in Figure 2.

An analysis of the reliability of these results has not been given. However, it seems reasonable to postulate an uncertainty of about ± 20% in the overpressure results at distances greater than one metre from the burst; uncertainties of ± 50% may well occur at smaller distances. For the impulse figures, an error of ± 30% seems reasonable.

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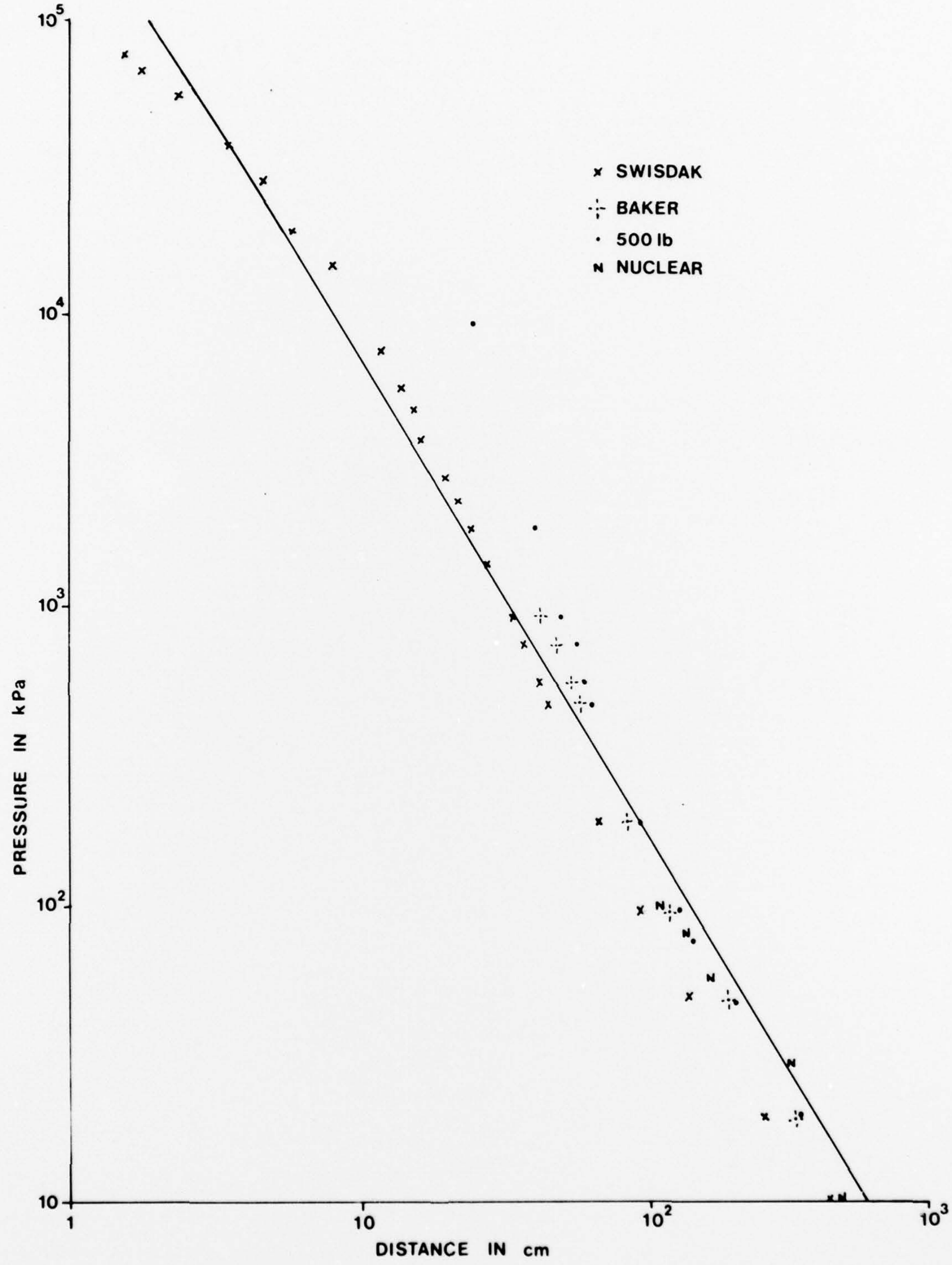

Fig 1 DEFA ROUND BLAST IN FREE AIR

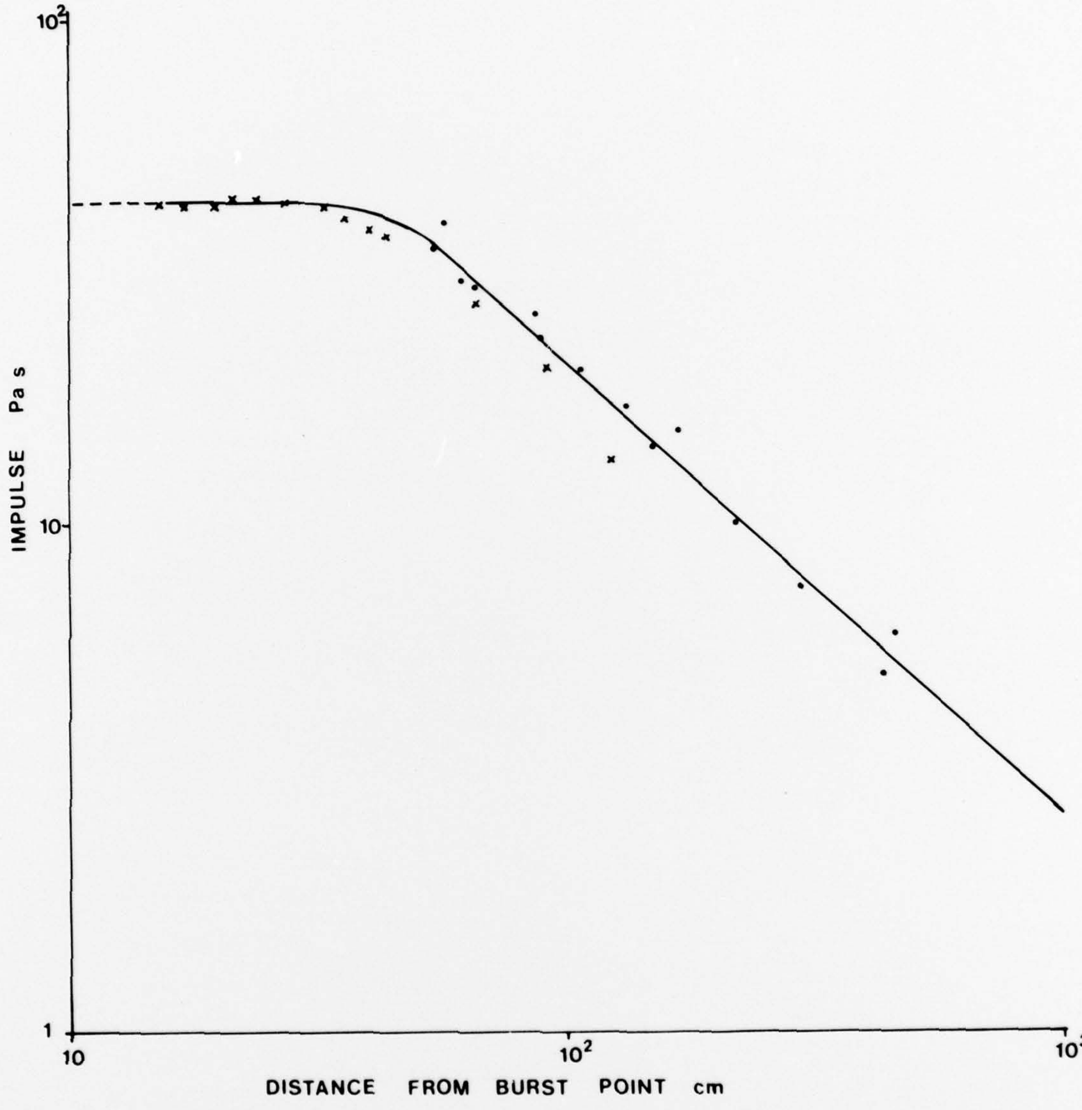

Fig 2 IMPULSE FROM DEFA PROJECTILE

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