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ON HEAT TRANSFER TO GUN BARREL IN SOME IMPORTANT GUNS

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ABSTRACT

In this communication the author has calculated the heat transfer to some important guns, on the basis of Thorn-hills' empirical formulae.

Precise methods have been developed by Hicks and Thornhill, and Hirschfelder and Nordheim for the investigation of heat transfer to barrels in guns whose internal ballistics has been precisely calculated. Thus calculations for heat transfer have been made for the following cases :—

(*i*) Two Pounder model.

(*ii*) 25-Pounder Gun.

(*iii*) 8″ Mark VIII Gun.

No calculations for other guns have been reported.

Thornhill[2] has fitted formulas, whose form has a rough theoretical backing to the heat transfer calculated for the above guns. The best thing to do, for calculations on heat transfer in other guns, whose internal ballistics is imperfectly known, is to use to these formulae.

Thus in this note, calculations for heat transfer to barrels have been made for the following guns (full charge)—

(*i*) Q.F. 3·7-IN. HOWITZER (ALL CHARGES)

(*ii*) B.L. 5·5-IN. GUN.

(*iii*) Q.F. 75-MM HOWITZER

(*iv*) Q.F. 6-PR. 7-CWT. GUN.

(*v*) Q.F. 17-PR. GUN.

(*vi*) Q.F. 3·7-IN. A.A. GUN.

Thornhill's Results :—

Let, d inches be the calibre,

C lbs. the charge,

T_o°K the temperature of uncooled explosion of the propellant,

U Cubic inches the total internal volume,

A square inches the bore area of the gun.

The maximum rise in temperature at the commencement of the rifling, θ°K (with an ambient temperature of 300°K) is given by—

$$\theta = \frac{T_o - 300}{1 \cdot 7 + \alpha} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\text{where } \alpha = 0 \cdot 38\, d^{\frac{1}{2}} \left(\frac{d^2}{c} \right)^{0.86} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The transfer at this point upto the shot ejection is H Cal/sq cm per round where

$$H = 1 \cdot 27 \times 10^{-2} \theta d^{\frac{1}{2}} \Omega \quad \ldots\ldots(3)$$

where $\Omega = 1 \cdot 25$ for heavy guns.

The total heat loss E cal, to the barrel upto the time of ejection is given by

$$E = \frac{U\pi}{2A} \times 6 \cdot 451 \text{ Hd} \quad \ldots\ldots(4)$$

The kinetic energy K (in calories) of the shot and charge at the muzzle is—

$$K = 5.03 \times 10^{-3} \left(W + \frac{C}{3}\right) V^2 \quad \ldots\ldots(5)$$

where V is the velocity in feet/sec.,
and W is the projectile weight in pounds.
He has defined a factor χ as—

$$\chi = \frac{E}{K} \quad \ldots\ldots(6)$$

Equations (3) and (4) may be put in a more convenient form

$$H = 1 \cdot 5875 \times 10^{-2} \times d^{\frac{1}{2}} \times \theta \quad \ldots\ldots(3A)$$

and $E = 12 \cdot 902 \frac{UH}{d}$ ......(4A)

Gun Data :—

The gun-data, given below and used in calculations has been taken from the range tables.

TABLE I.—*Gun Data*

S. No.	GUN	d	U	W	C lbs.	C oz.	C dms	V	To
1	Q.F. 3·7-IN. HOWR.	3·7	491·0	20(H.E.)	..	9	..	973	3220 (M.D.)
2	B.L. 5·5-IN. GUN	5·5	4078·0	82	9	2	..	1825	3220 (W.M.)
3	Q.F. 75-MM. HOWR.	2·95	640·0	14·7(HE)	..	15	8	1250	2510 (F.N.H.)
4	Q.F. 6-PR.7-CWT MK. 4. GUN.	2·244	489·5	6-4 oz-8 dms (A.P.)	2	5	6	2675	2680 (N.H.)
5	Q.F.17-PR GUN	3·0	1353·7	17(AP CPC).	8	2	..	2900	2680 (N.H.)
6	Q.F.3·7-IN A.A. GUN.	3·7	2515	28(H.E.)	7	1	8	2600	3220(W.N.)

Remarks

TABLE II

Heat Transfer to Gun Barrels

S. No.	GUN	θ	H	E	K	χ
1	Q.F. 3·7-IN. HOWR ..	223·3	6·821	$1{\cdot}168\times10^4$	$9{\cdot}614\times10^4$	·1187
2	B.L. 5·5-IN. GUN ..	695·5	25·90	$2{\cdot}478\times10^5$	$1{\cdot}425\times10^6$	·1739
3	Q.F. 75-MM. HOWR ..	382·2	10·42	$2{\cdot}918\times10^4$	$1{\cdot}18\times10^5$	·2472
4	Q.F. 6-PR. 7-CWT GUN ..	786·3	19·5	$5{\cdot}048\times10^4$	$2{\cdot}542\times10^5$	·1986
5	Q.F. 17-PR. GUN ..	986·0	27·07	$1{\cdot}576\times10^5$	$8{\cdot}339\times10^5$	·1891
6	Q.F. 3·7-IN. A.A. GUN ..	872·0	26·63	$2{\cdot}336\times10^5$	$1{\cdot}032\times10^6$	·2262

TABLE III

Heat transfer to Q.F. 3·7-in. Howr. for different charges

S. No.	C		O	H	E	K	χ
	ozs	dr					
I	2	15·5	93.46	2·854	$4{\cdot}888\times10^3$	$2{\cdot}625\times10^4$	·1862
II	3	10·5	110·6	3·379	$5{\cdot}786\times10^3$	$3{\cdot}410\times10^4$	·1697
III	5	0	141·9	4·335	$7{\cdot}423\times10^3$	$4{\cdot}868\times10^4$	·1524
IV	6	7·5	167·2	5·106	$8{\cdot}754\times10^3$	$6{\cdot}304\times10^4$	·1387
V	9	0	223·3	6·821	$1{\cdot}168\times10^4$	$9{\cdot}614\times10^4$	·1187

The results are illustrated graphically in Fig. 1.

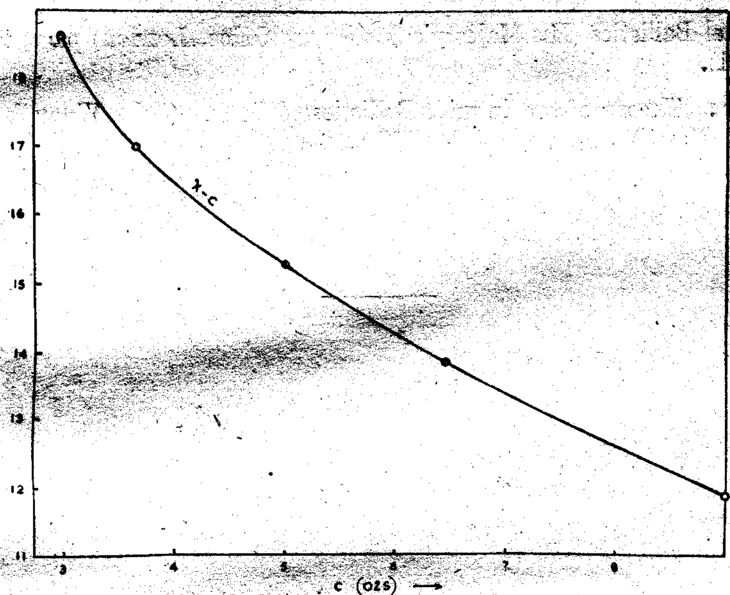

FIG. I. VARIATION OF χ WITH C

In Internal ballistics the specific heat of gases enters the equations as $(\gamma-1)$. Consideration of heat loss increases this to

$$(\bar{\gamma}-1)=(\gamma-1)\ (1+\chi) \quad \ldots\ldots(7)$$

TABLE IV

Values of γ

S. No.	GUN	CHARGE	PROPELLANT	χ	γ	$\bar{\gamma}$
1	Q.F. 3·7-IN. HOWR ..	I	M.D.	·1862	1·24	1·28
		II	M.D.	·1697	1·24	1·28
		III	M.D.	·1524	1·24	1·28
		IV	M.D.	·1387	1·24	1·27
		V	M.D.	·1187	1·24	1·27
2	B.L. 5·5-IN. GUN ..	FULL	W.M.	·1739	1·24	1·28
3	Q.F. 75-MM. HOWR. ..	FULL	F.N.H.	·2472	1·28	1·35
4	Q.F. 6-PR. 7 CWT GUN ..	FULL	N.H.	·1986	1·26	1·31
5	Q.F. 17-PR. GUN ..	FULL	N.H.	·1891	1·26	1·31
6	Q.F. 3·7-IN. A.A. GUN ..	FULL	W.M.	·2262	1·24	1·29

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