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APRIL 1958

SOME AERODYNAMIC PROPERTIES OF THREE 105MM SHELL, M1, T377 AND T107

EUGENE D. BOYER

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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EDBoyer/sc
Aberdeen Proving Ground, Md.
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ABSTRACT

The drag and some yaw properties of three 105-mm shell, M1, T377, and T107 shell are presented. These data were obtained from Transonic Range firings.

TABLE OF SYMBOLS

A	Axial moment of inertia
B	Transverse moment of inertia
d	Diameter
m	Mass
K_D	Drag coefficient
K_M	Overturning moment coefficient
K_L	Lift force coefficient
K_H-K_{MA}	Damping moment coefficient
K_T	Magnus moment coefficient
$\overline{\delta^2}$	Mean squared yaw
$K_{D_{\delta^2}}$	Yaw drag coefficient
$\lambda_{1,2}$	Yaw damping rates
s	Gyroscopic stability factor
$\bar{s}$	Dynamic stability factor
N	Number of yaw observations
N_T	Number of time observations
ϵy	Error in yaw fit
ϵ_s	Error in swerve fit
$K_{1,2}$	Size of yaw arms at mid range
$\phi'_{1,3}$	Turning rates of yaw arms
K_F	Magnus force coefficient

INTRODUCTION

There are some special 105-mm shell under current development that are to match the ballistics of the standard 105-mm shell M1. The 105-mm shell T107 and T377 are in this category. The T107 is not exactly similar to the M1 in external shape and early tests indicated that a drag match was improbable. The T377 is, in effect, a second attempt and has essentially the same contour as the M1 shell. Firings were made in the BRL Transonic Range[1], with shell furnished by Picatinny Arsenal, to test the drag match and other aerodynamic properties.

The shell were launched from a 105-mm Howitzer tube (1-20 twist) mounted on an M7 motor carriage. The T107 shell were tested over a range of Mach numbers, 0.65 to 1.28, and the T377 at M = 1.35. Some M1 shell were also fired to verify the drag coefficient given in Reference 2, and to extend the curve to M = 1.35. The physical properties of the different shell are given in Figure 1.

Drag Coefficient

The drag force coefficient, K_D, was obtained by fitting a cubic equation to the time - distance data for each round. These data (Tables 1, 2 and 3) were then reduced to zero-yaw by the relationship $K_D = K_{D_o} + K_{D_{\delta^2}} \overline{\delta^2}$. The yaw-drag coefficient, $K_{D_{\delta^2}}$, for the T377 and the M1, at M = 1.35, are given in Figure 2. $K_{D_{\delta^2}} = 7.12 \pm 1.3$ (square radians)$^{-1}$ for the T377, and 3.2 ± 0.8 for the M1. The difference in $K_{D_{\delta^2}}$ is attributed to slight differences in shell contours. A comparison of the shadowgraphs (Fig. 3 and 4) shows extra shocks on the bourrelet and at the base plug, for the T377 shell. The bourrelet difference may be due to a lot-to-lot variation in shell. Generally these shell would be expected to fly at yaws of less than one degree and if this is the case, the noted difference in $K_{D_{\delta^2}}$ would not markedly affect the drag property of the T377 shell relative to the M1.

The scarcity of data at any one Mach number prevented the determination of $K_{D_{\delta^2}}$ for the T107. In order to obtain K_{D_o} for the T107, values for $K_{D_{\delta^2}}$ of the M1 shell[2] were assumed; $K_{D_{\delta^2}} = 2.4$ for subsonic speeds, $K_{D_{\delta^2}} = 4.7$ for supersonic speeds. A shadowgraph of the T107 is given in Figure 5.

From the drag curve, (Figure 6) it is seen that the T377 and M1 agree at the velocity tested. The curve for the T107 is somewhat higher than that of the M1 and also has a different slope in the supersonic region.

STABILITY PROPERTIES OF THE T377 SHELL VERSUS THE M1 SHELL

While the basic purpose of the program was to establish the existence of a ballistic match with respect to drag, the other aerodynamic properties of the shell are also somewhat important. If the stability, damping, or sensitivity to initial conditions were to be much different, the average flight yawing pattern might be different enough to create a mismatch through yaw induced drag. The c.g. of the T377 shell is 0.09 calibers further from the base than the c.g. of the M1 shell. The test results (Tables 1 and 2) indicate that the lift force, K_L, is in agreement. By correcting K_M and K_T to the c.g. position of the M1[3], we see that they are in agreement. However, there is a difference in the damping moment coefficient, $K_H - K_{MA}$, for the two shell. The T377 shell have the greater damping ($K_H - K_{MA} = 4.4$) while $K_H - K_{MA} = 2.7$ for the M1. This might be due to the presence of the base plate on the T377. This, of course, will be reflected in a change in the physical damping of the shell in flight; but if the shell is launched at small yaws, it should not be a large enough effect to alter the ballistic match.

CONCLUSION

The T377 shell can be considered to be a ballistic match of the M1 shell with respect to drag properties. Minor difference in the damping properties probably will not effect the match in practice.

The T107 shell is not a ballistic match with the M1 shell.

Eugene D. Boyer

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REFERENCES

1. Rogers, W. D. The Transonic Free Flight Range, BRL Report 1044 (1958).

2. Roecker, E. T. The Aerodynamic Properties of the 105-mm HE Shell, M1, In Subsonic and Transonic Flight, BRLM Report 929 (1955).

3. Murphy, C. H. & Schmidt, L. E. The Effect of Length on the Aerodynamic Characteristics of Bodies of Revolution in Supersonic Flight, BRL Report 876 (1953) CONFIDENTIAL.

TABLE 1-A

AERODYNAMIC COEFFICIENTS
M1 - LOT NPK -30-20-1956
WITH DUMMY FUZE M73

RD	M	K_D	$\sqrt{\overline{\delta^2}}$ (DEG.)	K_M	K_L	$K_H - K_{MA}$	K_T	K_F	s	$\bar{s}$
4864	.675	.0475	.88							
4865	.685	.0481	1.20							
4863	1.046	.1610	.62							
4862	1.056	.1636	.93							
4860	1.105	.1669	1.37							
4861	1.115	.1624	.75							
4867	1.207	.1619	1.40							
4866	1.210	.1608	.95							
4868	1.281	.1555	1.54							
4869	1.288	.1563	.53							
4730	1.353	.1517	.45							
4739	1.355	.1547	1.81	1.51	.74	2.45	-.03	.42	2.7	.79
4740	1.355	.1536	1.60	1.54	.74	3.00	.01	.48	2.7	.47
4735	1.356	.1513	1.05							
4744	1.359	.1507	.50	1.51						

TABLE 1-B

REDUCTION AND MOTION PARAMETERS

RD	ϵy (RAD)	ϵ_s (FT)	K_1 (RAD)	K_2 (RAD)	ϕ_1' (DEG/FT)	ϕ_2' (DEG/FT)	$\lambda_1 x10^3$ $(FT)^{-1}$	$\lambda_2 x10^3$ $(FT)^{-1}$	N	N_T
4864										12
4865										12
4863										12
4862										12
4860										14
4861										12
4867										12
4866										14
4868										10
4869										12
4730										9
4739	.002	.008	.020	.024	4.90	.56	.43	.25	20	12
4740	.002	.006	.017	.022	4.92	.57	.64	.14	24	11
4735										13
4744										14

TABLE 2-A

AERODYNAMIC COEFFICIENTS
T377 - LOT S134
WITH DUMMY FUZE M73

RD	M	K_D	$\sqrt{\overline{\delta^2}}$ (DEG.)	K_M	K_L	$K_H - K_{MA}$	K_T	K_F	s	$\bar{s}$
4742	1.340	.1606	1.99	1.46	.74	4.31	-.04	.34	2.8	.52
4741	1.345	.1554	1.29	1.45	.71	4.85	-.06	.32	2.8	.53
4736	1.350	.1520	.84							
4731	1.352	.1548	.80							
4732	1.354	.1529	.77							

TABLE 2-B

REDUCTION AND MOTION PARAMETERS

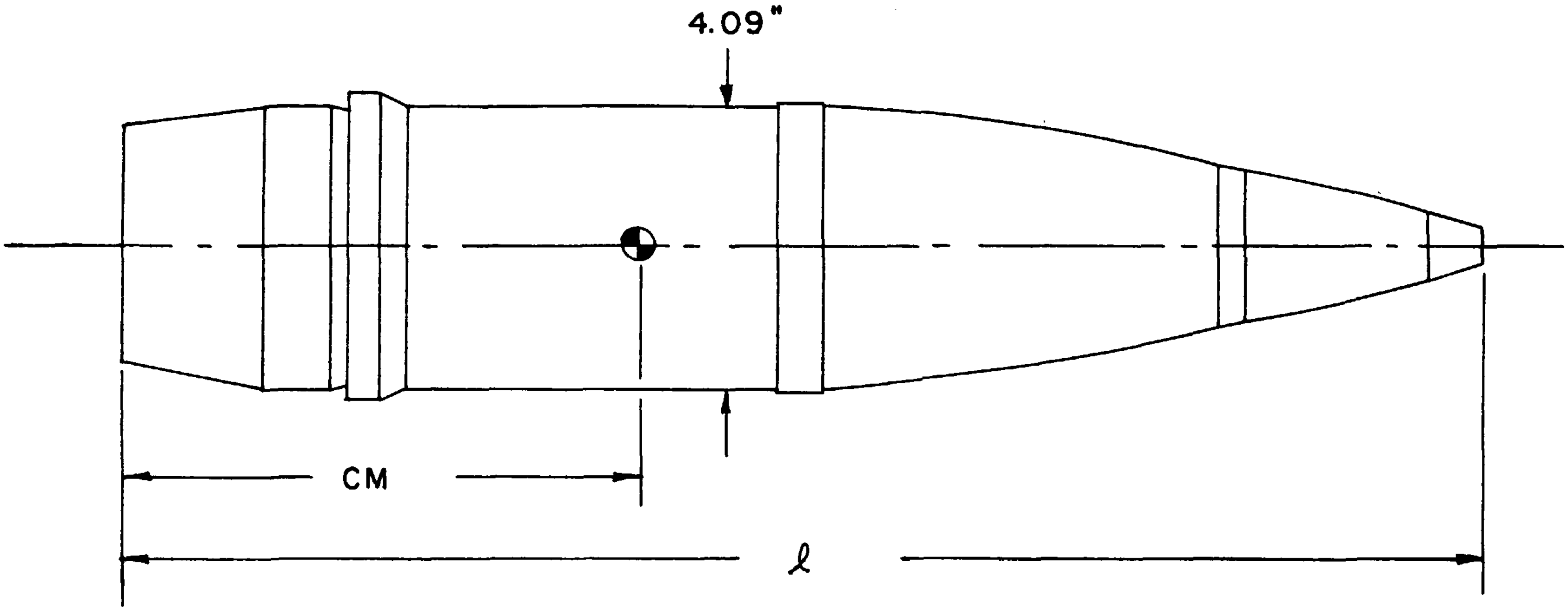
RD	ϵ_y (RAD)	ϵ_s (FEET)	K_1 (RAD)	K_2 (RAD)	ϕ_1' (DEG/FT)	ϕ_2' (DEG/FT)	$\lambda_1 x10^3$ $(FT)^{-1}$	$\lambda_2 x10^3$ $(FT)^{-1}$	N	N_T
4742	.002	.007	.020	.028	5.06	.57	.87	.22	22	12
4741	.002	.010	.012	.019	5.04	.57	.94	.25	22	12
4736										13
4731										9
4732										10

TABLE 3

DRAG DATA
T107 LOT LANSCO 4-57
WITH DUMMY FUZE M73

RD	M	K_D	$\sqrt{\overline{\delta^2}}$ (DEG.)	N_T
4692	.662	.0562	1.0	8
4690	.869	.0579	1.3	10
4688	.976	.1027	1.4	11
4689	1.024	.1611	1.3	9
4683	1.051	.1656	1.2	10
4684	1.090	.1749	1.1	8
4685	1.100	.1726	.8	8
4682	1.202	.1665	.8	10
4686	1.277	.1609	.5	8
4687	1.277	.1585	.5	7

PHYSICAL PROPERTIES–105mm SHELL



		M1	T377	T107
WT.	lbs.	32.12	32.12	30.05
A	lbs. IN^2	78.75	74.58	73.33
B	lbs. IN^2	770.8	710.9	756.9
CM	IN	7.16	7.53	7.54
ℓ	IN	19.36	19.40	19.67

FIG. 1

DRAG COEFFICIENT
VS
MEAN SQUARED YAW
M= 1.35

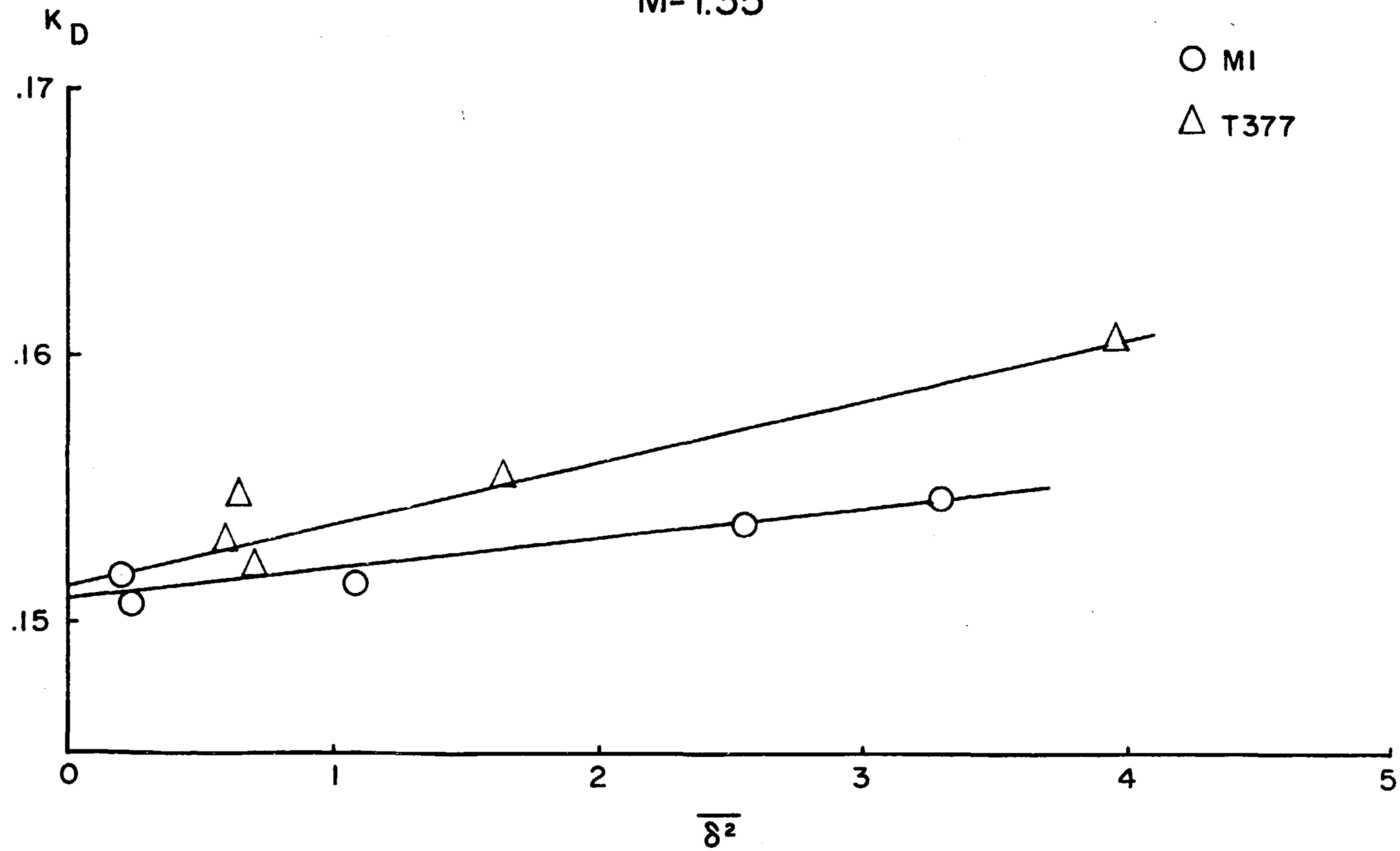


FIG. 2

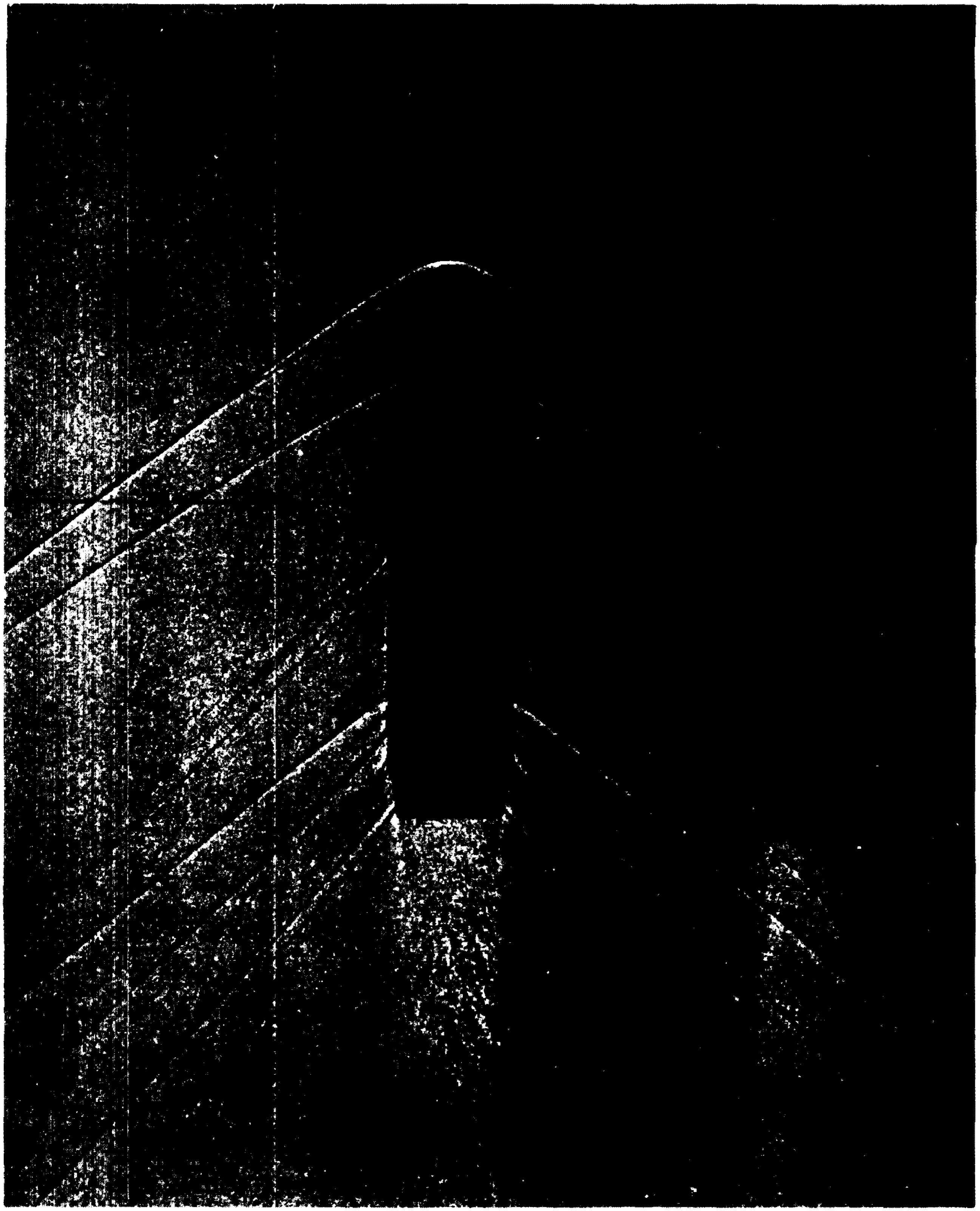


FIGURE 3

T377

M = 1.35

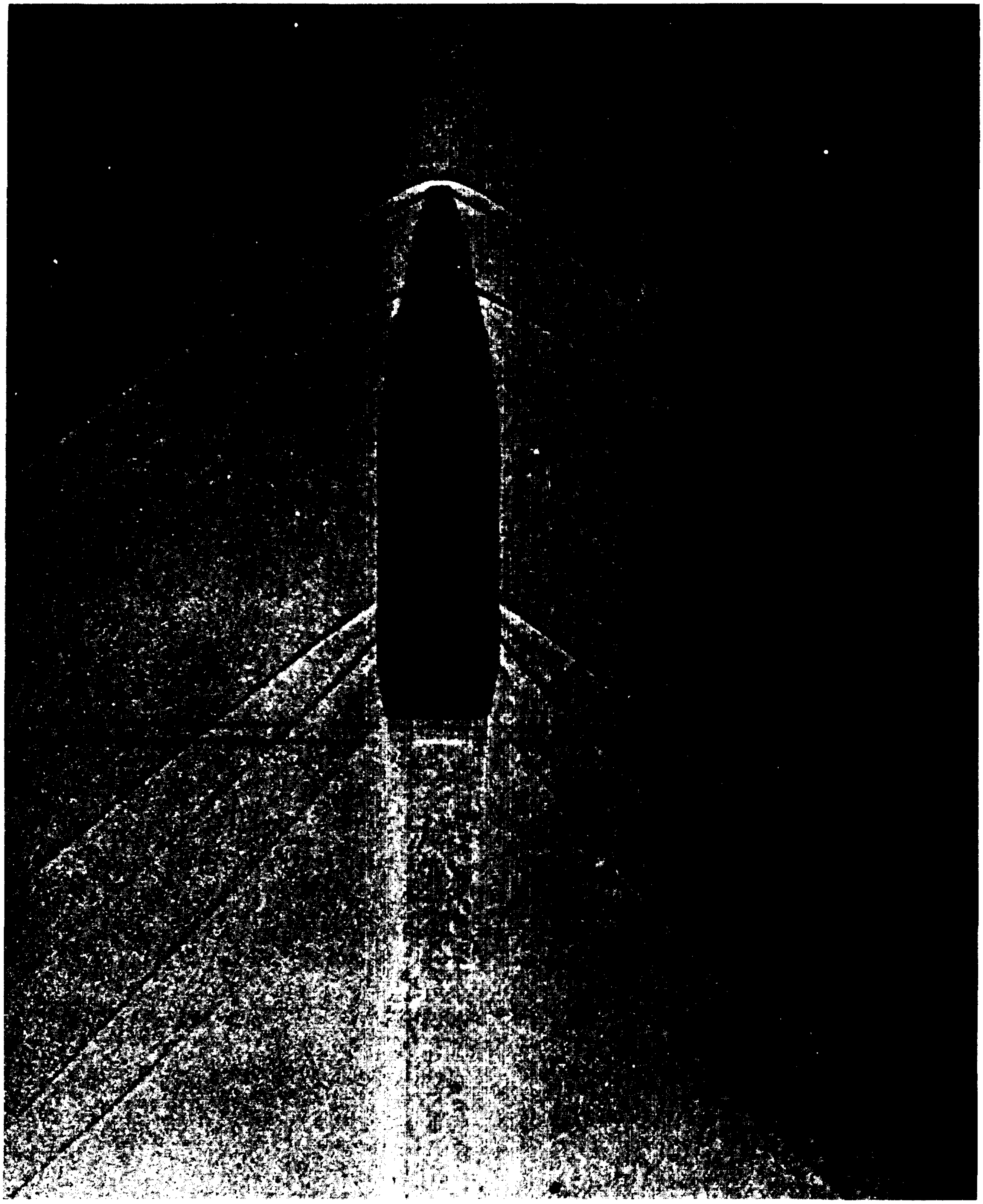


FIGURE 4

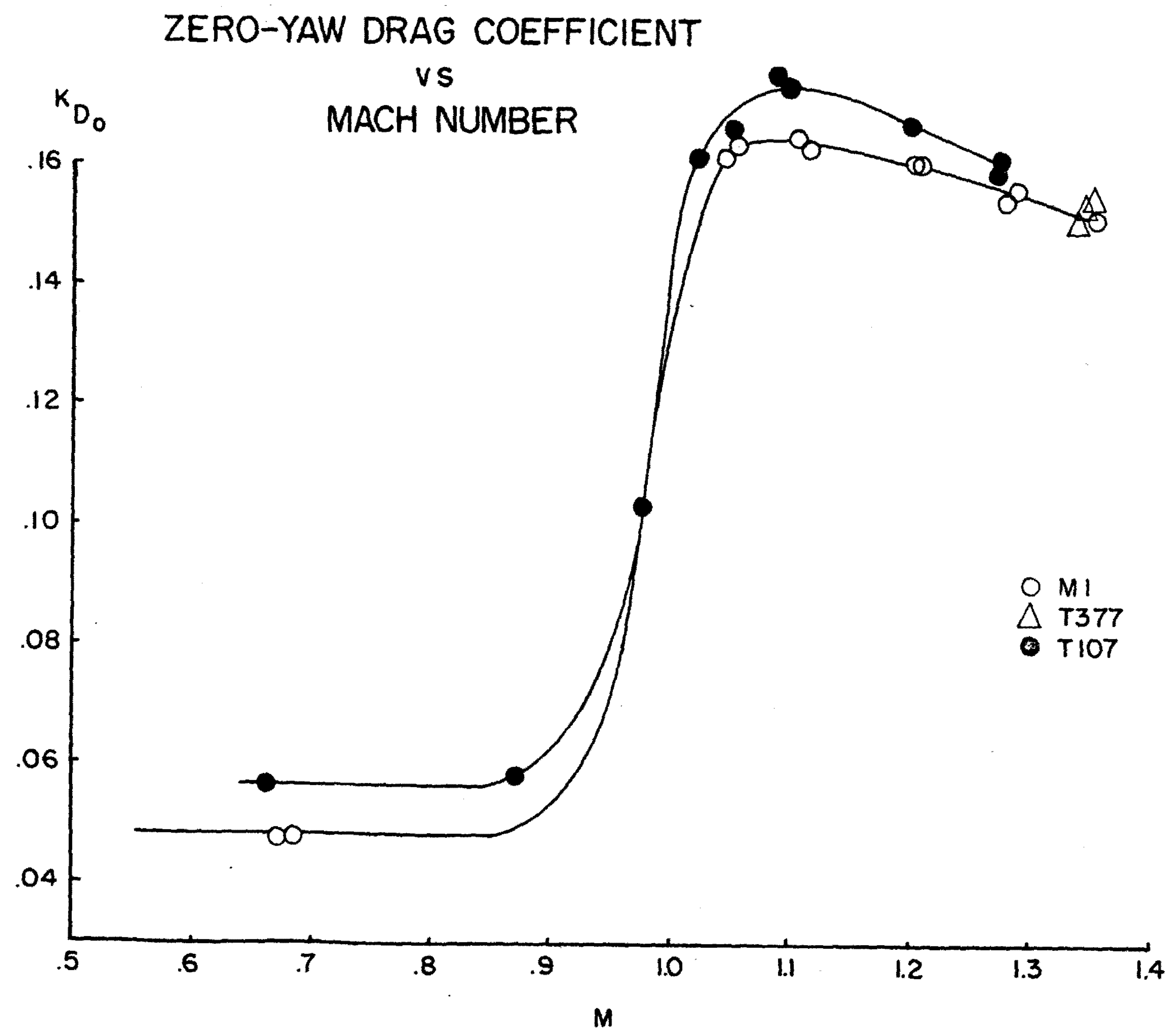
M1

M = 1.35

FIGURE 5

T107

M = 1.28



ZERO-YAW DRAG COEFFICIENT
VS
MACH NUMBER
K_{D_0}
.16
.14
.12
.10
.08
.06
.04
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
M
M1
T377
T107

FIG. 6

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