NASA TM- 87683

NASA-TM-87683 19860013082

NASA Technical Memorandum 87683

EFFECTS OF SOME GEOMETRIC VARIATIONS ON MISSILE AERODYNAMIC CHARACTERISTICS AT SUPERSONIC SPEEDS

M. LEROY SPEARMAN

FEBRUARY 1986

NASA
National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

SUMMARY

Tests of some missile-type configurations with some systematic variations in geometry, particularly the wing geometry, have been reviewed. Configurations included delta and rectangular planforms having a constant root chord but variations in span; planforms having a constant root chord and span but variations in tip chord; and a composite planform having a highly swept fore wing and a cranked tip.

The results indicated that variations in wing planform can have some significant effects on the aerodynamic behavior of missiles. In general, wings with a constant root chord but varying spans were better behaved than wings with a constant root chord and span but with varying tip chords. The composite planform appeared to be a reasonably good concept for high maneuver potential.

INTRODUCTION

Missile concepts have many applications with a variety of requirements in range, speed, maneuverability, launch constraints, payload, and so on. Accordingly, a variety of geometric arrangements might be developed in an effort to best satisfy a range of mission requirements. The concepts considered herein are representative of the generally shorter range tactical missile that might be required to maneuver over a fairly large Mach number range while, at the same time, having to meet certain restraints related to launch and storage.

The purpose of the present paper is to review the results of tests up to $M = 4.63$ of some generalized missile concepts with various wing planforms that permit comparisons of span effects for a constant area or area effects for a constant span. Such a comparison should provide some insight into the relative importance of certain geometric features as related to the aerodynamic behavior.

SYMBOLS

C_D drag coefficient

$C_{D,o}$ minimum drag coefficient

C_L lift coefficient

C_m pitching-moment coefficient

L/D lift-drag ratio

$(L/D)_{max}$ maximum lift-drag ratio

C_{L_α} lift curve slope near $\alpha = 0°$

a.c. aerodynamic center, percent body length

c.g. center of gravity

M Mach number

a_n instantaneous normal acceleration

α angle of attack, deg

δ control deflection, deg

b wing span including body

S_{EXP} exposed wing area (2 panels)

ℓ body length

W/A weight loading based on body cross-sectional area

Model Components:

L large wing

M mid wing

S small wing

0 wing off

W_0 wing with 0 tip chord

W_2 wing with tip chord 20 percent of root chord

W_4 wing with tip chord 40 percent of root chord

Coefficients for the configurations presented herein are nondimensional in various ways. Detailed information for the basic data may be found in the referenced papers. The numerical value of the coefficients, however, does not affect the interpretation of the results.

DISCUSSION

Wing Planform Models

A general research wing planform missile model (Fig. 1) has been extensively tested over a Mach number range up to 4.63. The wing planforms were a series of delta and rectangular shapes having a constant root chord but varying spans. In addition, one wing having a cranked planform and one rectangular wing with a shortened root chord were included. Some of the pertinent geometry for these models will be found in Table I and complete basic data will be found in reference 1.

A sample of the longitudinal characteristics at M = 4.63 is shown in Figure 2 for the delta wings and in Figure 3 for the rectangular wings. The general trends are not unexpected--the stability, lift, drag, and lift-drag ratio progressively increasing as wing size increases.

The effect of wing size on C_{L_α} and a.c. location as a function of Mach number is shown in Figure 4 for the delta and rectangular planforms. For each planform type, the general increase in lift and stability is again apparent as the wing size is increased. However, there is a difference in the behavior of the two planform types, the delta planforms generally producing higher values of C_{L_α} and a more rearward location of the a.c. This is particularly noticeable at the lower supersonic Mach numbers where the leading-edge shock impingement on the rectangular wings destroys a considerable amount of lift. The effect tends to diminish with increasing Mach number. Because of the differences in C_{L_α} and lift distribution, the a.c. variation with increasing Mach number tends to be forward with the delta planform and rearward with the rectangular planform. It is interesting to note the relatively large effect of the small wings on C_{L_α} and a.c. which probably results, to a large extent, from the lift carry-over effect to the body.

The effect of wing size on $C_{D,o}$ and $(L/D)_{max}$ as a function of Mach number is shown in Figure 5 for the delta and rectangular planforms. The general increase in $C_{D,o}$ and $(L/D)_{max}$ is apparent for both planforms as the wing size is increased with the effect again becoming less pronounced as M increases. The high-drag and low lift-drag ratio for the rectangular wing at the low supersonic Mach numbers is again a result of the leading-edge shock impingement.

The effect of wing planform, including the cranked wing, on C_{L_α} and a.c. equal root chord. The benefits of the cranked wing are particularly noticeable at the lower Mach numbers where the effect is a substantial increase in C_{L_α} and in stability. These effects tend to diminish with increasing M. The variation in a.c. location with Mach number shows substantial differences with a forward trend for the cranked wing, a rearward trend for the rectangular wing, and an essentially invariant trend with the delta wing. These trends are a reflection of the trends for C_{L_α}.

The wing planform effects on $C_{D,o}$ and $(L/D)_{max}$ are relatively small (Fig. 7). The cranked planform has a higher value of $C_{D,o}$ as a result of differences in sweep angle and in span. This higher value of $C_{D,o}$ negates the higher value of C_{L_α} so that little difference exists in $(L/D)_{max}$ for the three planforms.

The variation of C_{L_α} and a.c. with exposed wing area is shown in Figure 8 for all of the test wings at M = 1.50 and 4.63. Values at S_{EXP} = 0 are for the body alone. Generally, the value of C_{L_α} increases and the a.c. moves rearward as the wing area is increased. These variations are somewhat greater for the delta wings than for the rectangular wings, particularly at M = 1.50, with less difference between the two planforms at M = 4.63. The effectiveness of the cranked planform is obvious at M = 1.50 in that the value of C_{L_α} is considerably greater than either the delta or rectangular wings of equal area. In addition, the a.c. is further rearward.

Some results are also shown for a half-chord rectangular wing that was obtained by removing the forward half of the large rectangular wing. These results (Fig. 8) indicate that the lift-curve slope is essentially unchanged from the large wing even though the wing area is reduced by one-half. This is partly due to the increase in aspect ratio for the reduced chord wing and is a general indication of lift loss effect due to shock wave and boundary layer interference for the large chord wing. This effect is true only for small angles of attack, however. An examination of the data in reference 1 indicates that the lift provided by the full-chord rectangular wing at higher angles of attack is greater than that for the half-chord rectangular wing although not by a factor of two. The more rearward distribution of lift for the half-chord rectangular wing results in a further aft a.c. location. The differences in C_{L_α} and a.c. for various wing sizes and planforms are very distinct at M = 1.50 but the results at M = 4.63 show less effect of planform (Fig. 8).

The variation of C_{L_α} and a.c. with total span (including body) is shown in Figure 9 for M = 1.50 and 4.63 for all wing planforms. The values at b = 3 are for the body alone. The general trend is, of course, an increase in C_{L_α} and a rearward shift of a.c. as the span increases. For a given span, the rectangular wings provide a slightly higher C_{L_α} than the triangular wings, presumably because of the greater area. The distribution of lift is such, however, that the a.c. tends to be slightly more forward for the rectangular wings at M = 1.50 and slightly more rearward for the rectangular wings at M = 4.63. The cranked wing follows the general trend line of the triangular wings insofar as C_{L_α} is concerned at M = 1.50. The lift being distributed further aft for this wing, however, does result in a slightly further aft a.c. At M = 4.63, C_{L_α} for the cranked wing indicates a lower value than the trend value for delta wings, probably because of a loss in lifting efficiency for the cranked portion of the wing, and the a.c. location is on the trend line for the delta wings.

The half-chord rectangular wing compared to the full-chord rectangular wing at b = 7 indicates a slightly higher value of C_{L_α} and a considerably further aft a.c. at M = 1.50. At M = 4.63, the C_{L_α} is slightly lower for the half-chord wing and the a.c. location is about the same as that for the full chord wing. Several observations can be made from this figure and one is that, for span constrained missiles, the rectangular wings provide greater lift than the delta wings simply by virtue of the greater area.

Planform Variations with Constant Span

Some tests have been made with a span-constrained model in which the wing planform was changed by varying the taper ratio from 0 to 0.2 and to 0.4. The model is shown in Figure 10 and some geometry in Table II. Complete results for this model are contained in reference 2. Selected results are shown in Figure 11 for each wing at M = 1.60 and 2.86. These results indicate, to some extent, the complexity of anticipating the effects of geometric variations in wing planform for a complete wing-body-tail combination. The seemingly systematic variation in wing-taper ratio also causes changes in wing area, aspect ratio, leading-edge sweep, span- and chord-load distribution, induced wing-wake strength and location, and so on. Lift-curve slope changes are not systematic with the effects of wing aspect ratio, wing area, and leading-edge sweep, each being factors that affect the lift. The interference flow field from the wing also produces different effects on the carry-over lift to the body and on the tail lift. The pitching-moment results indicate an apparently progressive forward movement of the aerodynamic center (reduced longitudinal stability) as the wing tip chord is increased, but with an increasingly nonlinear pitching moment variation with lift. This nonlinearity is particularly disturbing near zero lift where a region of instability occurs for the wings with increased tip chord. This could result from a loss in tail lift caused by an increase in wing flow-field interference effects. Trim lift points are indicated for a tail deflection of -20 degrees. Progressively higher values of trim lift are available as the wing area increases because of the lower stability level. However, the unstable region near zero lift would have to be manageable in order to achieve these higher values of trim lift. On the other hand, it would appear that the zero taper wing (delta) could achieve comparable high trim lifts if the stability level was reduced through a forward shift in center of gravity--only about a 3-percent body-length shift being required.

Cranked Wing Concept

A wing-body-tail concept utilizing a cranked wing planform is shown in Figure 12. Complete details of the model and supersonic tests results will be found in reference 3. The longitudinal characteristics for this concept were linear and well behaved for M = 2.87 as illustrated in Figure 13. The longitudinal parameters, C_{L_α} and a.c., as a function of Mach number (Fig. 14) are also well behaved. Because of the linearity of the pitching-moment curves and the nearly constant a.c. location, the potential for high maneuverability exists. This potential is illustrated for Mach numbers of 1.50 and 2.87 at altitudes of 10,000 feet, 30,000 feet, and 60,000 feet. These results are for an arbitrary weight loading of 750 psf based on body cross-sectional area and for a control deflection of -20 degrees. At 10,000 feet, values of a_n well in excess of what is likely to be the structural load limit of a missile are easily obtainable. At 30,000 feet with the aft c.g. location shown, values of a_n of about 22 were obtained at M = 1.50 and about 60 at M = 2.87. At 60,000 feet, values of a_n of about 6 were obtained at M = 1.50 and about 15 at M = 2.87. For a control deflection of -30 degrees, even higher values of a_n would be obtained. Suffice it to say that this concept appears to be a reasonably good candidate for high maneuverability, primarily because of the high degree of linearity of the aerodynamic characteristics both with angle of attack and with Mach number.

CONCLUDING REMARKS

It has been the purpose of this paper to review the results of tests of some missile-type configurations with some systematic variations in geometry, particularly the wing geometry. Configurations included delta and rectangular planforms having a constant root chord but variations in span; planforms having a constant root chord and span but variations in tip chord; and a composite planform having a highly swept fore wing and a cranked tip.

Some concluding observations are:

o Geometric variations in wing planform can have some significant effects on the aerodynamic behavior and thus deserve some attention in the quest for desired performance within certain stowage and launch constraints.

o In general, wings with a constant root chord but varying spans were better behaved than wings with a constant root chord and span but with varying tip chords.

o The cranked planform appeared to be a reasonably good concept for high maneuver potential.

REFERENCES

1. Spearman, M. L.; and Trescot, C. D., Jr.: Effects of Wing Planform in the Static Aerodynamics of a Cruciform Wing-Body Missile for Mach Numbers Up to 4.63. NASA TM X-1839, 1969.

2. Spearman, M. L.; and Wallace C. Sawyer: Longitudinal Aerodynamic Characteristics at Mach Numbers from 1.60 to 2.86 for a Fixed-Span Missile with Three Wing Planforms. NASA TM-74088, 1977.

3. Monta, William J.: Aerodynamic Characteristics at Mach Numbers from 1.50 to 2.87 of a Dogfight Missile Configuration with Cruciform Cranked Wings and Trapezoidal Tail Controls (U). NASA TM X-2771, 1973.

Table I Geometric Characteristics of Wing Planform Models

	Large	Mid	Small
Body:			
Length, in.			30.00
Diameter, in.			3.00
Forebody			3.5 caliber ogive
Wings:			
Delta -	Large	Mid	Small
Root chord (exposed), in.	13.00	13.00	13.00
Tip chord, in.	0	0	0
Exposed span, in.	8.00	4.00	2.00
Exposed area, sq. ft.	0.361	0.181	0.090
Leading-edge sweep, deg.	72.9	81.3	85.6
Rectangular -			
Root chord (exposed), in.	13.00	13.00	13.00
Tip chord, in.	13.00	13.00	13.00
Exposed span, in.	4.00	2.00	1.00
Exposed area sq. ft.	0.361	0.181	0.090
Leading-edge sweep, deg.	0	0	0
Short-chord rectangular -			
Root chord (exposed), in.			6.50
Tip chord, in.			6.50
Exposed span, in.			4
Exposed area, sq. ft.			0.181
Leading-edge sweep, deg.			0
Leading-edge location from base, in.			6.50
Cranked -			
Root chord (exposed), in.			13.00
Tip chord, in.			1.95
Exposed span, in.			6.00
Exposed area, sq. ft.			0.181
Leading-edge sweep, deg. -			
Forewing			85.6
Tip			45.0
Thickness for all wings, in.			0.1875
Leading and trailing edges			10° bevel

Table II Geometric Characteristics for Models Having Planform Variation with Constant Span

Body:

Length, in.	30.0
Diameter, in.	2.0
Forebody	5.0 caliber ogive

Wings:

	W_0	W_2	W_4
Root chord (exposed), in.	14.0	14.0	14.0
Tip chord, in.	0	2.8	5.6
Exposed span, in.	7.0	7.0	7.0
Exposed area, sq. ft.	0.243	0.292	0.340
Taper ratio	0	0.20	0.40
Leading-edge sweep, deg.	79.9	77.4	73.4
Root thickness ratio	0.040	0.045	0.050

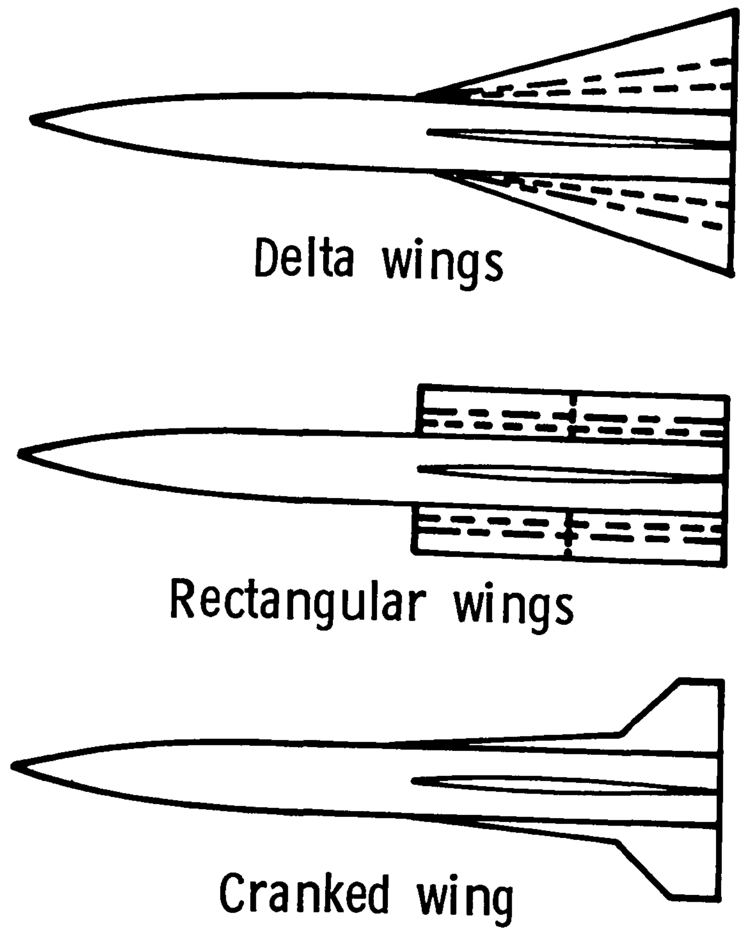

Figure 1.- Wing planform models.

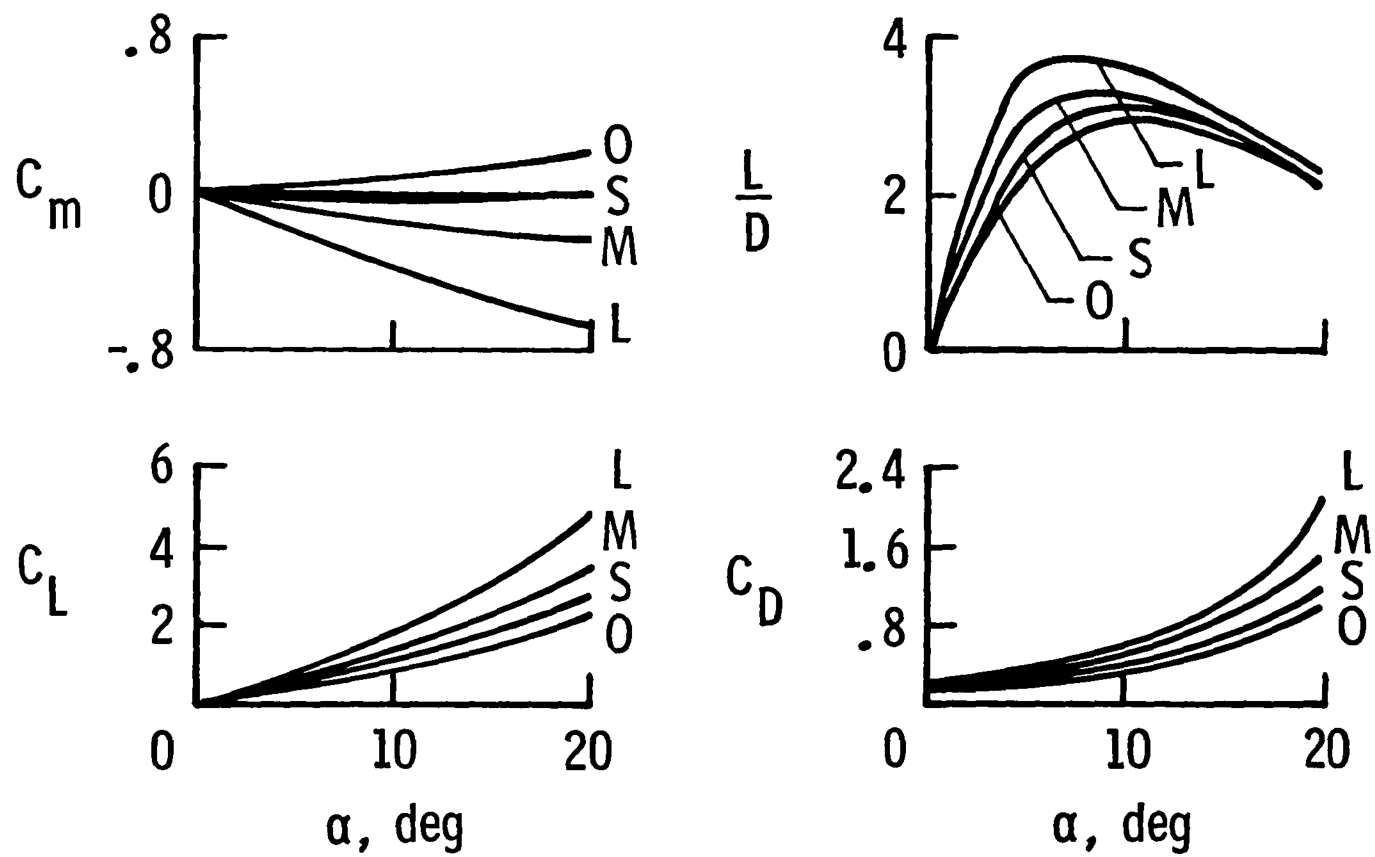

Figure 2.- Longitudinal characteristics for delta-wing-body model.
M = 4.63, c.g. = 0.53ℓ.

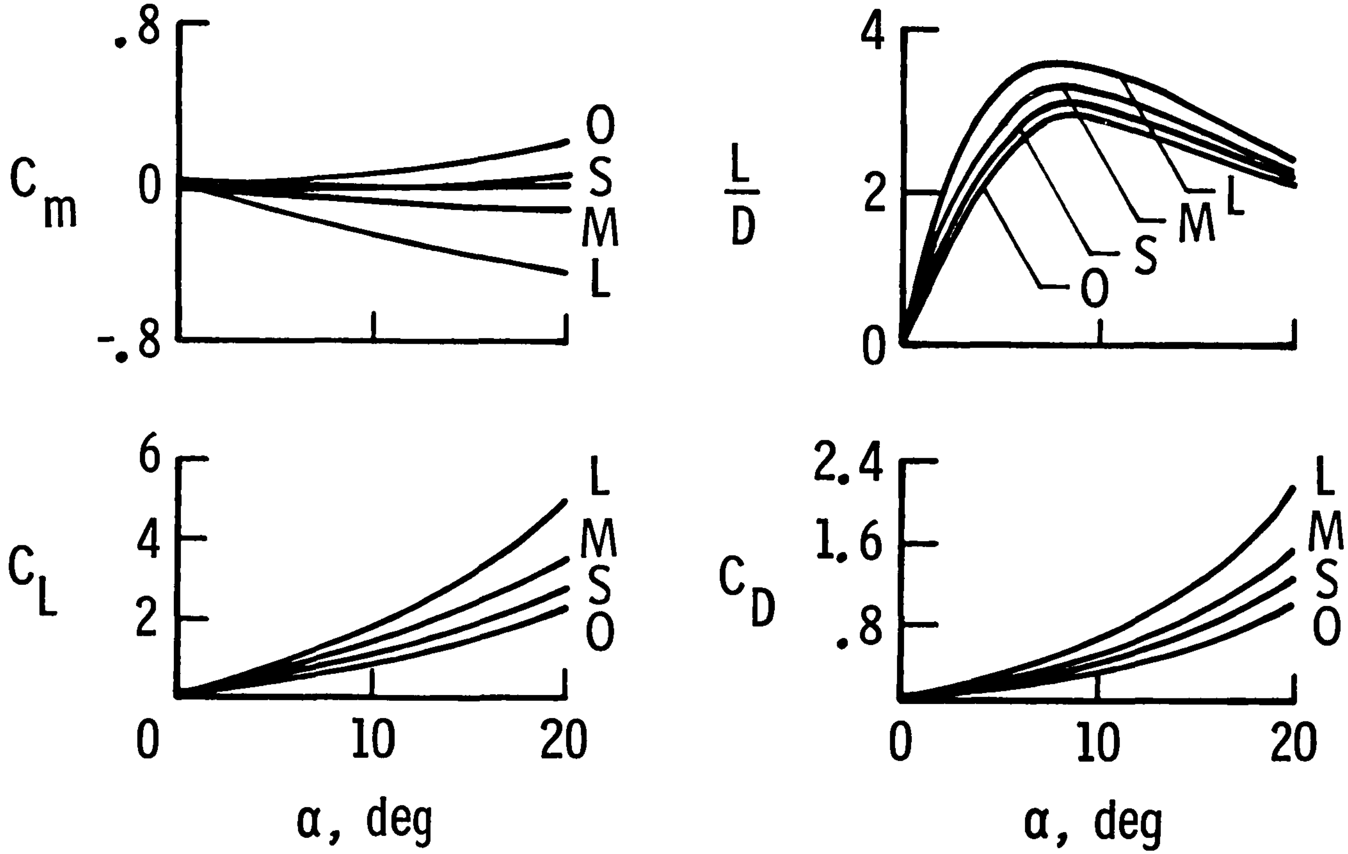

Figure 3.- Longitudinal characteristics for rectangular-wing-body model. M = 4.63, c.g. = 0.53ℓ.

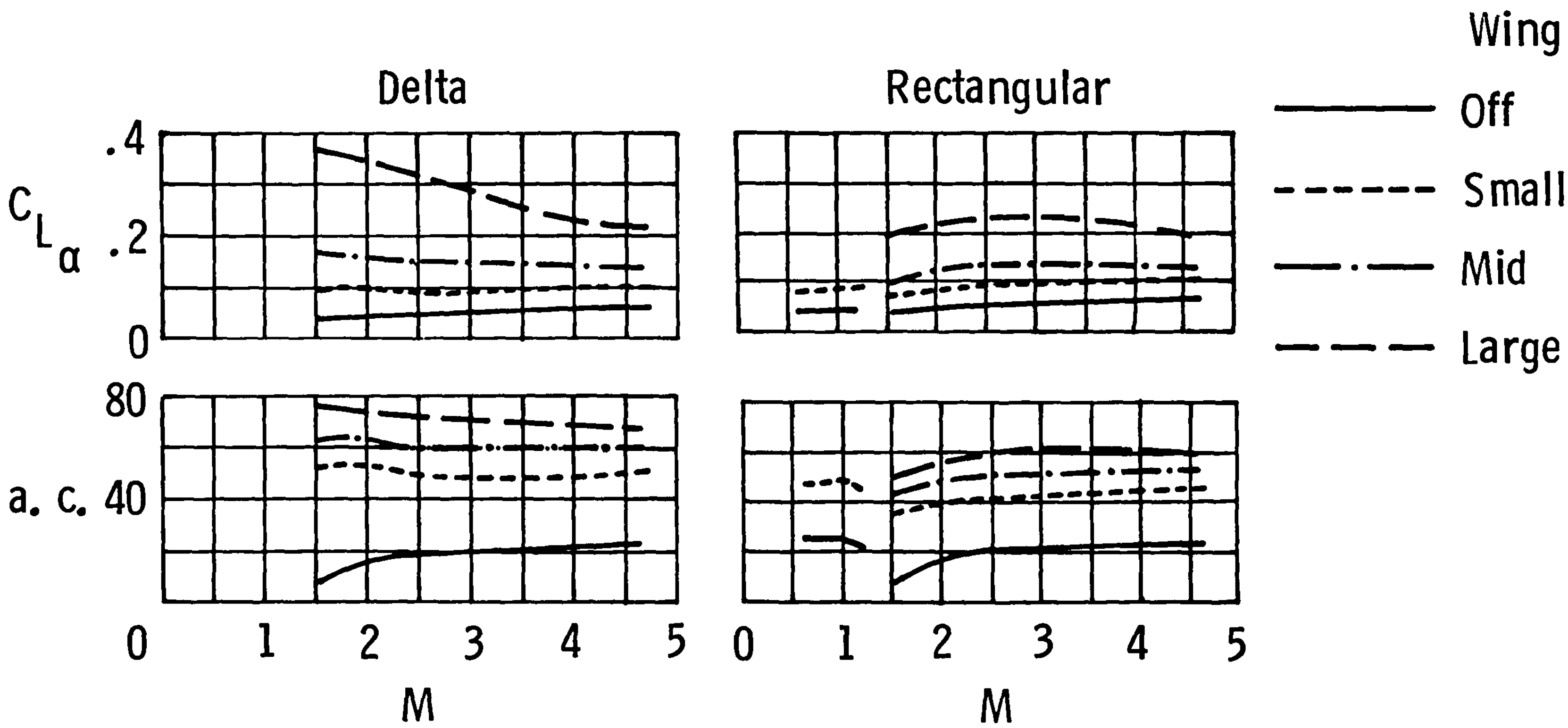

Figure 4.- Wing size effects on C_{L_α} and a.c. as a function of Mach number for delta and rectangular planforms.

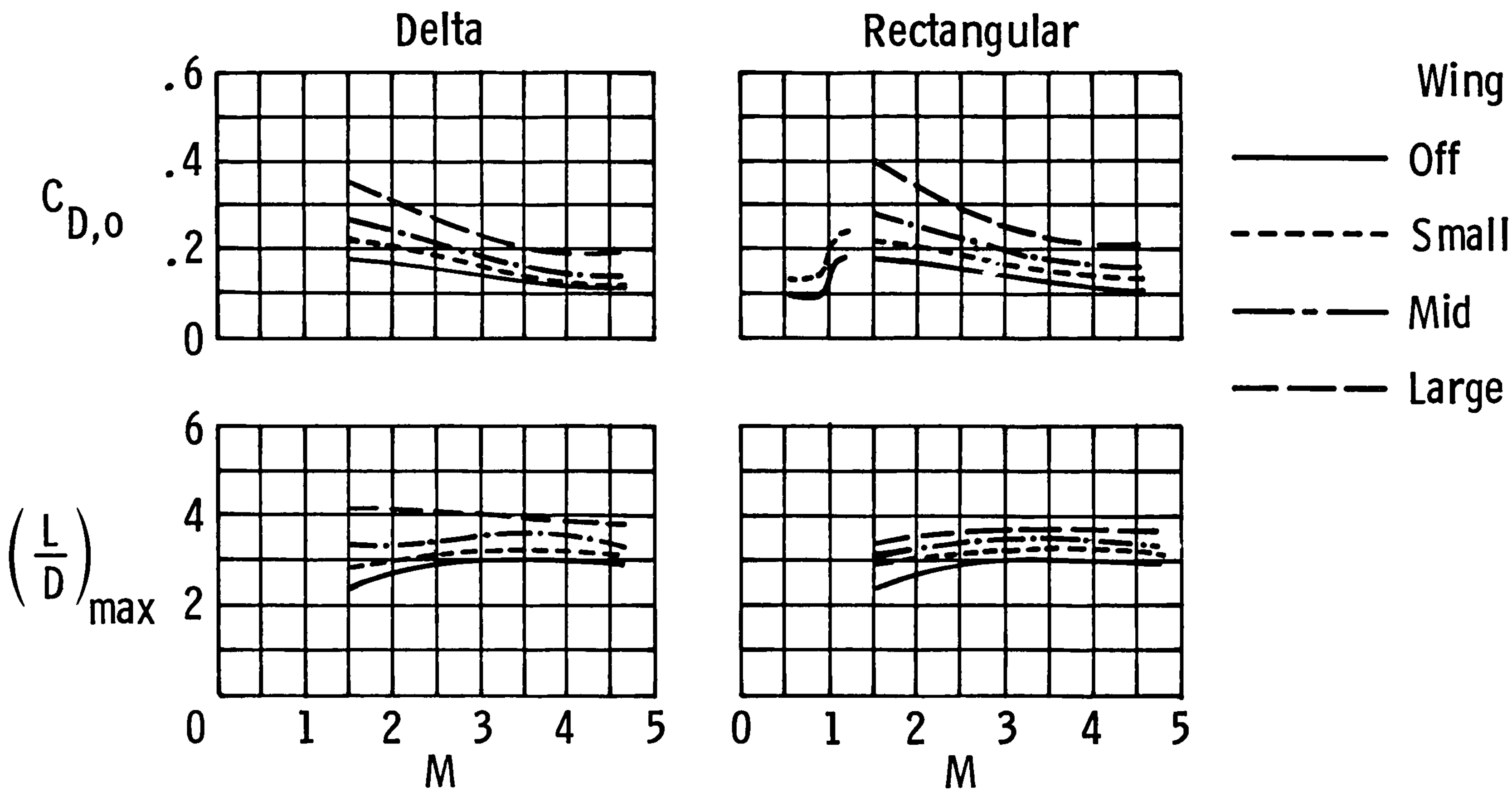

Figure 5.- Wing size effects on $C_{D,o}$ and $(L/D)_{max}$ as a function of Mach number for delta and rectangular planforms.

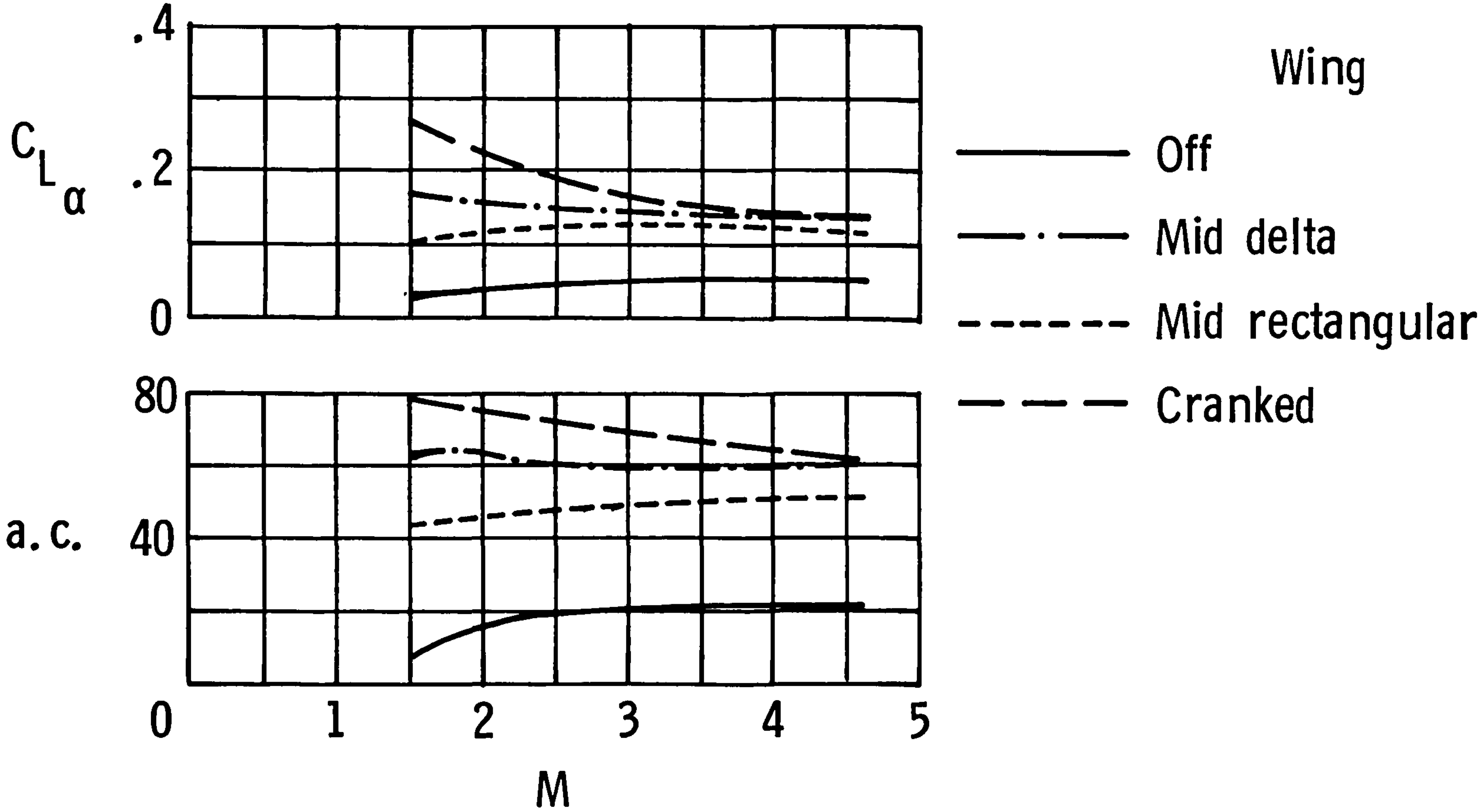

Figure 6.- Planform effects on C_{L_α} and a.c. as a function of Mach number for various wings having a constant exposed area of 0.18 sq. ft.

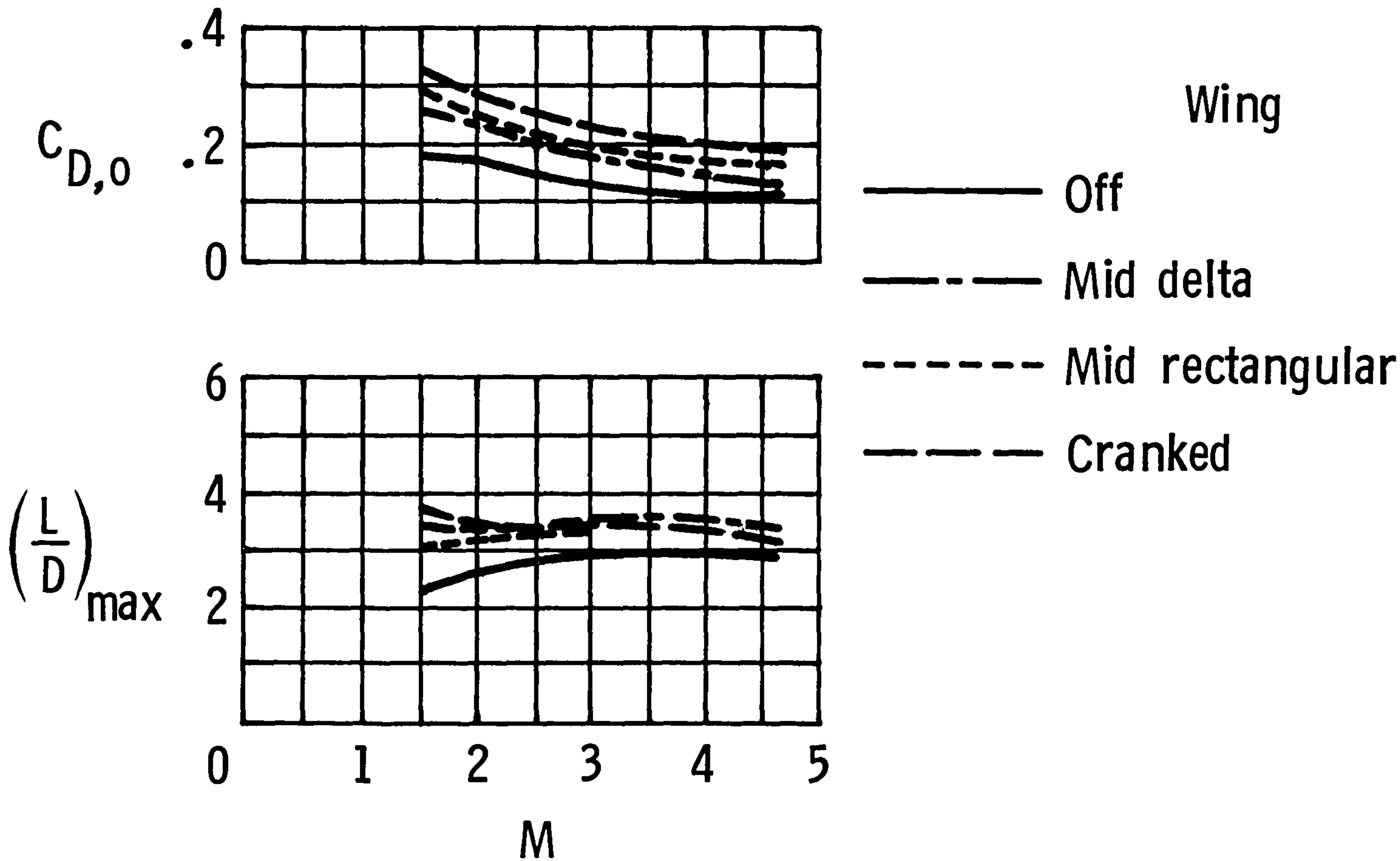

Figure 7.- Planform effects on $C_{D,o}$ and $(L/D)_{max}$ as a function of Mach number for various wings having a constant area of 0.18 sq. ft.

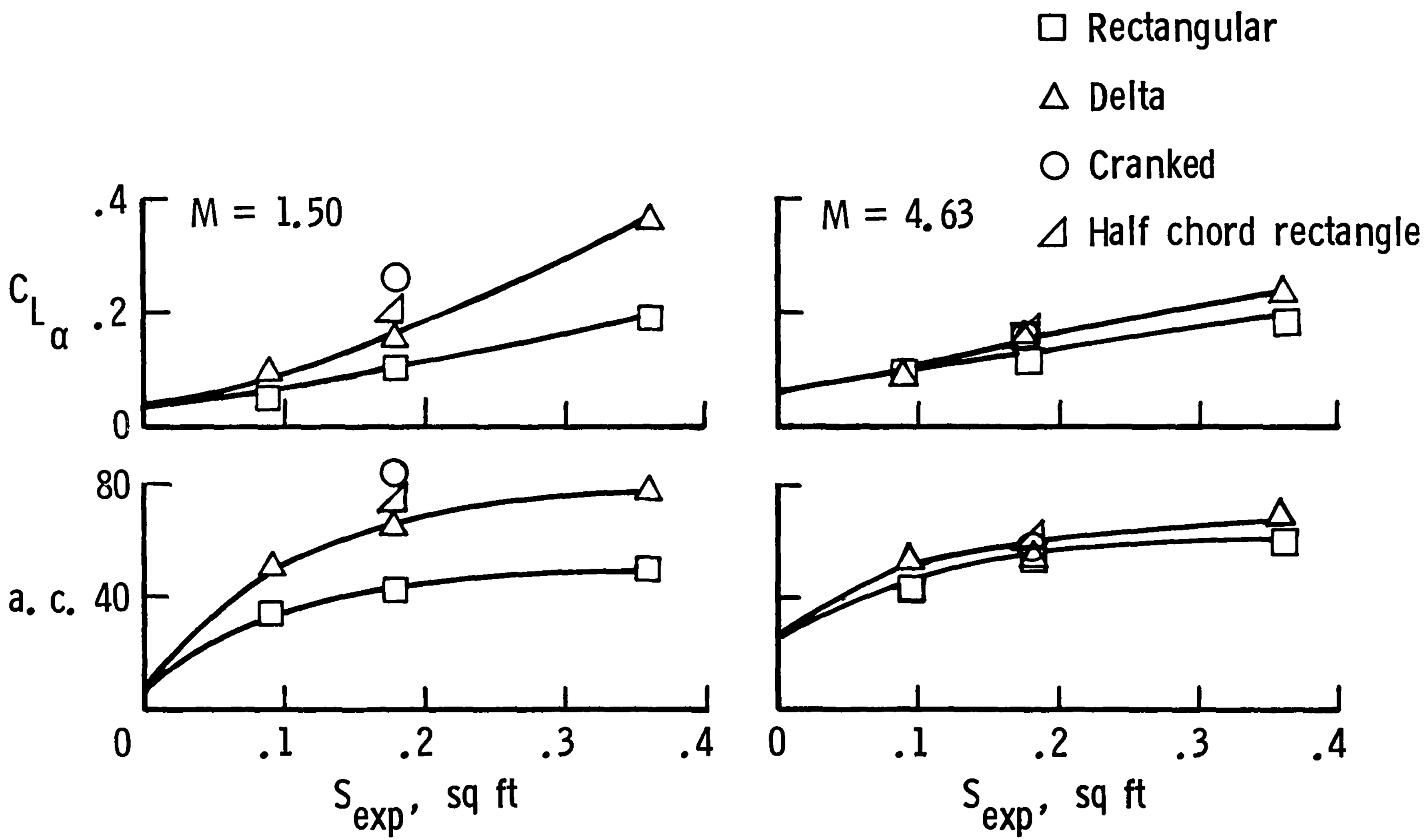

Figure 8.- Variation of C_{L_α} and a.c. with exposed wing area for various wing planforms, M = 1.50 and 4.63.

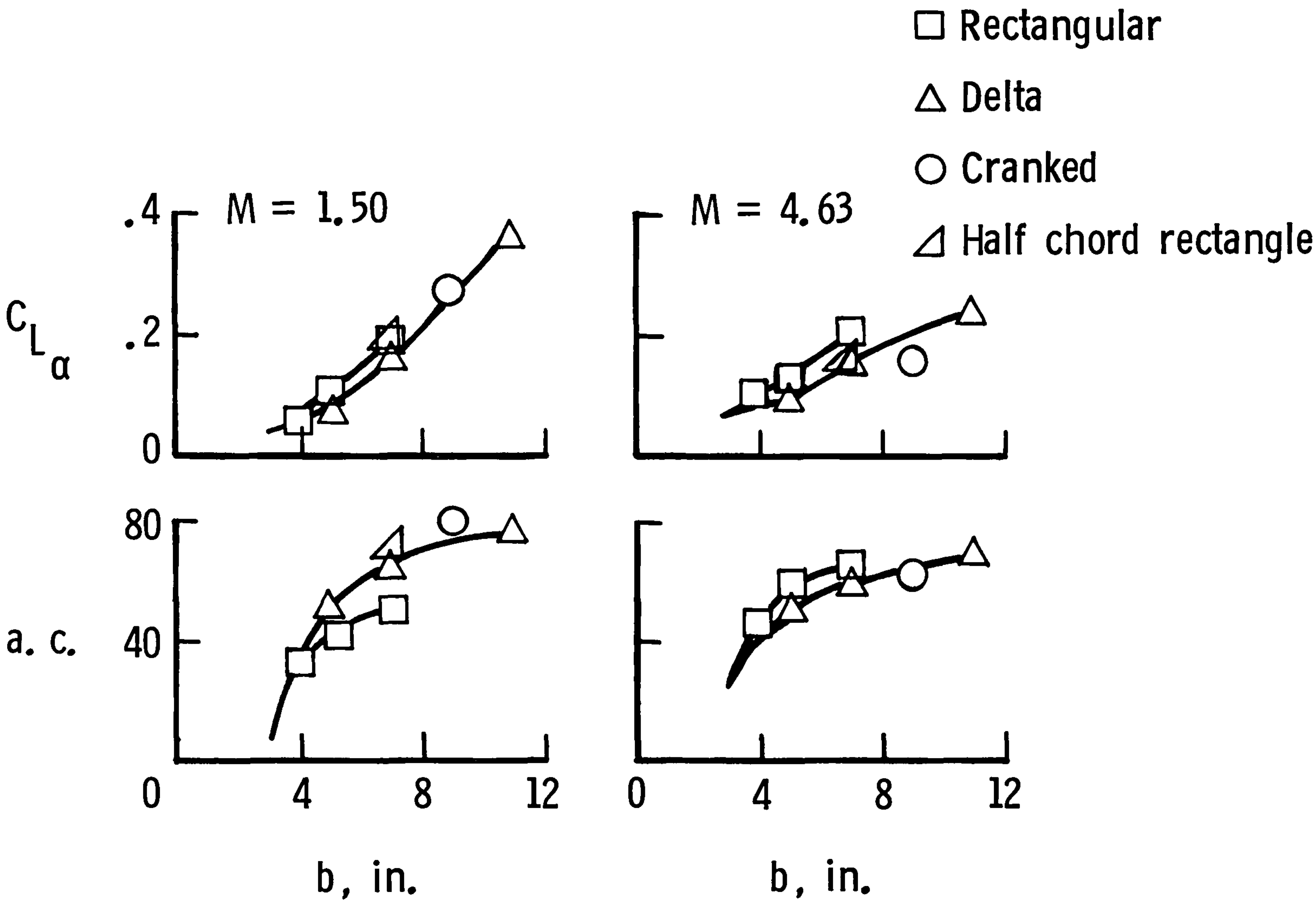

Figure 9.- Variation of C_{L_α} and a.c. with total span for various wing planforms, M = 1.50 and 4.63.

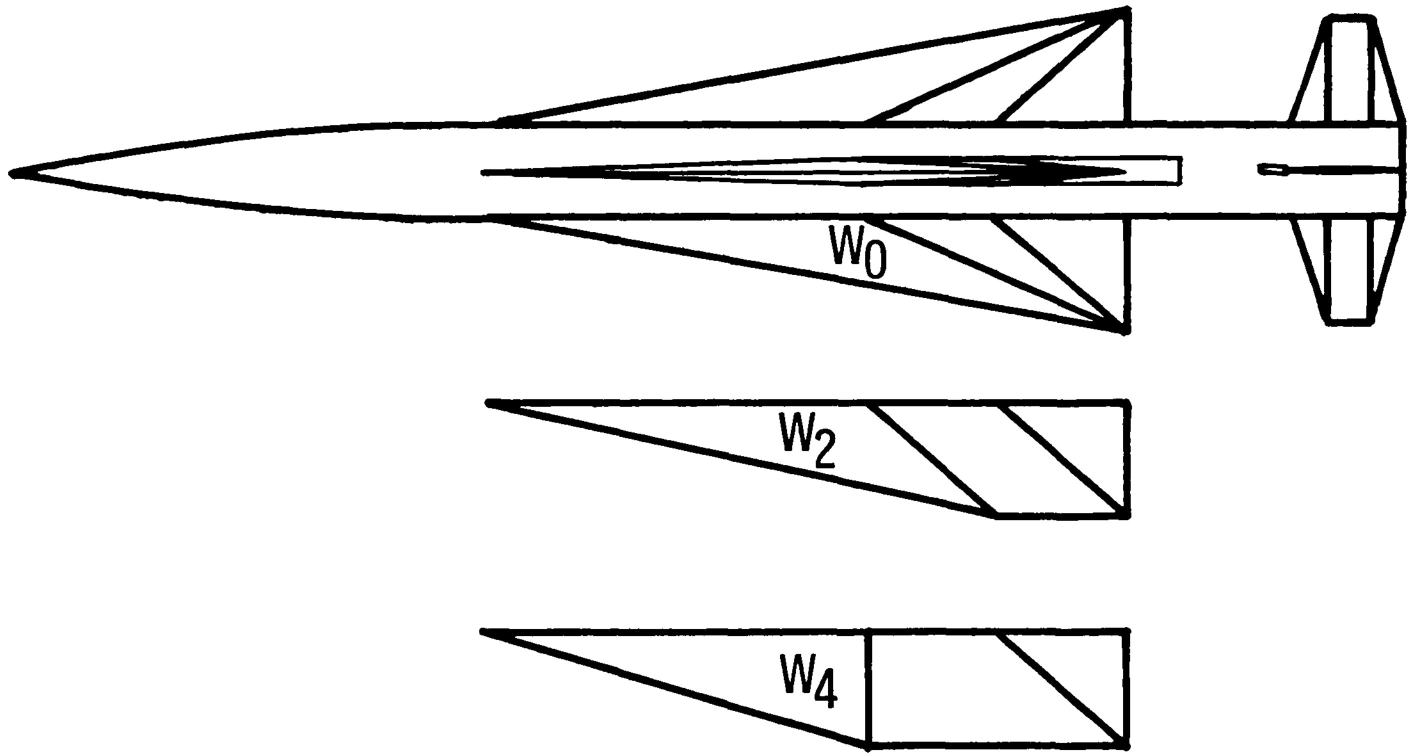

Figure 10.- Wing-body-tail model having planform variations with a constant wing span.

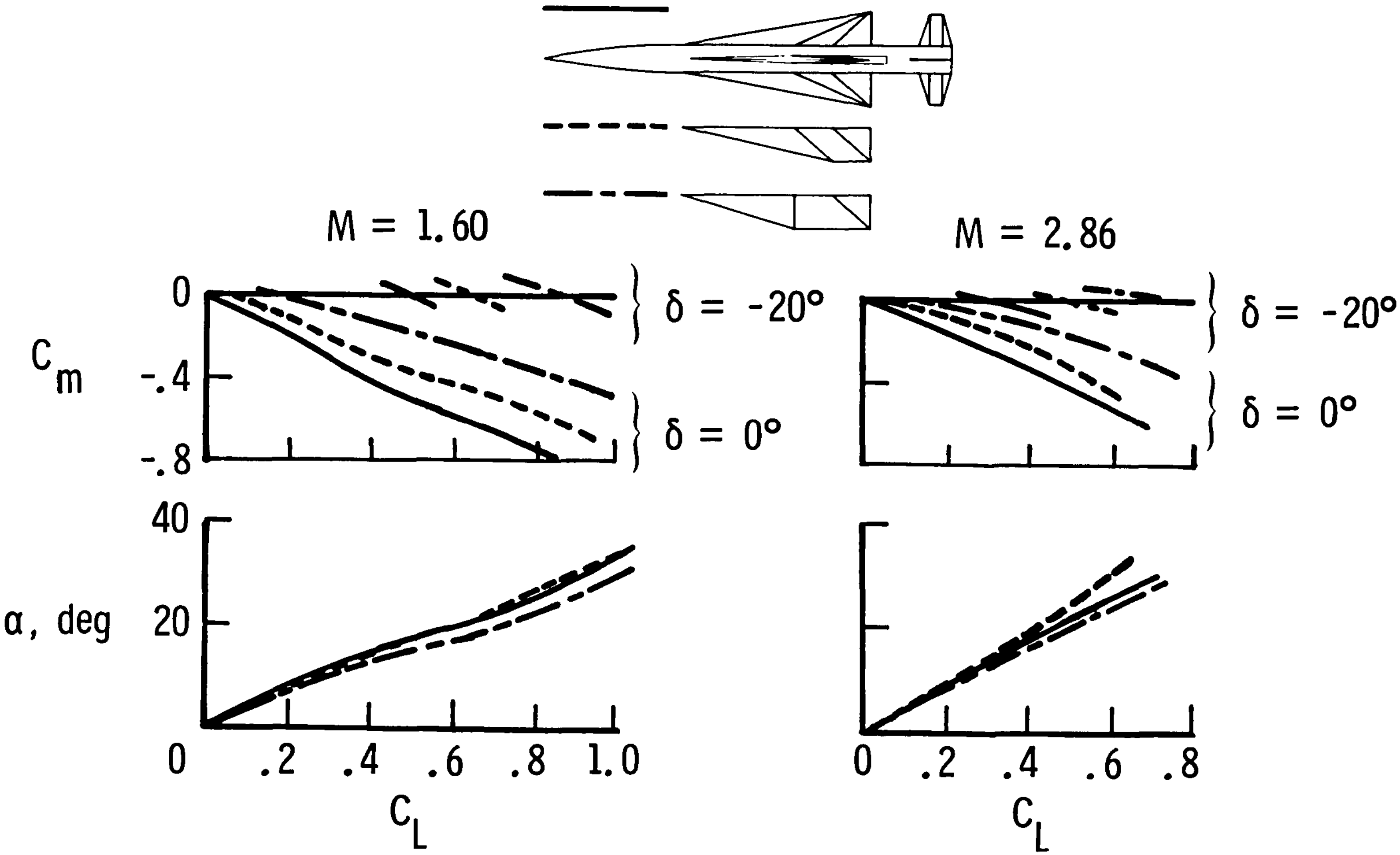

Figure 11.- Planform effects on longitudinal characteristics for configuration with fixed span, M = 1.60 and 2.86.

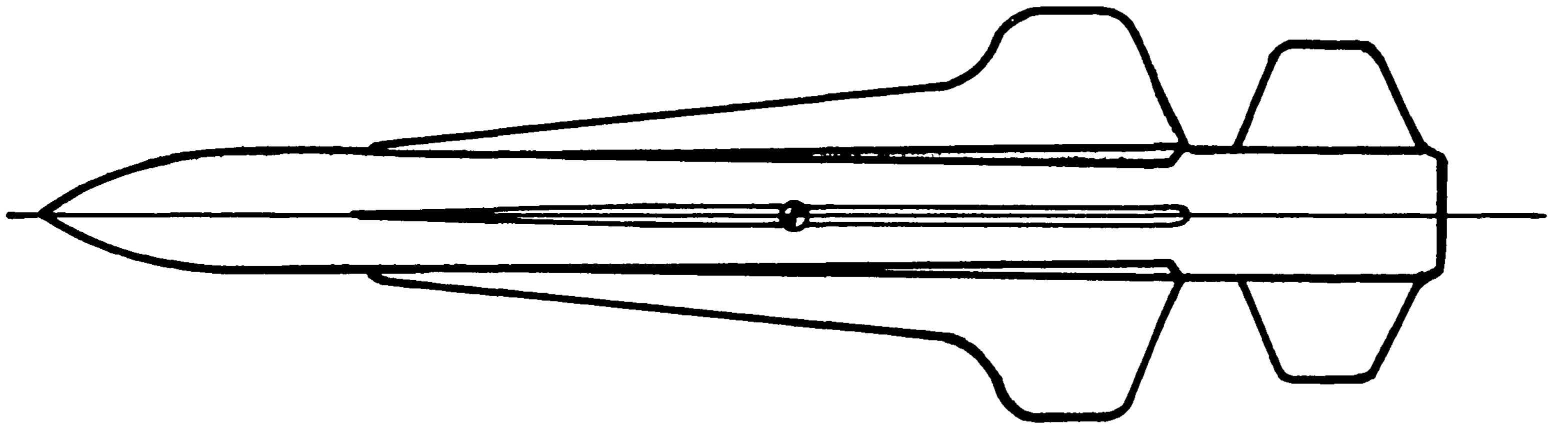

Figure 12.- Cranked wing concept.

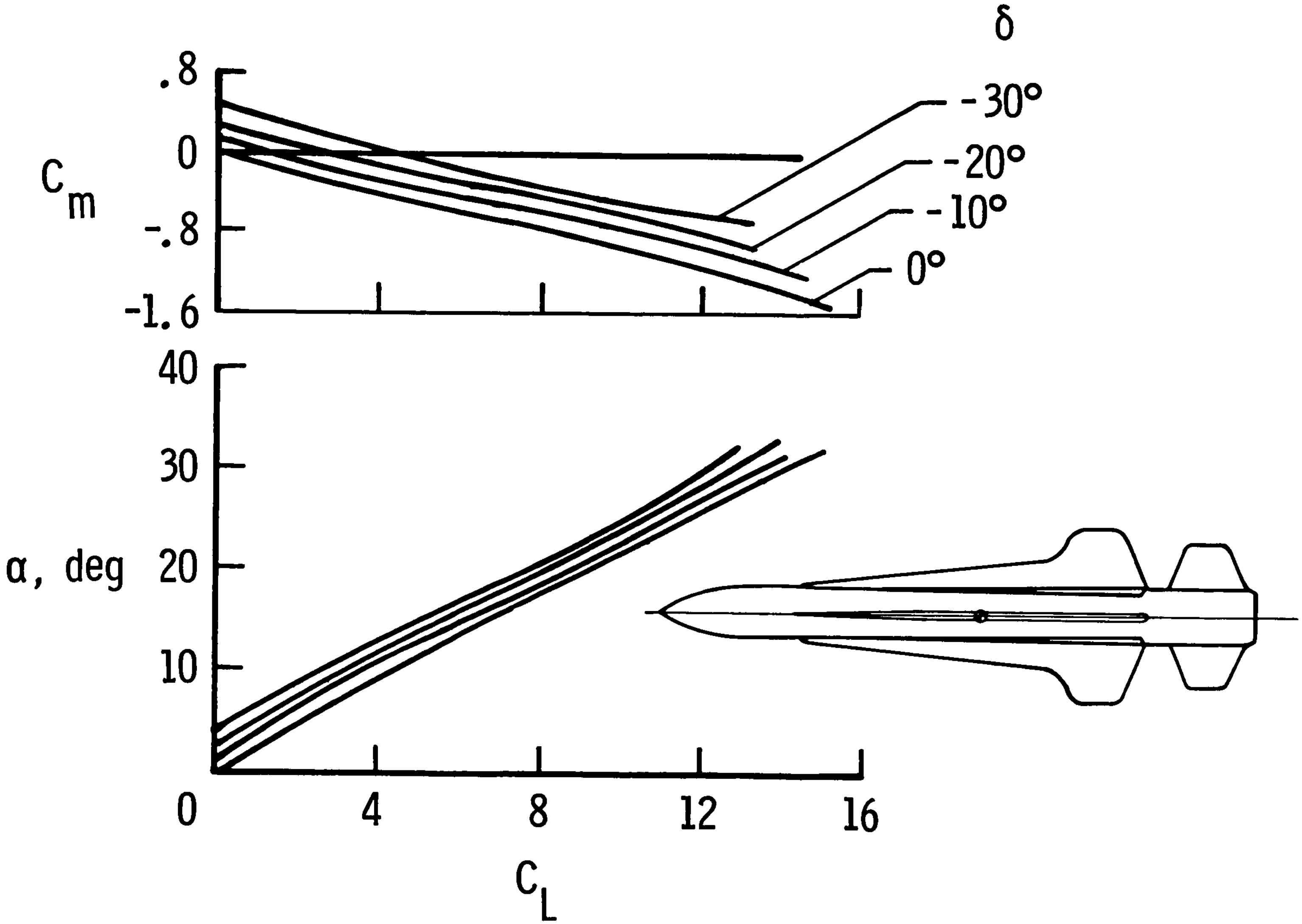

Figure 13.- Longitudinal characteristics for cranked wing concept, M = 2.87.

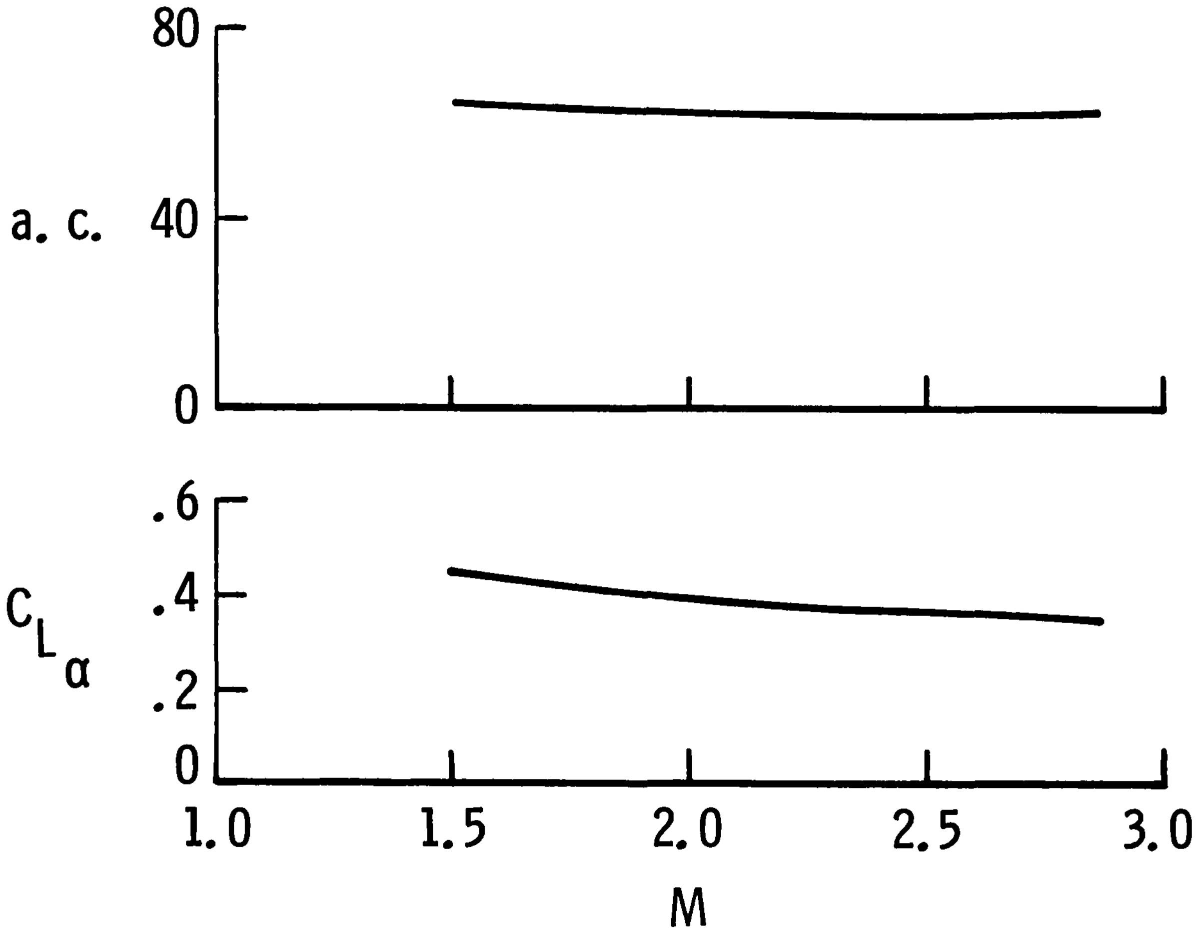

Figure 14.- Some longitudinal parameters as a function of Mach number, cranked wing concept.

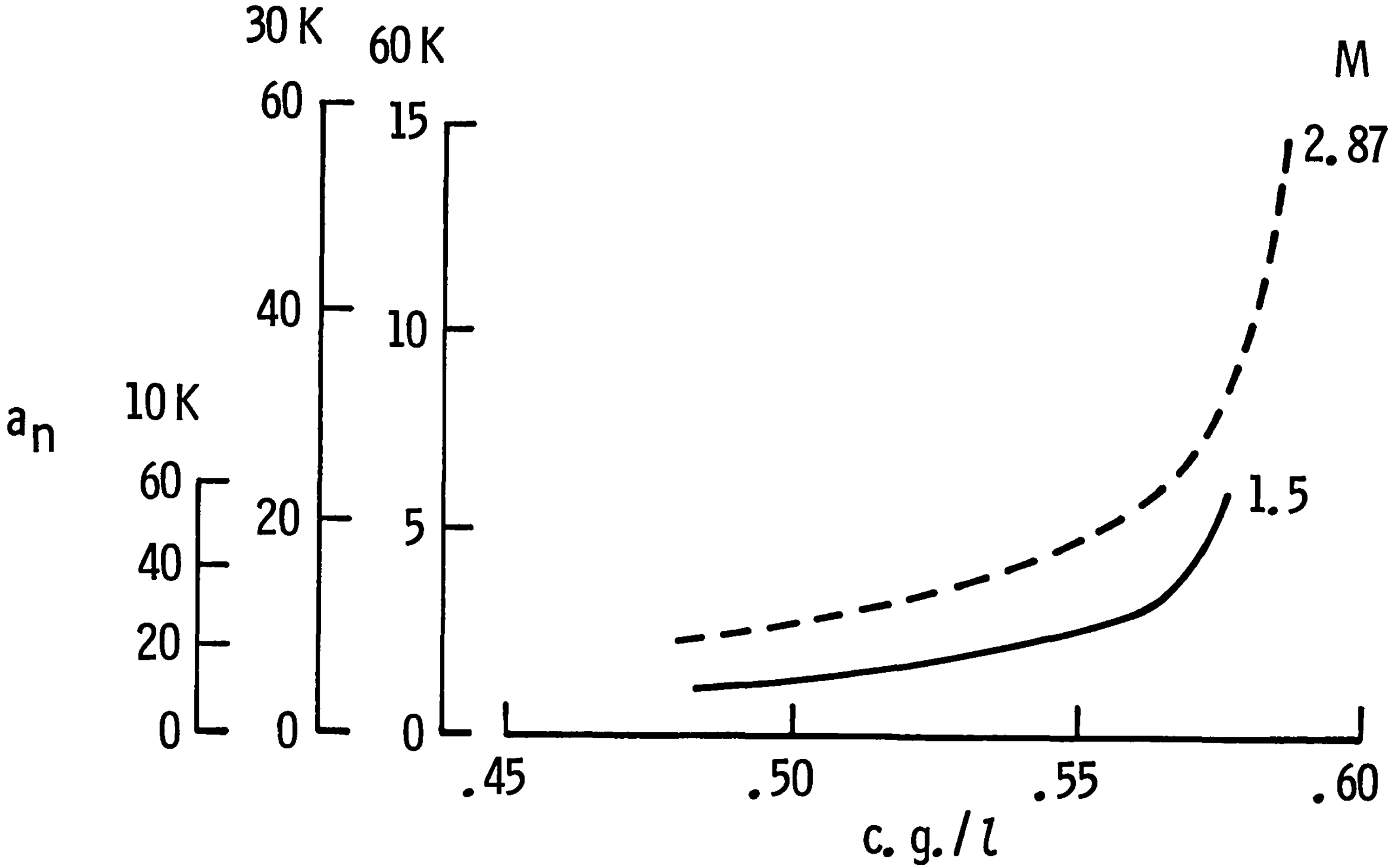

Figure 15.- Maneuver potential for cranked wing concept, W/A = 750, δ = -20°.

Standard Bibliographic Page

1 Report No
NASA TM-87683

2 Government Accession No

3 Recipient's Catalog No

4 Title and Subtitle

EFFECTS OF SOME GEOMETRIC VARIATIONS ON MISSILE AERODYNAMIC CHARACTERISTICS AT SUPERSONIC SPEEDS

5 Report Date
February 1986

6 Performing Organization Code
505-69-71-03

7 Author(s)
M. Leroy Spearman

8 Performing Organization Report No

9 Performing Organization Name and Address
NASA Langley Research Center
Hampton, VA 23665-5225

10 Work Unit No

11 Contract or Grant No

12 Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Washington, DC 20546

13 Type of Report and Period Covered
Technical Memorandum

14 Sponsoring Agency Code

15 Supplementary Notes
Colateral release with paper presented at the AIAA 24th Aerospace Sciences Meeting, Reno, Nevada, January 6-9, 1986.

16 Abstract

Some results from tests of a wing-body general research missile model are presented for a Mach number range up to 4.63. A basic ogive-cylinder body with a length-to-diameter ratio of 10 was used to which was attached a series of wing planforms. The planforms included a family of delta wings and a family of rectangular wings having a constant root chord but varying spans so that wings of constant exposed area could be compared. In addition, a cranked-tip planform was included and a rectangular planform with reduced chord. Some results are presented for wing-body-tail configurations--one utilizing a cranked wing planform and one with wings having a constant root chord and span, but tip chords that were 0, 20, and 40 percent of the root chord.

17 Key Words (Suggested by Authors(s))
Missile Aerodynamics
Missile maneuverability
Wing planform

18 Distribution Statement
Unclassified - Unlimited

Subject Category 02

19 Security Classif (of this report)
Unclassified

20 Security Classif (of this page)
Unclassified

21 No of Pages
25

22 Price
A02

End of Document