TARGET DAMAGES BY EXPLOSIVE CHARGES WITH LINED CONICAL CAVITIES

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1. INTRODUCTION

High explosive charges with metal-lined cavities (Shaped Charges) were extensively used during the last war by armed forces of the major combatants for destroying concrete fortifications, bridges, pillboxes, tanks and other war machines. The first fairly comprehensive explanation of this phenomena was published by Birkhoff, MacDougall, Pugh and Taylor (1948). They showed that when a detonation wave sweeps from apex to base along a conical liner, it collapses the liner into a small diameter jet (known as 'Munroe' jet) which shoots forward with a tremendous velocity (7 to 12×10^5 cm./sec.). When this high velocity jet impinges upon a target, it produces pressures close to a quarter million atmospheres and the target material flows plastically out of the path of the jet. Recently Pugh, Eichelberger and Rostoker (1952) extended the steady-state hydrodynamic theory and explained the formation of the entire jet (including the 'after jet') and the velocity gradient in the jet.

The aim of the present investigation is to study the damage to massive mild steel targets by explosive charges having (*a*) copper conical liners of different calibres and (*b*) copper and mild steel liners of different angles. As the penetration by high velocity 'Munroe' jet is independent of the striking velocity, so the experiments were done by hand placing and statically detonating the shaped charges.

2. COPPER CONICAL LINERS OF DIFFERENT CALIBRES

Let D represent the base diameter of the conical liner and be referred as calibre. The unit of length is assumed to be $1D$ and other parameters, e.g. thickness of conical liner ($0{\cdot}032D$), charge length ($0{\cdot}9D$) and stand-off ($1\frac{1}{2}D$) increase *pro rata* to the calibre.

Conical liners of angle 45°, thickness $0{\cdot}032D$ and of different calibres were machined from rods of copper. The conical liner was soldered at one end of a gas pipe. High explosive, which was a mixture of T.N.T. and tetryl (trinitrophenylmethylnitramine) in the ratio of 70 : 30, was cast. A tetryl pellet was used as a booster. The lay-out of the equipment for firing is shown in Fig. 1 and the relevant information is given in Table 1.

The plot of penetration P against calibre D (Fig. 2) suggests a linear relationship, which is as follows:—

$$P = 3{\cdot}96D - 0{\cdot}29 \qquad \ldots \quad (1)$$

Evans and Ubbelohde (1950) also suggested a linear relationship between penetration and calibre (in the range of 1 to 2 in.). The logarithmic plot of penetration against entry diameter E (Fig. 3) also suggests the following linear relation

$$P = 7{\cdot}96\, E^{0{\cdot}68} \qquad \ldots \quad (2)$$

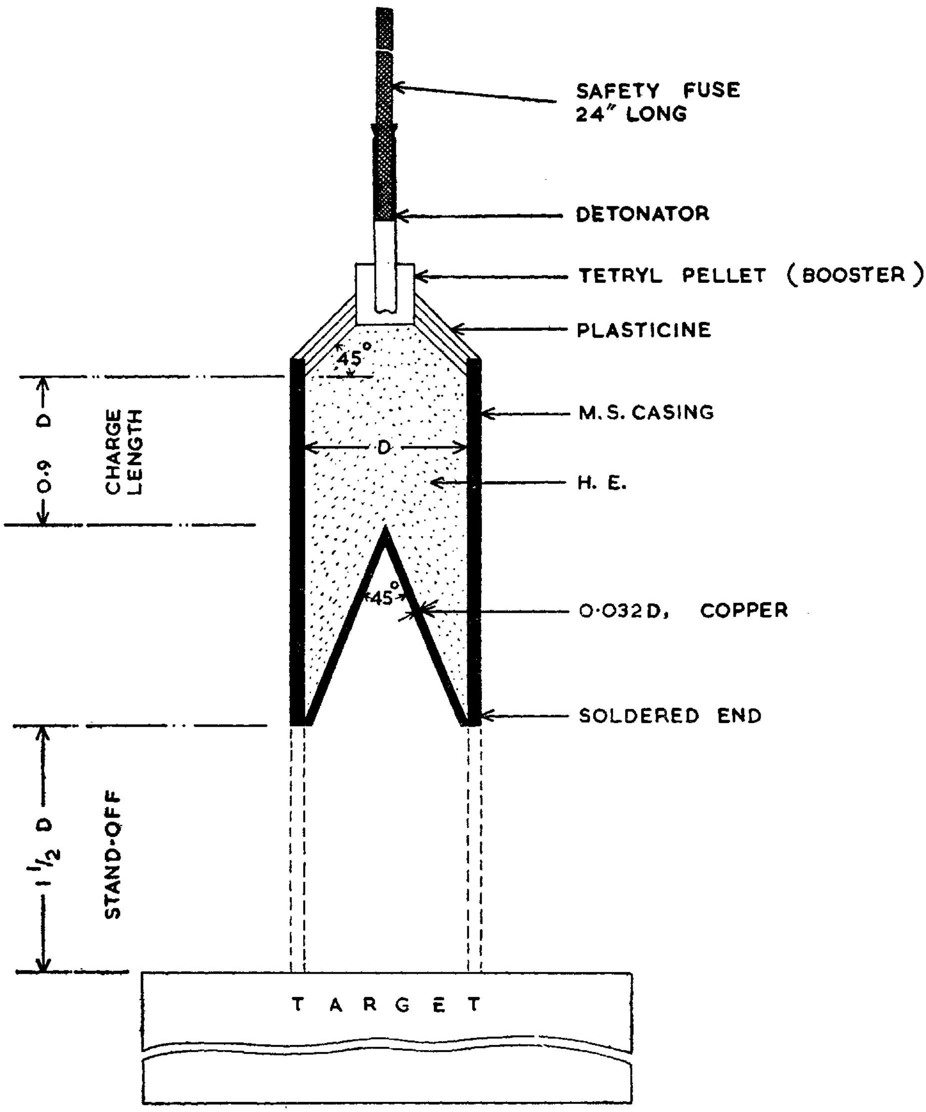

FIG. 1. Lay-out of shaped charge equipment for firing.

TABLE I

Target damages as a function of calibre.

Calibre (inch) *D*	Wt. of explosives. (lb.) *W*	Mean parameters of hole. Volume (c.c.) *V*	Entry dia. (inch) *E*	Penetration (inch) *P*	No. of firings.
1·38	0·198	13·7	0·58	5·27	5
1·5	0·258	14·7	0·58	5·67	5
2·0	0·611	46·8	0·85	7·35	5
2·5	1·193	99·1	1·43	9·69	5
3·0	2·061	190·0	1·68	11·63	5

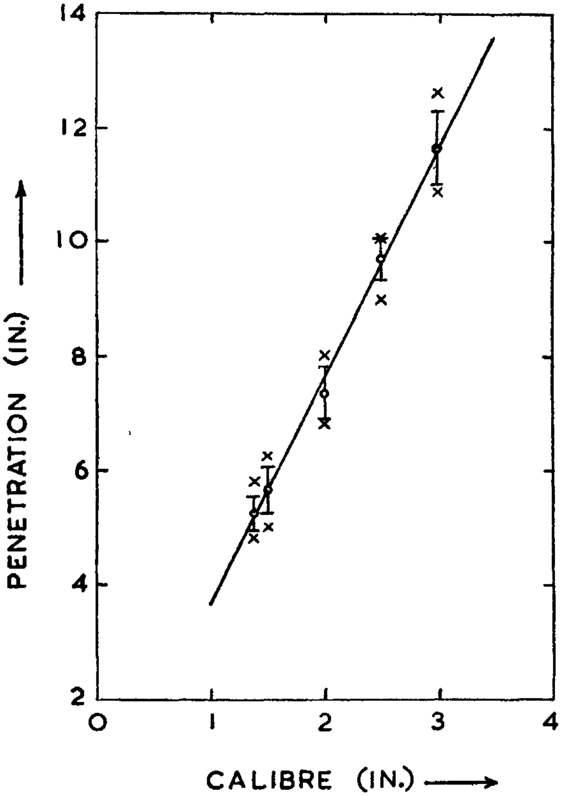

FIG. 2. Penetration in mild steel as a function of calibre. ⌶ indicates mean penetration with 95% confidence limits. × indicates maximum and minimum penetration.

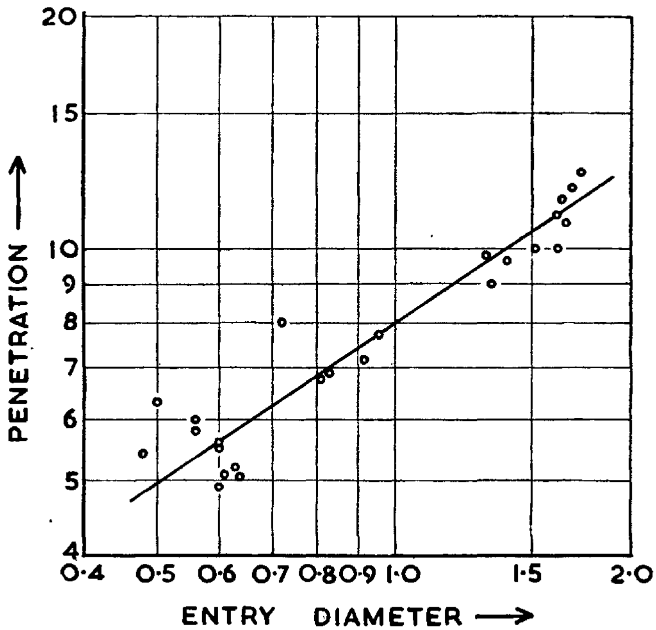

FIG. 3. Variation of the penetration with entry diameter in mild steel.

From the data in Table I, it appears that the relationship $V = KD^3$, where K is some constant, holds approximately. As volume of the hole depends on the kinetic energy of the jet, so kinetic energy of jet is also proportional to the cube of the calibre. Let 2α represent the original angle of the conical liner, D the calibre and ND the charge length. The weight of explosive W in the shaped charge is given by the expression

$$W = \frac{\pi}{12} D^3 \rho_0 [\cot \alpha + 3N] \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

In the experiments discussed above, ND is taken as $0{\cdot}9D$, ρ_0 is the cast density of the explosive in lbs./cu.in. (0·057 lbs./cu.in.). Eq. (3) reduces to

$$W = kD^3 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

where $k = 0{\cdot}076$ lbs. in. $^{-3}$.

3. Copper and Mild Steel Conical Liners of Different Angles

Conical liners of copper and mild steel, calibre $1\frac{3}{8}$ in., thickness 0·044 in. and of different angles—120°, 100°, 80°, 60°, 50°, 40°, 30°, 20° and 15°—were machined from rods of the metals. The liners were soldered with convenient length of gas pipes $\frac{1}{8}$ in. thickness. High explosive, which was a mixture of T.N.T. and tetryl in the ratio of 70 : 30, was cast. The charge length (3 in.) and stand-off ($2\frac{1}{16}$ in.) were kept constant in all the firings. The lay-out of the equipment for firing is the same as shown in Fig. 1 and the relevant information is given in Table II.

Table II

Target damages as a function of angle of conical liner.

Angle of conical liner. (deg.)	Copper conical liner.			Mild steel conical liner.		
	Mean penetration. (inch)	Mean entry dia. (inch)	No. of firings.	Mean penetration. (inch)	Mean entry dia. (inch)	No. of firings.
120	2·91	0·44	6	2·48	0·55	6
100	3·50	0·38	6	3·14	0·49	6
80	3·93	0·42	6	3·65	0·45	6
60	4·16	0·41	6	3·85	0·43	6
50	4·76	0·57	6	4·10	0·61	6
40	5·27	0·54	6	4·58	0·71	6
30	5·51	0·57	6	4·73	0·74	6
20	5·75	0·60	6	5·15	0·66	6
15	5·13	Irregular	5	4·14	Irregular	5

The data in Table II indicate that (*a*) as the angle of the conical liner decreases, the penetration increases both for copper and mild steel liners. The relation of penetration as a function of the angle is shown in Fig. 4. The firing data of 15° conical liner is wide spread; (*b*) the penetration by copper liner is about 14% more than that of mild steel liner of the same angle; and (*c*) the entry diameter by a copper liner is about 16% less than that of mild steel liner of the same angle.

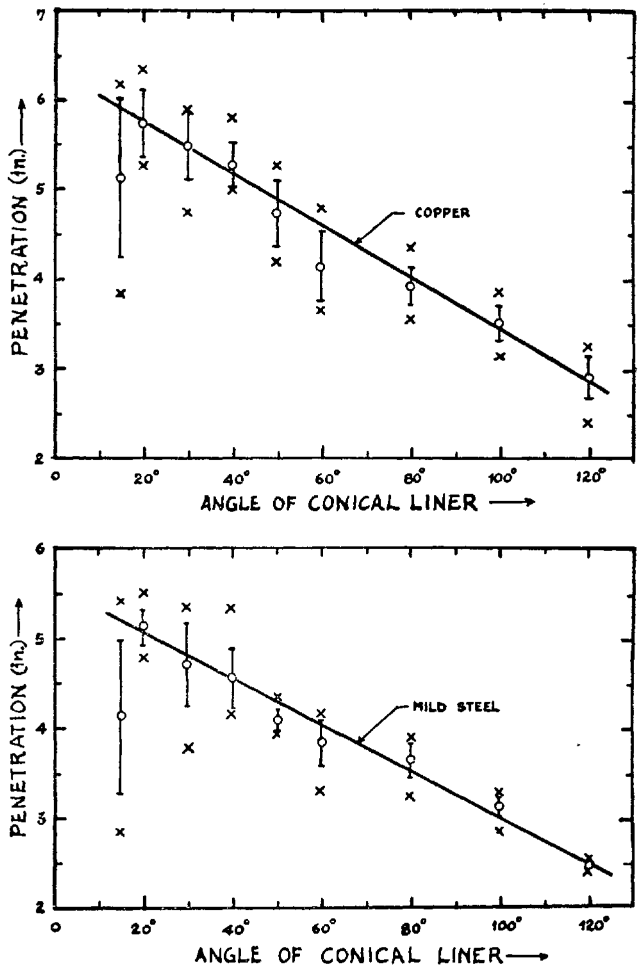

FIG. 4. Penetration versus angle of conical liner.

Ɨ indicates mean penetration with 95% confidence limits.

× indicates maximum and minimum penetration.

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Abstract

An investigation has been made of the damage to massive mild steel targets by explosive charges having (*a*) copper conical liners of different calibres and (*b*) copper and mild steel liners of different angles. The penetration and the calibre are linearly related. The penetration increases with the decrease of the angle of the copper and the mild steel liners. Copper liner gives more penetration and less entry diameter than that of mild steel liner.

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