

UNCLASSIFIED

AD NUMBER

AD262877

LIMITATION CHANGES

TO:

Approved for public release; distribution is unlimited.

FROM:

**Distribution authorized to U.S. Gov't. agencies and their contractors;
Administrative/Operational Use; JUN 1961. Other requests shall be referred to Ballistic Research Laboratories, Aberdeen Proving Ground, MD.**

AUTHORITY

USAARASCOM ltr, 24 Feb 1981

THIS PAGE IS UNCLASSIFIED

GENERAL DECLASSIFICATION SCHEDULE

**IN ACCORDANCE WITH
DOD 5200.1-R & EXECUTIVE ORDER 11652**

THIS DOCUMENT IS:

CLASSIFIED BY _____

**Subject to General Declassification Schedule of
Executive Order 11652-Automatically Downgraded at
2 Years Intervals- DECLASSIFIED ON DECEMBER 31, _____.**

BY

**Defense Documentation Center
Defense Supply Agency
Cameron Station
Alexandria, Virginia 22314**

THIS REPORT HAS BEEN DELIMITED
AND CLEARED FOR PUBLIC RELEASE
UNDER DOE DIRECTIVE 5200.20 AND
NO RESTRICTIONS ARE IMPOSED UPON
ITS USE AND DISCLOSURE.

DISTRIBUTION STATEMENT A

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

UNCLASSIFIED

AD 262 877

*Reproduced
by the*

ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA



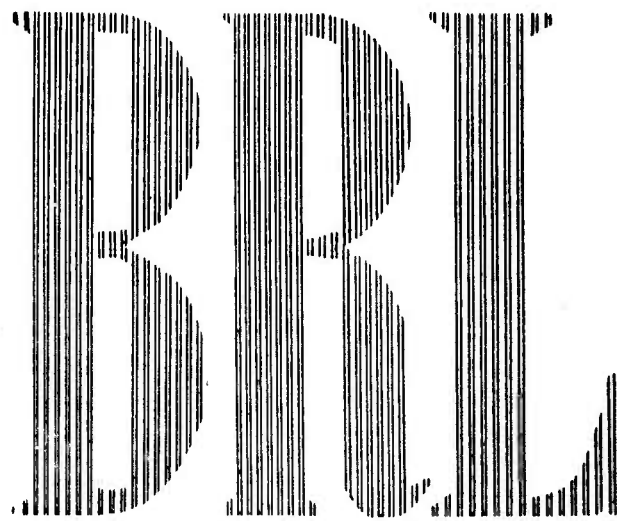
UNCLASSIFIED

**Best
Available
Copy**

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

CATALOGED BY STIA
AS AD NO.

262877



MEMORANDUM REPORT NO. 1354
JUNE 1961

THE EFFECTS OF MAGNUS MOMENT AT
SUBSONIC VELOCITIES ON
THE 105MM MORTAR PROJECTILE T-53

Maynard Piddington

XEROX



Department of the Army Project No. 503-03-001
Ordnance Management Structure Code No. 5010.11.814
BALLISTIC RESEARCH LABORATORIES



ABERDEEN PROVING GROUND, MARYLAND

ASTIA AVAILABILITY NOTICE

Qualified requestors may obtain copies of this report from ASTIA.

"FOREIGN ANNOUNCEMENT AND DISSEMINATION OF
THIS REPORT BY ASTIA IS LIMITED."

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1354

JUNE 1961

THE EFFECTS OF MAGNUS MOMENT AT SUBSONIC VELOCITIES ON THE
105MM MORTAR PROJECTILE T-53

Maynard Piddington

Exterior Ballistics Laboratory

Department of the Army Project No. 503-03-001
Ordnance Management Structure Code No. 5010.11.814

ABERDEEN PROVING GROUND, MARYLAND

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1354

MPiddington/clw
Aberdeen Proving Ground, Md.
June, 1961

THE EFFECTS OF MAGNUS MOMENT AT SUBSONIC VELOCITIES ON THE
105MM MORTAR PROJECTILE T-53

ABSTRACT

An analysis of the performance of the 105mm mortar shell T-53 with T1OE5 fins, at subsonic velocities, is presented and discussed. Emphasis is focused on the effect of Magnus moment. This shell, representative of one type of fin stabilized projectile, has an eight-bladed fin assembly with a span of one caliber, and has a low-drag, streamlined body. The performance of the T-53 is of particular interest, because little is known about Magnus in the subsonic region. The Magnus moment derivative, $C_{M_{p\alpha}}$, varied from 2.3 at $\phi' = 13$ to 4.5 at $\phi' = 27$. These values are several times larger than those experienced by spin stabilized projectiles. It was found that the static moment derivative, $C_{M_{\alpha}}$, was also a function of spin.

TABLE OF CONTENTS

	Page
I. TABLE OF SYMBOLS	7
II. INTRODUCTION	9
III. RESULTS	
1. Drag Force Coefficient	10
2. Righting Moment Derivative	10
3. Damping Moment Derivatives	11
4. Lift Force Derivative	11
5. Magnus Moment Derivative	11
IV. REFERENCES	13
V. TABLES AND FIGURES	14
VI. DISTRIBUTION LIST	23

I. TABLE OF SYMBOLS

a_2	Slope of the curve in figure 4 (per radian squared)
b_2	Slope of the curve in figure 7 (per radian squared)
C_D	$= \frac{\text{Drag force}}{qS}$
$C_{D\delta^2}$	Zero yaw drag derivative (per radian squared)
$C_{L\alpha}$	$= \frac{\text{Lift force}}{qS\alpha}$
$C_{M\alpha}$	$= \frac{\text{Static moment}}{qS\ell\alpha}$
$C_{M_q} + C_{M_{\dot{\alpha}}}$	$= \frac{\text{Damping moment}}{qS\ell \frac{(q\ell)}{(V)}}$
$C_{M_{p\alpha}}$	$= \frac{\text{Magnus moment}}{qS\ell \frac{(p\ell)}{(V)} \alpha}$
d	Missile diameter (inches)
I_x	Axial moment of inertia (lbs. - in ²)
I_y	Transverse moment of inertia (lbs. - in ²)
K_1	Magnitude of slow arm (radians)
K_2	Magnitude of fast arm (radians)
ℓ	Reference length, $\ell = d$ (inches)
q	$= 1/2 \rho V^2$
S	$= \pi d^2/4$
V	Velocity of missile (feet per second)
Wt.	Weight of missile (lbs.)
α	Angle of attack (degrees)

I. TABLE OF SYMBOLS (continued)

$$\delta^2 = K_1^2 + K_2^2 \text{ (mean squared yaw) (radians squared)}$$

$$\delta_e^2 = K_1^2 + K_2^2 + \frac{K_1^2 \phi_1' - K_2^2 \phi_2'}{\phi_1' - \phi_2'} \text{ (radians squared)}$$

$$\delta_{e_1}^2 = K_1^2 + 2 K_2^2 \text{ (radians squared)}$$

λ_1, λ_2 Damping rates (1/foot)

ρ Air density (lbs. per cubic foot)

ϕ' Spin (degrees per foot)

ϕ_1' Turning rate of slow arm (degrees per foot)

ϕ_2' Turning rate of fast arm (degrees per foot)

II. INTRODUCTION

It has become fairly standard practice to launch fin stabilized ammunition with a small amount of spin so as to average out the effects of fin misalignment caused either by machining inaccuracies or during launch.¹ Spin, however, produces a Magnus torque which could lead to dynamic instability. While this Magnus problem has been known to exist, it had generally been thought to be a problem only when the spins were much larger than were employed in practice.

Limited Magnus data have been obtained on several fin stabilized models, both spiked-nosed and streamlined, particularly at supersonic velocities. In some cases, the spin has caused dynamic instability at spins as low as that of resonance.² Hence, the effects of spin on this type of shell must be considered an important factor in the design of a model so that stable flight can be assured.

The main purpose of this report is to present additional Magnus information pertaining to one of the several types of fin stabilized projectiles. The projectile selected for this test was the 105mm mortar shell T-53. This shell has a fin span of one caliber and a streamlined, low drag body. The rounds were fired for a mid-range velocity of 900 ft/sec. - a region in which very little is known about Magnus effects.

Eleven rounds were fired through the Transonic Range³ of the Ballistic Research Laboratories. Three guns were used in which spins of 13, 22 and 27 degrees per foot were obtained. Unfortunately, only drag and static moment data were obtained at the 22 level. A drawing of the T-53 and some of its physical properties are given in Figure 1, and a photograph of the shell in flight in Figure 2. Standard drag, yaw and swerve reductions⁴ were performed; the results are given in the Table of Aerodynamic Data and in Figures 3 through 8.

III. RESULTS

The normal drag, yaw and swerve reductions yield considerably more than merely Magnus data. This additional information is also presented in this section mainly to supplement the data reported on in Reference 5.

1. Drag Force Coefficient

The drag force coefficient, C_D , is plotted in Figure 3 versus mean squared yaw, δ^2 . It is assumed that the Mach number effect on C_D is negligible. For some unexplained reason the data points appear to make up two distinct curves. One curve is about 5.5% lower than the other. Since each curve contains drag values obtained from rounds of different spin, spin is not considered a variable. No evidence which would logically explain the discrepancy in drag could be observed in the shadowgraphs of the shell in flight. This may mean that, because of the velocity of the projectile and the texture of the photographs, any flow phenomenon which could cause the discrepancy was not observable (note Figure 2). Another possible explanation is that the rounds may have come from separate lots and hence, may have had some slight manufacturing differences. Again, there is no evidence to back this up. The zero yaw drag derivative, $C_{D\delta^2}$, in each case is about 9 per radian squared.

2. Righting Moment Derivative

The righting moment derivative, C_{M_α} , is plotted versus the effective squared yaw in Figure 4. Again, no Mach number correction was made, but obviously there is a variation with spin. Assuming that the moment derivative variation with yaw is of the form $C_{M_\alpha} = (C_{M_\alpha})_0 + a_2 \delta_e^2$, $(C_{M_\alpha})_0$ can be plotted as a function of spin (Figure 5).

By using Figures 4 and 5, one can easily determine the static moment derivative for any reasonable spin and yaw.

One high spin C_{M_α} data point, at $\delta_e^2 = .00027$, appears to be considerably higher than the curve drawn for that group. No reason can be given to explain this large discrepancy.

3. Damping Moment Derivatives

The damping moment derivatives, $C_{M_q} + C_{M_{\dot{\alpha}}}$, are given in the Table. $C_{M_q} + C_{M_{\dot{\alpha}}}$ are evaluated from a combination of both arms and hence, their accuracy depends upon how well the damping of the fast and slow rates are determined. $C_{M_q} + C_{M_{\dot{\alpha}}}$, within its scatter, appears to be fairly constant at about 55.

4. Lift Force Derivative

The lift force derivative, $C_{L_{\alpha}}$, appears to be fairly constant at about 3.0.

5. Magnus Moment Derivative

Perhaps the greatest effect of spin can be observed in the damping of the slow arm. It should be pointed out that when a Magnus torque is present it will adversely affect one of the damping rates and cause the other rate to damp faster than if no spin were present. As a result, one of the arms, in this case the slow arm, will have a much better determination than the other. This rate is plotted versus δ_{e1}^2 in Figure 6. It can be observed from these curves that the damping of the slow rate varies with both yaw and spin. This curve also indicates that to insure dynamic stability spins no greater than 18 deg/ft should be employed.

The Magnus moment derivative, $C_{M_{p\alpha}}$, is plotted versus δ_e^2 in Figure 7. Assuming that the $C_{M_{p\alpha}}$ variation with yaw is of the form $C_{M_{p\alpha}} = (C_{M_{p\alpha}})_0 + b_2 \delta_e^2$, $(C_{M_{p\alpha}})_0$ can be plotted versus the spin as shown in Figure 8. There seems to be a definite correlation with spin. A value of about 2.3 was obtained for the low spin group and about 4.5 for the high spin group.

$C_{M_{p\alpha}}$ values of the size obtained in this test are several times

larger than those experienced by spin stabilized projectiles. While this is not necessarily disastrous by itself, it does limit the amount of spin that can be safely employed for shell of this general type.

Maynard Piddington

MAYNARD PIDDINGTON

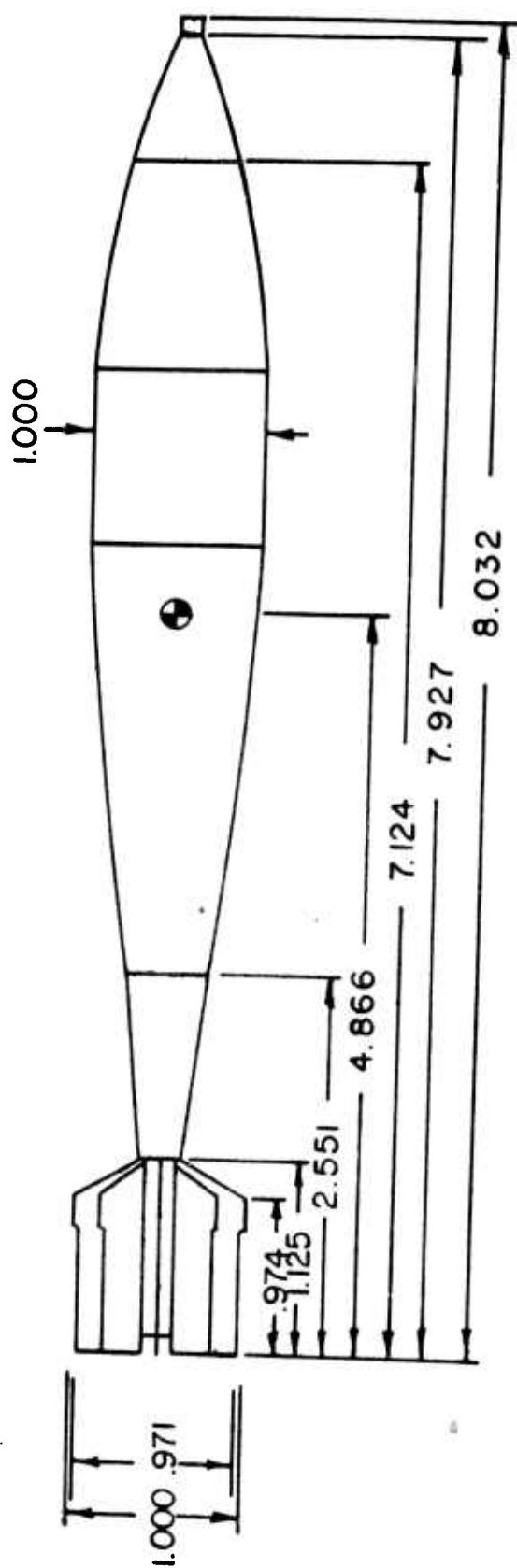
IV. REFERENCES

1. Nicolaides, J. D. On the Free Flight Motion of Missiles Having Slight Configurational Asymmetries. BRL Report 858, 1953.
2. Piddington, Maynard J. The Effects of Spin and Magnus Torque on a Spiked-Nose, Fin Stabilized, HEAT Projectile - 76mm T180E23. BRL M 1310, Confidential, 1960.
3. Rogers, Walter K., Jr. The Transonic Free Flight Range. BRL Report 1044, 1958.
4. Murphy, Charles H. Data Reduction for the Free Flight Spark Ranges. BRL Report 900, 1956.
5. MacAllister, L. C. and Roecker, E. T. Aerodynamic Properties, Spin and Launching Characteristics of 105mm Mortar Shell T53E1 with Two Types of Fins. BRL M 618, 1952.

TABLE OF AERODYNAMIC DATA

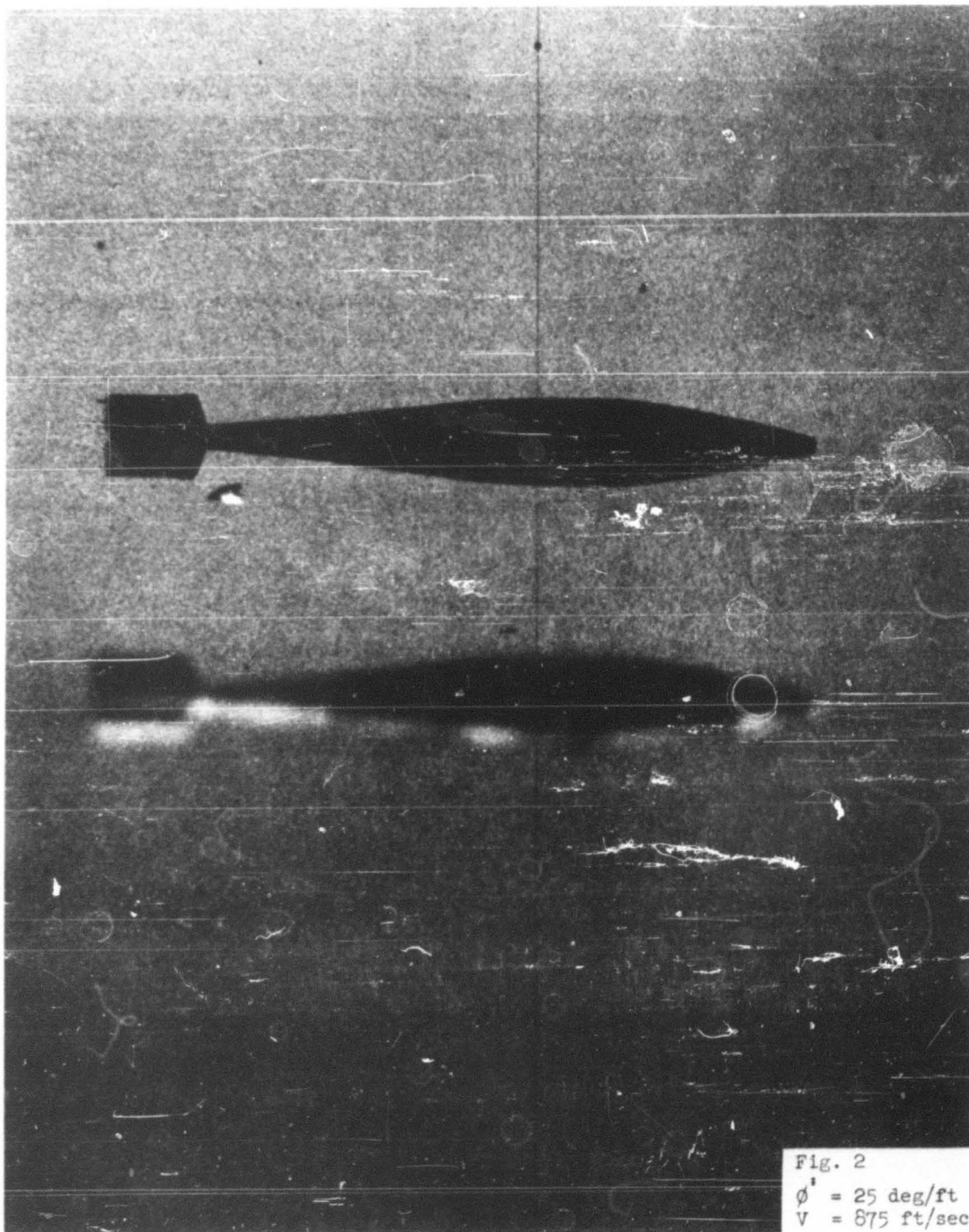
M	ϕ^* (deg/ft)	δ^2 (rad)	C_D	C_{M_α}	$C_{M_q} + C_{M_{\dot{\alpha}}}$	C_{L_α}	$C_{M_{pa}}$	$\lambda_1 \times 10^3$ (1/ft)	$\lambda_2 \times 10^3$ (1/ft)	ϕ_2^* (deg)	ϕ_1^* (deg)	K_2 (rad)	K_1 (rad)	Range Rd
.755	27	.00124	.177	-4.347	-71	3.23	-5.1	-.78	5.01	2.19	-	.004	.035	4839
.816	25	.00092	.185	-4.380	-51	2.97	-4.5	-.75	3.70	2.11	-	.004	.030	5108
.817	26	.00018	.182	-4.530						2.14	-1.01	.003	.013	5109
.818	28	.00234	.202	-4.586	-61	3.08	-4.2	-.59	4.09	2.23	-1.01	.006	.048	4837
.839	28	.00277	.203	-4.545	-59	2.98	-4.0	-.53	3.94	2.21	-1.00	.008	.052	4838
.846	22	.00015	.183	-4.10						1.96	-1.00	.002	.012	5110
.790	13	.00009	.179											4834
.808	13	.00058	.184	-3.891	-50	3.13	-3.26	.50	2.42	1.68	-1.12	.007	.023	4833
.818	13	.00181	.184	-3.998	-54	2.80	-1.93	.86	2.22	1.70	-1.12	.021	.037	5105
.826	13	.00164	.186	-4.194	-59	2.92	-2.33	.85	2.44	1.73	-1.14	.022	.034	5106
.824	14	.00266	.194	-4.254	-52	3.33	-2.07	.80	2.21	1.74	-1.15	.027	.044	5104
Average error			1.5%		9.5%	5.6%	10%							

PHYSICAL PROPERTIES 105-mm T53



NOTE: ALL DIMENSIONS ARE IN CALIBERS

FIG. 1



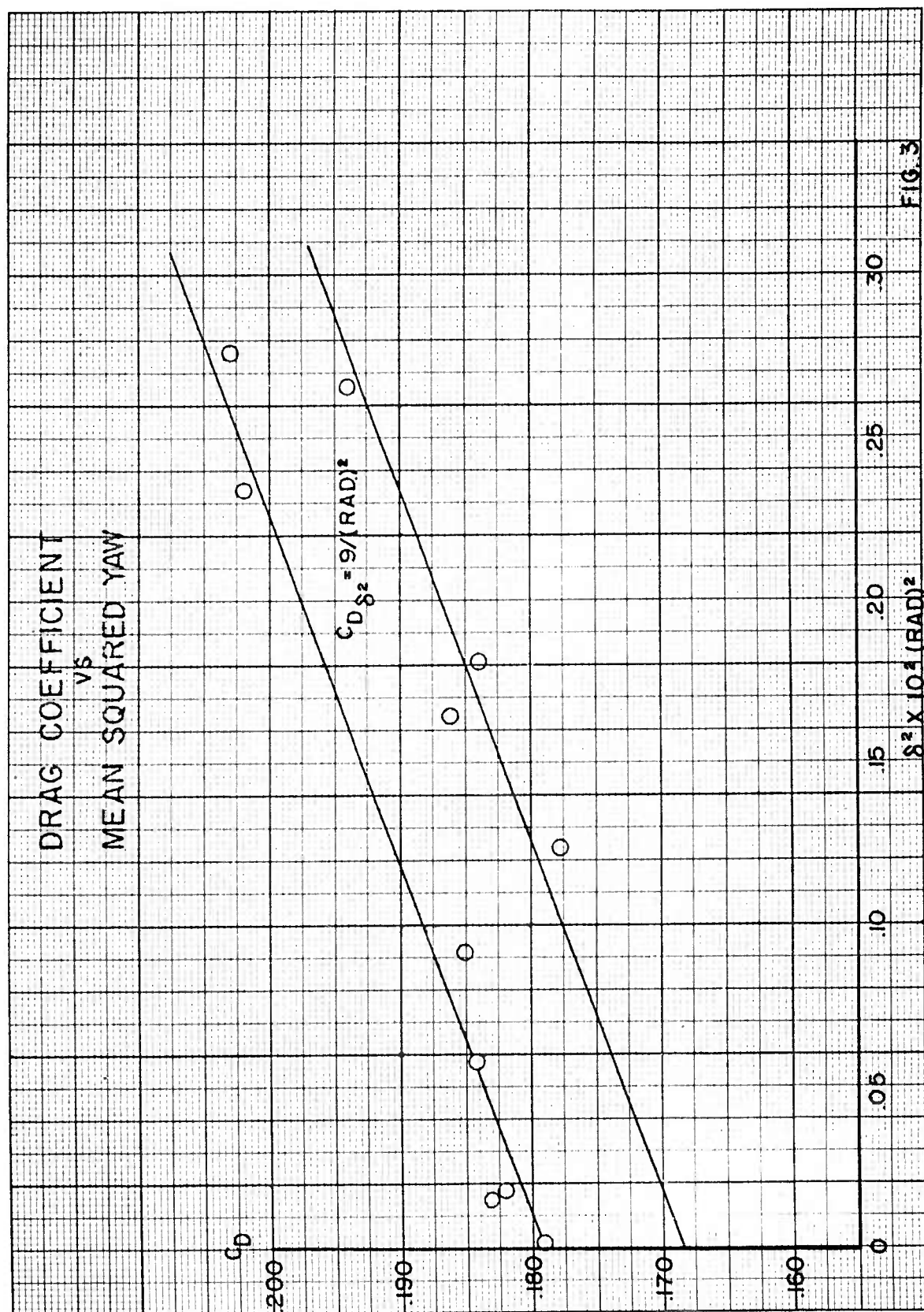


FIG. 3

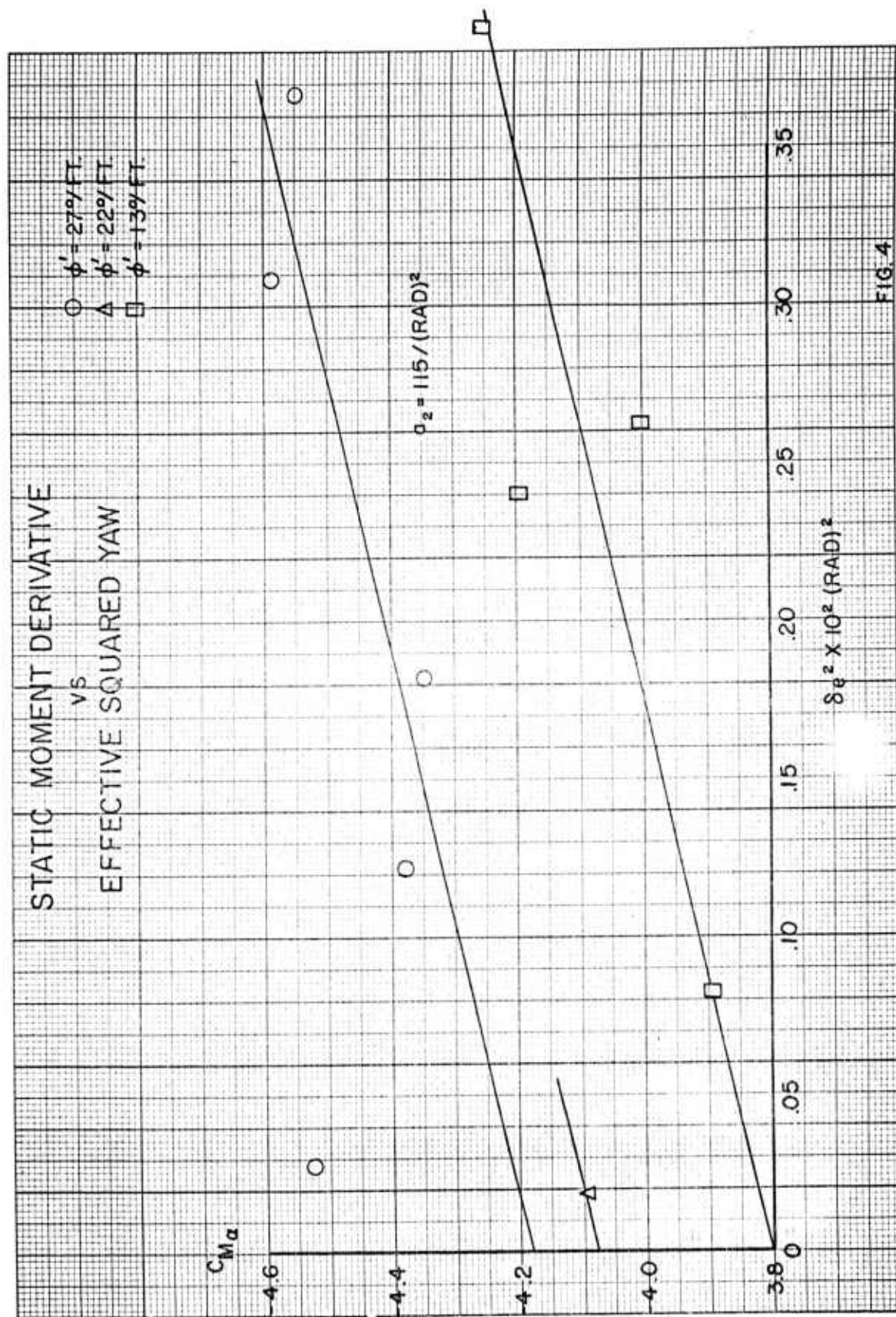
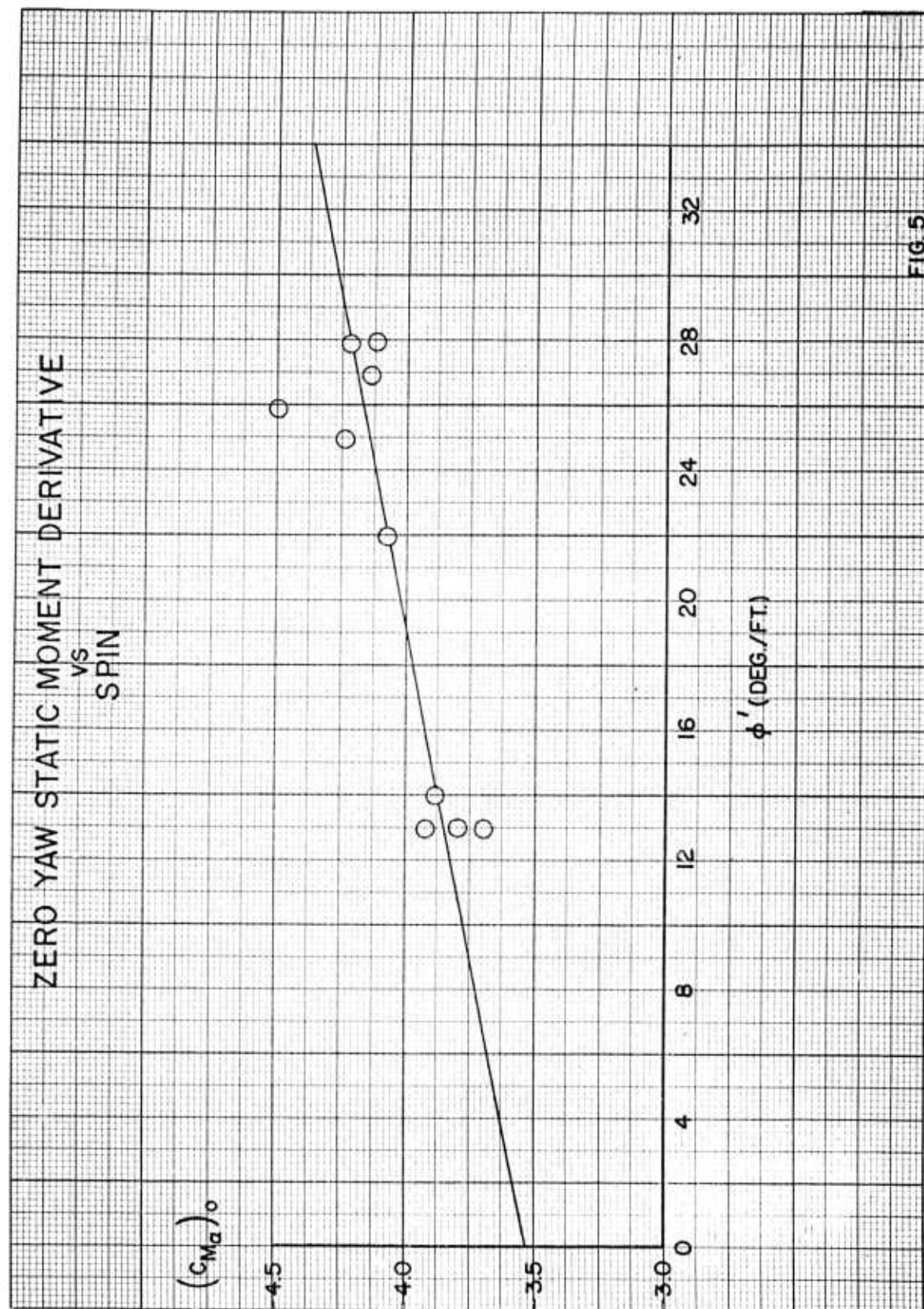


FIG. 4



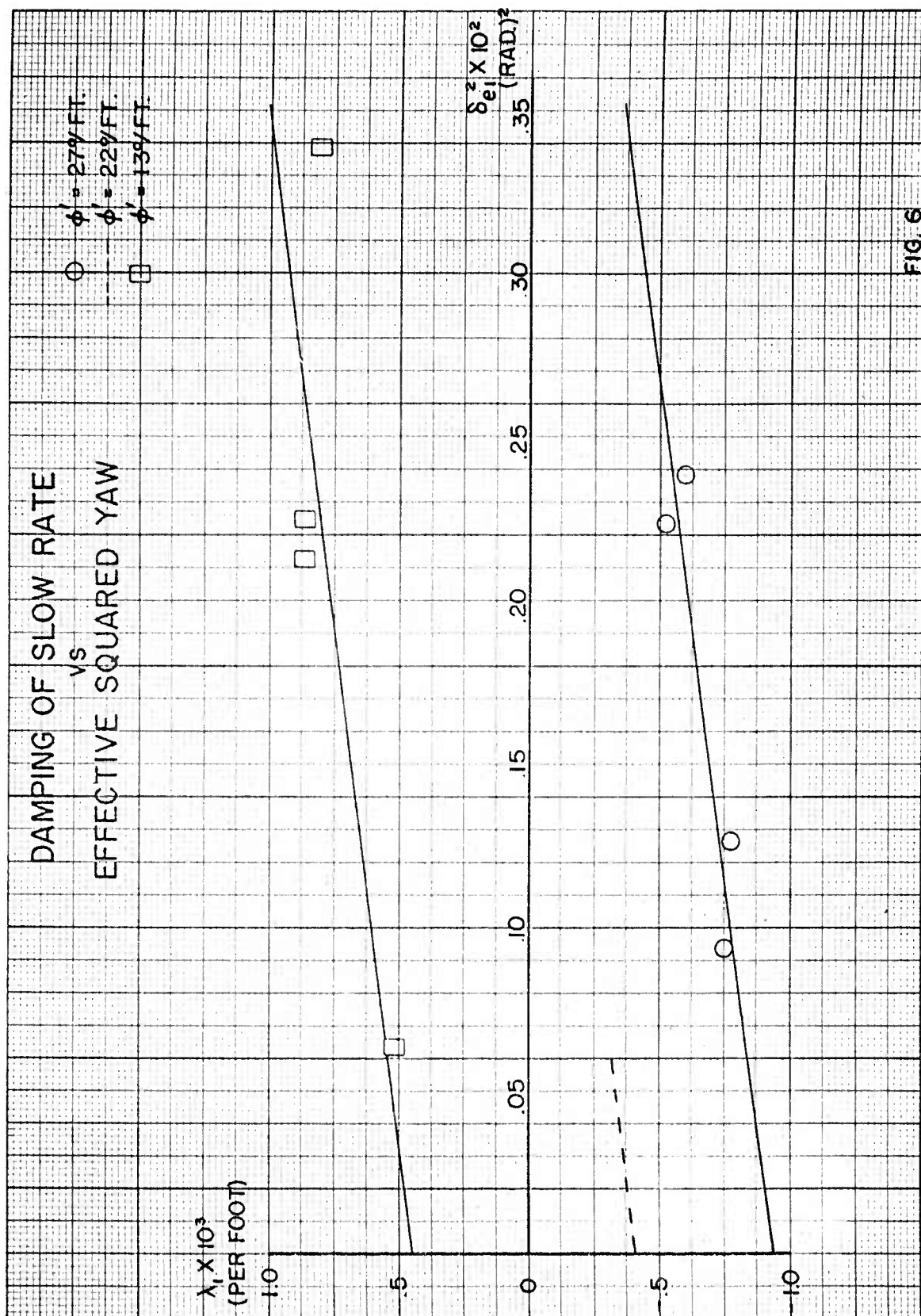


FIG. 6

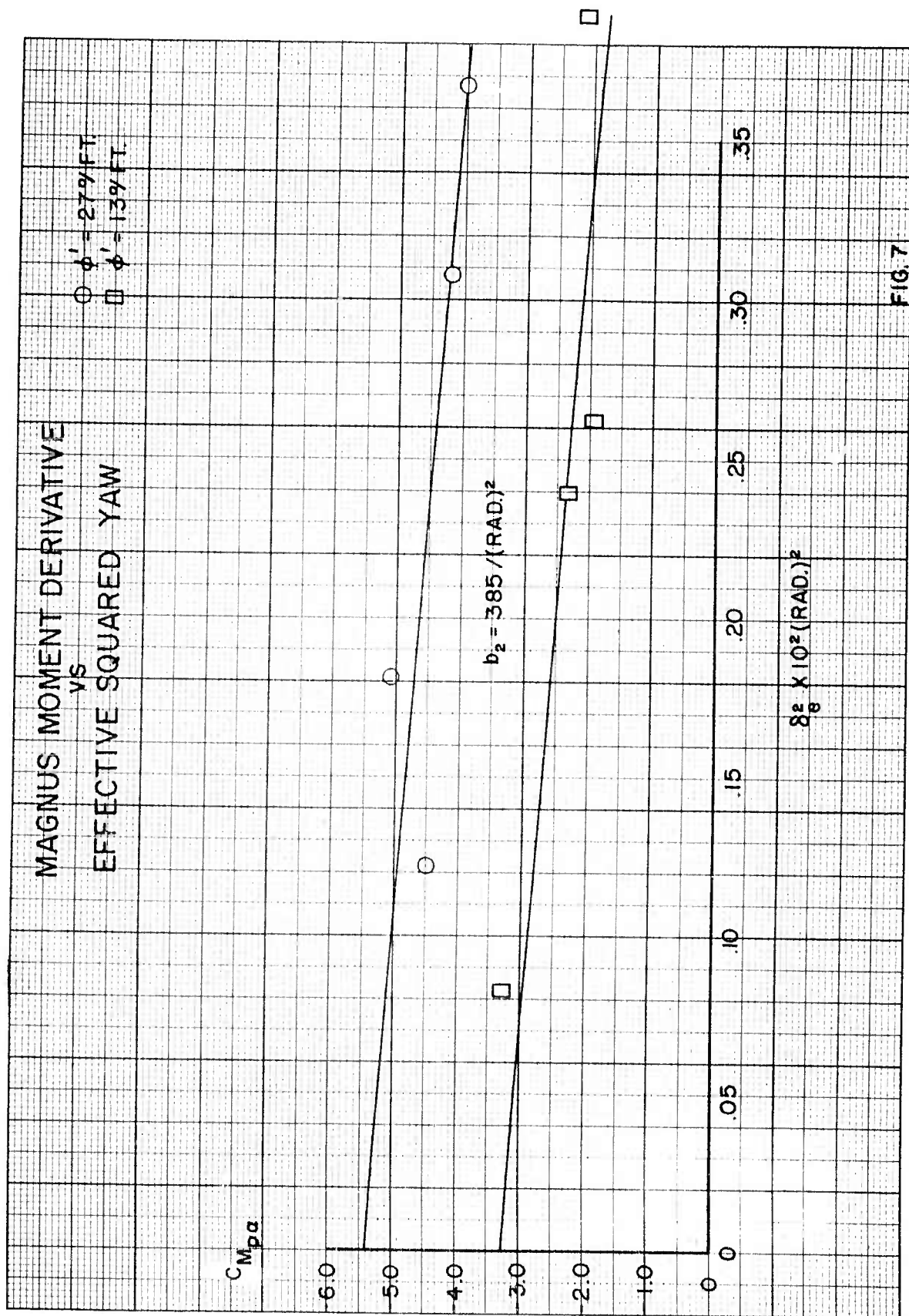
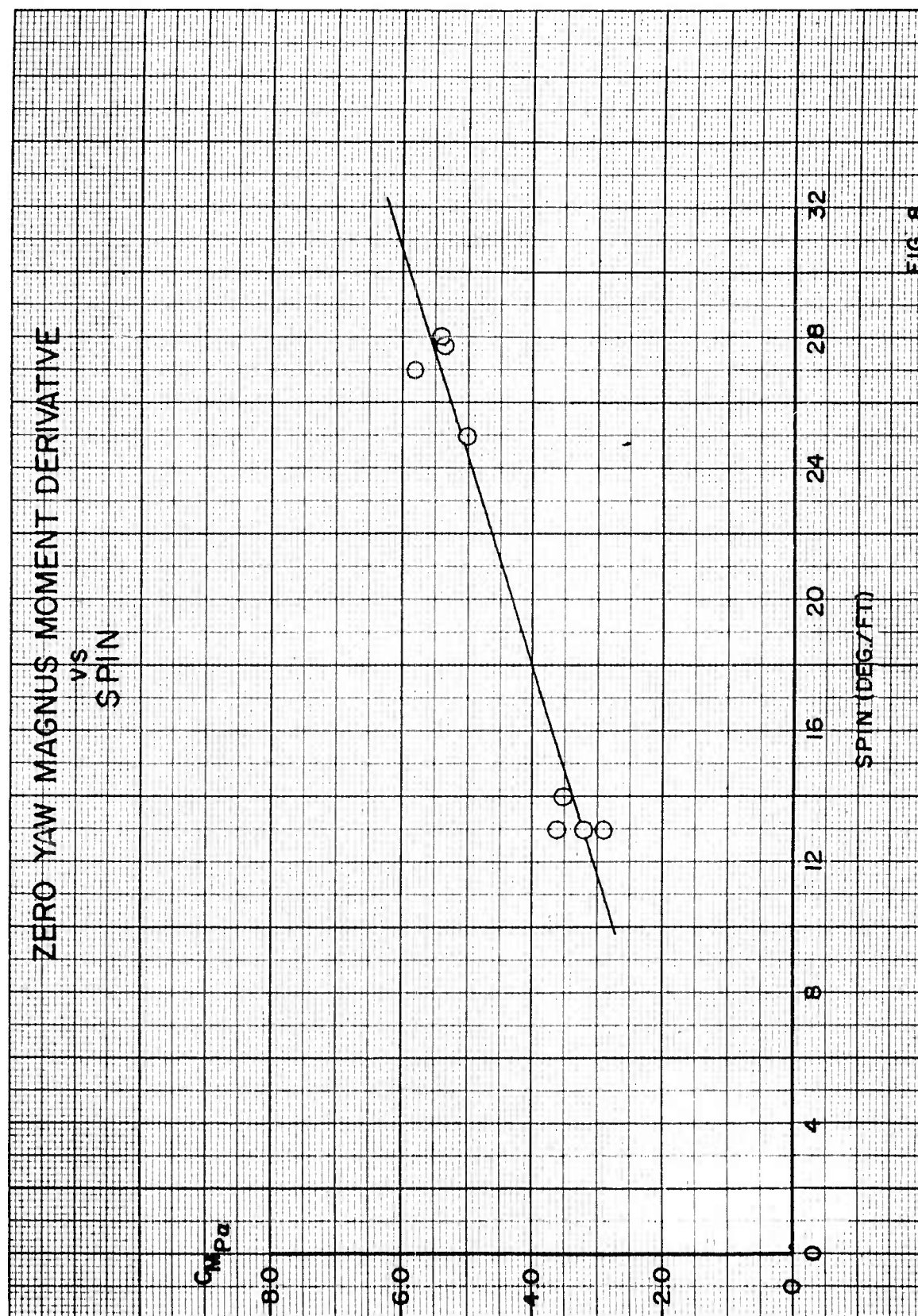


FIG. 7



DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
3	Chief of Ordnance ATTN: ORDTB - Bal Sec ORDTW ORDTS Department of the Army Washington 25, D. C.	1	Commander U. S. Naval Weapons Laboratory Dahlgren, Virginia
		2	Commander U. S. Naval Missile Center Point Mugu, California
1	Commanding Officer Diamond Ordnance Fuze Laboratories ATTN: Technical Information Office Branch 012 Washington 25, D. C.	2	Commander Naval Ordnance Laboratory White Oak, Silver Spring 19, Maryland
10	Commander Armed Services Technical Information Agency ATTN: TIPCR Arlington Hall Station Arlington 12, Virginia	1	Commanding Officer & Director David W. Taylor Model Basin ATTN: Aerodynamics Laboratory Washington 7, D. C.
		1	Commander Air Proving Ground Center Eglin Air Force Base, Florida
10	Commander British Army Staff British Defence Staff (W) ATTN: Reports Officer 3100 Massachusetts Avenue, N. W. Washington 8, D. C.	1	Commanding Officer Ogden Air Materiel Area Hill Air Force Base, Utah
		1	Commanding General U. S. Continental Army Command ATTN: MD-2 Fort Monroe, Virginia
4	Defence Research Member Canadian Joint Staff 2450 Massachusetts Avenue, N. W. Washington 8, D. C.	1	President U. S. Army Armor Board Fort Knox, Kentucky
3	Chief, Bureau of Naval Weapons ATTN: DIS-33 Department of the Navy Washington 25, D. C.	3	Commanding General Frankford Arsenal ATTN: Mr. Lapinski Mr. Bushe Library Branch, 0270, Bldg. 40 Philadelphia, Pennsylvania
3	Commander U. S. Naval Ordnance Test Station ATTN: Technical Library Aeroballistics Laboratory - Code 5034 China Lake, California	3	Commanding Officer Picatinny Arsenal ATTN: Feltman Research & Engineering Laboratories Dover, New Jersey

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
3	Commanding General Army Rocket & Guided Missile Agency ATTN: Technical Library Gregg S. Maskkoff (2 cys) Redstone Arsenal, Alabama	1	Jet Propulsion Laboratory ATTN: Mr. Irl E. Newlan, Reports Group 4800 Oak Grove Drive Pasadena, California
1	Commanding Officer U. S. Army Chemical Warfare Laboratories Army Chemical Center, Maryland	1	Director, Operations Research Office Department of the Army 6935 Arlington Road Bethesda, Maryland Washington 14, D. C.
1	Commanding Officer U. S. Army Research Office (Durham) ATTN: Mr. J. Lane Box CM, Duke Station Durham, North Carolina	1	Chief of Staff, U. S. Army Research & Development ATTN: Director/Development Washington 25, D. C.
1	Director National Aeronautics & Space Administration 1520 H Street, N. W. Washington 25, D. C.	1	Chief of Staff, U. S. Army Army Research Office Arlington Hall, Virginia
1	Director National Aeronautics & Space Administration Ames Research Center ATTN: Mr. H. J. Allen Moffett Field, California	1	Armour Research Foundation Illinois Institute of Technology Center ATTN: Mr. W. Casier Chicago 16, Illinois
1	Director National Aeronautics & Space Administration Langley Research Center Langley Field, Virginia	1	The Budd Company Red Lion Plant Philadelphia 15, Pennsylvania
2	Applied Physics Laboratory The Johns Hopkins University ATTN: Mr. G. L. Seielstad 8621 Georgia Avenue Silver Spring, Maryland	1	Cornell Aeronautical Laboratory, Incorporated ATTN: Mr. J. Desmond, Librarian 4455 Genessee Street Buffalo, New York
		1	Firestone Tire & Rubber Company ATTN: Mr. William Davis Akron 17, Ohio

AD	Accession No.	UNCLASSIFIED	Projectiles-Aerodynamic characteristics Mortar shell-Magnus moment
Ballistic Research Laboratories, APG	THE EFFECTS OF MAGNUS MOMENT AT SUBSONIC VELOCITIES ON THE 105MM MORTAR PROJECTILE T-53 Waynard Piddington	THE EFFECTS OF MAGNUS MOMENT AT SUBSONIC VELOCITIES ON THE 105MM MORTAR PROJECTILE T-53 Waynard Piddington	Projectiles-Aerodynamic characteristics Mortar shell-Magnus moment
BRIM Report No. 1354	June 1961	BRIM Report No. 1354	June 1961
DA Proj 503-03-001, OMSC No. 5010.11.814	UNCLASSIFIED Report	DA Proj 503-03-001, OMSC No. 5010.11.814	UNCLASSIFIED Report
An analysis of the performance of the 105mm mortar shell T-53 with T10E5 fins, at subsonic velocities, is presented and discussed. Emphasis is focused on the effect of Magnus moment. This shell, representative of one type of fin stabilized projectile, has an eight-bladed fin assembly with a span of one caliber, and has a low-drag, streamlined body. The performance of the T-53 is of particular interest, because little is known about Magnus in the subsonic region. The Magnus moment derivative, $C_{M_{\dot{\alpha}}}$, varied from 2.3 at $\phi' = 13$ to 4.5 at $\phi' = 27$. These values are several times larger than those experienced by spin stabilized projectiles. It was found that the static moment derivative, $C_{M_{\dot{\alpha}}}$, was also a function of spin.			
AD	Accession No.	UNCLASSIFIED	Projectiles-Aerodynamic characteristics Mortar shell-Magnus moment
Ballistic Research Laboratories, APG	THE EFFECTS OF MAGNUS MOMENT AT SUBSONIC VELOCITIES ON THE 105MM MORTAR PROJECTILE T-53 Waynard Piddington	THE EFFECTS OF MAGNUS MOMENT AT SUBSONIC VELOCITIES ON THE 105MM MORTAR PROJECTILE T-53 Waynard Piddington	Projectiles-Aerodynamic characteristics Mortar shell-Magnus moment
BRIM Report No. 1354	June 1961	BRIM Report No. 1354	June 1961
DA Proj 503-03-001, OMSC No. 5010.11.814	UNCLASSIFIED Report	DA Proj 503-03-001, OMSC No. 5010.11.814	UNCLASSIFIED Report
An analysis of the performance of the 105mm mortar shell T-53 with T10E5 fins, at subsonic velocities, is presented and discussed. Emphasis is focused on the effect of Magnus moment. This shell, representative of one type of fin stabilized projectile, has an eight-bladed fin assembly with a span of one caliber, and has a low-drag, streamlined body. The performance of the T-53 is of particular interest, because little is known about Magnus in the subsonic region. The Magnus moment derivative, $C_{M_{\dot{\alpha}}}$, varied from 2.3 at $\phi' = 13$ to 4.5 at $\phi' = 27$. These values are several times larger than those experienced by spin stabilized projectiles. It was found that the static moment derivative, $C_{M_{\dot{\alpha}}}$, was also a function of spin.			

AD	Accession No.	UNCLASSIFIED
Ballistic Research Laboratories, ARS THE EFFECTS OF MAGNUS MOMENT AT SUBSONIC VELOCITIES ON THE 105MM MORTAR PROJECTILE T-53 Maynard Piddington		Projectiles-Aerodynamic characteristics Mortar shell-Magnus moment
BRIM Report No. 1354 June 1961		
DA Proj 503-03-001, OMSC No. 5010.11.814 UNCLASSIFIED Report		
An analysis of the performance of the 105mm mortar shell T-53 with T10E5 fins, at subsonic velocities, is presented and discussed. Emphasis is focused on the effect of Magnus moment. This shell, representative of one type of fin stabilized projectile, has an eight-bladed fin assembly with a span of one caliber, and has a low-drag, streamlined body. The performance of the T-53 is of particular interest, because little is known about Magnus in the subsonic region. The Magnus moment derivative, $C_{M_{\dot{\alpha}}}$, varied from 2.3 at $\phi' = 13$ to 4.5 at $\phi' = 27$. These values are several times larger than those experienced by spin stabilized projectiles. It was found that the static moment derivative, $C_{M_{\alpha}}$, was also a function of spin.		
AD	Accession No.	UNCLASSIFIED
Ballistic Research Laboratories, ARS THE EFFECTS OF MAGNUS MOMENT AT SUBSONIC VELOCITIES ON THE 105MM MORTAR PROJECTILE T-53 Maynard Piddington		Projectiles-Aerodynamic characteristics Mortar shell-Magnus moment
BRIM Report No. 1354 June 1961		
DA Proj 503-03-001, OMSC No. 5010.11.814 UNCLASSIFIED Report		
An analysis of the performance of the 105mm mortar shell T-53 with T10E5 fins, at subsonic velocities, is presented and discussed. Emphasis is focused on the effect of Magnus moment. This shell, representative of one type of fin stabilized projectile, has an eight-bladed fin assembly with a span of one caliber, and has a low-drag, streamlined body. The performance of the T-53 is of particular interest, because little is known about Magnus in the subsonic region. The Magnus moment derivative, $C_{M_{\dot{\alpha}}}$, varied from 2.3 at $\phi' = 13$ to 4.5 at $\phi' = 27$. These values are several times larger than those experienced by spin stabilized projectiles. It was found that the static moment derivative, $C_{M_{\alpha}}$, was also a function of spin.		