UNCLASSIFIED

AD NUMBER
AD242497
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 1960. Other requests shall be referred to Army Ballistic Research Laboratory, Aberdeen Proving Groung, MD 21005.**
AUTHORITY
USABRL ltr, 22 Apr 1981

THIS PAGE IS UNCLASSIFIED

File Copy

242497

BRL

MEMORANDUM REPORT NO. 1284
JUNE 1960

THE EFFECTS OF ANNULAR RINGS AND GROOVES, AND OF BODY UNDERCUTS ON THE AERODYNAMIC PROPERTIES OF A CONE-CYLINDER PROJECTILE AT M = 1.72

Elizabeth R. Dickinson

Department of the Army Project No. 5B03-03-001
Ordnance Management Structure Code No. 5010.11.814

BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

MEMORANDUM REPORT NO. 1284

JUNE 1960

THE EFFECTS OF ANNULAR RINGS AND GROOVES, AND OF BODY UNDERCUTS ON THE AERODYNAMIC PROPERTIES OF A CONE-CYLINDER PROJECTILE AT M = 1.72

Elizabeth R. Dickinson

Department of the Army Project No. 5B03-03-001
Ordnance Management Structure Code No. 5010.11.814
(Ordnance Research and Development Project No. TB3-0108)

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

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

MEMORANDUM REPORT NO. 1284

ERDickinson/ks
Aberdeen Proving Ground, Md.
June 1960

THE EFFECTS OF ANNULAR RINGS AND GROOVES, AND OF BODY UNDERCUTS ON THE AERODYNAMIC PROPERTIES OF A CONE-CYLINDER PROJECTILE AT M = 1.72

ABSTRACT

This report presents the effects, on drag, overturning moment, lift, and center of pressure, of annular rings and grooves on the nose of a cone-cylinder projectile. Also shown are the effects, on the same parameters, of undercuts on the body of the projectile. There is, in addition, a discussion of the four types of flow which developed over the undercut bodies.

TABLE OF CONTENTS

I. INTRODUCTION

Often, in a projectile's progress from the designer's drafting board to the assembly line, there are many changes made in the details of the projectile's contour. As a result, the actual aerodynamic performance of the projectile may differ from that of the designer's prediction.

Almost all of the basic design on projectiles concerns itself with smooth contours and simple geometric shapes. When practical considerations enter the picture and fuzes have to be attached, reliefs have to be machined, rotating bands have to be added, a projectile which may have been, originally, an optimum one, often falls short of expectations.

The engineer, who translates the ballistician's design data into a practical piece of ammunition, should be cognizant of the differential corrections that have to be made to the predicted behavior of the projectile. The purpose of this report is to show the effect, on some of the aerodynamic characteristics, of depressions and protrusions on the surface of a body of revolution. Unfortunately, there were insufficient data to determine effects on the damping and Magnus moments and forces.

During the course of the experiments, a multi-flow phenomenon developed, which was then investigated more fully.

II. RESULTS AND CONCLUSIONS

A. Nose Modifications

The basic projectile used for this program was a 20-mm cone-cylinder. The first part of the experiment consisted in putting first rings and then grooves on the nose (Fig. 1). All of the models were fired in the Aerodynamics Range(1) of the Ballistic Research Laboratories, at Mach number 1.72. The data obtained were reduced in the conventional manner.(2) Many rounds of the basic cone-cylinder model had been fired at a previous time*, and served as the basis for comparison.

*Reference 3, and unpublished drag data.

A.1 Rings. Three thicknesses of rings were used: 0.005, 0.010, and 0.020 caliber; all were 0.075 caliber wide. The ringed rounds were few in number, and fired at a time when the only interest was in drag. Consequently, none of the other aerodynamic coefficients could be obtained from the meager data. The effect of the rings on drag, however, was well determined. Up to the ring thickness tested (0.02 caliber) the drag coefficient, C_D, is a linear function of the ring thickness. For the model tested, at a Mach number of 1.72, the relationship is:

$C_D = .3214 + 1.35t$, where t is ring thickness in calibers (Figs. 2 & 3).

This part of the experiment indicates clearly that protrusions on fuzes or other portions of the nose of a projectile must be taken into account in estimating drag, hence range, of the projectile.

A.2 Grooves. Two depths of grooves were used: 0.020 and 0.041 caliber; and two widths of grooves were used: 0.076 and 0.153 caliber. Data obtained from the firings of these models indicated no discernible effect of the grooves on the drag coefficient (Fig. 2). The spark photographs (Fig. 4) clearly show that shock waves originate at the nose grooves. Any resultant increase in drag, however, is so small that it cannot be measured by the present methods. There was no discernible effect of the grooves on the other aerodynamic coefficients. The only apparent effect was a slight thickening of the boundary layer, hence a slightly larger "effective" body diameter.

There is a possibility, however, that a groove could indirectly cause a significant flow change along a more complex contour. In the case of a shell with a rounded base, significant differences in the aerodynamic properties were observed when the shell was fired with a smooth, and then with a punched, fuze cover.[4]

It should be noted that both rings and grooves are effective in causing transition from laminar to turbulent flow.

B. Body Modifications

The second part of the experiment consisted in putting a driving band on the basic projectile, and in making undercuts on the body (Fig. 5). The resulting models thus more nearly represented actual ammunition. Two depths of body undercuts were machined: 0.1 and 0.2 caliber. Again, all rounds were fired at or near Mach 1.72.

B.1 Rotating Band. The model, shown at the top of figure 5, differed from that of the smooth cone-cylinder shown at the top of figure 1, only by the addition of a rotating band. Hence it was possible to obtain the drag coefficient of the band: $C_{D(band)} = .3275 - .3214 = .0061$. It must be emphasized, however, that this value applies only to this specific band (Fig. 5, bottom) at a Mach number of 1.72. A different band, at a different location on this same basic contour, had a drag coefficient of .0084 at Mach 2.3.[5, pg. 9] There was no measurable effect of the band on: the overturning moment coefficient, the normal force coefficient or the center of pressure. There were insufficient data to determine differences in damping and Magnus moments and forces.

B.2 Undercuts. All artillery shell have forward bourrelets (many have rear bourrelets, also), hence have slightly sub-caliber bodies. In the case of conventional artillery shell, this relief or "undercut" is only about .005 caliber deep. Recently, however, there have been received at the Ballistic Research Laboratories several projectiles in the development stage whose bodies have been undercut as deeply as .050 caliber. In addition, there have been high-velocity, armor-piercing projectiles developed from time to time whose body diameters were deeply undercut in order to reduce the weight of the projectile. The undercuts on this type of projectile range in depth from just over 0.1 caliber to just over 0.2 caliber.* Because abnormal aerodynamic behavior has been observed in the testing of models with appreciable undercuts, a limited

*Many projectiles of this type can be seen in the Ordnance Museum, Aberdeen Proving Ground.

experiment was conducted to determine the effects of undercuts on the various aerodynamic coefficients.

B.2.1 Flow and Drag. Originally, twelve undercut models were fired in the Aerodynamics Range: six with 0.1-caliber undercut (three with forward centers of mass and three, rearward) and six with 0.2-caliber undercut (again, three each forward and rearward centers of mass). Of these twelve rounds fired, six developed large swerve almost immediately and traveled only forty to fifty yards. (A possible explanation of this large swerve will be discussed later in section B.2.2.) Of the remaining six rounds, two had a 0.2-caliber undercut and four had a 0.1-caliber undercut. The four rounds having body undercuts of 0.1-caliber showed markedly different behavior.

There appeared to be two basic types of flow (Fig. 6): attached (associated with high drag) and separated (associated with low drag). Each type of flow appears to be stable; that is, it persists throughout the observed flight of the projectile. In both wind tunnel and free flight tests, a similar phenomenon has been observed to occur on long, blunt nose spikes.[6, 7, 8] Although this phenomenon is not new, the details of the mechanism, by which one or the other type of flow is established, are still not clear.

Present observations indicate that with attached flow there are variations in the flow pattern, resulting in differences in drag. For example, higher drag occurs with a steeper convergence of the wake behind the undercut. As the angle diminishes, the drag decreases. With separated flow, the lowest drag occurs with a divergent wake behind the undercut. As this divergence diminishes, the drag increases (Figs. 6, 7, 8).

Thus, within each type of stable flow, there appear to be slightly different flow patterns, which lead to different drags. These variations, however, are relatively small compared with the variation between the two fundamental types of flow. In the present experiment, no continuous variation of flow (that is, no continuous variation of wake angle behind the corner) was observed.

In the initial experiment, it was found that the highest drag, with attached flow, occurred in conjunction with a laminar boundary layer on the nose, extending all the way to the undercut. The lowest drag, with separated flow, occurred with a well-developed turbulent boundary layer on the nose, extending all the way to the undercut (Fig. 6). Intermediate cases (attached and separated flow) with mixed boundary layers, partially turbulent and partially laminar, led to intermediate drag results. To explore these results further, eight additional rounds were tested: four had highly polished noses to assure a laminar boundary layer; and four had trip-rings on the nose, to assure a well-developed turbulent boundary layer (Fig. 5).*

Two of the polished rounds had completely laminar boundary layers back to the undercut, and developed high-drag flow. Although the other polished round had a laminar boundary layer back to the undercut, there was, on one portion of the projectile just ahead of the undercut, the type of disturbance in the boundary layer that is indicative of the beginning of transition to turbulence. This round developed intermediate-high-drag flow.

The trip-ring on the nose produced a thick, turbulent boundary layer, and low-drag flow on all four rounds (Fig. 9). Each of the low-drag rounds, including the two with a 0.2-caliber undercut, had a turbulent boundary layer ahead of the corner, and a divergent wake behind the corner (Figs. 6, 8 and 9). Only one round developed intermediate-low-drag, with a mixed boundary layer ahead of the corner, and a slightly convergent wake behind the corner (Figs. 7 and 8). Indications are, that if the angle of the wake behind the corner tends to become steeper than about 1°, the wake will converge all the way into intermediate-high-drag flow, or still further into high-drag flow.

These experimental results show that, for the geometry of this projectile at a Mach number of 1.7 and a Reynolds number at the corner of

*One of the highly polished rounds developed yaw too large to be used in this analysis.

2.4×10^6, a laminar boundary layer back to the undercut favors the establishment of attached flow; whereas, a well-developed turbulent boundary layer back to the undercut favors the establishment of separated flow.

The significance of relatively small differences in flow patterns, associated with small differences in drag, was not initially recognized. These small differences in flow pattern, however, led to significant differences in other aerodynamic coefficients.

Because the added drag of the trip-ring had already been determined (II.A.1), the drag coefficients of the four ringed rounds could be corrected to a no-ring condition. All rounds were then corrected to zero yaw and Mach number 1.72 by means of the following relationships:

$$C_D = C_{Do} + C_{Do} \overline{\delta^2}$$

$$C_{Do} = \frac{Q^2 - 8/\pi}{M^2}, \text{ where } Q = a + b\ M$$

The plot of C_{Do} versus depth of undercut is shown in figure 10. It should be noted that, depending on the type of flow which develops, a 0.1-caliber body-undercut can increase the drag coefficient from about 20% to nearly 100% of that for an unmodified cone-cylinder.

B.2.2. Overturning Moment, Lift and Center of Pressure. The overturning moment and lift coefficients, and the center of pressure of the normal force are plotted in figures 11 and 12. Provided that low-drag flow has been established, these parameters appear to be relatively unaffected by an increase of body undercut from 0.1 to 0.2 caliber. The type of flow, however, has a marked effect on all three parameters.

It has been stated previously that some of the first group of undercut rounds developed large swerve, and traveled only forty or fifty yards. These rounds, with forward centers of mass (approximately two calibers from the base), developed low-drag flow, with its associated rearward shift of the center of pressure (Fig. 12). This resulted in a very small overturning moment coefficient, C_{M_α}, (it may even have been slightly negative) and a large gyroscopic stability factor.

This condition has two consequences. First, the initial jump due to yaw, which is inversely proportional to C_{M_α}, becomes large. Thus the original direction of the trajectory cannot be adequately controlled. Second, because of high gyroscopic stability with its slow precessional motion, the lift vector changes direction very slowly, resulting in a large amplitude of the helical motion of the center of mass of the shell. Thus the trajectories of these rounds could not be continued within the limited area of the instrumented range. Had the rounds developed high-drag flow, their centers of pressure would have been far enough forward to have assured lower gyroscopic stability and more normal flight.

Thus the abnormal behavior of projectiles with appreciable undercuts can be at least partially explained by this rearward shift of the center of pressure.

Elizabeth R. Dickinson

ELIZABETH R. DICKINSON

REFERENCES

1. Braun, Walter F. The Free Flight Aerodynamics Range. Ballistic Research Laboratories: BRL-R1048, Jul 1958.

2. Murphy, C. H. Data Reduction for the Free Flight Spark Ranges. Ballistic Research Laboratories: BRL-R900, Feb 1954.

3. Schmidt, L. E. The Dynamic Properties of Pure Cones and Cone-Cylinders. Ballistic Research Laboratories: BRL-MR759, Jan 1954.

4. MacAllister, L. C. Comments on the Effect of Punched and Plain Fuze Covers on the Aerodynamic Properties of the 90-mm T91E1 Shell at M = 1.2. Ballistic Research Laboratories: BRL-TN1119, May 1957.

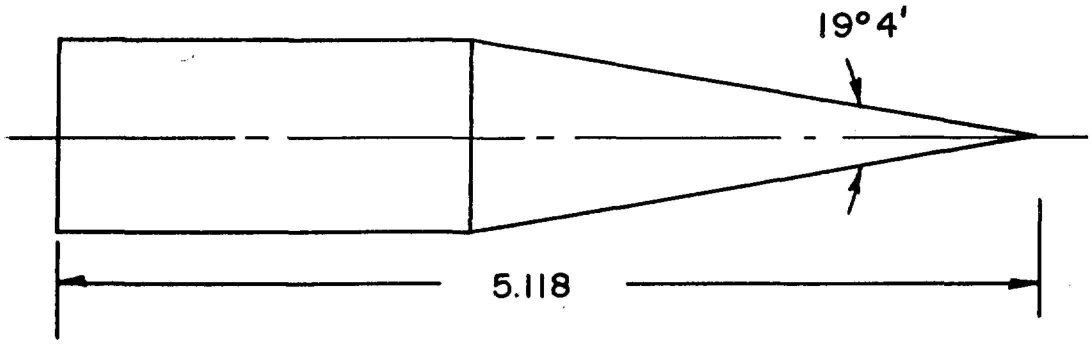
5. Dickinson, Elizabeth R. The Effect of Boattailing on the Drag Coefficient of Cone-Cylinders at Supersonic Velocities. Ballistic Research Laboratories: BRL-MR842, Nov 1954.

6. Platou, A. S. Body Nose Shapes for Obtaining High Static Stability. Ballistic Research Laboratories: BRL-MR592, Feb 1952.

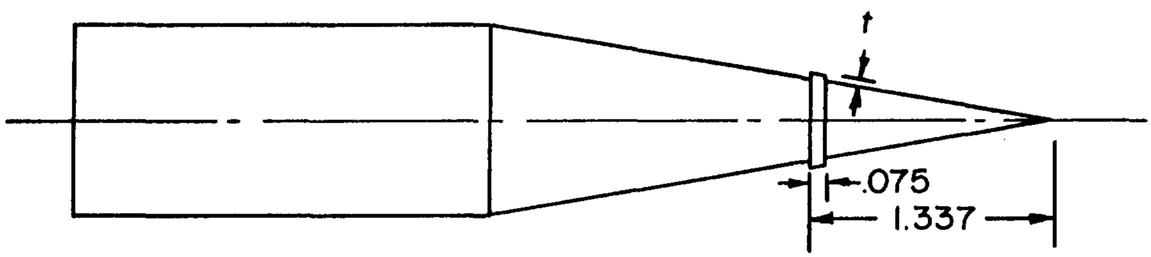
7. Karpov, B. G. and Piddington, M. J. Effect on Drag of Two Stable Flow Configurations Over the Nose Spike of the 90-mm T316 Projectile. Ballistic Research Laboratories: BRL-TN955, Oct 1954.

8. Roschke, E. J. and Piddington, M. J. Drag and Dispersion of Banded Spheres with and without Stings. Ballistic Research Laboratories: BRL-MR995, Apr 1956.

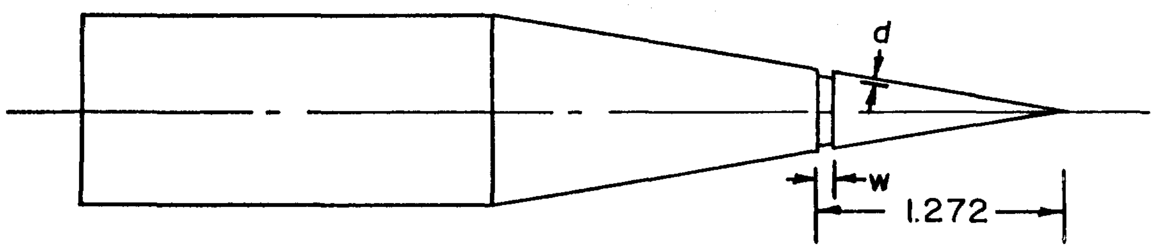
NOSE MODIFICATIONS



BASIC CONE-CYLINDER



RING MODIFICATION   RING THICKNESS (t) VARIED UP TO 0.02 CAL.



GROOVE MODIFICATION   GROOVE DEPTH (d) VARIED UP TO 0.041 CAL.
GROOVE WIDTH (w) VARIED UP TO 0.153 CAL.

NOTE: ALL DIMENSIONS IN CALIBERS

FIG. 1

DRAG COEFFICIENT
vs
NOSE-MODIFCATION PARAMETERS
M=1.72

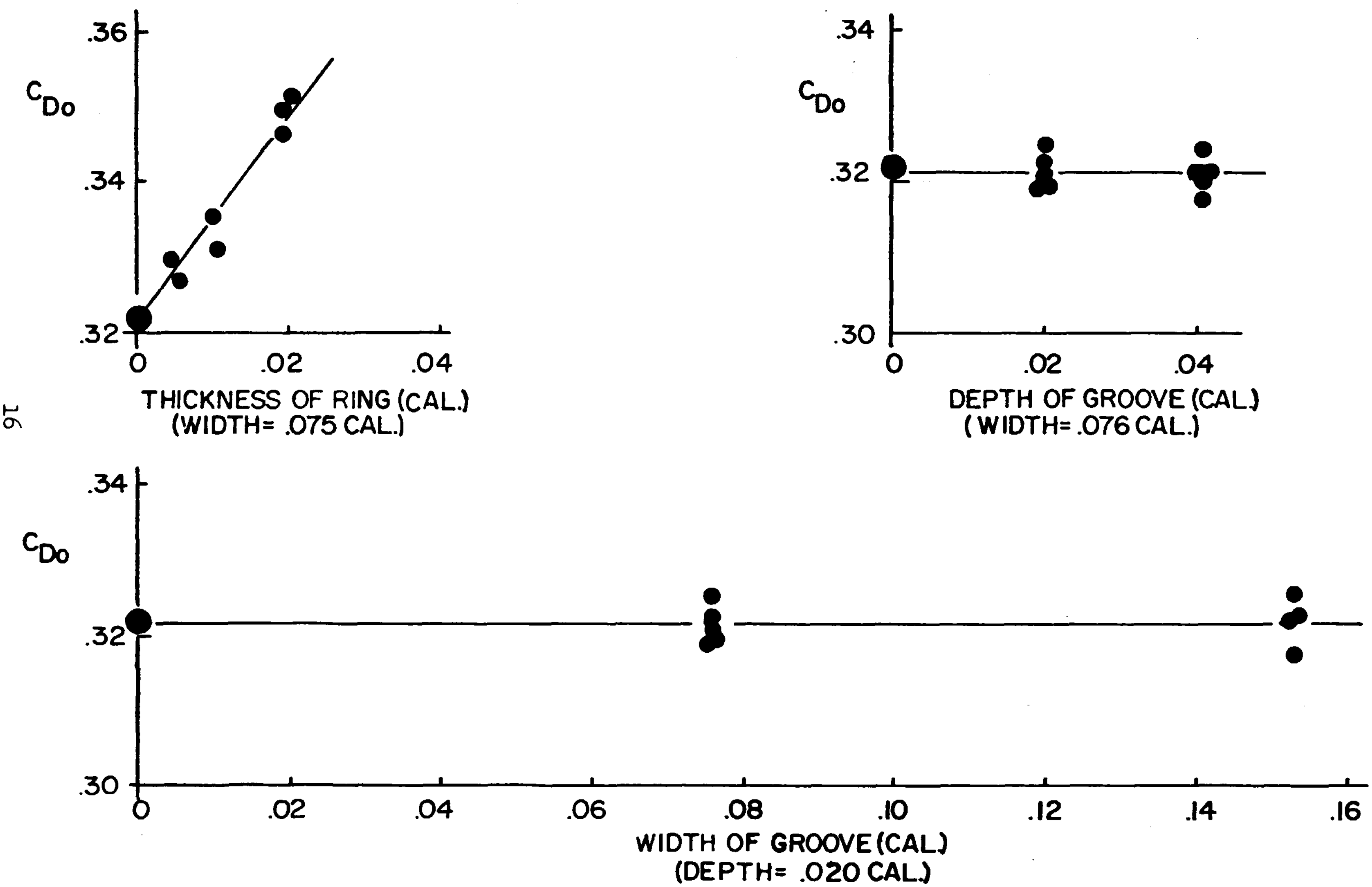
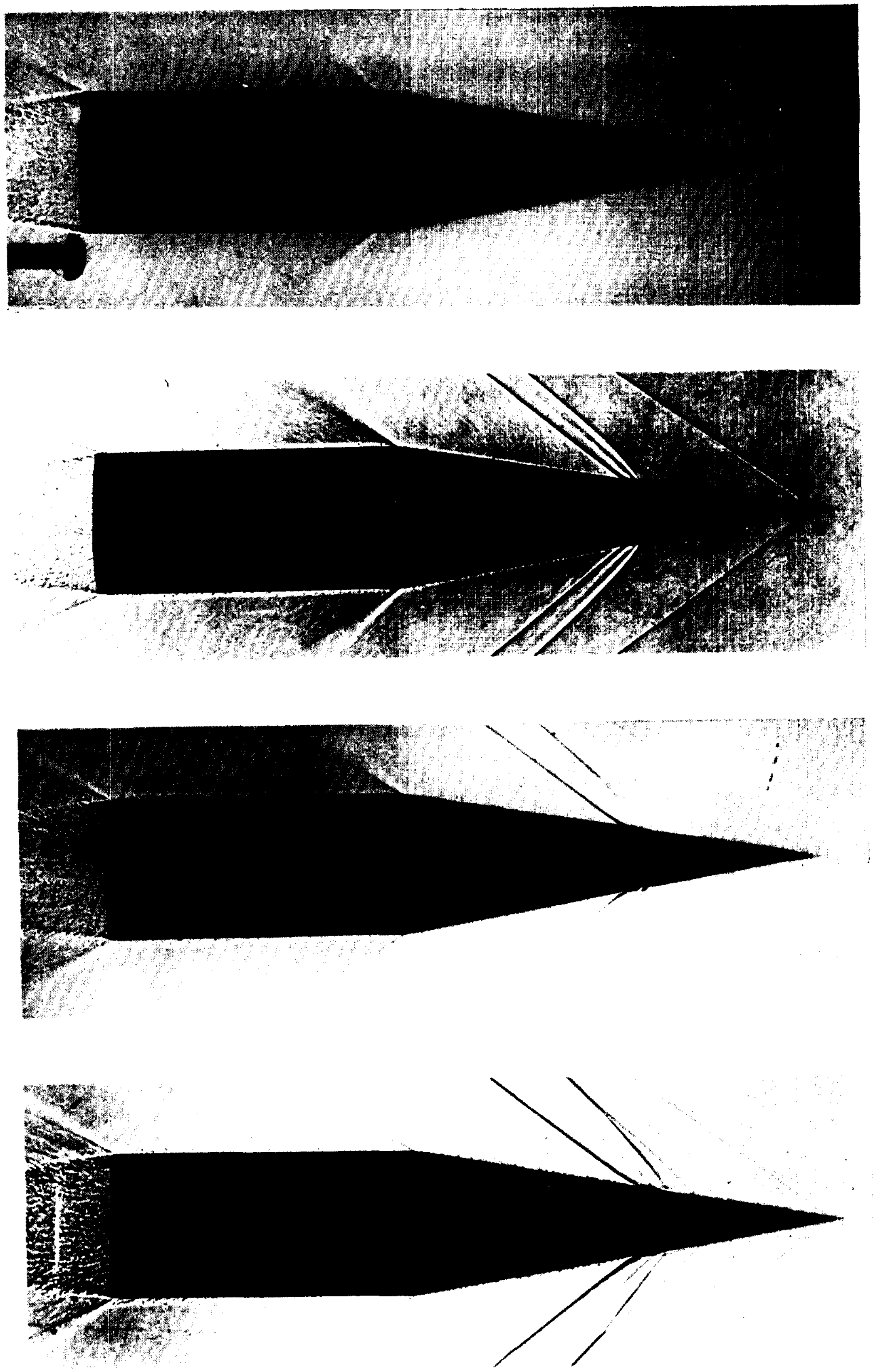


FIG. 2

NOSE MODIFICATIONS: RINGS



Rd. 1730
Basic
Cone-Cylinder

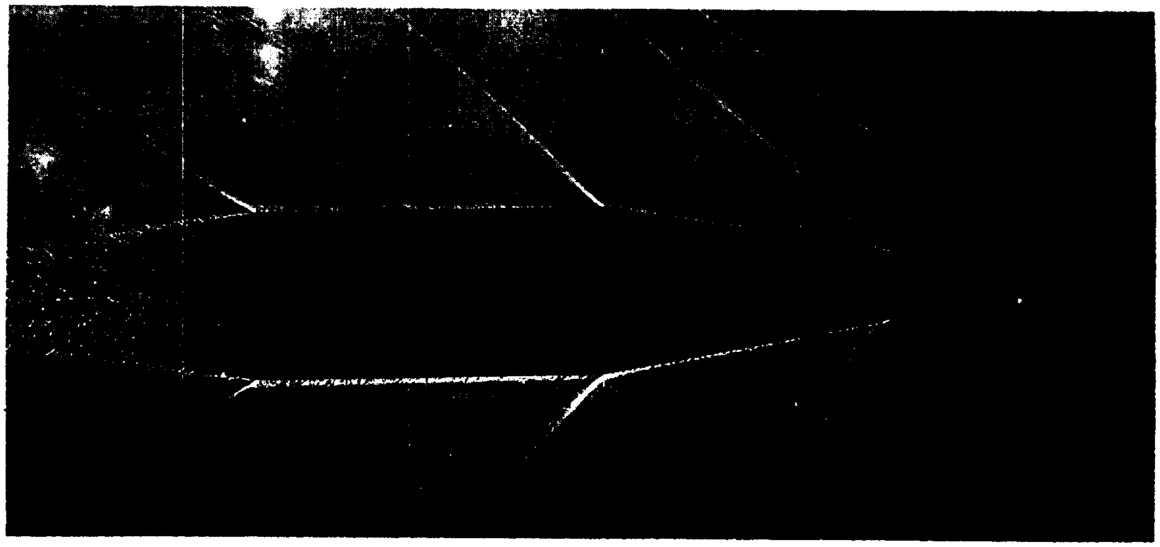
Rd. 1744
t = .005 cal.

Rd. 1742
t = .010 cal.

Rd. 1745
t = .020 cal.

FIG. 3

NOSE MODIFICATIONS: GROOVES



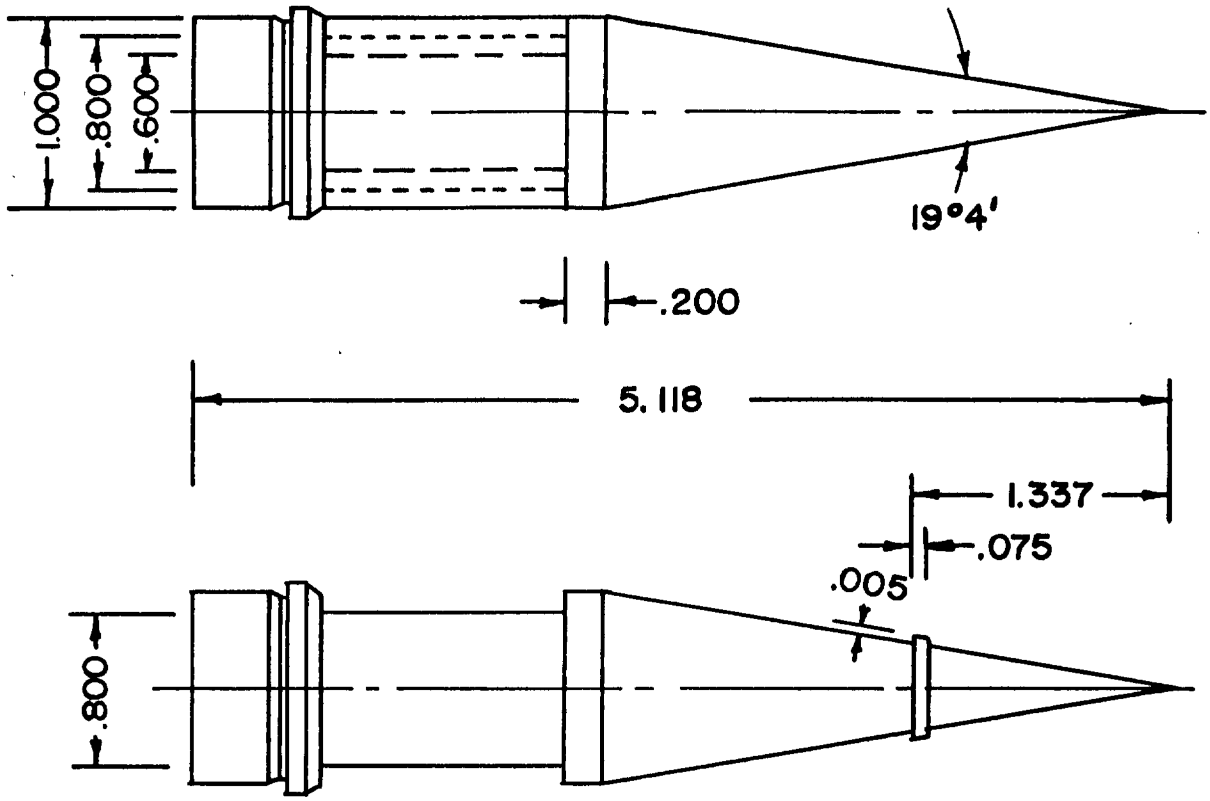
Rd. 4650-30V
d: .020 cal.
w: .153 cal.

Rd. 4656-4V
d: .040 cal.
w: .076 cal.

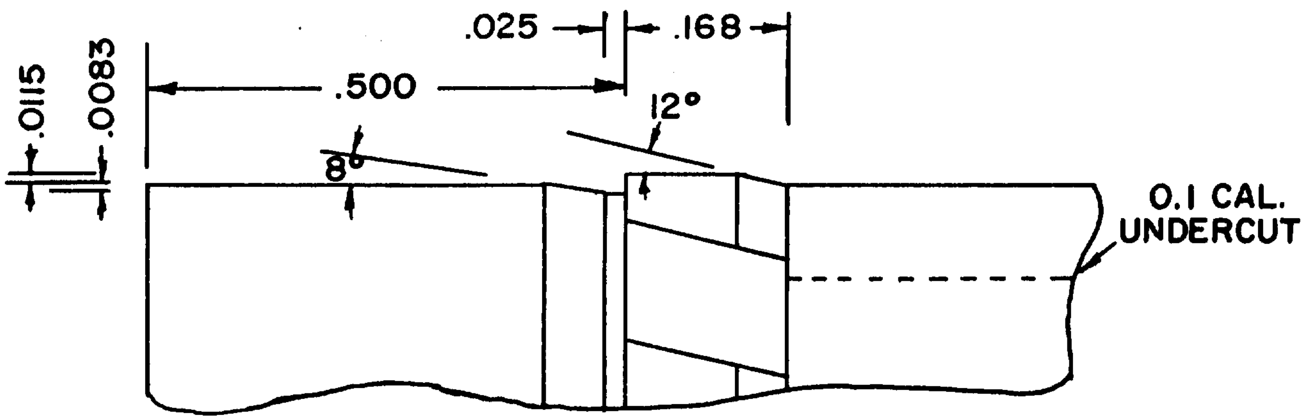
Rd. 4651-3V
d: .020 cal.
w: .076 cal.

FIG. 4

BODY MODIFICATIONS



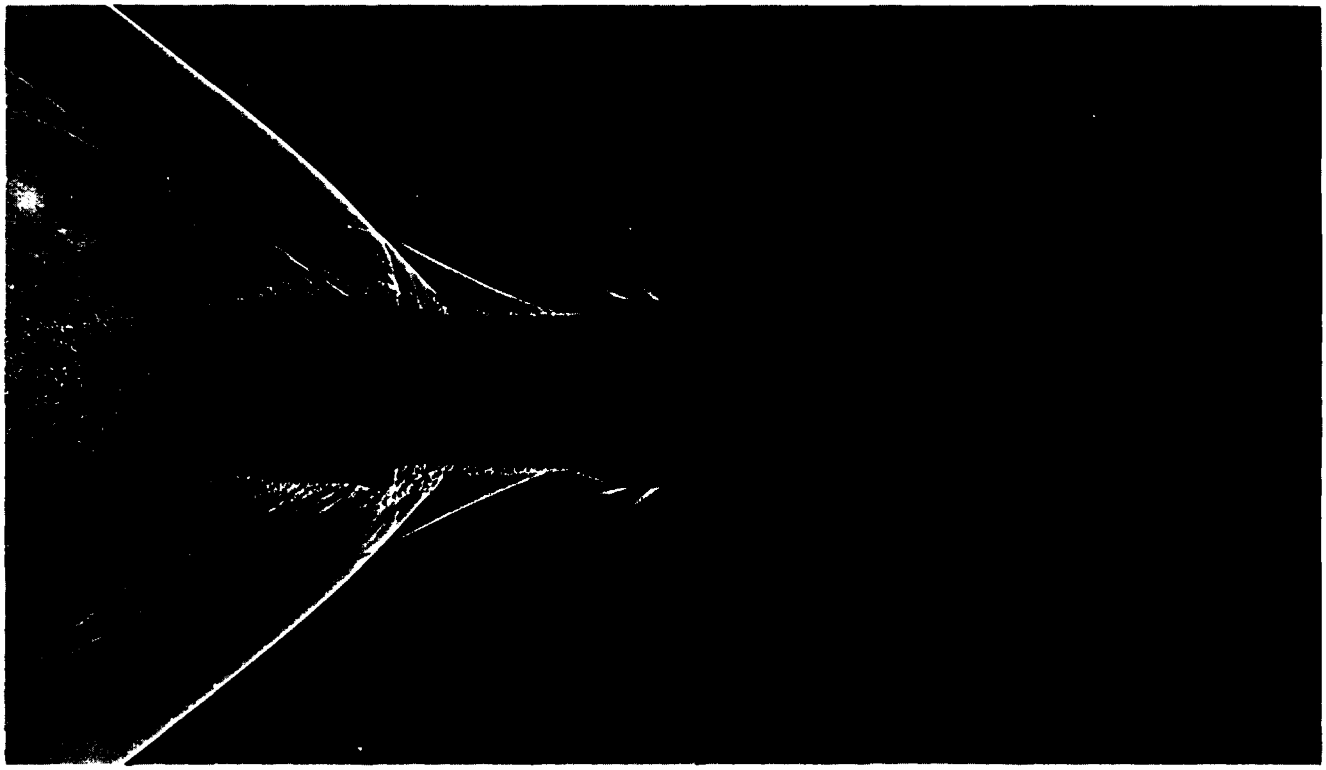
BAND DETAILS



BAND PRE-ENGRAVED: 1/25 TWIST
(9 GROOVES 0.1193 CAL. WIDE)

NOTE: ALL DIMENSIONS IN CALIBERS

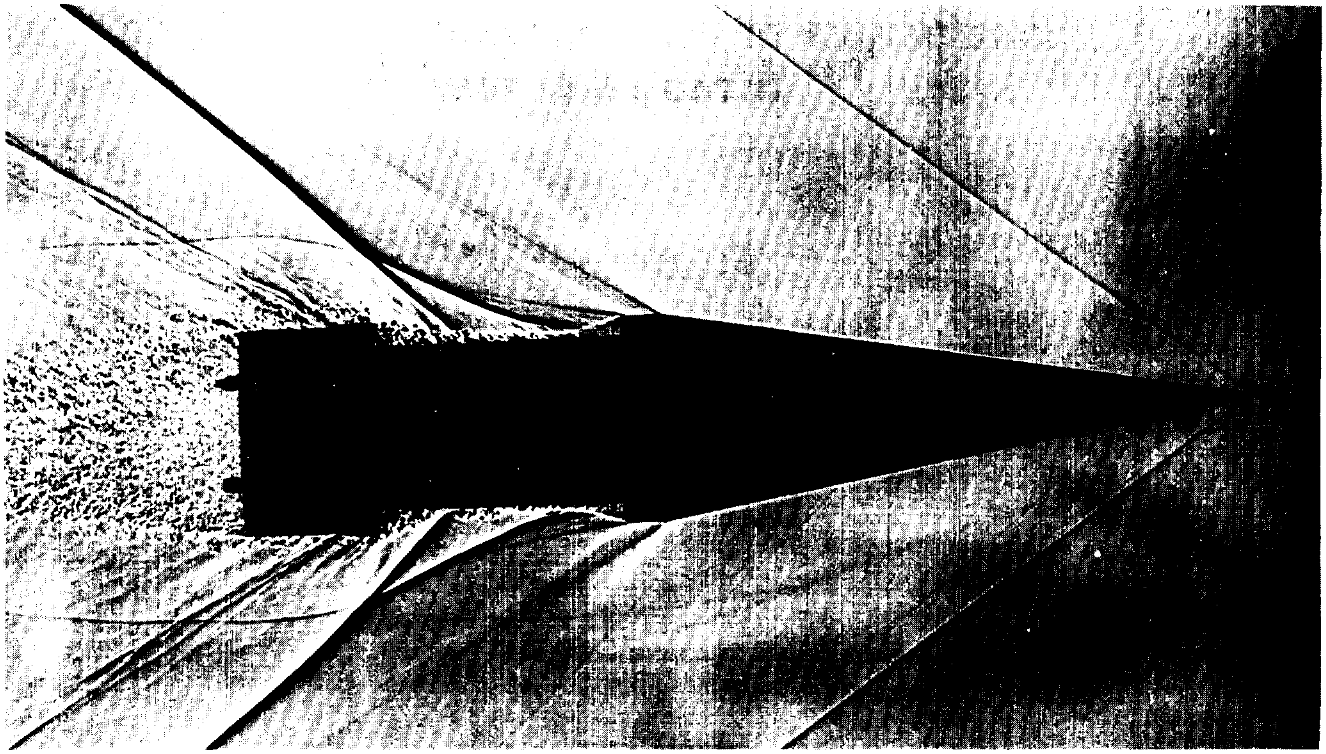
FIG. 5



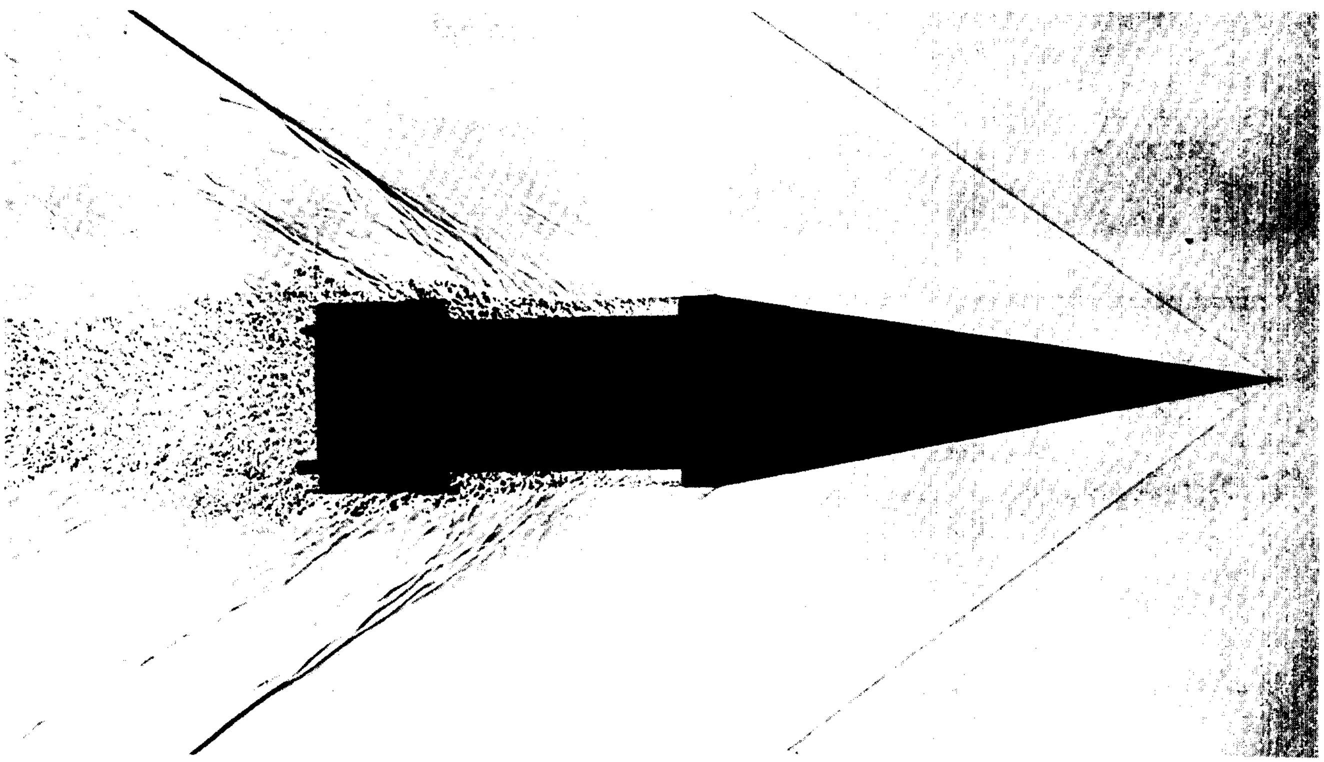
High-drag Flow, 0.1-cal. undercut Plate 26V Rd. 4674 Local M=1.740

Low-drag Flow, 0.1-cal. undercut Plate 28V Rd. 4667 Local M=1.744

FIG. 6



Intermediate-high-drag Flow, 0.1-cal. undercut Plate 30V Rd. 4669 Local M = 1.745



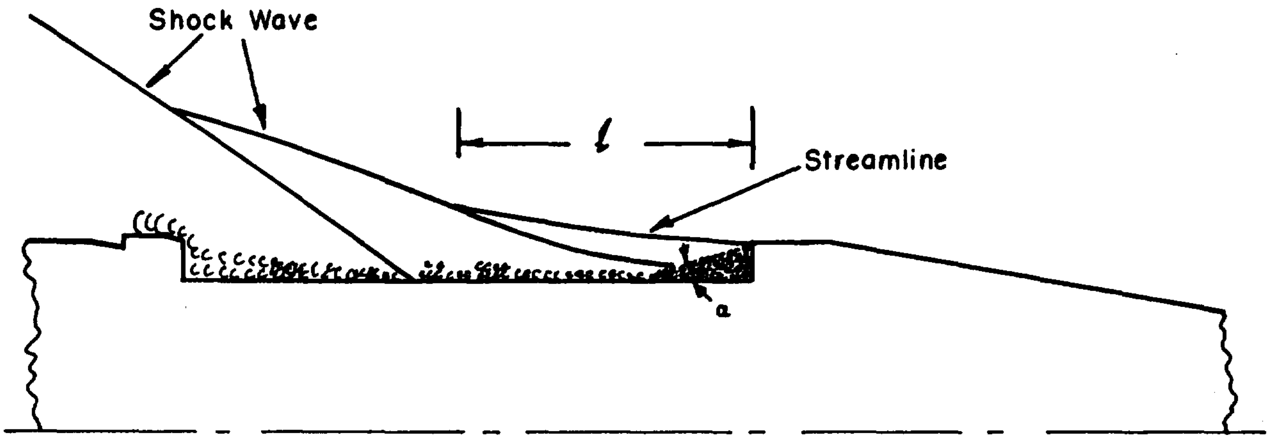
Intermediate-low-drag Flow, 0.1-cal. undercut Plate 42V Rd. 4675 Local M = 1.744

FIG. 7

SOME DETAILS OF FLOW PATTERNS BEHIND CORNER
($1.740 \leq M \leq 1.745$)

C_{D_o} (no undercut) = .328

R_e (at corner) = 2.4×10^6 (M_∞ = 1.74)



	a (av.)	ℓ (av.)	C_{D_o}
Plate 26V Rd. 4674 High-drag flow	−18.75°	.665 cal.	.646
Plate 30V Rd. 4669 Intermediate-high-drag flow	−17.50°	.810 cal.	.639

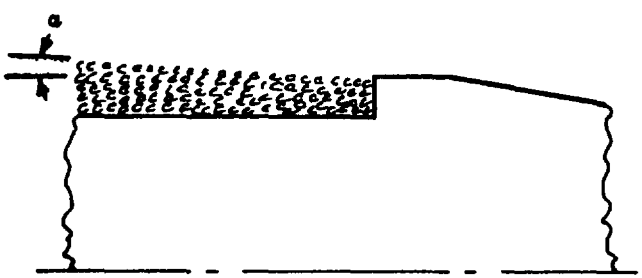


Plate 28V Rd. 4667
Low-drag flow

a (av.) = +2.0°
C_{D_o} = .403

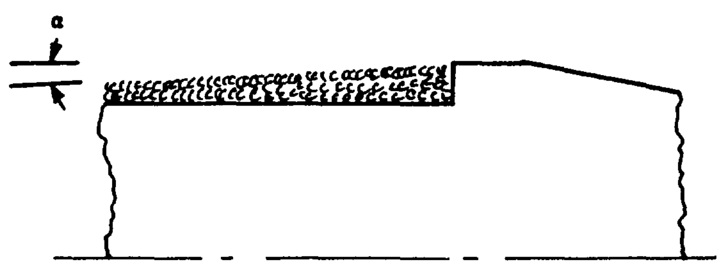
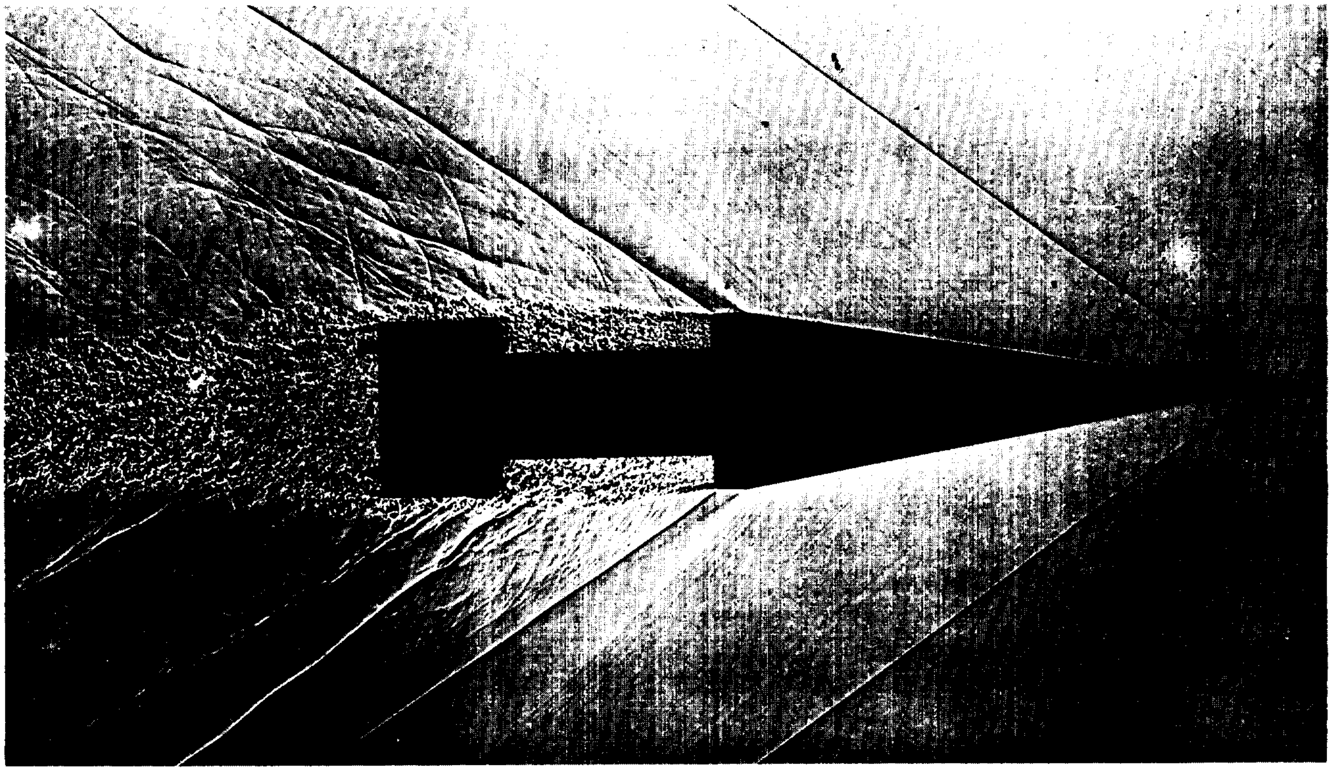


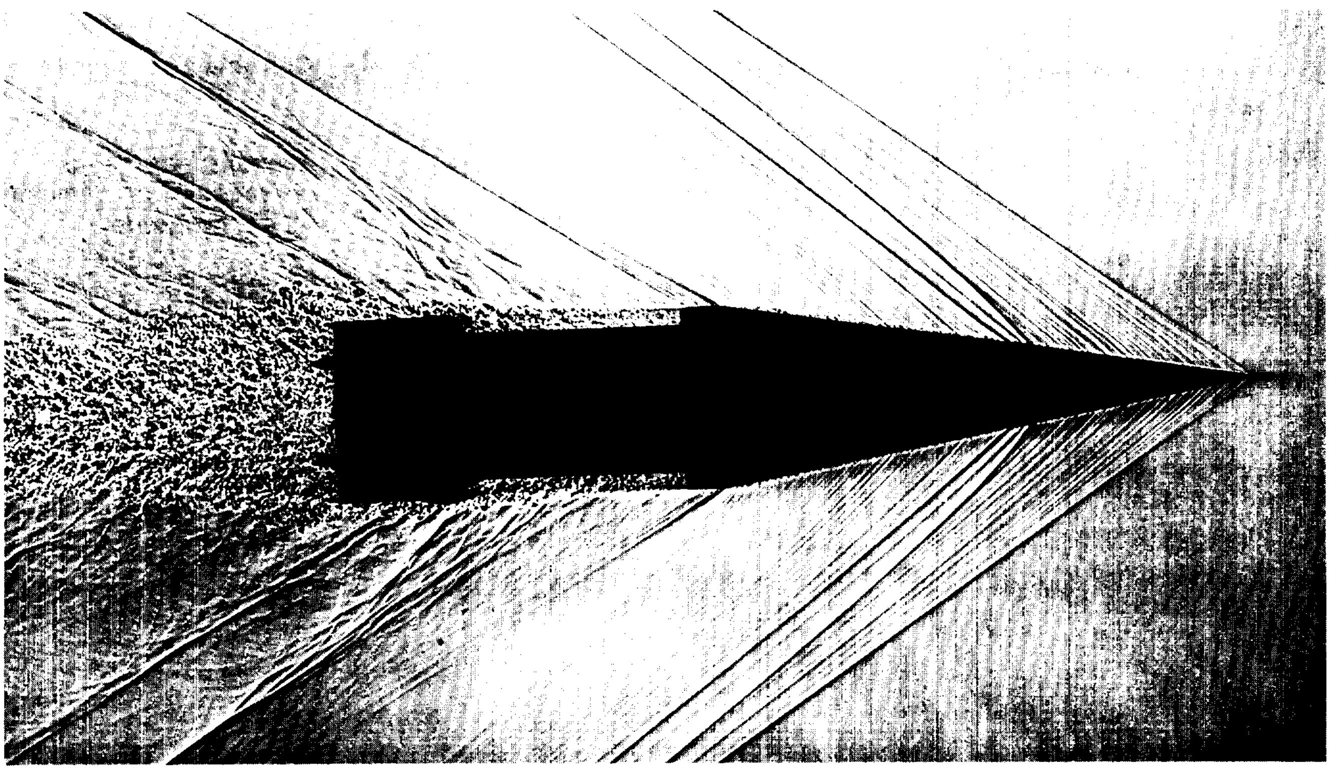
Plate 42V Rd. 4675
Intermediate-low-drag flow

a (av.) = −1.0°
C_{D_o} = .431

FIG. 8



Low-drag Flow, 0.2-cal. undercut Plate 4V Rd. 4666 Local M = 1.750



Low-drag Flow, 0.1-cal. undercut, with Trip-Ring Plate 4V Rd. 5405 Local M = 1.810

FIG. 9

DRAG COEFFICIENT vs DEPTH OF BODY UNDERCUT
M = 1.72

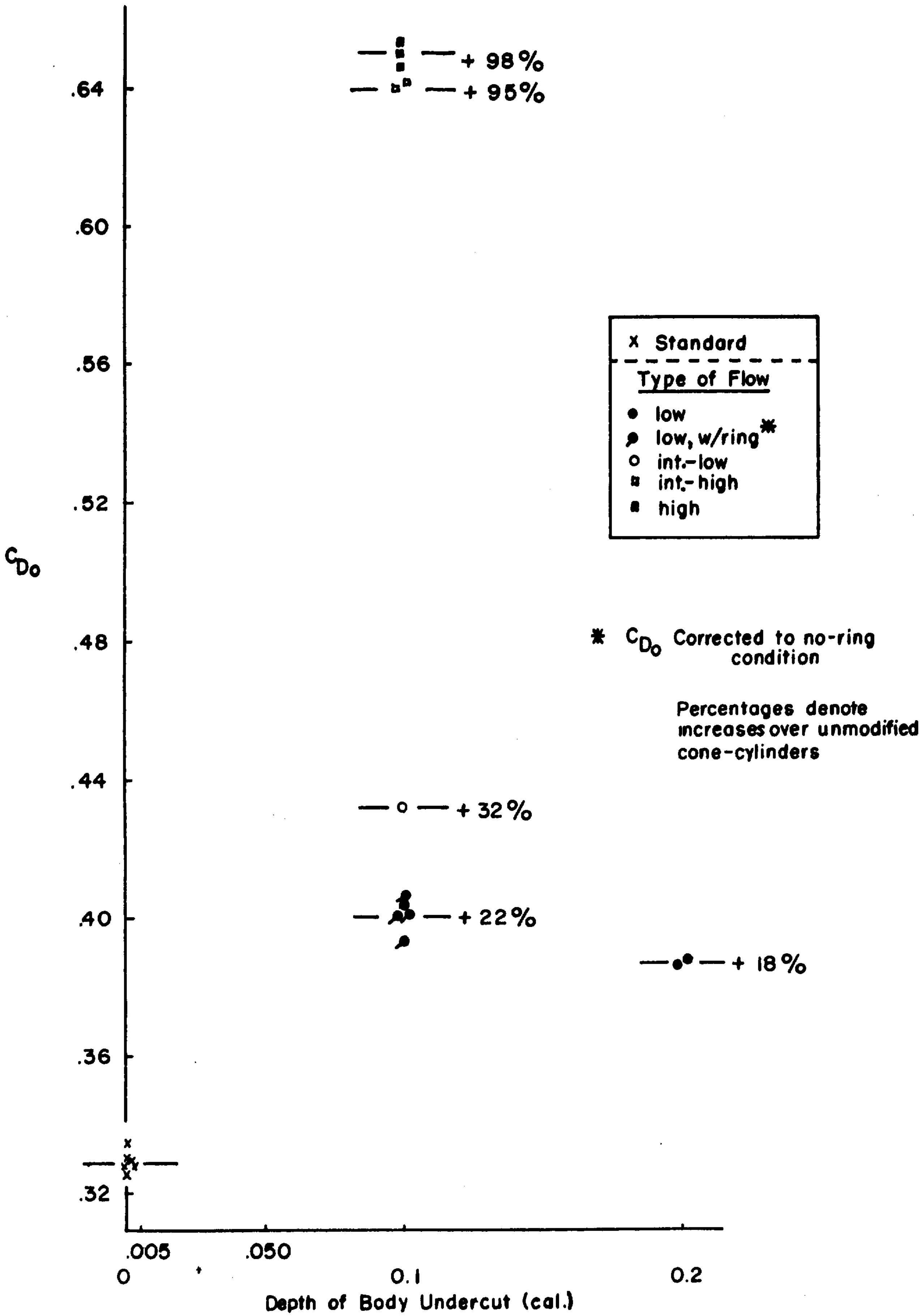


FIG. 10

OVERTURNING MOMENT COEFFICIENT

vs

DEPTH OF BODY UNDERCUT

M= 1.72

c.m. = 1.25 cal. from base

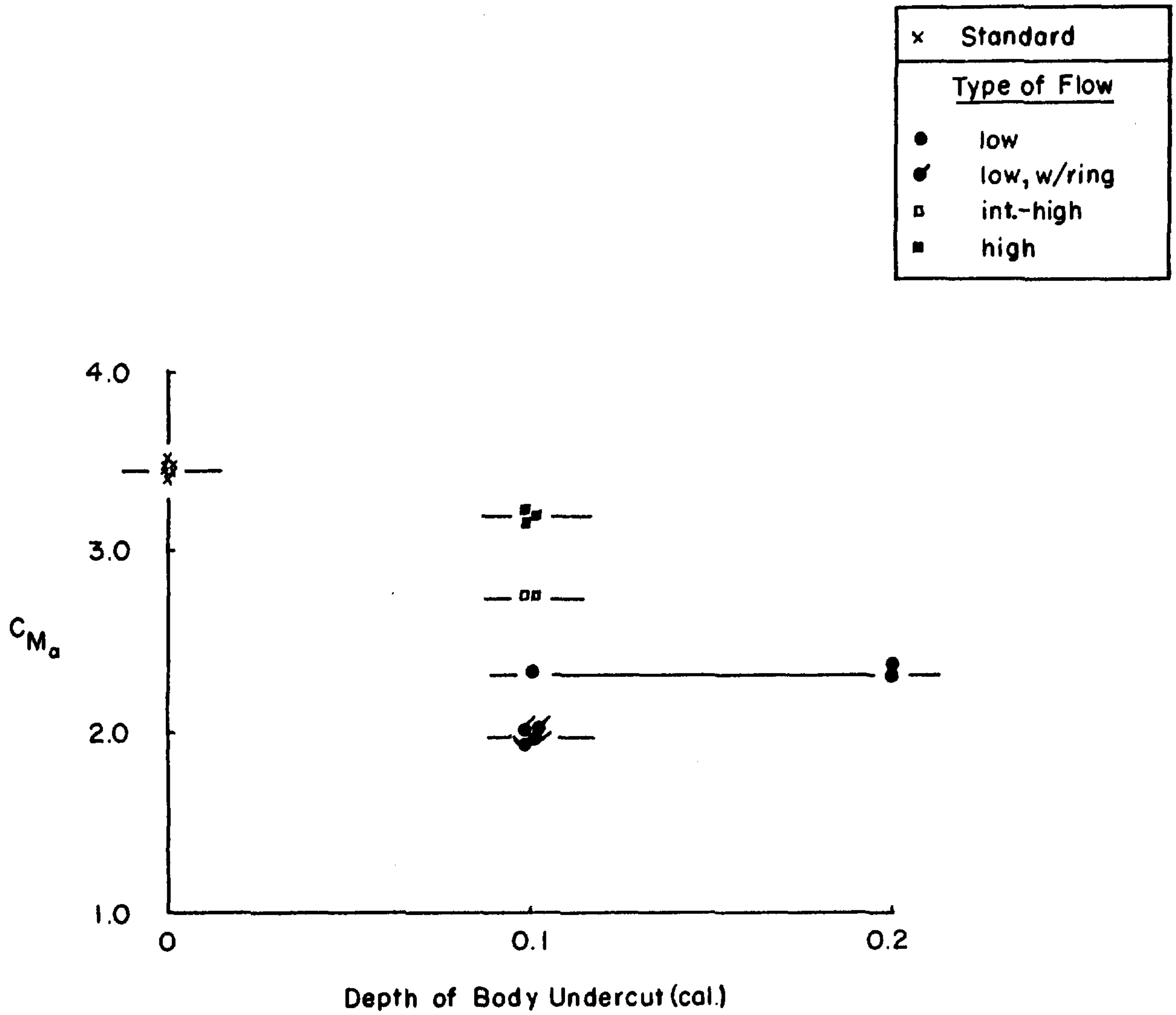


FIG. 11

LIFT COEFFICIENT AND CENTER OF PRESSURE

vs

DEPTH OF BODY UNDERCUT

M= 1.72

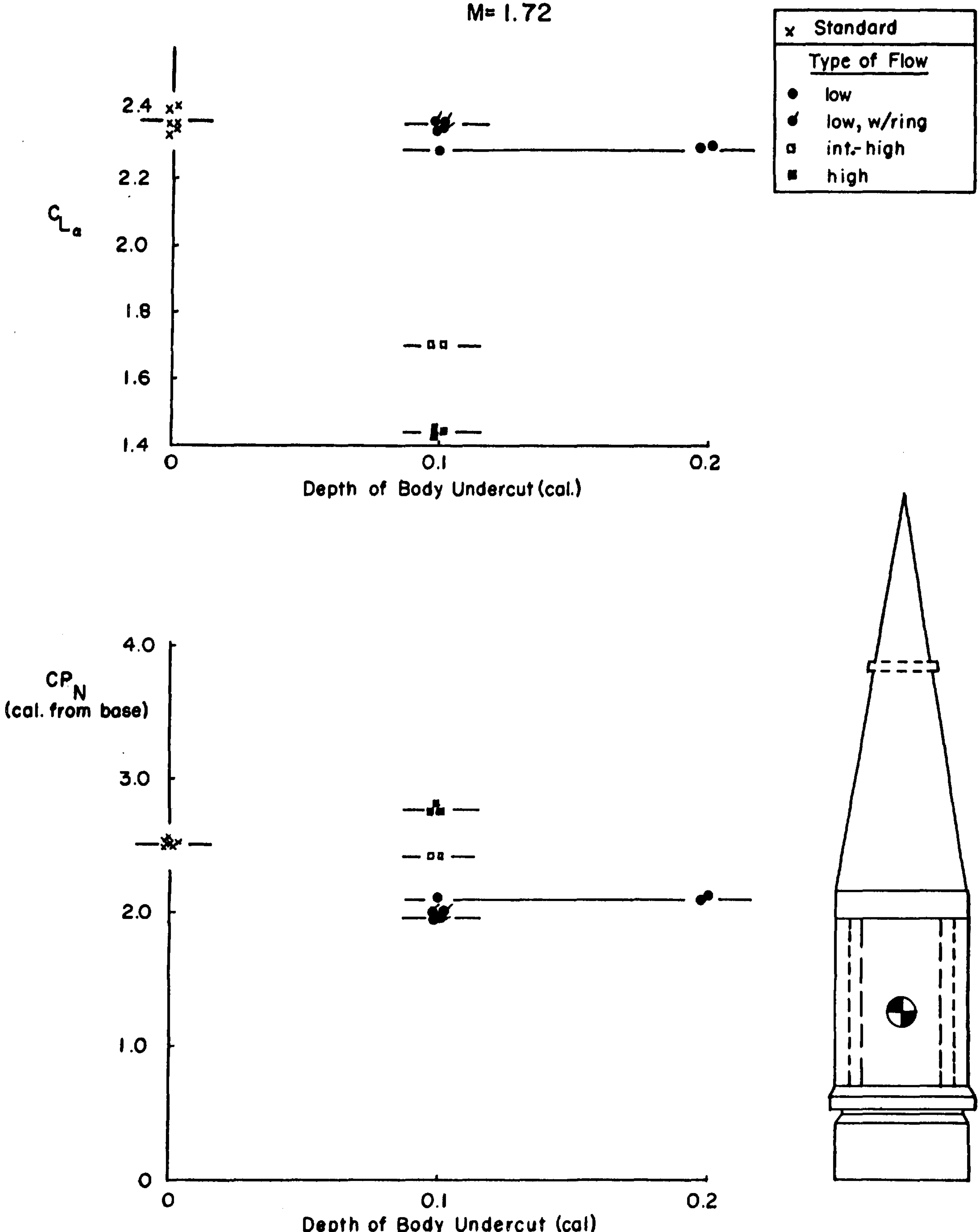


FIG. 12

DISTRIBUTION LIST

No. of Copies	Organization
1	Chief of Ordnance Department of the Army Washington 25, D.C. Attn: ORDTB - Bal Sec
1	Commanding Officer Diamond Ordnance Fuze Laboratories Washington 25, D.C. Attn: ORDTL - 012
10	Commander Armed Services Technical Information Agency Arlington Hall Station Arlington 12, Virginia Attn: TIPCR
10	British Joint Services Mission 1800 K Street, N.W. Washington 6, D.C. Attn: Reports Officer
4	Canadian Army Staff 2450 Massachusetts Avenue Washington 8, D.C.
3	Chief, Bureau of Naval Weapons Department of the Navy Washington 25, D.C. Attn: DIS-33
2	Commander U.S. Naval Weapons Laboratory Dahlgren, Virginia
2	Commander Naval Ordnance Laboratory White Oak Silver Spring 19, Maryland Attn: Mr. Nestinger Dr. May
2	Commander U.S. Naval Missile Center Point Mugu, California
1	Commanding Officer David W. Taylor Model Basin Washington 7, D.C. Attn: Aerodynamics Laboratory
1	Commander U.S. Naval Air Development Center Johnsville, Pennsylvania
1	Commanding Officer U.S. Naval Air Rocket Test Station Lake Denmark Dover, New Jersey
2	Commander U.S. Naval Ordnance Test Station China Lake, California Attn: Technical Library
1	Commander Air Proving Ground Center Eglin Air Force Base, Florida Attn: PGTWR
1	Commander Arnold Engineering Development Center Tullahoma, Tennessee Attn: Deputy Chief of Staff, R&D
1	Commander Wright Air Development Division Wright-Patterson Air Force Base, Ohio Attn: Mr. Otto Walchner Aero Research Laboratory
1	Director National Aeronautics and Space Administration 1520 H Street, N.W. Washington 25, D.C.

DISTRIBUTION LIST

No. of Copies	Organization
2	Director National Aeronautics and Space Administration Ames Research Center Moffett Field, California Attn: Dr. A. C. Charters Mr. H. J. Allen
1	Director National Aeronautics and Space Administration Langley Research Center Langley Field, Virginia
1	Director National Aeronautics and Space Administration Lewis Research Center Cleveland Airport Cleveland, Ohio
1	Commanding General U.S. Army Ordnance Missile Command Redstone Arsenal, Alabama
3	Commanding Officer Picatinny Arsenal Dover, New Jersey Attn: Feltman Research and Engineering Laboratories
2	Commanding General Frankford Arsenal Phialadelphia 37, Pennsylvania Attn: Library Branch, 0270, Bldg. 40 (1 cy)
1	Commanding Officer U.S. Army Chemical Warfare Laboratories Army Chemical Center, Maryland Attn: Engineering Laboratory
1	John J. Glennon, Librarian Institute of the Aeronautical Sciences 2 East 64th Street New York 21, New York
1	Mr. M. H. Smith James Forrestall Research Center Princeton University Princeton, New Jersey
1	Professor George F. Carrier Division of Engineering and Applied Physics Harvard University Cambridge 38, Massachusetts
1	Professor Clark B. Millikan Director, Guggenheim Aeronautical Laboratory California Institute of Technology Pasadena 4, California
1	Dr. A. E. Puckett Systems Development Laboratories Hughes Aircraft Company Culver City, California
1	Dr. L. H. Thomas Watson Scientific Computing Laboratory 612 West 116th Street New York 25, New York
1	Professor Frances H. Clauser, Jr. Chairman, Department of Aeronautics The Johns Hopkins University Baltimore, Maryland

AD ____________ Accession No. ____________ UNCLASSIFIED

Ballistic Research Laboratories, APG
THE EFFECTS OF ANNULAR RINGS AND GROOVES, AND OF BODY UNDERCUTS ON THE AERODYNAMIC PROPERTIES OF A CONE-CYLINDER PROJECTILE AT M = 1.72

Elizabeth R. Dickinson

BRLM Report No. 1284 June 1960

DA Proj. No. 5B03-03-001, OMSC No. 5010.11.814, ORD Proj. No. TB3-0108
UNCLASSIFIED Report

Bodies of revolution - Aerodynamics characteristics
Projectiles - Exterior ballistics
Aerodynamic properties - Projectiles

This report presents the effects, on drag, overturning moment, lift, and center of pressure, of annular rings and grooves on the nose of a cone-cylinder projectile. Also shown are the effects, on the same parameters, of undercuts on the body of the projectile. There is, in addition, a discussion of the four types of flow which developed over the undercut bodies.

AD ____________ Accession No. ____________ UNCLASSIFIED

Ballistic Research Laboratories, APG
THE EFFECTS OF ANNULAR RINGS AND GROOVES, AND OF BODY UNDERCUTS ON THE AERODYNAMIC PROPERTIES OF A CONE-CYLINDER PROJECTILE AT M = 1.72

Elizabeth R. Dickinson

BRLM Report No. 1284 June 1960

DA Proj. No. 5B03-03-001, OMSC No. 5010.11.814, ORD Proj. No. TB3-0108
UNCLASSIFIED Report

Bodies of revolution - Aerodynamics characteristics
Projectiles - Exterior ballistics
Aerodynamic properties - Projectiles

This report presents the effects, on drag, overturning moment, lift, and center of pressure, of annular rings and grooves on the nose of a cone-cylinder projectile. Also shown are the effects, on the same parameters, of undercuts on the body of the projectile. There is, in addition, a discussion of the four types of flow which developed over the undercut bodies.

AD ____________ Accession No. ____________ UNCLASSIFIED

Ballistic Research Laboratories, APG
THE EFFECTS OF ANNULAR RINGS AND GROOVES, AND OF BODY UNDERCUTS ON THE AERODYNAMIC PROPERTIES OF A CONE-CYLINDER PROJECTILE AT M = 1.72

Elizabeth R. Dickinson

BRLM Report No. 1284 June 1960

DA Proj. No. 5B03-03-001, OMSC No. 5010.11.814, ORD Proj. No. TB3-0108
UNCLASSIFIED Report

Bodies of revolution - Aerodynamics characteristics
Projectiles - Exterior ballistics
Aerodynamic properties - Projectiles

This report presents the effects, on drag, overturning moment, lift, and center of pressure, of annular rings and grooves on the nose of a cone-cylinder projectile. Also shown are the effects, on the same parameters, of undercuts on the body of the projectile. There is, in addition, a discussion of the four types of flow which developed over the undercut bodies.

AD ____________ Accession No. ____________ UNCLASSIFIED

Ballistic Research Laboratories, APG
THE EFFECTS OF ANNULAR RINGS AND GROOVES, AND OF BODY UNDERCUTS ON THE AERODYNAMIC PROPERTIES OF A CONE-CYLINDER PROJECTILE AT M = 1.72

Elizabeth R. Dickinson

BRLM Report No. 1284 June 1960

DA Proj. No. 5B03-03-001, OMSC No. 5010.11.814, ORD Proj. No. TB3-0108
UNCLASSIFIED Report

Bodies of revolution - Aerodynamics characteristics
Projectiles - Exterior ballistics
Aerodynamic properties - Projectiles

This report presents the effects, on drag, overturning moment, lift, and center of pressure, of annular rings and grooves on the nose of a cone-cylinder projectile. Also shown are the effects, on the same parameters, of undercuts on the body of the projectile. There is, in addition, a discussion of the four types of flow which developed over the undercut bodies.