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MEMORANDUM REPORT No. 1108

OCTOBER 1957

Aerodynamic Properties Of A Caliber 0.50 Bullet With Reflex Boattail

MAYNARD J. PIDDINGTON

DEPARTMENT OF THE ARMY PROJECT No. 5B03-03-001
ORDNANCE RESEARCH AND DEVELOPMENT PROJECT No. TB3-0108

BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

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Department of the Army Project No. 5B03-03-001
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A B E R D E E N   P R O V I N G   G R O U N D,   M A R Y L A N D

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MJPiddington/mmv
Aberdeen Proving Ground, Md.
October 1957

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ABSTRACT

The aerodynamic characteristics of a caliber 0.50 bullet with reflex boattail and a modification of this design are presented and discussed.

INTRODUCTION

It is a commonly known fact that a projectile in supersonic flight experiences a considerable increase in drag relative to its subsonic value. In the past, many designs have been suggested and tested with the common hope that this supersonic drag could be reduced. It was with this idea that Mr. K. W. Horton of Watervliet Arsenal designed and tested* the bullet shown in Figure 1.

The projectile consists of a one-caliber long cylindrical section with symmetric nose and tail sections. The nose, or tail, section is formed of portions of two ogives. The forward part of the nose is concave and is formed from the arc of a circle tangent to the axis at the tip of the nose. A second convex ogive, of different radius and centered on the perpendicular bisector of the model, completes the surface. This curve is tangent to the forward and rear sections and secant to the cylindrical section, fore and aft.

Mr. Horton strongly felt that this design would greatly reduce the drag of standard ammunitions at supersonic velocities. The Ballistic Research Laboratories was asked by the Patent Section at the Springfield Arsenal for an evaluation of Mr. Horton's claims.

Since the specifications of radii in Figure 1 did not give a smooth junction of the two circles, the radius of the larger circle was slightly altered for a proper tangency condition.

Models of the Horton projectile were manufactured according to Figure 2A and fired through the Aerodynamics Range from a 0.50 caliber 1/30 twist gun. The main objective of these firings was to determine whether or not the drag of the Horton projectile was substantially lower than the drag of standard small arms ammunition.

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* The tests were of an indirect nature and did not involve measurement of the drag or retardation. Basically, inferences were drawn from differences in drop of the new and the old bullets as measured at various ranges, at best, a very delicate procedure.

The results of these firings will be more fully discussed later in this paper, but in essence, they reveal that the drag of the Horton projectile is considerably higher than the drag of the more conventional projectiles fired at supersonic velocities (Fig. 6).

An examination of the photographic plates, however, did reveal interesting after-body flow characteristics, i.e., very small wake diameter, (Fig. 3) which warranted further investigation. As a result, a new projectile (Fig. 2B) was manufactured converting the nose to the proper secant ogive with a rounded tip to insure a minimum head drag for the Horton's head length*. The tail section remained the same except for the removal of about 3/8 inch from the end since the flow separated at this point. For purposes of this paper this model will be referred to as "Modified Horton". Some physical properties for both shell are tabulated in Table I.

The purpose of this program was twofold: first, to study the drag as compared to that of the more conventional shapes: and secondly, to observe the effects on the remaining aerodynamic coefficients due to the reflex boat-tailing. A spark photograph of one of these rounds is shown in Figure 4.

Since the Horton rounds, being a part of a pure drag study, were fired at essentially zero yaw, it was desirable to produce yaw on about half of the Modified Hortons so that yaw properties could be studied. Yaw was induced by attaching a half barrel 1/2 inch long to the end of the gun tube. Then as the shell emerged from the gun, the pressure differential about the round would cause the model to yaw initially. This method performed successfully giving from 2 to 5 degrees of yaw. The results of both programs are given in the remaining section of this report.

---

* The head length of the Modified Horton is too short in comparison with some modern bullets. This, of course, is principally responsible for its high drag.

RESULTS

Drag

The drag force coefficient, K_D, was obtained from both programs by fitting a cubic equation to the time-distance data for each round. K_D was reduced to zero yaw by the relationship:

$$K_D = K_{D_0} + K_{D_{\delta^2}} \overline{\delta^2}$$

where

K_{D_0} = zero yaw drag coefficient

$K_{D_{\delta^2}}$ = yaw drag coefficient

$\overline{\delta^2}$ = mean squared yaw.

A yaw drag coefficient, $K_{D_{\delta^2}}$ = 1.0 per radian squared, obtained at M = 2.4 was used for all the rounds tested.

Figure 5 compares the drag coefficients of the original and modified Horton projectiles. Higher drag of the original arises largely as a result of its peculiar head shape. In figure 6 these drag curves are further compared, primarily, with the drag curves of other small caliber, body-engraved projectiles.[1] The drag of the Horton projectile is higher than any of the other configurations even the square-based, short-ogive, cal. 0.60 T32. The drag of the modified Horton is less than that of the Horton projectile and the T32 but still greater than that of the boattailed, long-ogive, cal. 0.50 M8. Most of the drag difference between the M8 and the modified Horton is probably accounted for by the short head length of the modified Horton.[2]

Yaw

Standard yaw reductions[3] were performed by fitting an epicycle curve to the yawing histories for those rounds for which there was sufficient yaw to produce reliable aerodynamic coefficients. This procedure was limited mainly to the Modified Horton but included two of the Horton rounds. A summary of these various coefficients are given in Table 2.

The overturning moment and the lift coefficients are given in Figure 7, along with the center of pressure from the nose.

The yaw damping moment, $K_H - K_{MA}$, and Magnus torque, K_T, coefficients are given in Figure 8. The Magnus torque is rather unusual, by becoming large positive so early in the supersonic regime. The transition from negative to positive values, for boattailed projectiles, usually occurs at transonic speeds. However, such early change of sign of K_T may be due to an exceptionally steep boattail angle of the order of 17° not usually encountered in more conventional designs. Such behavior of the Magnus torque is reflected in the yaw damping rates shown in Figure 9. Large positive Magnus torque adversely affects the damping of the precessional mode. Large negative Magnus torque of the original Horton design adversely affects its nutational mode. Both of these effects are shown by the yaw damping rates in Figure 9. Such dynamic instability is usually of a character which cannot be eliminated by a resort to higher axial spins or steeper twist of rifling. Both projectiles gyroscopically are amply stable in a twist of 1:30.

CONCLUSIONS

The proposed design is unsatisfactory. It has considerably higher drag than more conventional small arms bullets. Also, at certain velocities, it appears to be dynamically unstable at small yaws. The modified design suffers, essentially, from the same ills. Although its head drag is considerably lower than that of the original design, its drag is still considerably higher than that of longer bullets in current use. It also suffers from the same type of dynamic instability probably in virtue of its relatively steep and long boattail.

Maynard J. Piddington
MAYNARD J. PIDDINGTON

REFERENCES

1. Hitchcock, H. P. Aerodynamic Data for Spinning Projectiles, BRL Report 620 (1947).
2. Dickinson, Elizabeth R. Design Data for a Series of HE Projectile-Shapes at Mach Number 3.0 BRLM 920 (1955).
3. Murphy, C. H. Data Reduction for the Free Flight Spark Ranges, BRL Report 900 (1954).

TABLES AND FIGURES

TABLE I

Average Physical Constants

	Weight Grams	Center of Gravity Calibers from Nose	Moments of Inertia Axial gm-in^2	Transverse gm-in^2
Horton	31.182	2.276	.825	4.594
Modified Horton	33.805	1.692	.893	5.798

TABLE II

Summary of Various Aerodynamic Coefficients

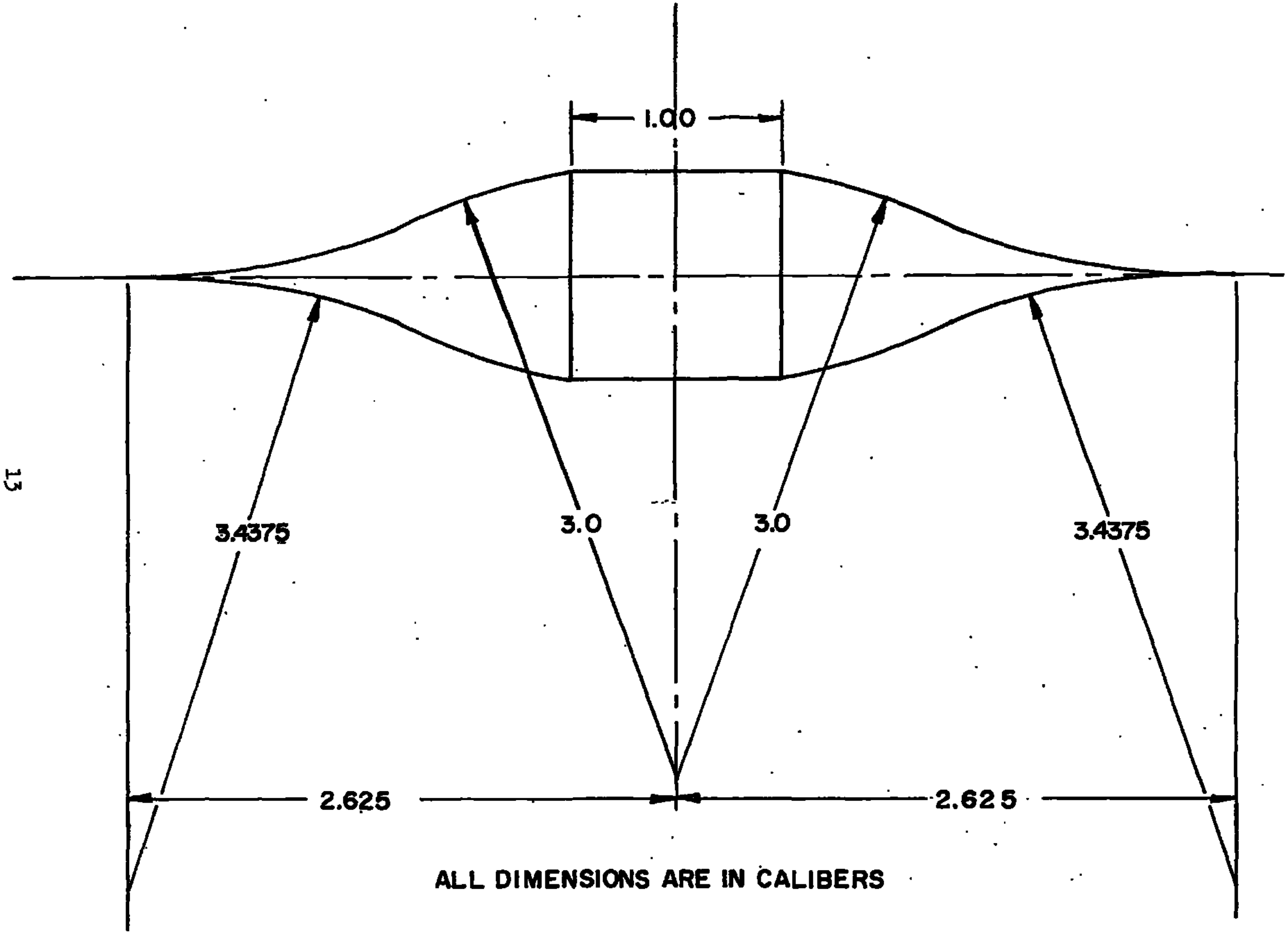
Modified Horton

Round	M	K_D	$\overline{\delta^2}$	K_M	$\lambda_1 x10^3$ per foot	$\lambda_2 x10^3$ per foot	K_H-K_{MA}	K_T	K_L	K_N	CP_N (cal from nose)
4596	1.400	.202	8.44	.836	5.60	-3.82	.12	.24	.74	.94	1.16
4595	1.923	.160	1.30	.819	4.76	.34	1.26	.04	.81	.97	1.21
4594	2.130	.155	.36								
4599	2.285	.151	25.47	.748	2.66	2.23	1.15	-.03	.88	1.03	1.32
4601	2.408	.142	12.58	.752	2.13	2.55	1.10	-.05	.89	1.03	1.32
4589	2.470	.134	1.21	.767							
4602	2.538	.134	8.20	.732	2.02	2.41	1.03	-.04	.86	.99	1.31
4600	2.549	.140	21.49	.729	2.40	2.48	1.16	-.04	.90	1.04	1.35
4597	2.968	.119	1.03								
4590	3.150	.113	4.66	.700	2.89	1.37	.97	.01	.87	.98	1.34

Horton

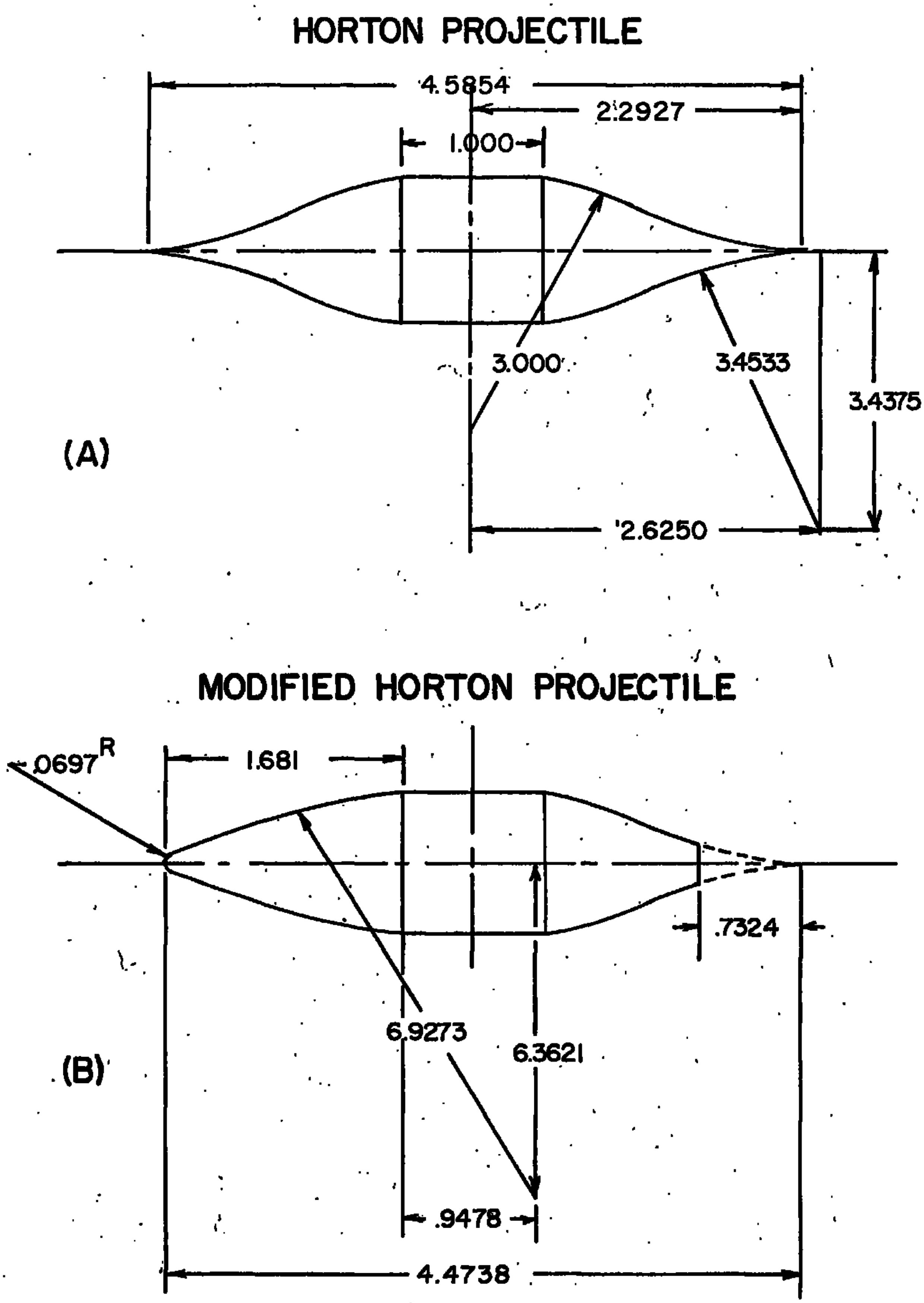
Round	M	K_D	$\overline{\delta^2}$	K_M	$\lambda_1 x10^3$ per foot	$\lambda_2 x10^3$ per foot	K_H-K_{MA}	K_T	K_L	K_N	CP_N (cal from nose)
4390	1.574	.227	.30								
4389	1.908	.202	.15								
4388	2.080	.192	.80								
4387	2.145	.188	2.30								
4379	2.436	.173	.30								
4381	2.574	.167	.20								
4384	3.006	.146	2.46	.72	-1.36	5.44	.77	-.18	.76	.91	
4383	3.214	.133	.70								
4382	3.312	.152	15.48	.650	-.31	4.42	.68	-.12	.88	1.03	

HORTON DESIGN



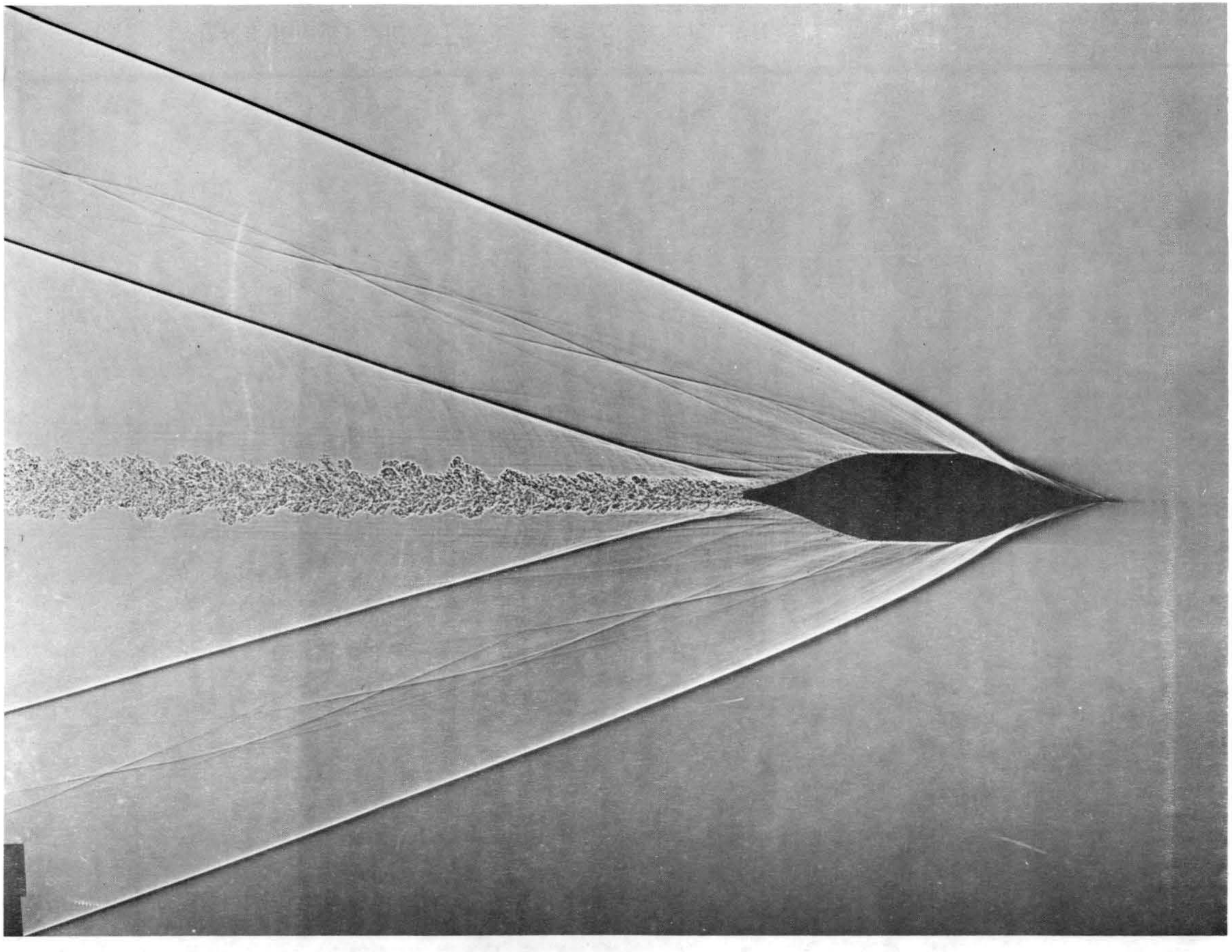
ALL DIMENSIONS ARE IN CALIBERS

FIG. I



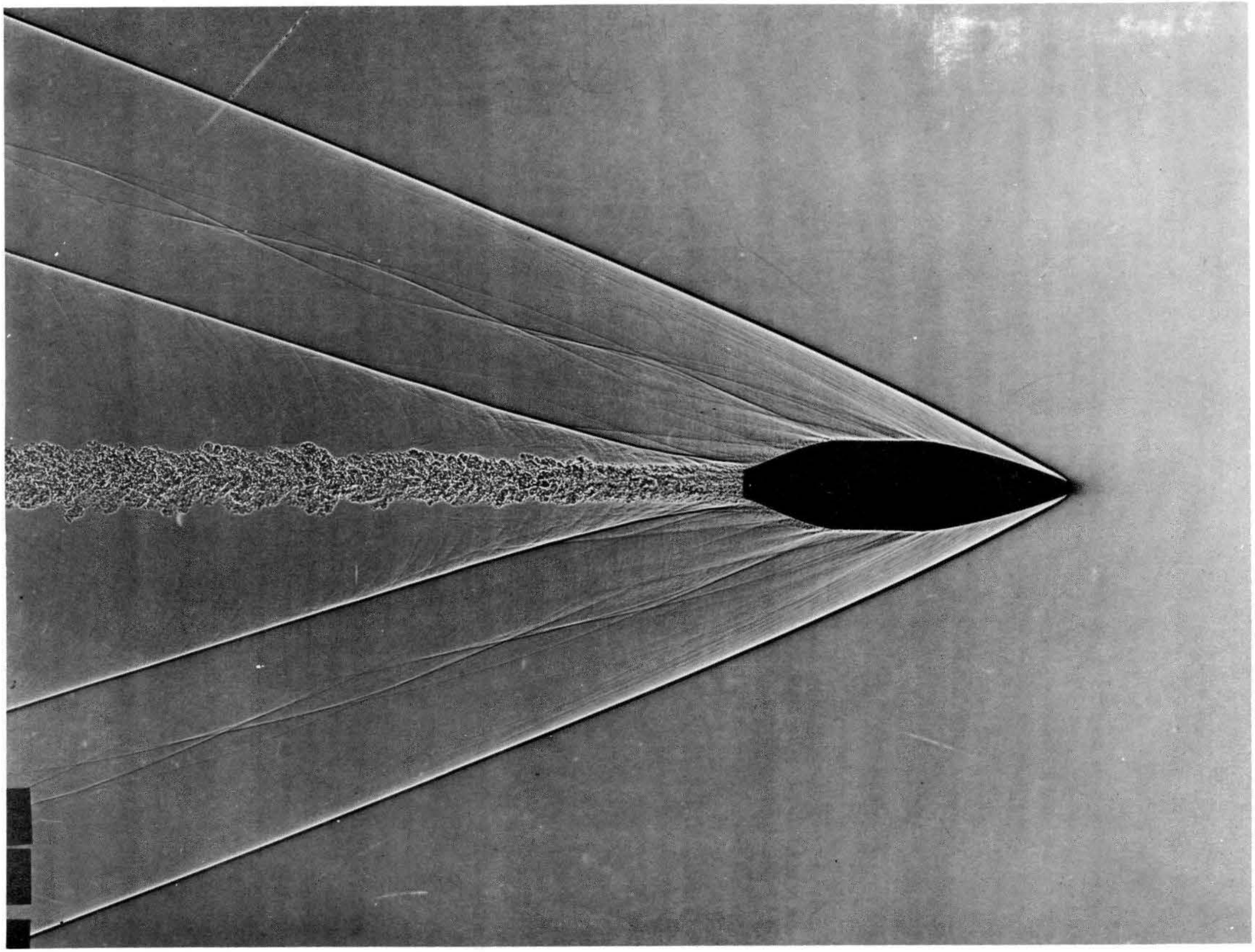
NOTE: All Dimensions are in Calibers

FIG. 2



HORTON $M = 3.0$ $K_D = .146$

FIG. 3



MODIFIED HORTON $M = 3.0$ $K_D = .119$

FIG. 4

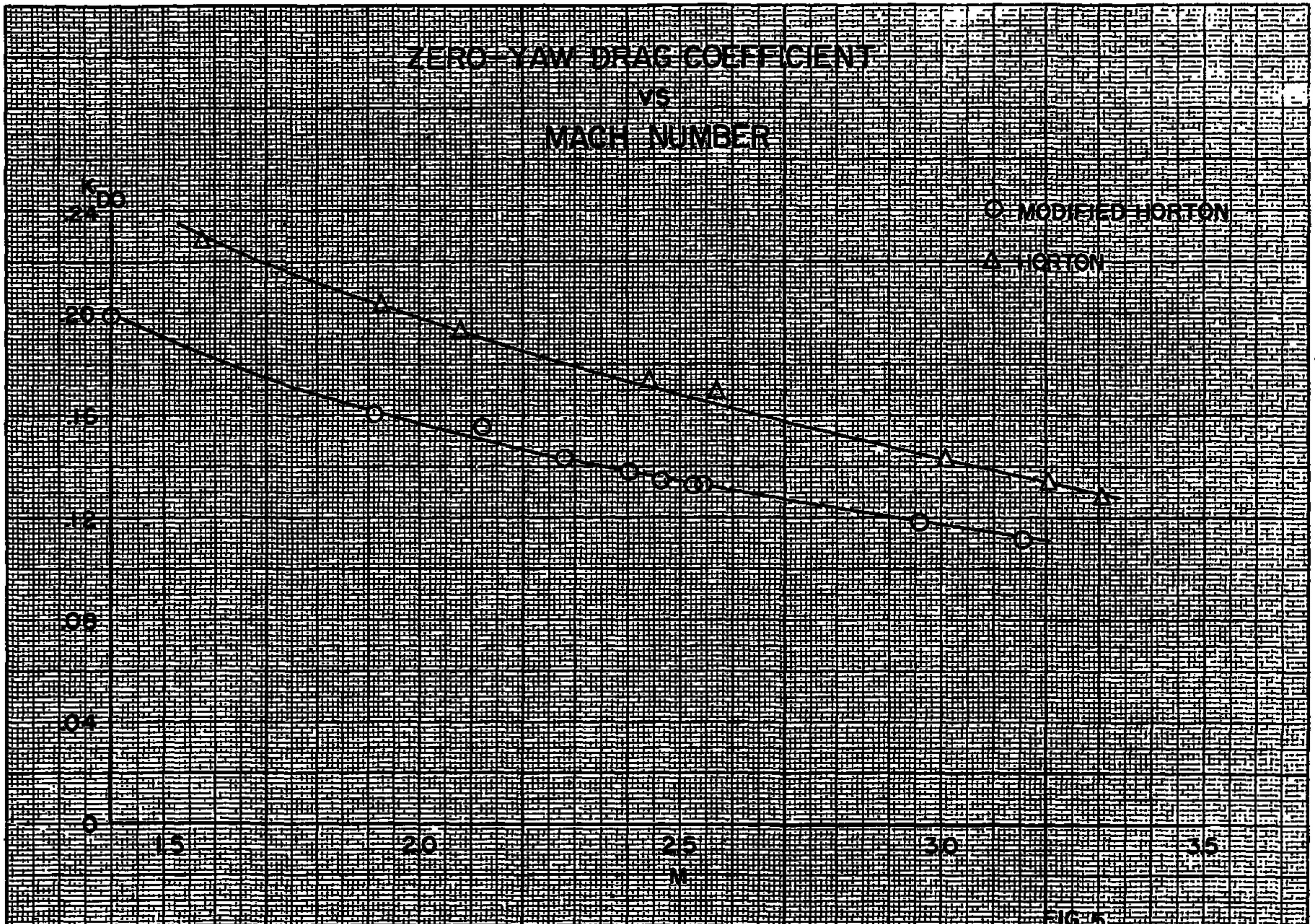
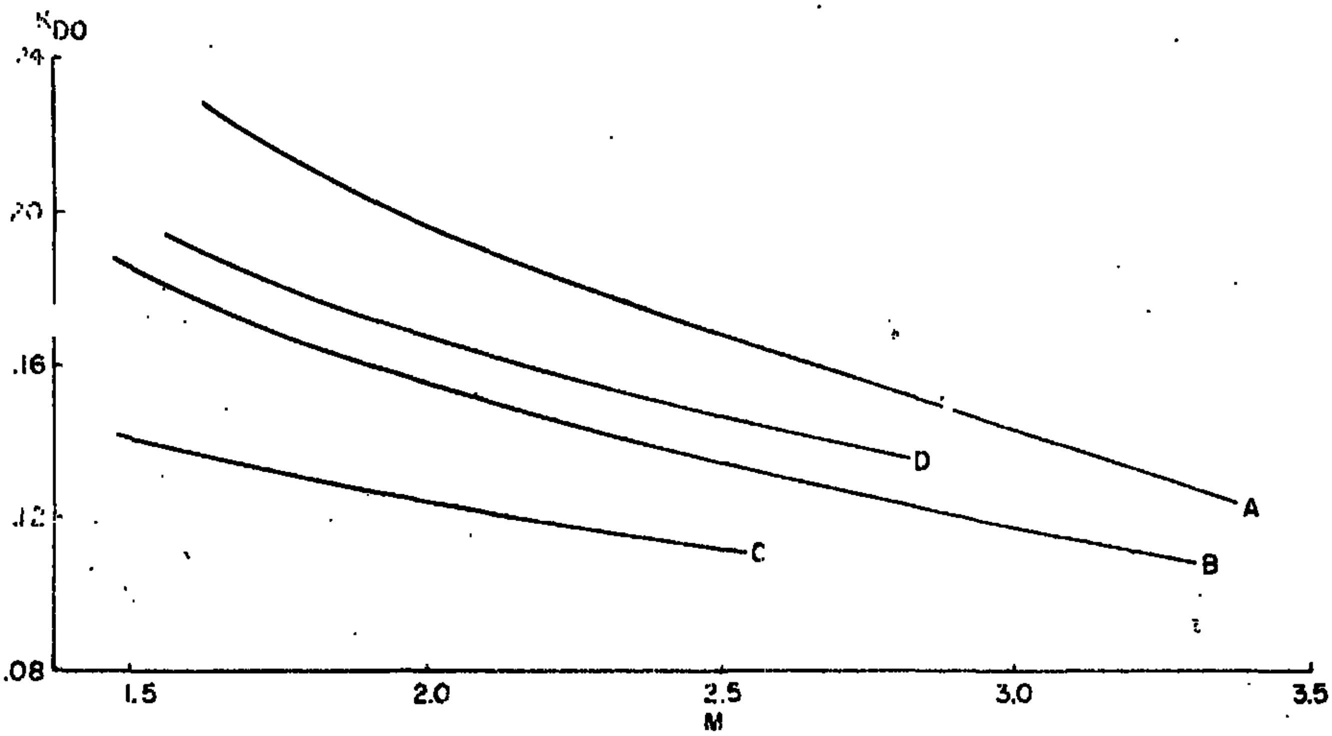

ZERO-YAW DRAG COEFFICIENT
VS
MACH NUMBER
K_{DO}
.24
.20
.16
.12
.08
.04
0
1.5
2.0
2.5
3.0
3.5
M
MODIFIED HORTON
HORTON

FIG 5

DRAG COMPARISON OF VARIOUS SMALL ARMS BULLETS VS MACH NUMBER



	LENGTH*			
TYPE	OVERALL	NOSE	BOAT-TAIL	CURVE
HORTON	4.585	1.793	1.793	A
MODIFIED HORTON	3.741	1.681	1.08	B
BULLET, API CAL. 0.50, M8	4.58	2.72	.772	C
BULLET, BALL CAL. 0.60, T32	4.55	1.64		D

* ALL DIMENSIONS ARE IN CALIBERS

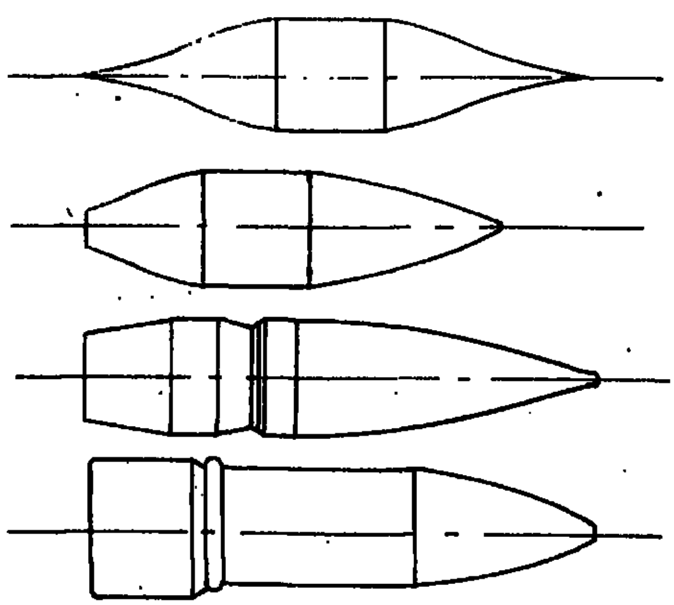


FIG. 6

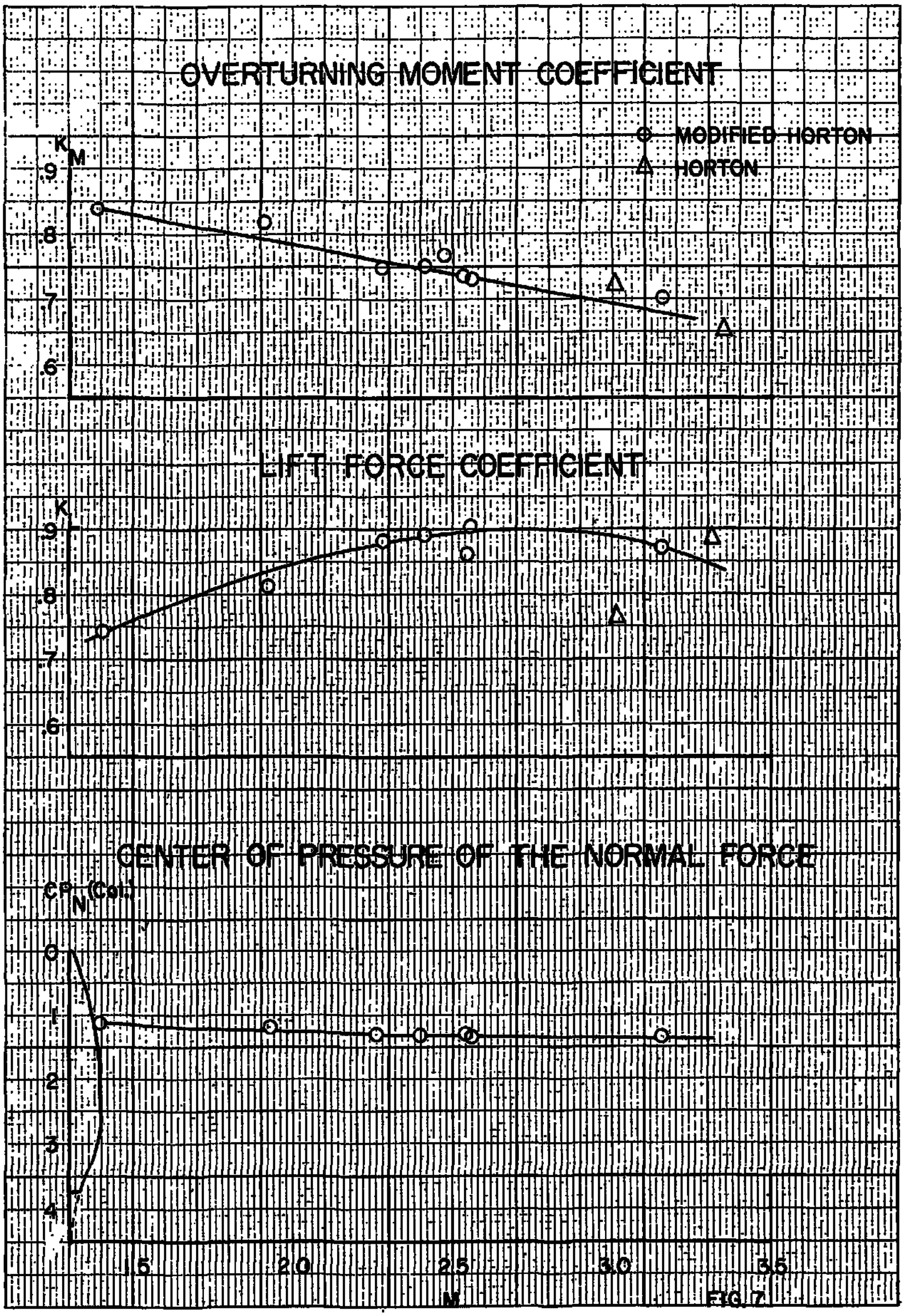
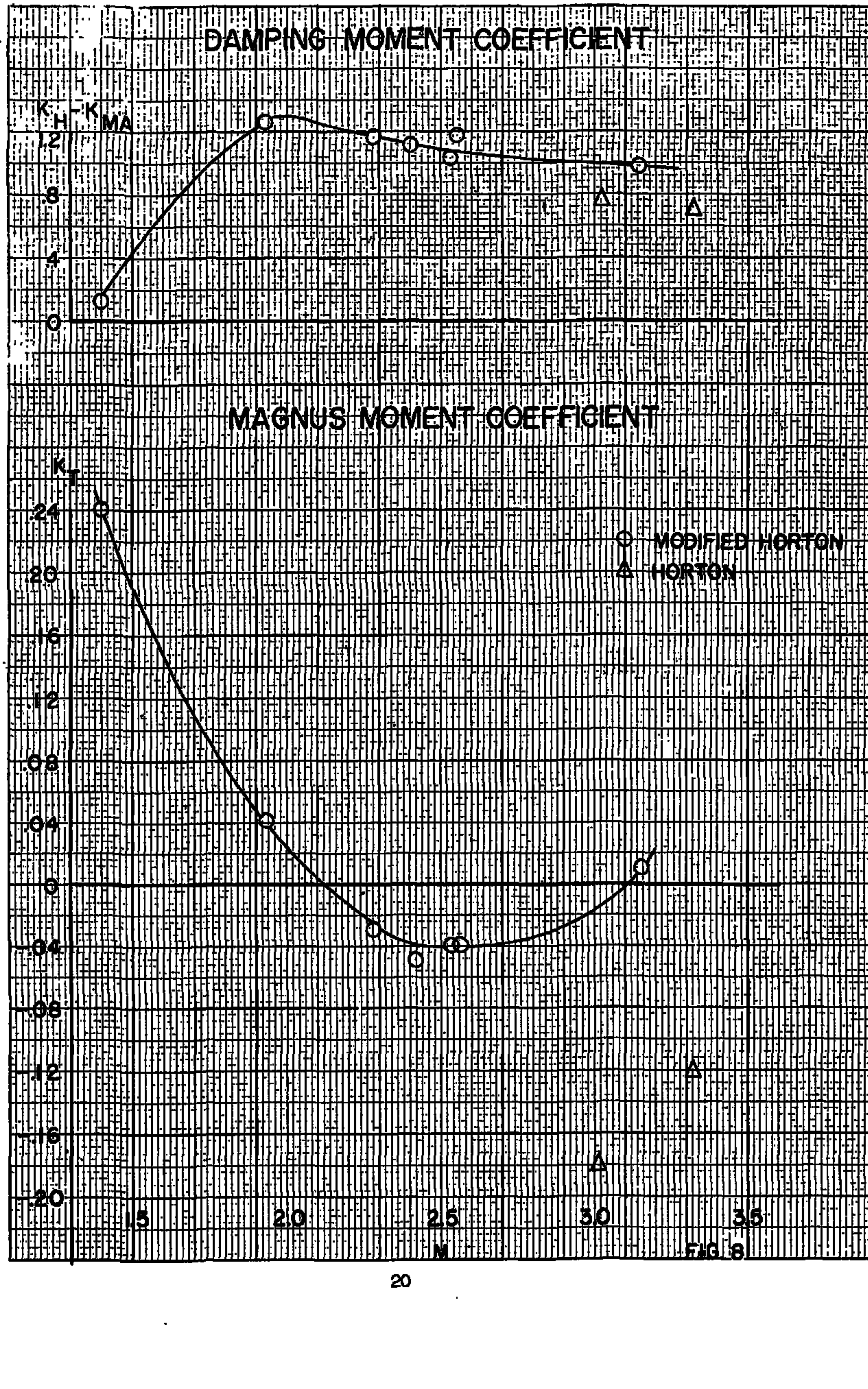
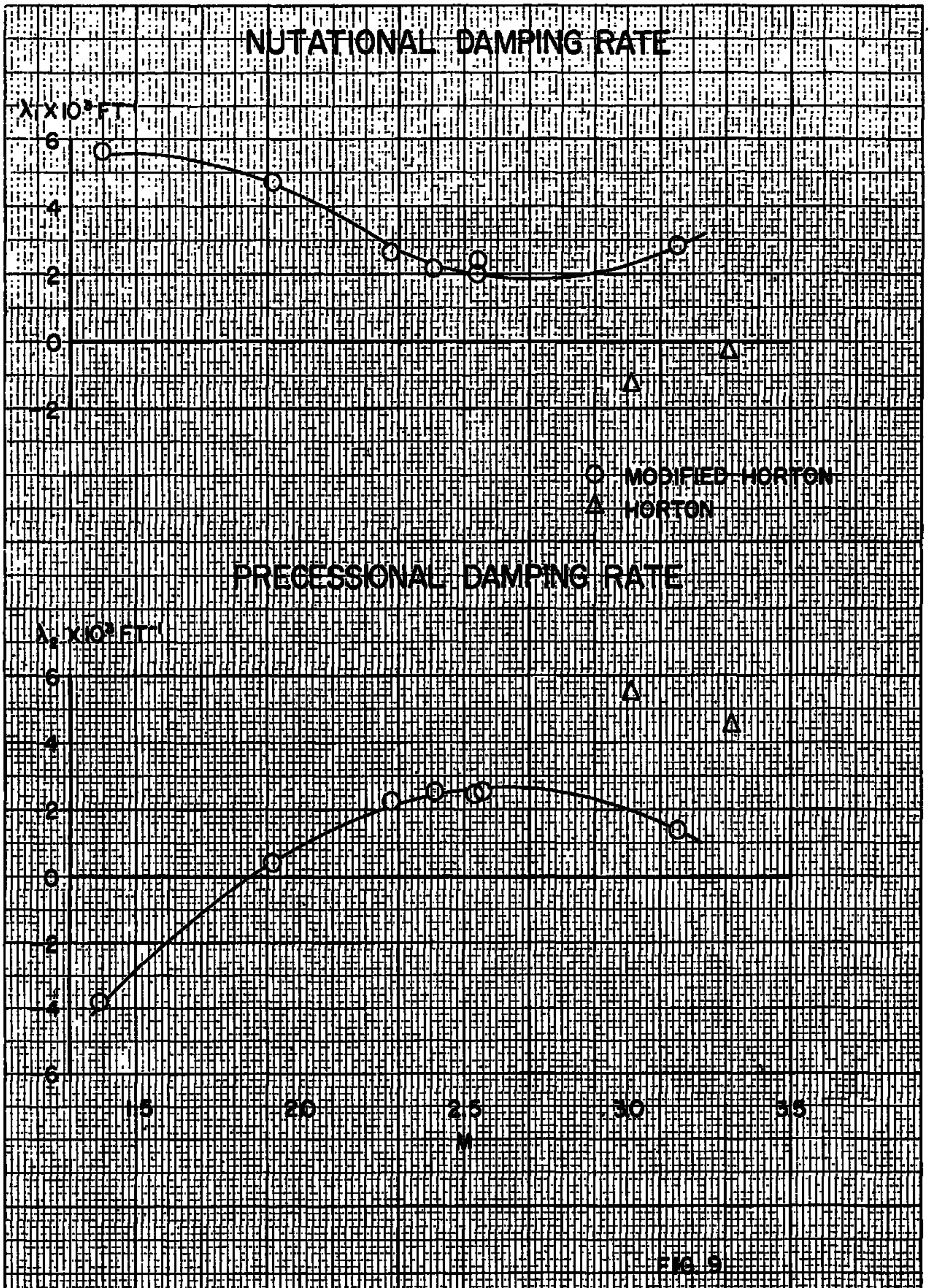

OVERTURNING MOMENT COEFFICIENT
MODIFIED HORTON
HORTON
K_M
.9
.8
.7
.6
LIFT FORCE COEFFICIENT
K_L
.9
.8
.7
.6
CENTER OF PRESSURE OF THE NORMAL FORCE
CP_N (Cal.)
0
1
2
3
4
1.5
2.0
2.5
3.0
3.5
M

FIG. 7



DAMPING MOMENT COEFFICIENT
$K_H - K_{MA}$
1.2
.8
.4
0
MAGNUS MOMENT COEFFICIENT
K_T
.24
.20
.16
.12
.08
.04
0
-.04
-.08
-.12
-.16
-.20
MODIFIED HORTON
HORTON
1.5
2.0
2.5
3.0
3.5
M

FIG. 8



NUTATIONAL DAMPING RATE
$\lambda_1 \times 10^3$ FT^{-1}
6
4
2
0
-2
MODIFIED HORTON
HORTON
PRECESSIONAL DAMPING RATE
$\lambda_2 \times 10^3$ FT^{-1}
6
4
2
0
-2
-4
-6
1.5
2.0
2.5
3.0
3.5
M

FIG. 9

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Caliber 0.50 Bullet

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