AD-750 872

WIND TUNNEL TESTS OF MODIFIED BLU-87/B FRAGMENTATION BOMBS

Mark O. Schlegel

Air Force Armament Laboratory
Eglin Air Force Base, Florida

July 1972

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AD 750872

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
Guns and Rockets Division
Air Force Armament Laboratory
Eglin Air Force Base, Florida 32542

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP
N/A

3. REPORT TITLE
WIND TUNNEL TESTS OF MODIFIED BLU-87/B FRAGMENTATION BOMBS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final Report (March - April 1972)

5. AUTHOR(S) (First name, middle initial, last name)
Mark O. Schlegel, Captain, USAF

6. REPORT DATE
July 1972

7a. TOTAL NO. OF PAGES
35

7b. NO. OF REFS
3

8a. CONTRACT OR GRANT NO.

b. PROJECT NO
5974

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
AFATL-TR-72-132

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES
Available in DDC

12. SPONSORING MILITARY ACTIVITY
Air Force Armament Laboratory
Air Force Systems Command
Eglin Air Force Base, Florida

13. ABSTRACT

This report presents wind tunnel static and free oscillation aerodynamic data on the BLU-87/B fragmentation bomb for the standard and 11 modified configurations. The tests were conducted to obtain increased dispersion of the BLU-87/B bomb. The bomb was modified to obtain an S-shaped pitching-moment curve where the bomb trims at a non-zero angle of attack. This incidence produces a lift force which increases the amount of dispersion as compared to dispersion from ram air only. Modifications were developed which produced trim angles of ±14 to 16 degrees and a lift force coefficient of 0.36 to 0.40 at trim. These modifications consisted of adding various radii nose caps to the standard flat nose and decreasing the ringtail diameter from 4.555 inches to 3.500 inches and the ringtail chord from 2.815 inches to 1.875 inches. Computer trajectory predictions indicate that for typical function conditions (1000 ft/sec, 80 degree dive, 2000 feet slant range), the modified submunitions will produce an impact pattern of 200 to 350 feet diameter.

Details of illustrations in this document may be better studied on microfiche

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
BLU-87/B Fragmentation Bomb						
Wind Tunnel Tests						
Computer Trajectory Predictions						

Wind Tunnel Tests of Modified BLU-87/B Fragmentation Bombs

Mark O. Schlegel, Captain, USAF

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FOREWORD

This report contains aerodynamic data from wind tunnel tests of the BLU-87/B fragmentation bomb conducted from March to April 1972. The tests were conducted by the Gun Range Operations Branch, Guns and Rockets Division, at the Ballistic Aerodynamics Research System (BARS) Facility, Test Area A22, Air Force Armament Laboratory, Eglin Air Force Base, Florida.

This technical report has been reviewed and is approved.

DALE M. DAVIS
Acting Chief, Guns and Rockets Division

ABSTRACT

This report presents wind tunnel static and free oscillation aerodynamic data on the BLU-87/B fragmentation bomb for the standard and 11 modified configurations. The tests were conducted to obtain increased dispersion of the BLU-87/B bomb. The bomb was modified to obtain an S-shaped pitching-moment curve where the bomb trims at a non-zero angle of attack. This incidence produces a lift force which increases the amount of dispersion as compared to dispersion from ram air only. Modifications were developed which produced trim angles of ±14 to 16 degrees and a lift force coefficient of 0.36 to 0.40 at trim. These modifications consisted of adding various radii nose caps to the standard flat nose and decreasing the ringtail diameter from 4.555 inches to 3.500 inches and the ringtail chord from 2.815 inches to 1.875 inches. Computer trajectory predictions indicate that for typical function conditions (1000 ft/sec, 80 degree dive, 2000 feet slant range), the modified submunitions will produce an impact pattern of 200 to 350 feet diameter.

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LIST OF ABBREVIATIONS AND SYMBOLS

C_A	Axial-force coefficient, measured axial force/$q_\infty S$
C_D	Drag-force coefficient, measured drag force/$q_\infty S$
C_{D_t}	Drag-force coefficient, at trim, i.e., $C_m = 0$
C_L	Lift-force coefficient, measured lift force/$q_\infty S$
C_{L_α}	Lift-force curve slope, measured $d(C_L)/d\alpha$
C_{L_t}	Lift-force coefficient at trim, i.e., $C_m = 0$
C_m	Pitching-moment coefficient, measured pitching moment/$q_\infty Sd$
C_{m_α}	Pitching-moment curve slope, measured $d(C_m)/d\alpha$
C_N	Normal-force coefficient, measured normal force/$q_\infty S$
d	Model body diameter (reference diameter), 0.381 ft
M_∞	Free-stream Mach number
q_∞	Free-stream dynamic pressure, psf
Re/1	Reynolds number per foot
Re	Reynolds number
S	Model cross-sectional area (reference area), 0.114 ft^2
α	Model angle of attack with respect to velocity vector, deg
α_t	Model angle of attack at trim, i.e., $C_m = 0$

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SECTION I

INTRODUCTION

A series of wind tunnel tests of the standard and modified BLU-87/B fragmentation bomb was conducted. Utilizing the standard BLU-87/B submuntions, which trim at zero angle of attack, with normal function conditions an impact pattern of about 100 to 150 feet diameter is produced. It is desired to increase this pattern diameter to about 300 feet without increasing the function slant range.

One technique is the use of a trim angle of attack generated by a highly nonlinear aerodynamic restoring moment characteristic (S-curve moment variation)(Reference 1). This S-curve moment variation provides an unstable restoring moment at small angles of attack and a stable pitching moment slope at a large trim angle of attack. The lift force resulting from this large trim angle of attack causes the trajectory to deflect, thereby providing the desired dispersion.

The proper nonlinear restoring moment characteristics are determined by the geometry of the bomb and its center-of-gravity position. In this case, it was desired to leave the bomb case and fuzing assembly unchanged so as to utilize existing off-the-shelf hardware. This precluded any radical change of center-of-gravity (CG) position. The possible geometric variables were to (1) change the ringtail and (2) add a nose cap to the front of the case.

The tests examined the effect of shortening the ringtail moment arm, decreasing the size of the ringtail, adding ogive and hemispherical nose caps, and combinations of reduced ringtail size and nose caps.

The tests were conducted in the subsonic wind tunnel at the Air Force Armament Laboratory (AFATL). Data were obtained at a Mach number of 0.18 (200 ft/sec) at angles of attack from -10 to 30 degrees.

References 2 and 3 discuss the aerodynamic and static stability characteristics of models used in other wind tunnel tests.

SECTION II

APPARATUS

1. TEST FACILITY

The AFATL subsonic wind tunnel is a continuous-flow, nonreturn wind tunnel capable of being operated at velocities of up to 230 ft/sec. The velocity is controlled by varying the inlet area of the centrifugal compressor. The compressor is powered by a 150 horsepower, 440 volt, 3-phase electric motor. The total temperature is the same as the total temperature of free air at the facility site. The test section is 28 inches high, 40 inches wide, and 66 inches long with Plexiglas walls for viewing. The general arrangement of the tunnel and its associated equipment is shown in Figure 1.

2. TEST ARTICLE

The model was a full-scale BLU-87/B empty bomb. The BLU-87/B is a symmetrical body of revolution with a ringtail attached to an extendable tail boom. Due to the requirement that any successful modification would use off-the-shelf components of the present BLU-87/B, the following guidelines were used:

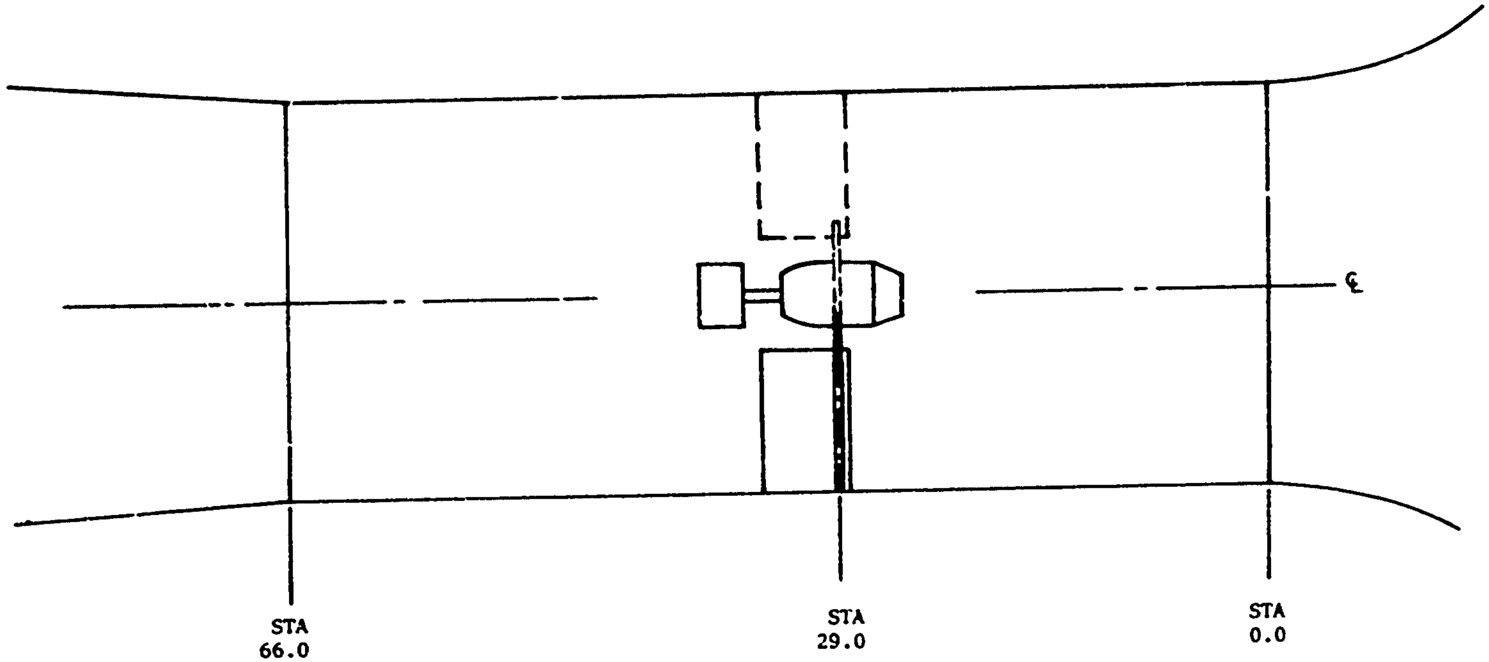
a. The fragmentation case must be unchanged.

b. The standard impact fuze must be used.

c. The tail boom length must be unchanged to prevent any changes in the fuze arming technique.

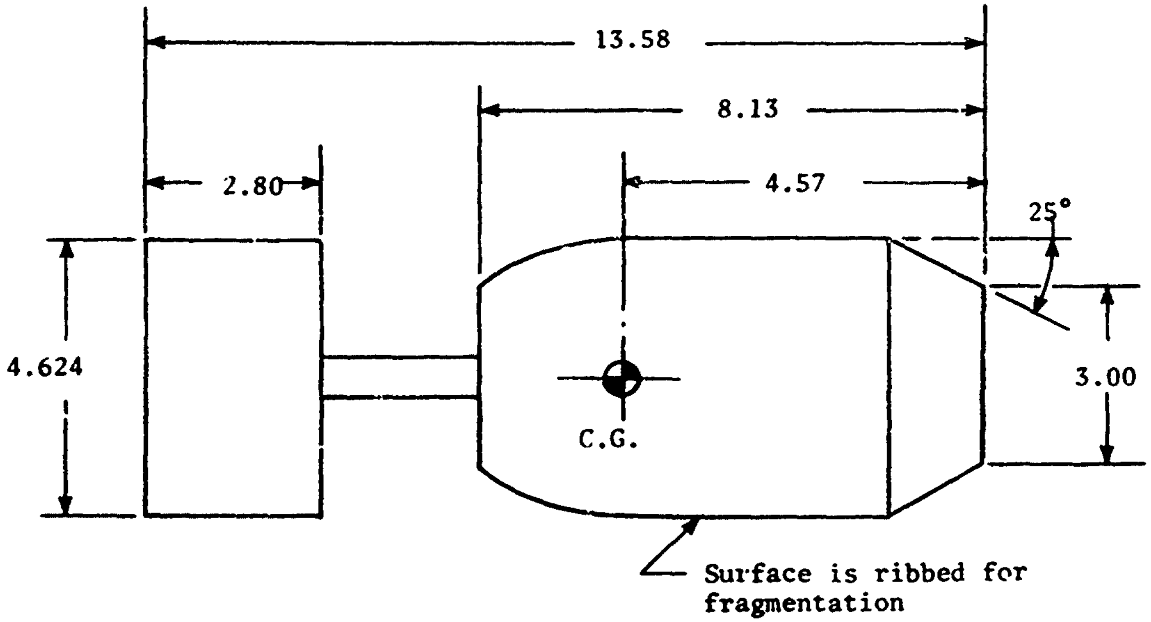
These requirements narrowed the choice of geometric modifications to the ringtail and/or a nose cap over the fuze installed in the truncated conical nose of the bomb. The CG position was assumed to remain unchanged. This was considered valid due to the light weight of any plastic nose cap or ringtail change as compared to the weight of the loaded fragmentation case.

The BLU-87/B was tested with the standard ringtail in the standard position, as well as 1, 2, and 3 inches forward of the standard position. Tails of 3.5 inch diameter and two different chord lengths were tested both as individual modifications and combined with spherical nose caps of three different radii and a modified ogive nose. The tunnel blockage at zero angle of attack was 1.5 percent. Details of the model components are shown in Figures 2 and 3, and typical model installations in the tunnel are shown in Figure 4.



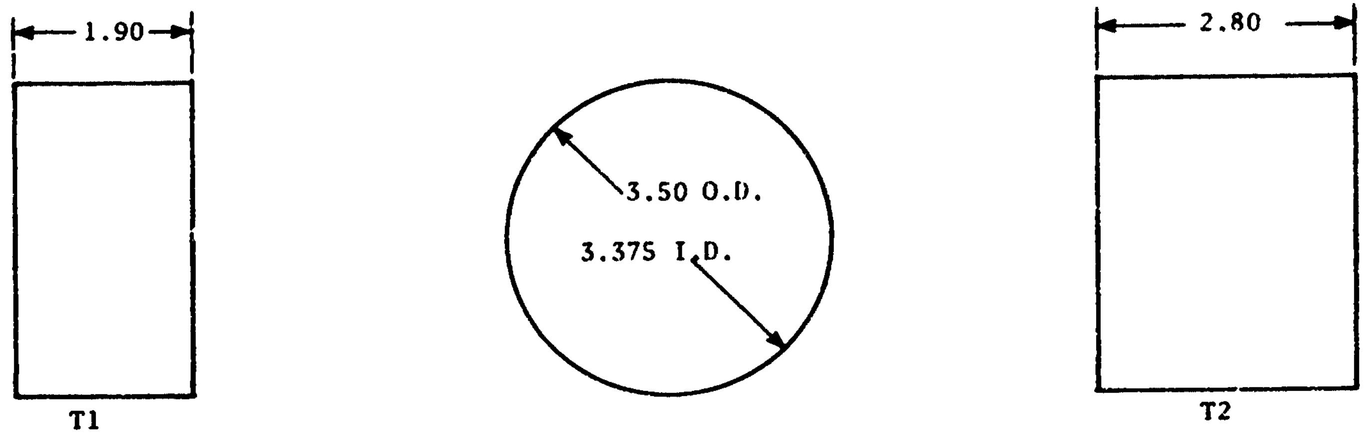
NOTE: TUNNEL STATIONS AND DIMENSIONS IN INCHES

Figure 1. Schematic of Tunnel Installation for Static Force Test

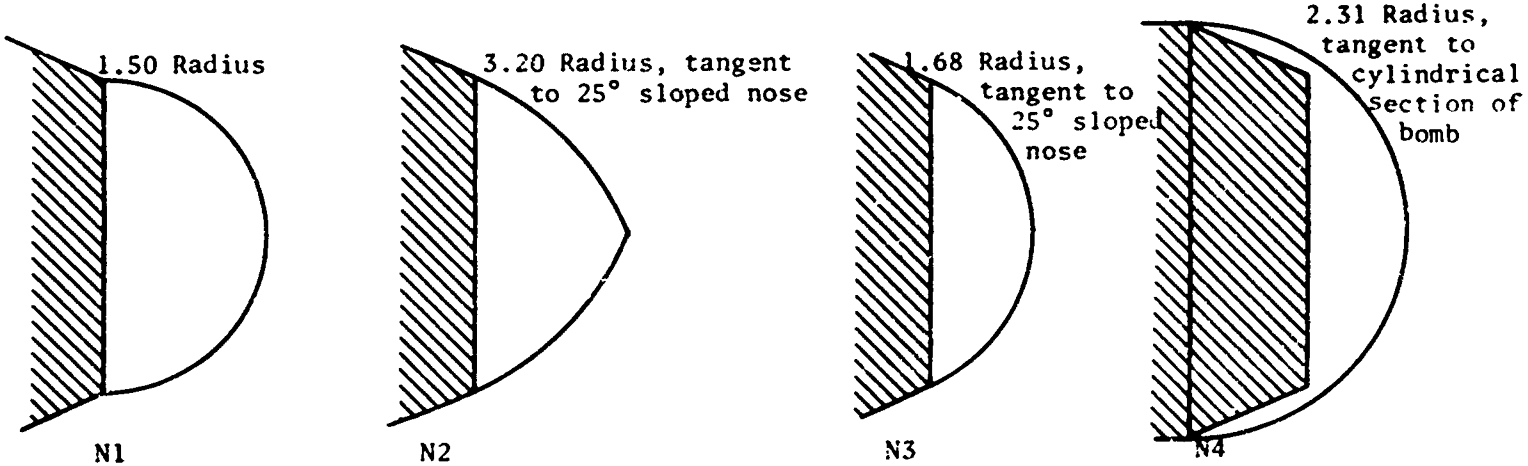


NOTE: EXCEPT AS INDICATED, ALL DIMENSIONS IN INCHES

Figure 2. Details and Dimensions of BLU-87/B



a. Ringtails (both utilize same cross-section)

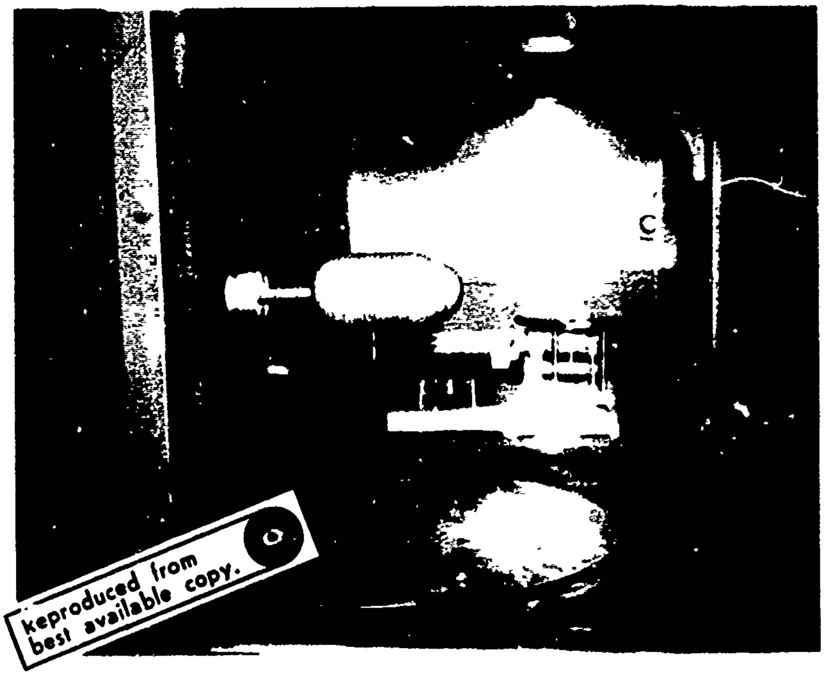


b. Nose Caps

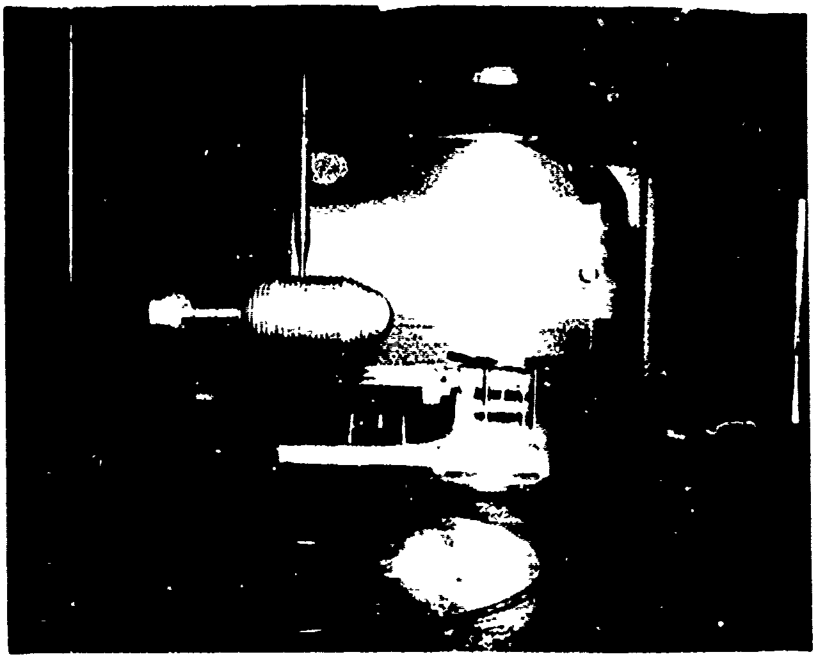
NOTE: ALL DIMENSIONS IN INCHES

N5 IS THE STANDARD NOSE.

Figure 3. Details and Dimensions of Nose and Tail Modifications



a. Static Test Installation



b. Dynamic Test Installation

Figure 4. Photographs of Tunnel Installation

3. INSTRUMENTATION

The static aerodynamic loads on the model were measured with a six-component, external, pyramidal, strain-gage balance. Only three components (drag and side forces and yawing moment) were used. The model was mounted by a transverse sting at the moment reference center. Tare and interference corrections were made by using an image strut and fairing. The image strut was attached to the model and extended into the image fairing.

The free-oscillation tests were conducted with a transverse sting mounted at the model moment reference center. The sting was free to rotate in the yaw plane by ball bearings in the mounting base. These tests consisted of only observing the model trim angle, which provided supporting data for the static force and moment data.

SECTION III

TEST DESCRIPTION

1. TEST PROCEDURES AND CONDITIONS

Static force and moment data were obtained at angles of attack from -10 to 30 degrees. The angles of attack were corrected for zero shift by using a combination of pitching moment and lift force being zero at the true zero angle of attack. (NOTE: Although the data were obtained by rotating the model in the yaw plane, the side force and yawing moment are referred to as lift force and pitching moment, respectively.) Both the static and free-oscillation tests were conducted at a velocity of 200 ft/sec (Mach 0.18). Tunnel air density and temperature were determined and equal to that of atmospheric air at the tunnel inlet. Reynolds numbers per unit length were 1.23 to 1.27×10^6 per foot and Reynolds numbers were 0.469 to 0.484×10^6.

The axial location of the moment reference center was 4.57 inches aft of the nose of the fragmentation case.

2. PRECISION OF MEASUREMENTS

The estimated uncertainties which can be attributed to instrumentation errors and data acquisition techniques are:

$$\Delta C_L = \pm 0.025$$

$$\Delta C_D = \pm 0.025$$

$$\Delta C_m = \pm 0.025$$

For this test article, the C_m values were non-symmetric for plus and minus angles of attack. This is primarily due to flexibilities in the ringtail boom. The boom had approximately 3 degrees of travel in the vertical and horizontal planes.

The precision of setting and maintaining velocity is estimated to be ± 0.5 ft/sec (0.25 percent), whereas the uncertainty in setting angle of attack is estimated to be ± 0.1 degree.

SECTION IV

RESULTS

1. STATIC FORCE/MOMENT TESTS

The data obtained from the wind tunnel tests were reduced to standard aerodynamic coefficient form and are presented in Figures 5 to 13. The data are presented in coefficients of drag-force (C_D), lift-force (C_L), and pitching-moment (C_m) rather than the normal aeroballistic coefficients of axial-force (C_A), normal-force (C_N), and pitching-moment (C_m). This was done to allow easier comparison of the lifting capability and, therefore, the trajectory dispersion of each modification.

The aerodynamic characteristics of the standard BLU-87/B are presented in Figure 5. The standard BLU-87/B is statically stable throughout the angle of attack region examined. The effects of moving the ringtail forward on the tail boom are presented in Figure 6. For each inch of forward movement of the ringtail, C_{L_α} decreased approximately 10 percent, and C_{m_α} increased approximately 30 percent. The drag-force remained relatively unchanged with movement of the ringtail.

The effect of reducing the ringtail diameter and chord is shown in Figure 7. This tail was chord sized to allow the overall length of the stowed bomb to remain unchanged from the unmodified bomb. The ringtail was positioned with the trailing edge in the standard ringtail trailing edge position. This smaller ringtail decreased the magnitude of the drag-force curve and the slope of the lift-force curve. The pitching-moment curve had the desired S-curve characteristics except that the magnitude of the pitching-moment coefficient was smaller than desired within the unstable region. This is believed to occur due to the ringtail being blanketed by the larger diameter body at small angles of attack. However, while the ringtail is ineffective at these small angles, the flat truncated conical nose imparts sufficient body stability to prevent the overall instability from reaching the desired magnitude.

The effects of four different nose additions (caps), combined with the reduced size tail, are shown in Figures 8 to 11. These nose caps were, respectively, a hemisphere of the diameter of the truncated conical nose of the bomb, a modified ogive nose tangent to the truncated conical nose and the same length as the hemispherical nose, a spherical section tangent to the conical faces, and a hemisphere of the reference body diameter. All of these combinations produced the desired S-curve pitching moment characteristics. The trim incidence angles, lift coefficients at trim, drag coefficients, and relative magnitude of the pitching-moment within the unstable region are shown in Table I.

The non-symmetry of some of the pitching moment curves is believed to be due to lateral movement of the extendable tail boom.

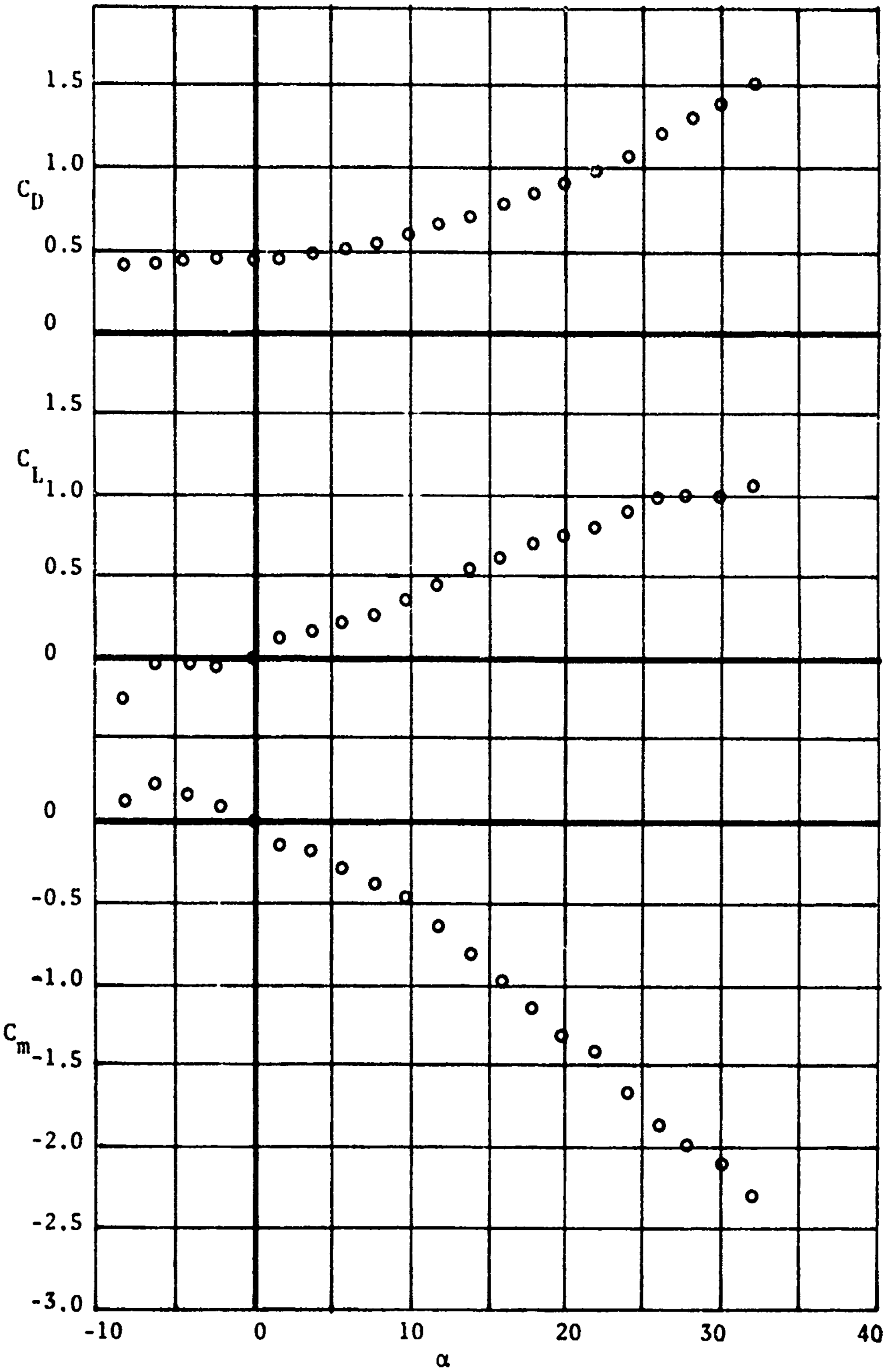


Figure 5. Aerodynamic Characteristics of Standard BLU-87/B

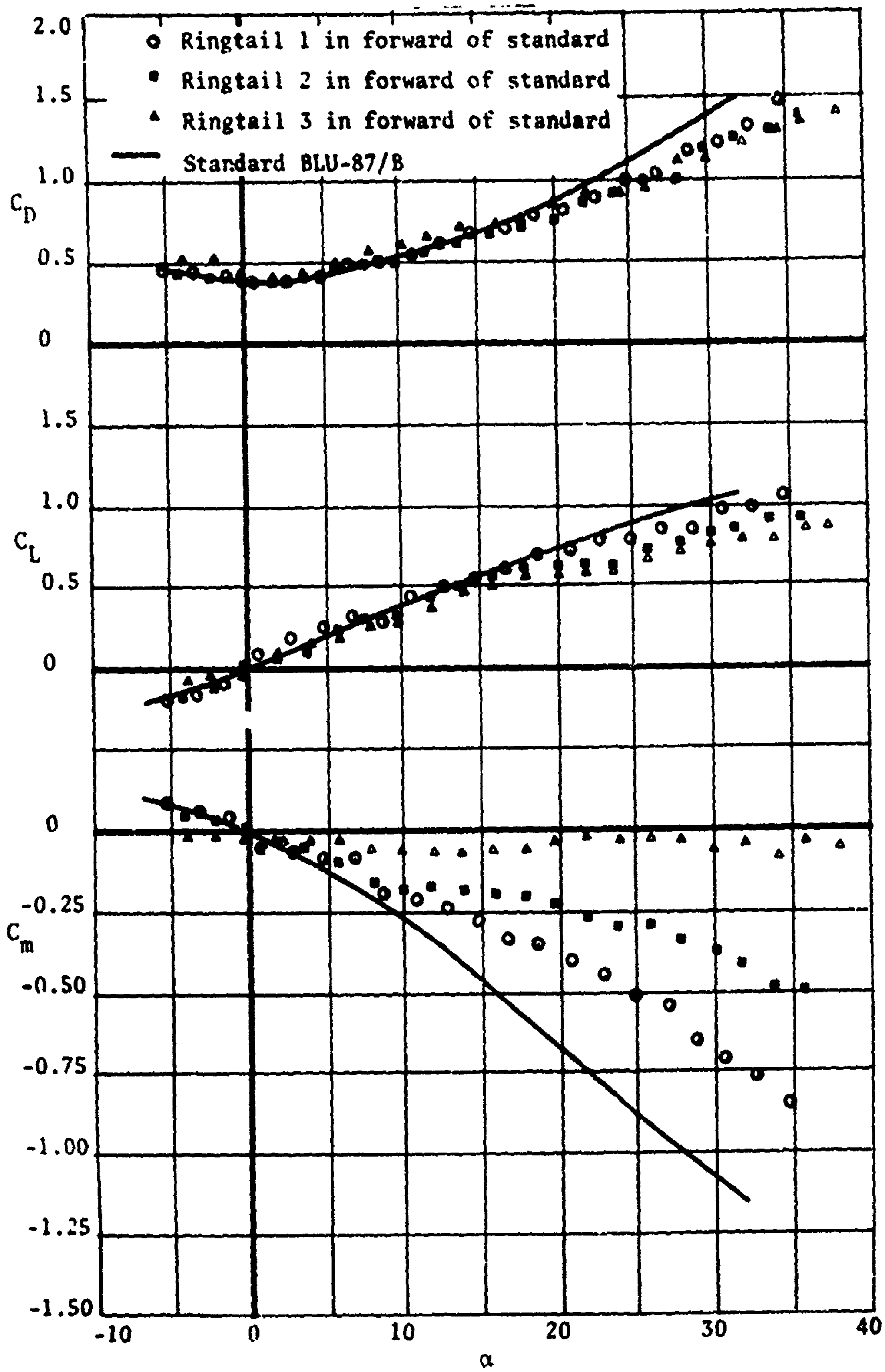


Figure 6. Effects of Ringtail Position

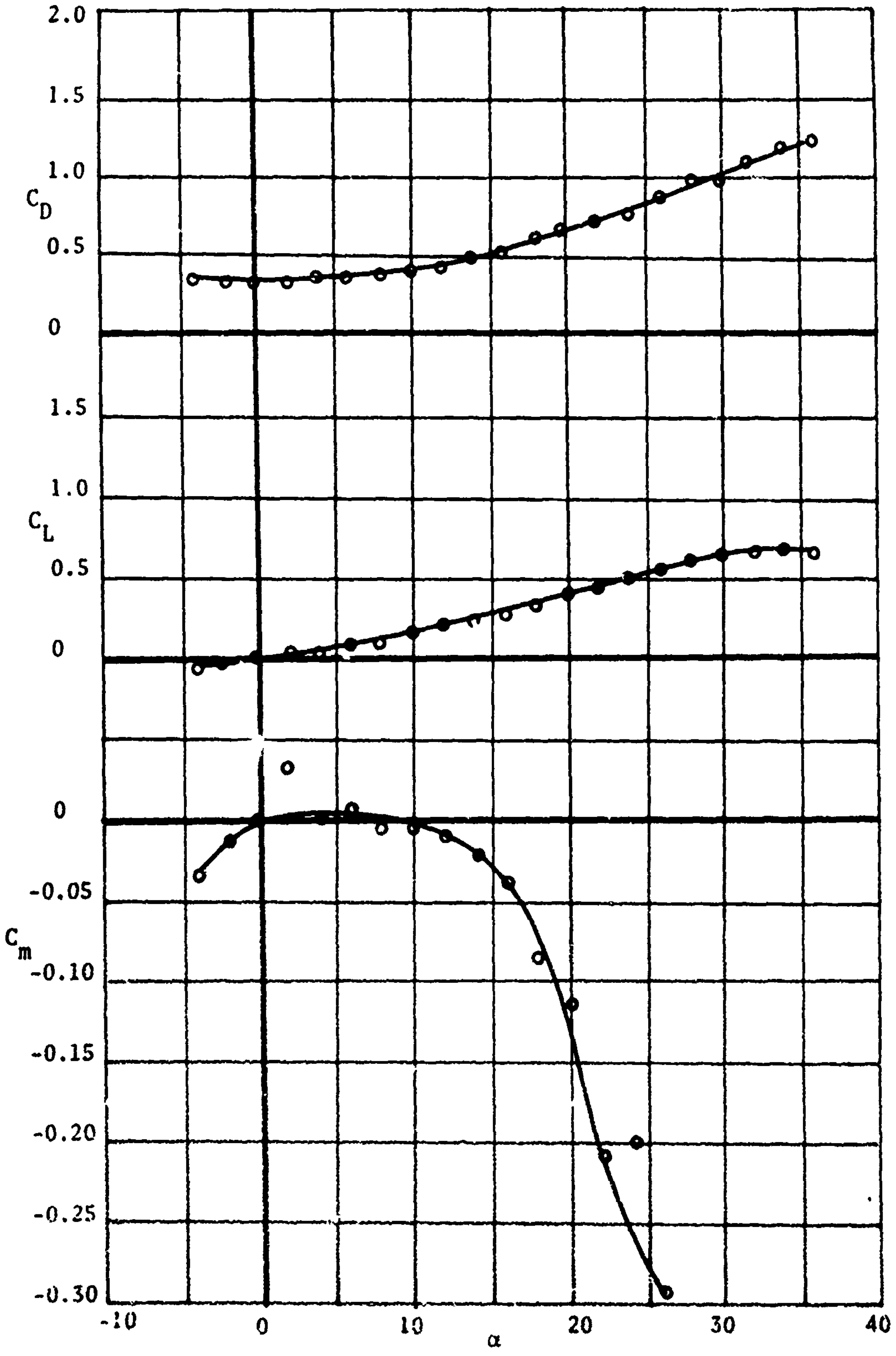


Figure 7. Effects of Reducing Ringtail Diameter and Chord (T1, N5)

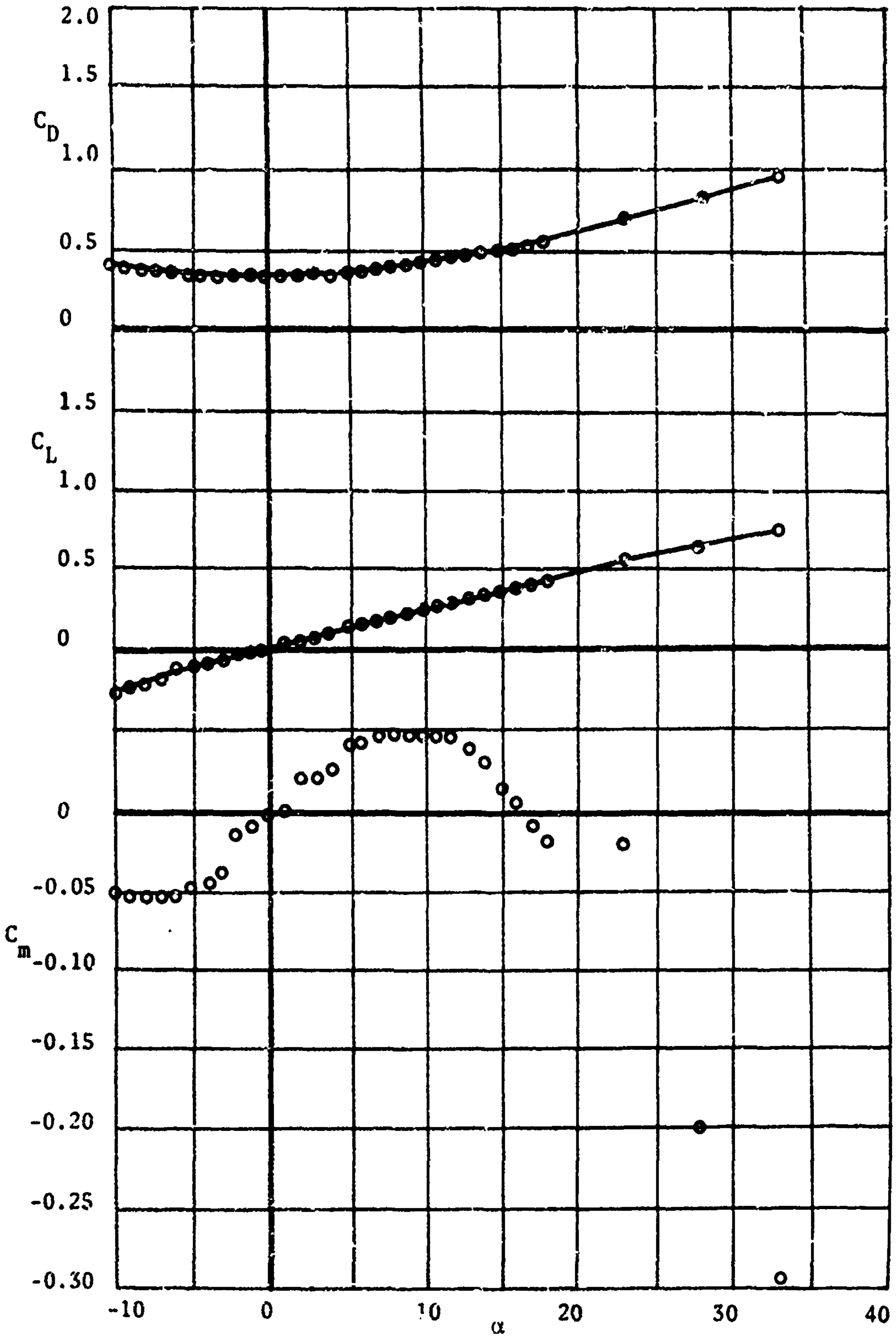


Figure 8. Effects of Reduced Ringtail Diameter and Chord with a Small Hemispherical Nose Cap (T1, N1)

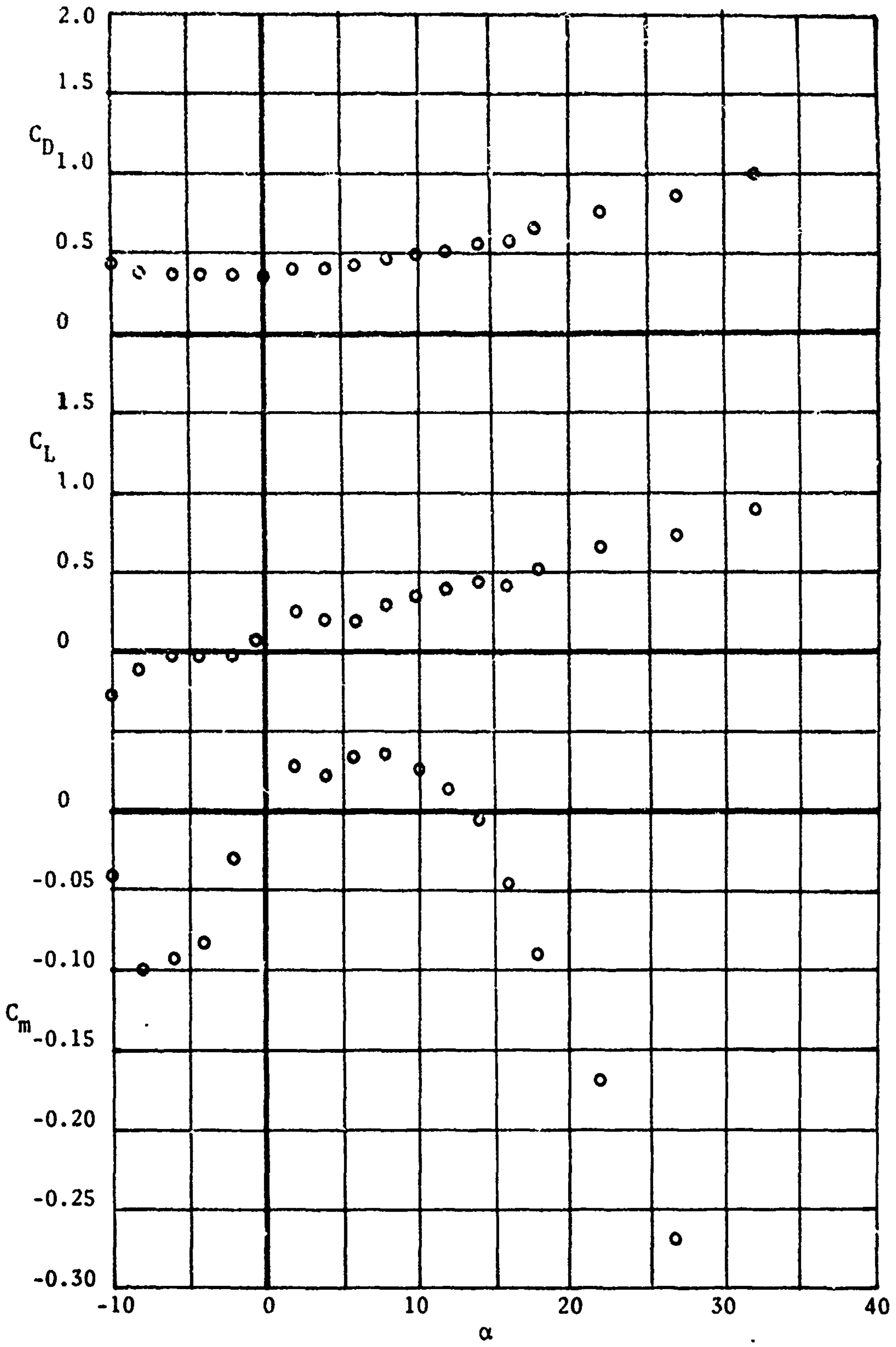


Figure 9. Effects of Reduced Ringtail Diameter and Chord with a Modified Ogive Nose Cap (T1, N2)

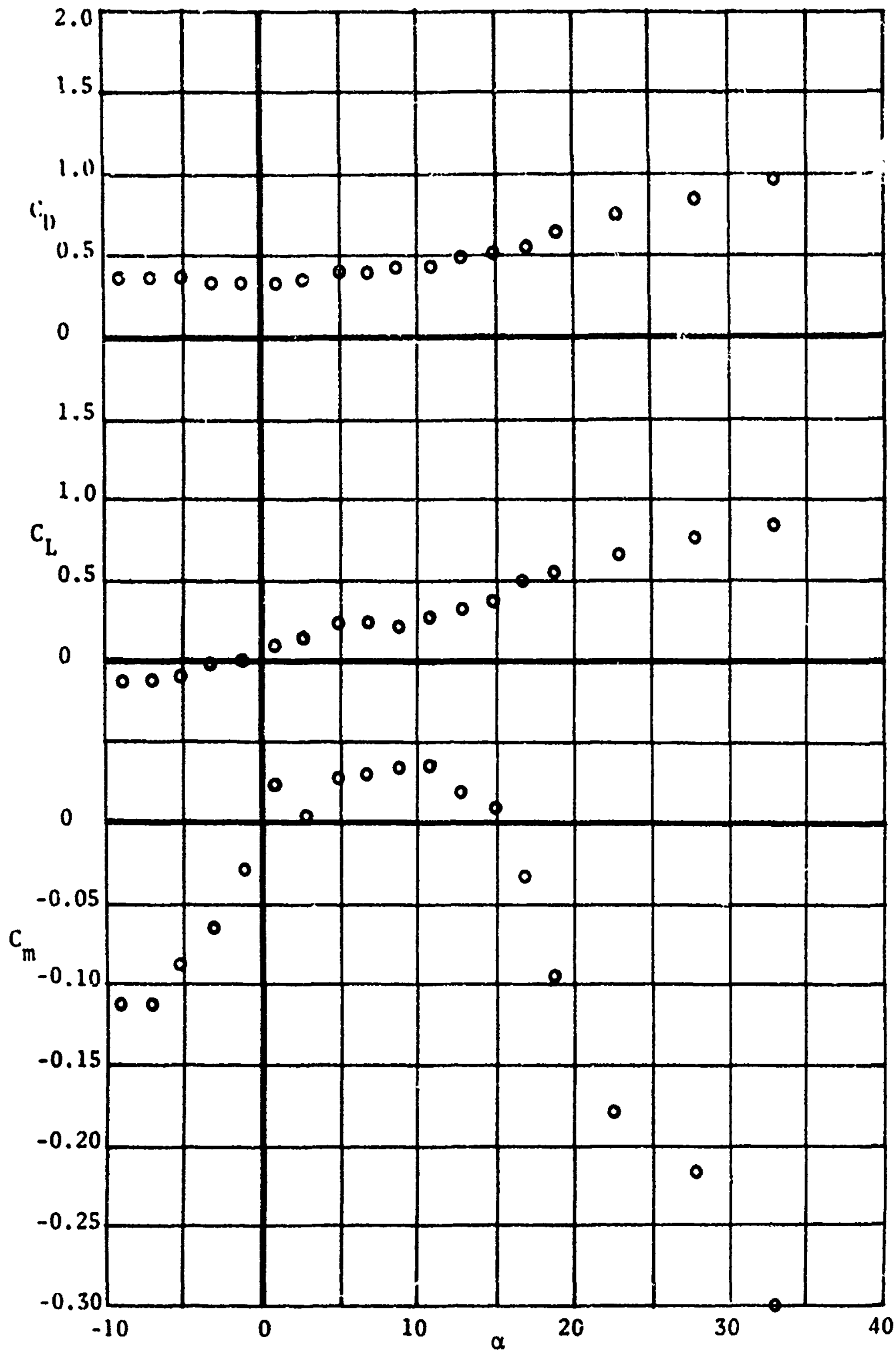


Figure 10. Effects of Reduced Ringtail Diameter and Chord with a Tangent Spherical Nose Cap (T1, N3)

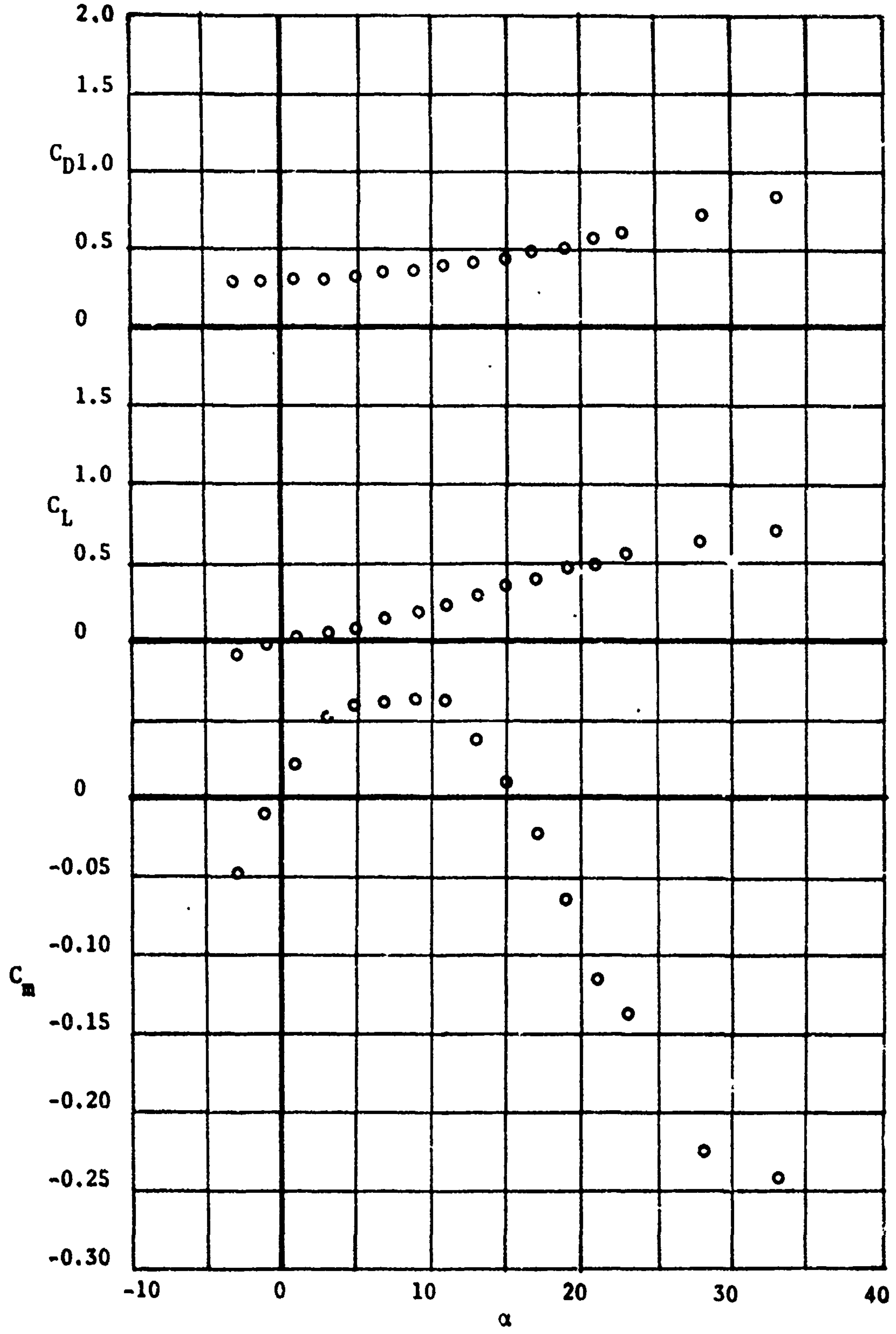


Figure 11. Effects of Reduced Ringtail Diameter and Chord with a Large Hemispherical Nose Cap (T1, N4)

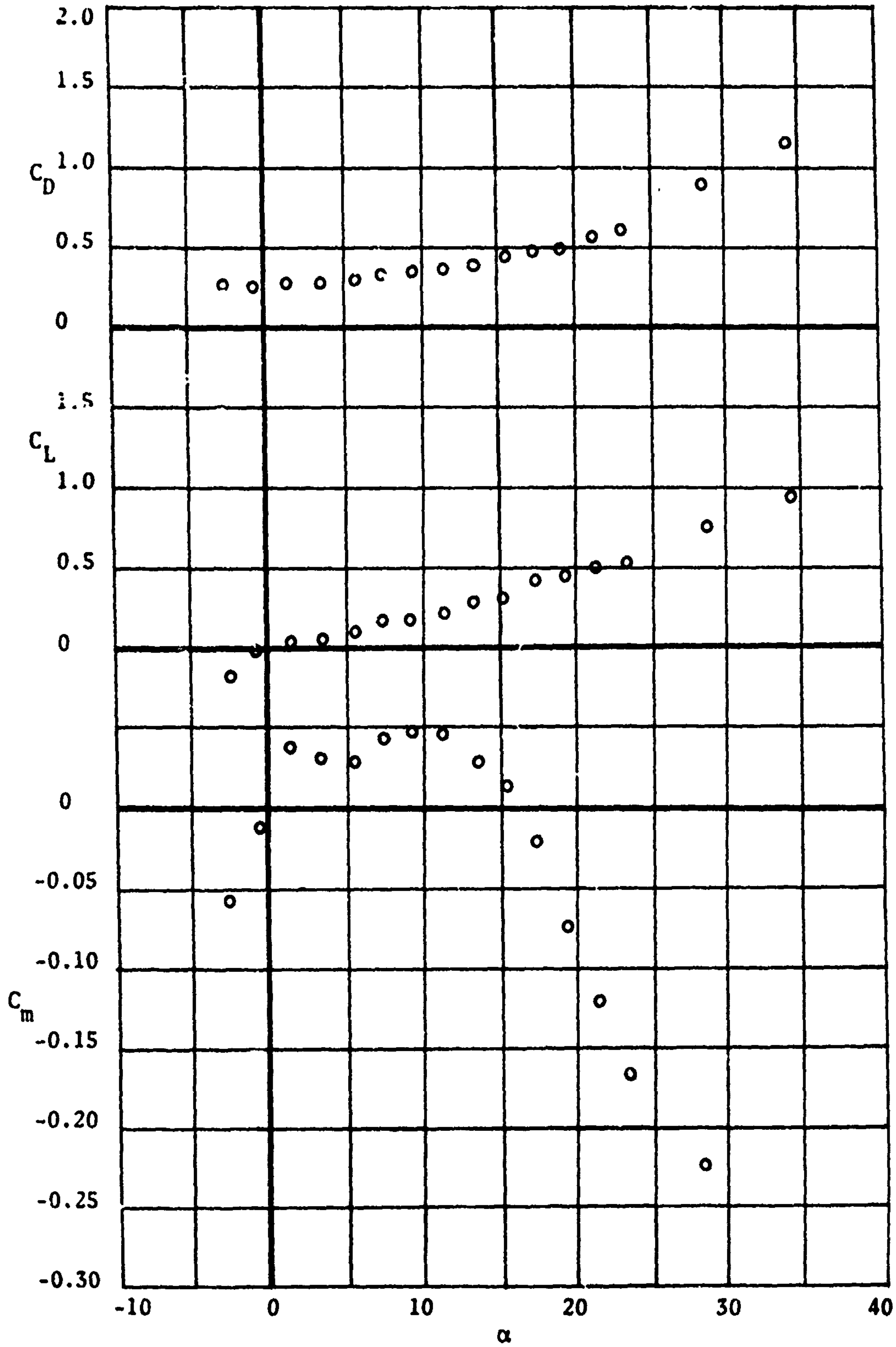


Figure 12. Effects of Reduced Ringtail Diameter with a Tangent Spherical Nosecap (T2, N2)

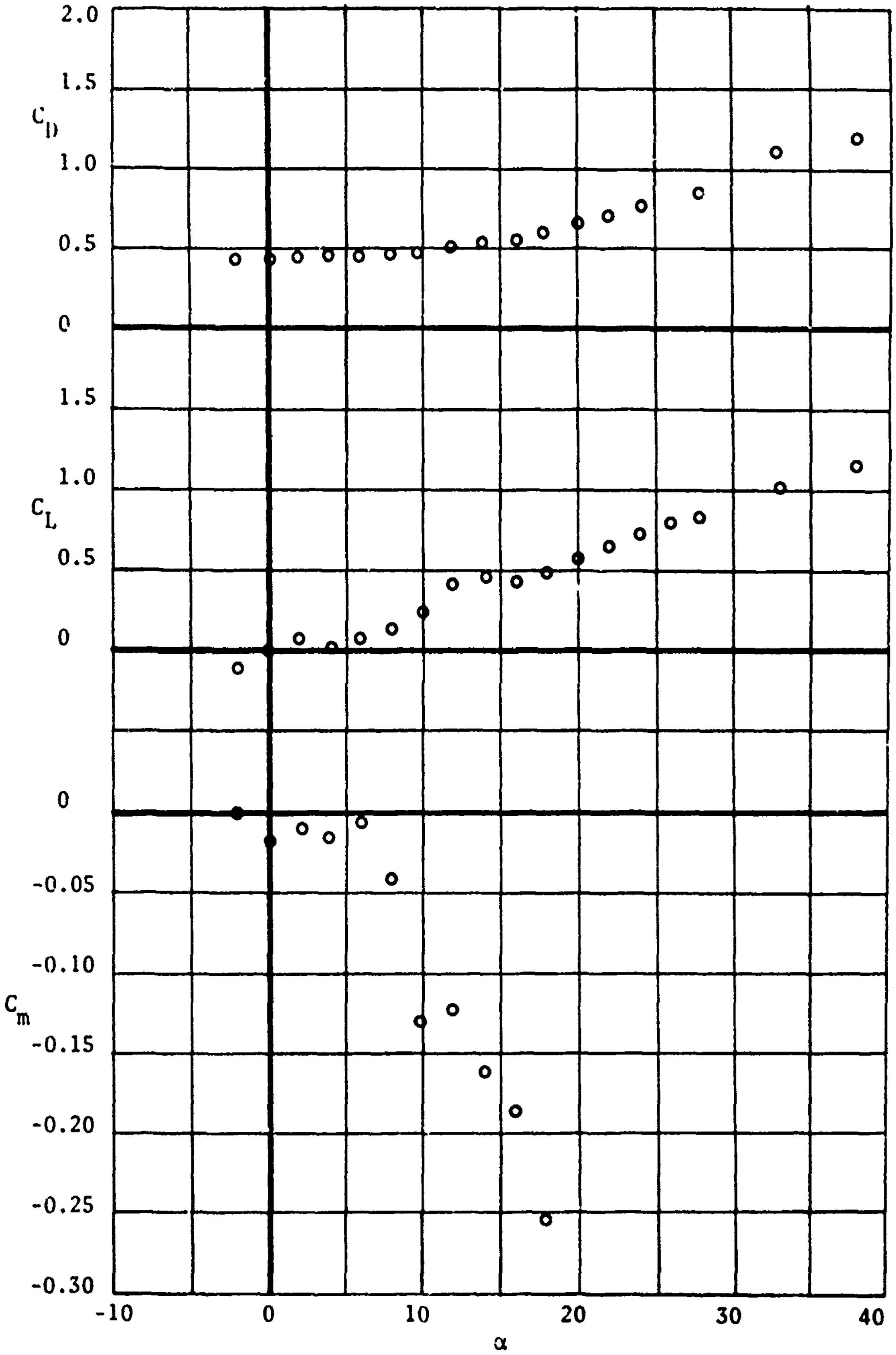


Figure 13. Effects of Small Hemispherical Nose Cap with Standard Ringtail (N1, T5)

TABLE I. REDUCED DIAMETER/CHORD RINGTAIL WITH VARIOUS NOSE CAPS

NOSE	α, degrees	C_{L_t}	C_{D_t}	DEGREE OF INSTABILITY
Hemispherical (D = $D_{\text{bomb nose}}$)	± 16	0.37	0.52	Medium
Ogive	± 16	0.38	0.56	Low
Tangent Spherical	± 14	0.40	0.53	Low
Hemispherical (D = D_{bomb})	± 16	0.36	0.46	High

Figure 12 shows the effect of the tangent spherical nose with a reduced diameter ringtail of standard chord length. The major change, as compared with the same configuration with the shorter chord tail, was a change in α_t from ± 14 degrees to ± 16 degrees and an increase in the magnitude of C_{m_α} in the stable region; C_{L_t} is 0.37, and C_{D_t} is 0.46.

It is important to note that all of the configurations with the reduced diameter tail, of either chord length, combined with any of the four nose caps had very similar values of α_t, C_{L_t}, and C_{D_t}. If considerations are made for uncertainties in the data, almost identical results are indicated.

Also examined was the effect of using a nose cap with the standard ringtail as shown in Figure 13. These results indicate that a nose cap, by itself, is insufficient to obtain the desired S-curve pitching-moment characteristics.

2. FREE-OSCILLATION TESTS

The free-oscillation tests were conducted to visually confirm that the configurations tested statically would trim at the indicated incidence angles. These tests indicated that all configurations performed as indicated by the static data. The degree of trim angle stability was proportional to the amount of instability in the unstable region and the magnitude of the pitching moment slope (C_{m_α}) at trim incidence.

3. COMPUTER TRAJECTORY PREDICTIONS

Trajectory predictions were made using a point-mass computer program with lift, drag, and gravity as the forces upon the item. It was assumed that C_{L_t} equaled 0.35, C_{D_t} equaled 0.52, and the item weighed 15.0 pounds. Trajectories were run for various function conditions at 3000 feet above ground level. For a given set of conditions, two trajectories were run: one with a positive lift coefficient value, and the other with zero lift to simulate a ballistic, non-lifting trajectory. After plotting these two trajectories, the mirror image of the lift-up trajectory was obtained by plotting the radius of the flight envelope perpendicular to the instantaneous velocity vectors of the non-lifting trajectory. This radius is also the lateral displacement for items with crossrange lift. This flight envelope can be visualized as a horn deflected downward due to gravity. Finally, an imaginary ground plane can be inserted at any desired level to simulate various function altitudes less than 3000 feet.

The trajectories for three different function conditions are summarized in Table II and plotted in Figures 14 to 16 for trajectories 1 to 3, respectively.

Figure 17 shows the maximum uprange, downrange, and crossrange impact points for these three conditions at a slant range of 2000 feet. These trajectories assume that the aerodynamic coefficients are constant with Mach number and that the items trim instantaneously upon release. In actuality, there will be changes in the aerodynamic coefficients above about Mach 0.8 (900 ft/sec) and it will require a finite time period for the items to trim. Therefore, the pattern sizes may actually be from 10 to 50 percent smaller than indicated.

TABLE II. TRAJECTORY INITIAL CONDITIONS

TRAJECTORY	VELOCITY, ft/sec	DIVE ANGLE, Degree
1	750	-25
2	1000	-45
3	1000	-80

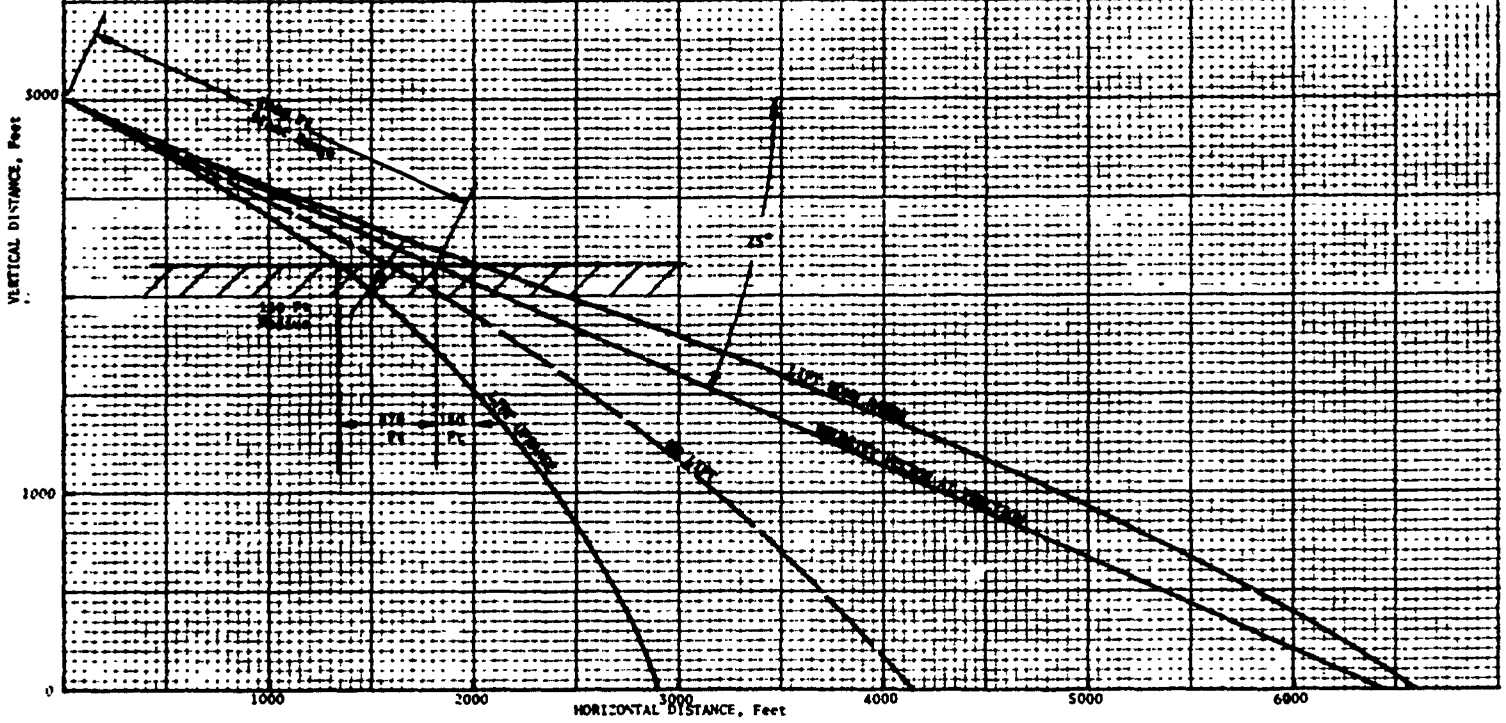


Figure 14. Trajectory Profile for 750 ft/sec, 25 Degree Dive

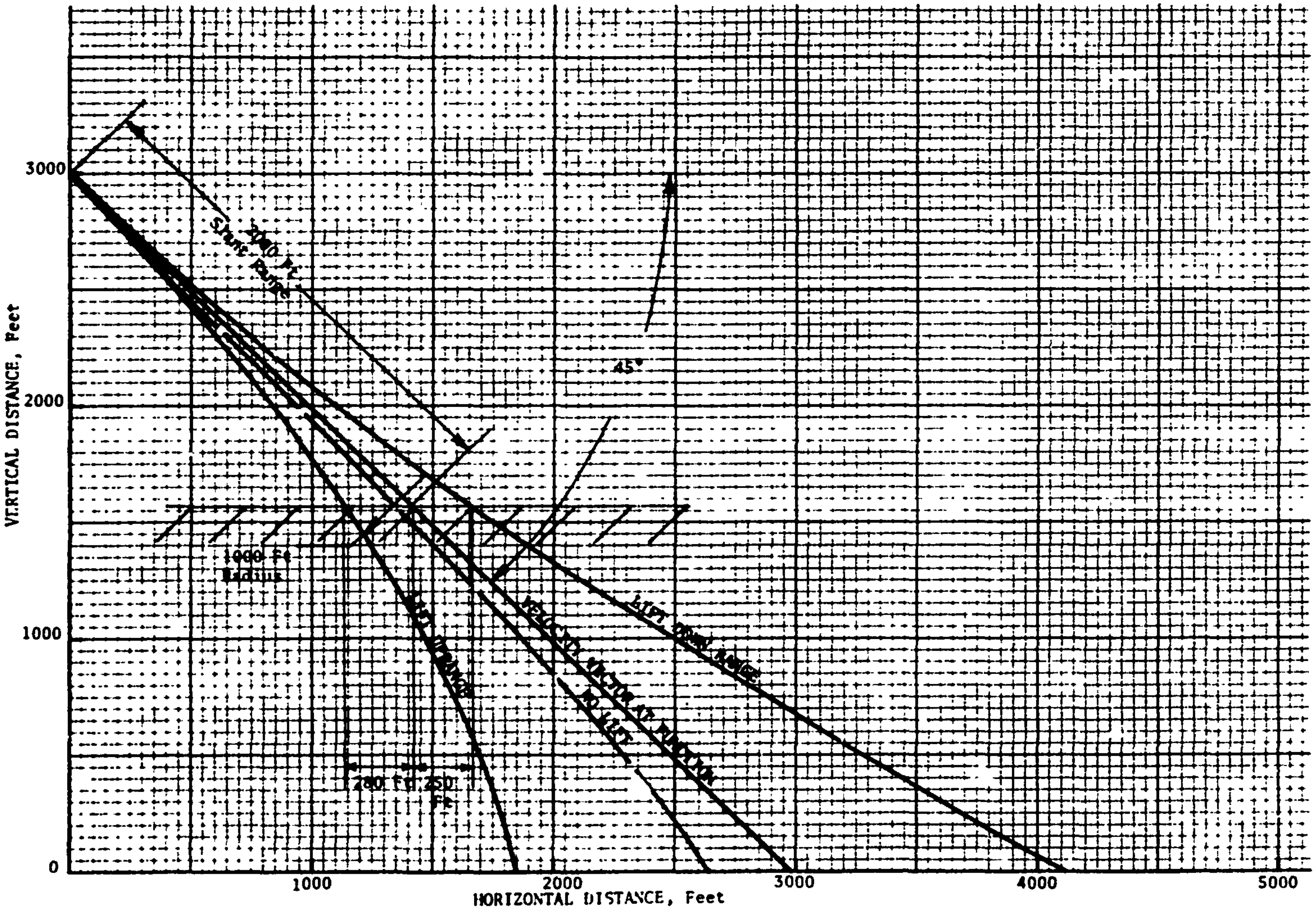


Figure 15. Trajectory Profile for 1000 ft/sec, 45 Degree Dive

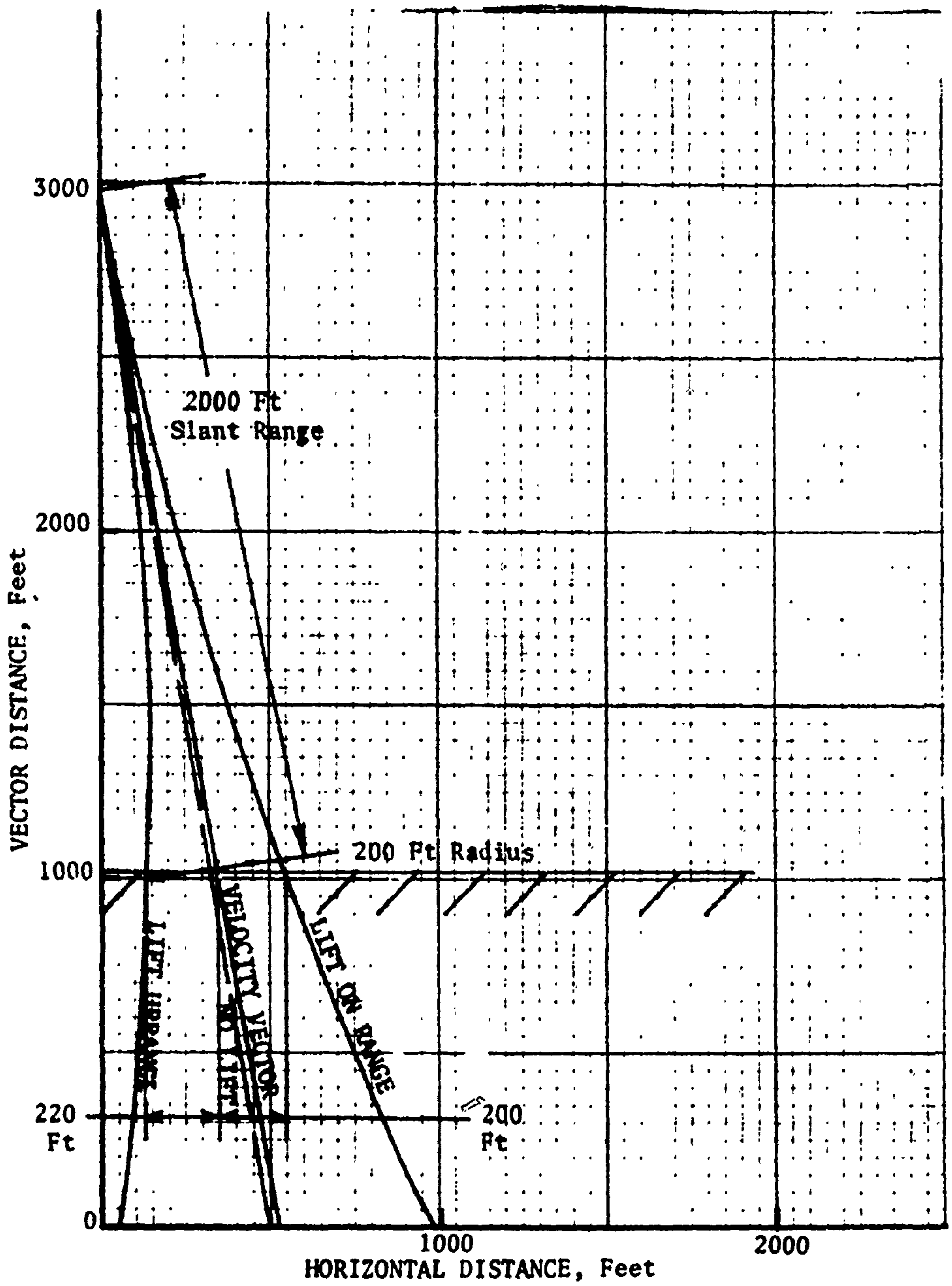


Figure 16. Trajectory Profile for 1000 ft/sec, 80 Degree Dive

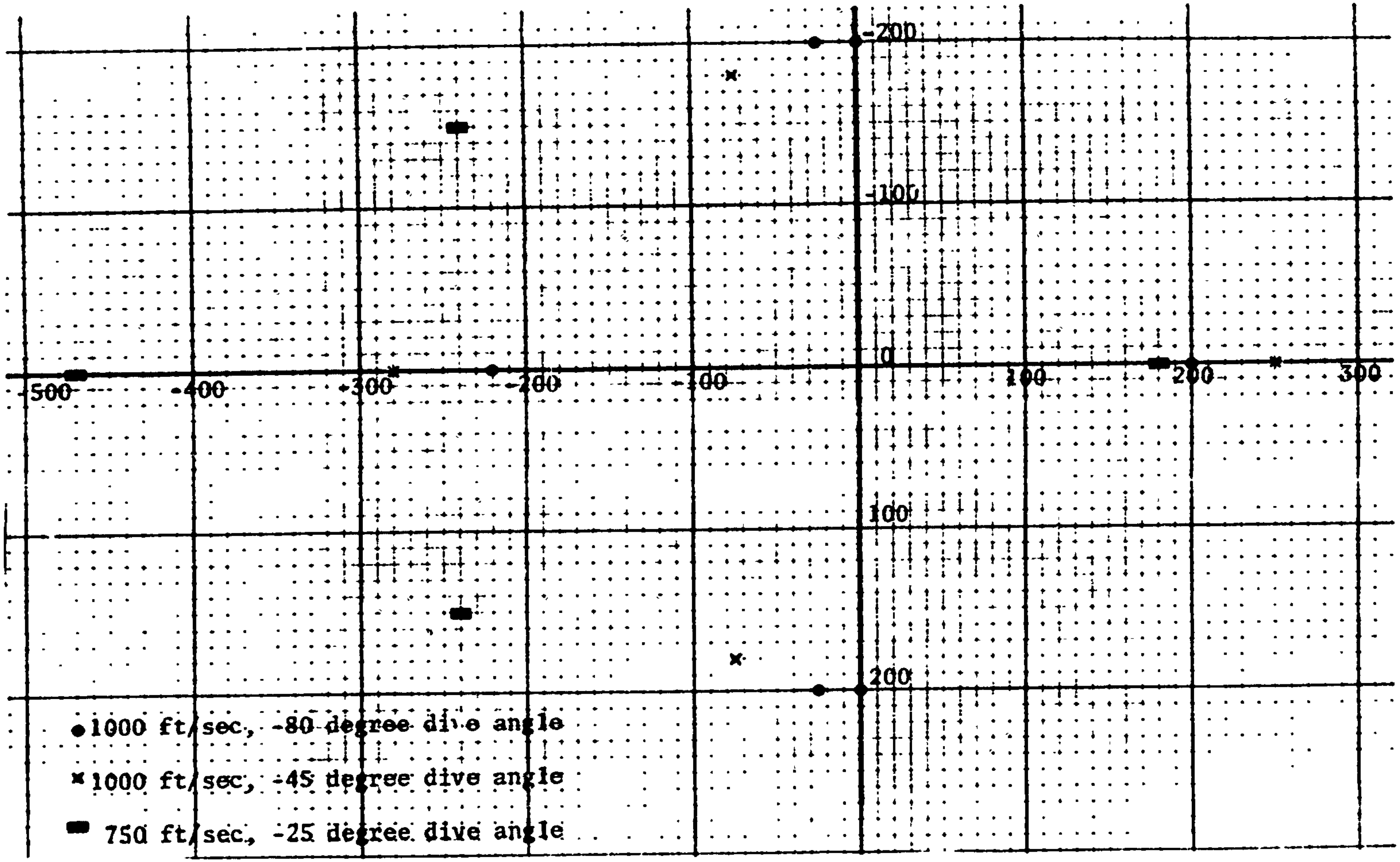


Figure 17. Impact Pattern Extremities

SECTION V

CONCLUSIONS

Based on the results of this investigation of the BLU-87/B bomb configurations, the following conclusions are drawn:

1. A reduction in the ringtail diameter is necessary to obtain an S-curve pitching moment characteristic. The ringtail chord can be reduced for packaging advantages with little effect on performance.

2. Decreasing the bluffness of the truncated, conical nose of the BLU-87/B is necessary to obtain sufficient instability in the unstable region for angular position stability at the trim incidences.

3. There is little difference in results between extending the present nose into a hemisphere or ogive, or changing the entire nose into a hemisphere. The only significant difference is that using a hemispherical nose or body diameter has the lowest drag and the highest magnitude of C_{m_α} at trim.

4. Computer predictions estimate that an impact pattern 200 to 350 feet in diameter will be produced with function conditions of 1000 ft/sec, 80 degrees dive angle, and 2000 feet slant range.

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