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RESEARCH MEMORANDUM

FREE-FLIGHT INVESTIGATION OF CONTROL EFFECTIVENESS OF FULL-SPAN, 0.2-CHORD PLAIN AILERONS AT HIGH SUBSONIC, TRANSONIC, AND SUPERSONIC SPEEDS TO DETERMINE SOME EFFECTS OF WING SWEEPBACK, TAPER, ASPECT RATIO, AND SECTION-THICKNESS RATIO

By

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[redacted]

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

FREE-FLIGHT INVESTIGATION OF CONTROL EFFECTIVENESS OF FULL-SPAN, 0.2-CHORD PLAIN AILERONS AT HIGH SUBSONIC, TRANSONIC, AND SUPERSONIC SPEEDS TO DETERMINE SOME EFFECTS OF WING SWEEPBACK, TAPER, ASPECT RATIO, AND SECTION-THICKNESS RATIO

By Carl A. Sandahl

SUMMARY

An aerodynamic-control-effectiveness investigation using free-flight rocket-propelled RM-5 test vehicles is being conducted by the Pilotless Aircraft Research Division of the Langley Memorial Aeronautical Laboratory. Results have been obtained recently which indicate some of the effects of wing taper ratio, section-thickness ratio, wing aspect ratio, and sweepback on the rolling effectiveness of plain full-span 0.2-chord sealed ailerons. The aileron control characteristics of untapered, 45° sweptback wings of aspect ratio 3.0 were found to be generally the same for the NACA 65-006 and NACA 65-009 airfoil sections, neither configuration exhibiting abrupt changes in effectiveness in the Mach number range investigated. The tapered 45° sweptback wings of aspect ratio 3.0 and NACA 65-009 airfoil section exhibited a small abrupt change in rolling effectiveness in the Mach number range from 0.92 to 1.00 which was not characteristic of untapered wings tested having the same sweep, aspect ratio, and section. A reduction in aspect ratio from 3.0 to 1.75 for unswept, untapered wings resulted in an appreciable increase of rolling effectiveness. Both aspect-ratio configurations exhibited undesirable control characteristics at transonic speeds.

INTRODUCTION

At the present time the Pilotless Aircraft Research Division of the Langley Memorial Aeronautical Laboratory is engaged in an experimental investigation of aerodynamic control effectiveness at high subsonic, transonic, and supersonic speeds using rocket-propelled free-flight test vehicles. The exploratory phase of this program is being conducted with the RM-5 test vehicle which is described in reference 1. Also included in reference 1 is a description of the RM-5 instrumentation and measurements, a discussion of the capabilities and limitations of the testing technique, and a presentation of first results obtained using the RM-5 technique. These first results indicated some of the effects of wing sweepback and section-thickness ratio on the rolling effectiveness of plain flap-type sealed ailerons over the Mach number range from about 0.75 to 1.40.

The present report includes results of recent RM-5 launchings which indicate some of the effects of wing aspect ratio, taper ratio, section-thickness ratio, and wing sweepback on the rolling effectiveness of plain full-span 0.2-chord ailerons. Also included in the present report are results which indicate the influence of the finite torsional rigidity of the RM-5 wings on the effectiveness of the ailerons. Certain data from reference 1 are reproduced in the present report for comparison.

SYMBOLS

$\frac{pb}{2V}$ wing-tip helix angle, radians

p rolling velocity, radians per second

b diameter of circle swept by wing tips, feet

V flight-path velocity, feet per second

C_D drag coefficient based on the total exposed wing area of 1.563 square feet

M Mach number

Λ wing sweepback of 50-percent-chord line

A aspect ratio $\left(b_1{}^2/S_1\right)$

b_1 diameter of circle swept by wing tips minus fuselage diameter

S_1 exposed area of two wing panels

λ wing taper ratio (c_t/c_r)

c_r wing root chord at side of fuselage

c_t wing-tip chord

δ_a control deflection measured in free-stream direction

I_x moment of inertia about longitudinal axis

m_θ wing torsional stiffness parameter $\left(\frac{m}{\theta}\right)$

m concentrated couple applied at wing tip in plane parallel to model center line and normal to wing chord plane, inch-pounds

θ angle of twist produced by m at any section along wing span in plane parallel to model center line, radians

DESCRIPTION OF TEST VEHICLES AND TESTS

Test Vehicles

The general arrangement of the RM-5 test vehicles used in the present investigation is shown in the drawing of figure 1 and the photographs of figure 2. The models are constructed mainly of wood for ease of construction and lightness. The body is of balsa except at the wing attachment where spruce is used. The wings are constructed of laminated spruce with metal stiffeners inlaid into the upper and lower wing surfaces to provide the required torsional rigidity.

A summary of the characteristics of the configurations for which results are presented in this report is given in the following table:

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Model number	Aspect ratio A	Taper ratio λ	Sweepback, Λ (deg)	NACA airfoil section	Average aileron deflection, δ_a (deg)	I_X (slug-ft^2)	Source
50(a)	3.0	1.0	0	65-009	4.4	0.1095	Reference 1
50(b)	3.0	1.0	0	65-009	4.0	.1110	Reference 1
53(a)	3.0	1.0	45	65-009	5.6	.1110	Reference 1
54(a)	3.0	1.0	45	65-006	5.0	.0862	Present tests
55(a)	3.0	.5	45	65-009	6.0	.0911	Present tests
56(a)	3.0	.5	45	65-009	6.0	.0770	Present tests
57(a)	1.75	1.0	0	65-009	5.0	.0901	Present tests
57(b)	1.75	1.0	0	65-009	5.0	.0911	Present tests

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In all tests, the body shape, the exposed wing area (225 sq in.) and the control (0.2c full-span sealed plain flap, $\delta_a \approx 5^\circ$) were constant. The airfoil sections and control deflections were always measured in the free-stream direction. The aileron was formed by deflecting the section chord line at the 0.8c point.

Test Method

A complete discussion of the RM-5 testing technique, accuracy of measurements, reduction of data, and the evaluation of results is given in reference 1; however, a brief description of the testing method follows.

The RM-5 test vehicle consists of a pointed cylindrical body at the rear of which are attached three wings having preset, fixed aileron controls. The models are propelled by a rocket motor which produces a thrust of about 1600 pounds for about 1 second. The models are launched at an elevation angle of 75° from a rail-type launcher. At the end of the 1-second rocket-burning period, the flight velocity is of the order of 1500 feet per second. In flight, the rolling velocity produced by the ailerons is measured by means of special radio equipment designated "spinsonde." The rolling velocity measurements, in conjunction with Doppler radar flight-path velocity measurements and atmospheric data obtained with radiosondes, permit the evaluation of the aileron control effectiveness in terms of the parameter $pb/2V$ as a function of Mach number. The above-described measurements are obtained in a 12-second period following rocket burnout during which period the flight path is essentially straight. It should be noted that, since the tests described in reference 1, the range of the Doppler radar has been extended, thereby increasing the useful part of the flight from 5 seconds to the aforementioned 12 seconds.

Typical curves of Reynolds number versus Mach number for the present tests are given in figure 3. The Reynolds number is based on the average exposed wing chord in the flight direction.

Effect of Wing Torsional Stiffness

It was recognized at the outset of the present investigation that the loss of aileron rolling power due to wing twisting would have to be reduced to a satisfactory minimum. Using available methods of calculation, (reference 2), it was possible to design the unswept wings so that the loss in rolling power due to wing twisting did not exceed about 20 percent at a Mach number of 0.8.

Furthermore, approximate calculations for unswept wings at a Mach number of 1.4 indicated that the loss of rolling power would be of the same order as at a Mach number of 0.8. It was possible, therefore, to design rationally the unswept wings so that the loss in aileron effectiveness would not be excessive.

The design of the swept wings was necessarily arbitrary because no rational procedure was available. It was therefore decided to test two swept-wing configurations which would be identical except for the degree of wing torsional stiffness. These wings were sweptback 45° and were of aspect ratio 3.0, taper ratio 0.5, and NACA 65-009 airfoil section. In one configuration (model 55a), 0.20-steel inlay stiffeners were employed; this construction is generally used in this investigation. (See fig. 1.) In the other configuration (model 56a), 0.20-aluminum inlay stiffeners were employed. (See fig. 1.) The wing-stiffness curves of figure 4 indicate that the wings of model 55a were approximately twice as stiff as the wings of model 56a except for the part of the wing span outboard of the end of the metal inlays. Despite the difference in wing stiffness, the curves of $pb/2V$ versus Mach number for the two models, figure 5, agree well within the order of accuracy, as indicated by tests of supposedly identical models. This agreement indicates that the wing torsional stiffness for both models was sufficient to keep the loss of aileron rolling power due to wing twisting to a minimum satisfactory for the purposes of the present tests. Furthermore, for all of the wings used in this control investigation of the same order of stiffness, or stiffer than the aforementioned wings, it may be concluded that the effects of wing twisting are small over the range of Mach numbers investigated in these tests.

RESULTS AND DISCUSSION

The results of the present investigation are presented in figure 5 as curves of wing-tip helix angle and drag coefficient versus Mach number using the method of data reduction described in reference 1. These results are compared with some of the results from reference 1 in figures 6 and 7.

Aileron Control Characteristics

Effect of section-thickness ratio.- The effect of section-thickness ratio on aileron effectiveness for 45° sweptback, untapered wings is shown in figure 6. In general, the aileron characteristics for the two section-thickness ratios (0.06 and 0.09) investigated are in agreement except at the higher Mach numbers where the lower effectiveness of the thinner section is attributed to greater wing twisting. For both configurations the rolling effectiveness decreased with increasing Mach number for the Mach number range investigated.

Effect of taper ratio.- The effect of taper ratio on the rolling power of plain ailerons of 45° sweptback wings of aspect ratio 3 and NACA 65-009 airfoil section is shown by the comparison of the result for models 53a and 55a, figure 6. Whereas the variation of $pb/2V$ over the Mach number range investigated is substantially smooth for the untapered wings, a small abrupt loss in effectiveness is measured for the tapered wings in the Mach number range from about 0.92 to 1.00. Above Mach number 1.0, the rolling effectiveness decreases with increasing Mach number over the Mach number range investigated.

Effect of aspect ratio.- The effect of aspect ratio on the rolling effectiveness of the ailerons tested on unswept, untapered wings of NACA 65-009 airfoil section is shown in figure 7. The aileron-effectiveness characteristics as a function of Mach number are, in general, the same for the two aspect ratios investigated with the exception that, for the lower aspect ratio wings, the break in the effectiveness curves occurs at a slightly higher Mach number. The aileron effectiveness for the low-aspect-ratio configurations is markedly greater over the entire Mach number range investigated. At Mach numbers above 1.0 the lower aspect ratio wing retains a larger part of the subsonic rolling effectiveness than does the higher aspect ratio wing. Above Mach number 1.0, the rolling effectiveness for both configurations decreased with increasing Mach number. Both configurations exhibited undesirable control characteristics at transonic speeds. In examining the $pb/2V$ data in the Mach number range from 0.9 to 1.0, figure 7, it should be noted, as pointed out in reference 1, that the effects of finite rolling moment of inertia on the instantaneous values of $pb/2V$ can be relatively large, of the order of ±20 percent, for abrupt changes in $pb/2V$. For gradual changes in $pb/2V$ the effect of finite moment of inertia is negligible. Part of the differences in the rolling power of models 50a and 50b and models 57a and 57b is due to inadvertent differences in aileron deflections. The average aileron deflections for models 50a, 50b, 57a, and 57b were approximately 4.4°, 4.0°, and 5.0°, respectively. No attempt has been made to correct the $pb/2V$ data to a common aileron deflection because the variation of the aileron effectiveness with deflection is uncertain.

Drag Measurements

The drag-coefficient data obtained in the present investigation are included as a matter of interest and to illustrate the relation between transonic drag rise and control effectiveness. In examining these data, consideration should be made of the section angle-of-attack distribution along the wing span caused by model rotation. The trends of the results, however, are in agreement with the results of the free-flight rocket-propelled drag investigation described in reference 3. It is interesting to note that the configurations which exhibited abrupt changes in control effectiveness at transonic speeds also exhibited the largest drag increases at transonic and supersonic speeds.

CONCLUSIONS

The following conclusions relating to the aerodynamic control effectiveness of plain, 0.2-chord, full-span sealed ailerons are indicated by the tests reported herein:

1. The control characteristics of untapered, 45° sweptback wings of aspect ratio 3.0 were generally the same for both the NACA 65-006 and NACA 65-009 airfoil sections, neither configuration exhibiting abrupt changes in effectiveness in the Mach number range investigated.

2. The tapered, 45° sweptback wings of aspect ratio 3.0 and NACA 65-009 airfoil section exhibited a small abrupt change in rolling effectiveness in the Mach number range from 0.92 to 1.00 which was not characteristic of untapered wings tested having the same sweep, aspect ratio, and section.

3. A reduction in aspect ratio from 3.0 to 1.75 for unswept, untapered wings resulted in a marked increase of rolling effectiveness. Both aspect-ratio configurations exhibited undesirable control characteristics at transonic speeds

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REFERENCES

1. Sandahl, Carl A., and Marino, Alfred A.: Free-Flight Investigation of Control Effectiveness of Full-Span 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds to Determine Some Effects of Section Thickness and Wing Sweepback. NACA RM No. L7D02, 1947.

2. Pearson, Henry A., and Aiken, William S., Jr.: Charts for the Determination of Wing Torsional Stiffness Required for Specified Rolling Characteristics or Aileron Reversal Speed. NACA ACR No. L4L13, 1944.

3. Tucker, Warren A., and Nelson, Robert L.: Drag Characteristics of Rectangular and Swept-Back NACA 65-009 Airfoils Having Various Aspect Ratios as Determined by Flight Tests at Supersonic Speeds. NACA RM No. L7C05, 1947.

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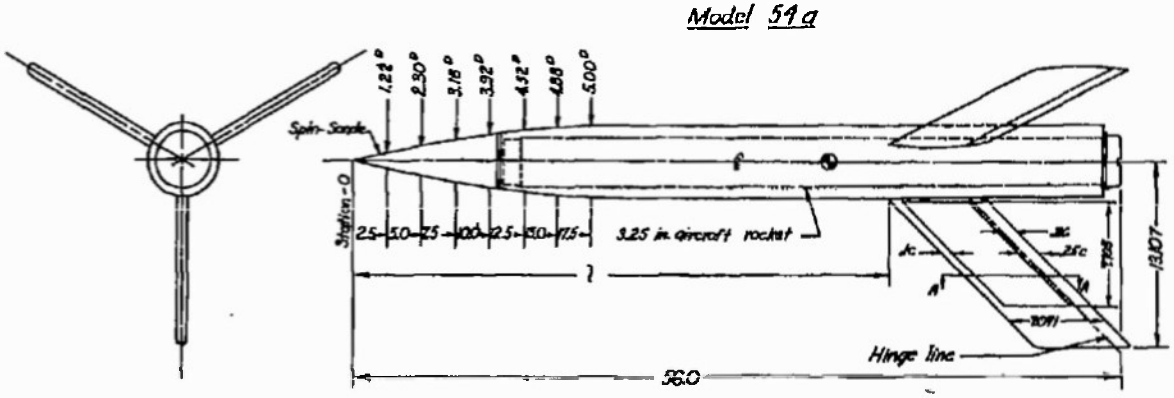
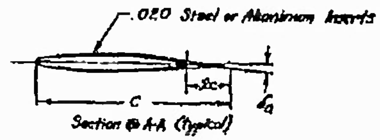
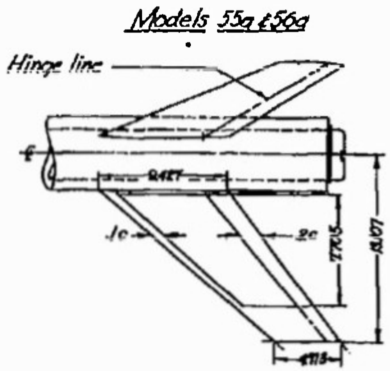




Aileron extends over entire span

Center of gravity is at station 35 (approx.)

All dimensions are in inches



Model no.	Sweep-back deg.	l in.	δ_a deg.	Inserts (optional)
54a	45	33.94	5.0	.020 Steel
55a	45	32.15	6.0	do
56a	45	32.75	6.0	.020 Alum.
57a&b	0	45.44	5.0	.020 Steel

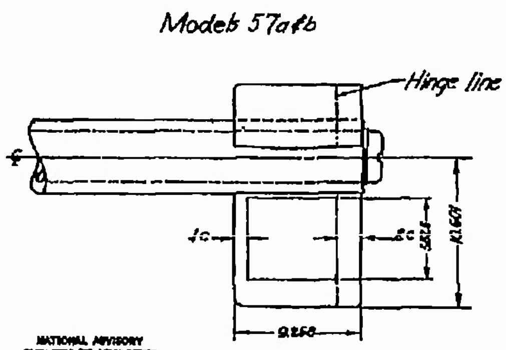


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Figure 1.- General arrangement of RM-5 Models.

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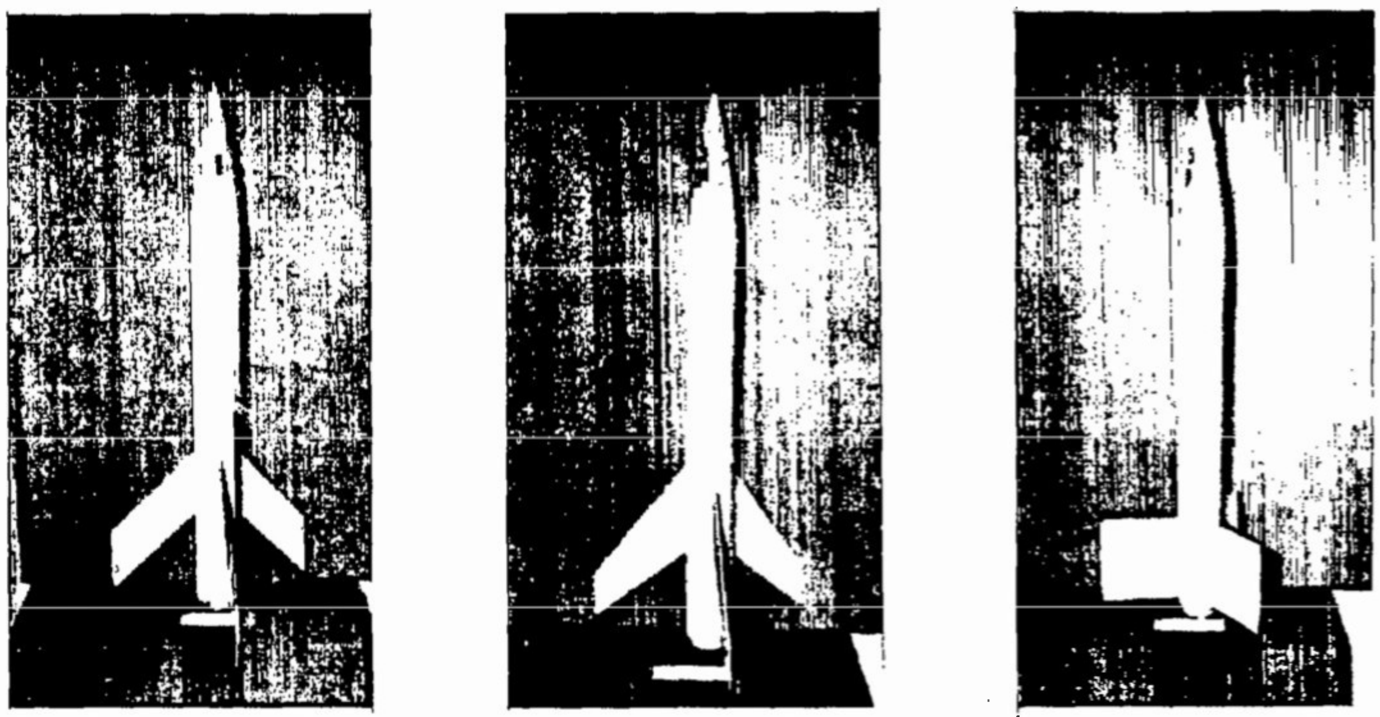

(a) Configuration 54. (b) Configuration 55. (c) Configuration 57.

Figure 2.- Model configurations tested.

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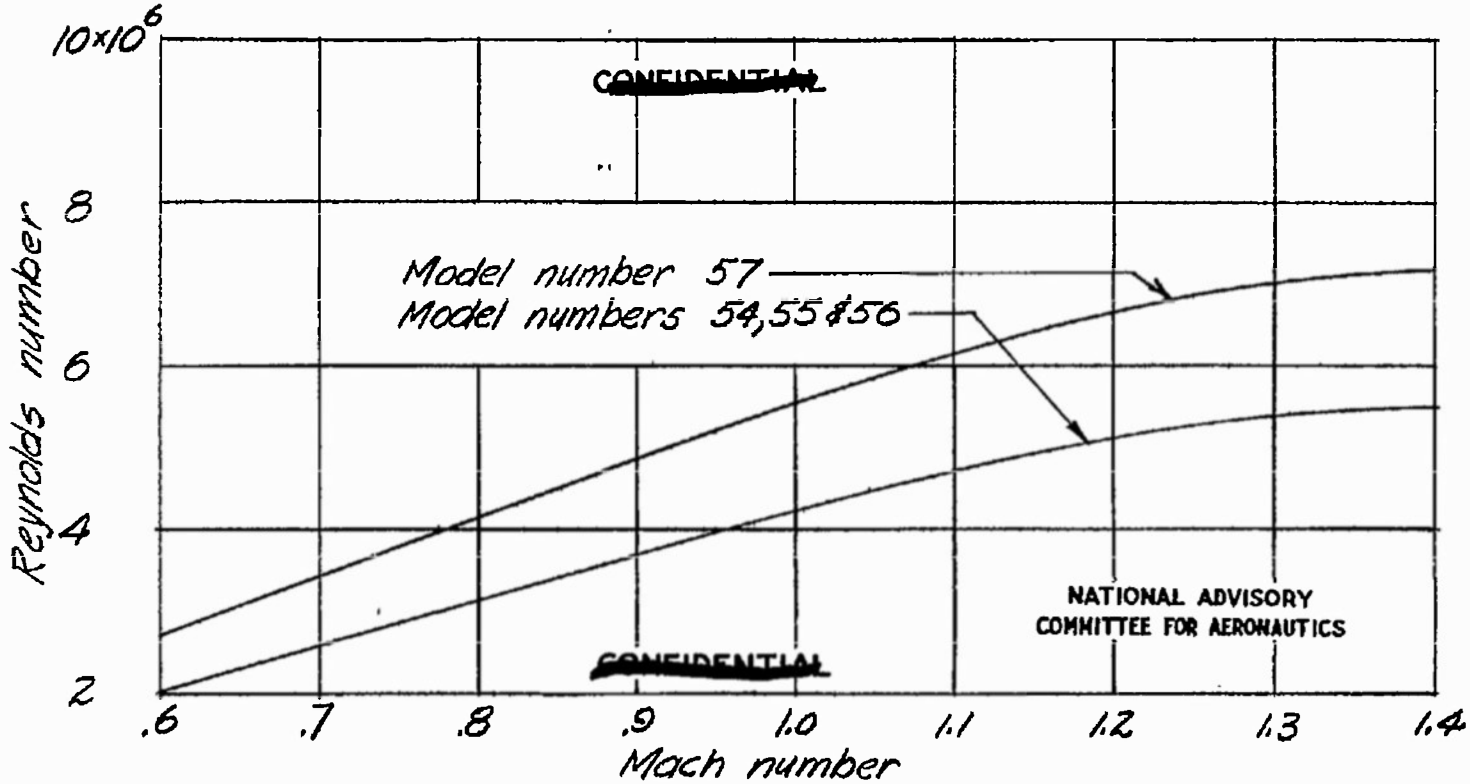

Figure 3.- Typical variation of Reynolds number with Mach number.

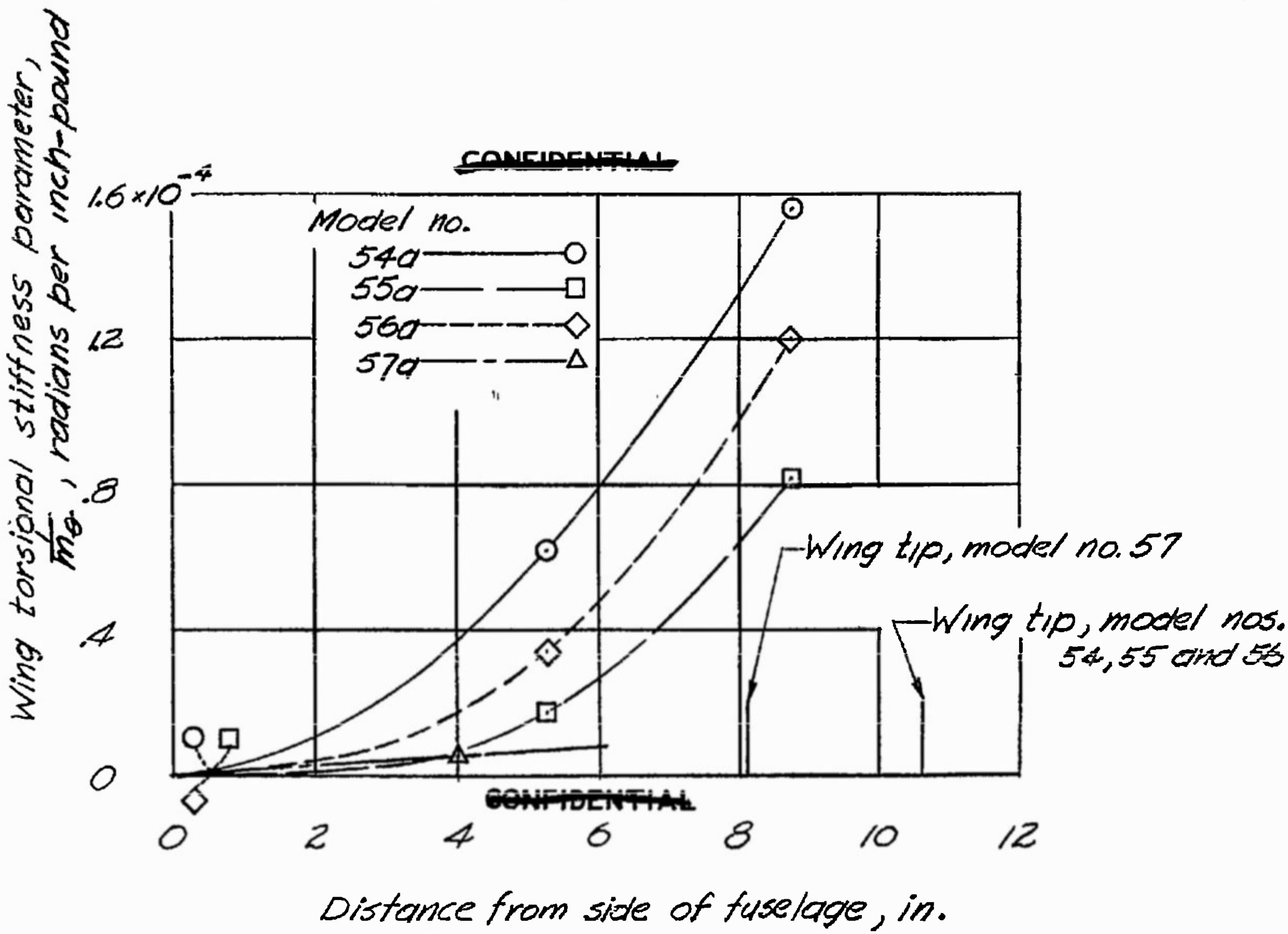

Figure 4.- Wing stiffness curves.

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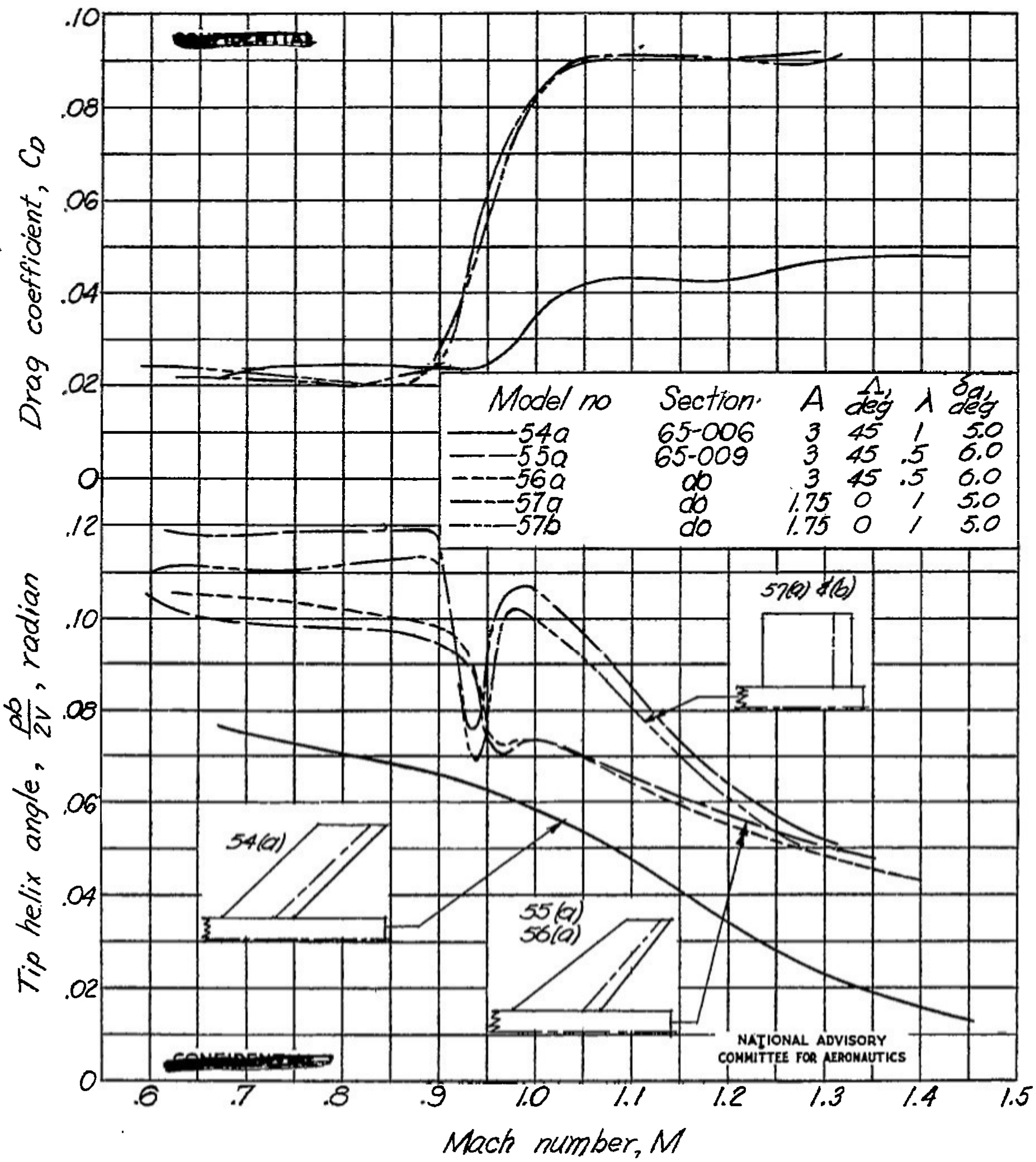

Figure 5.- Variation of tip helix angle and drag coefficient with Mach number for models of present investigation.

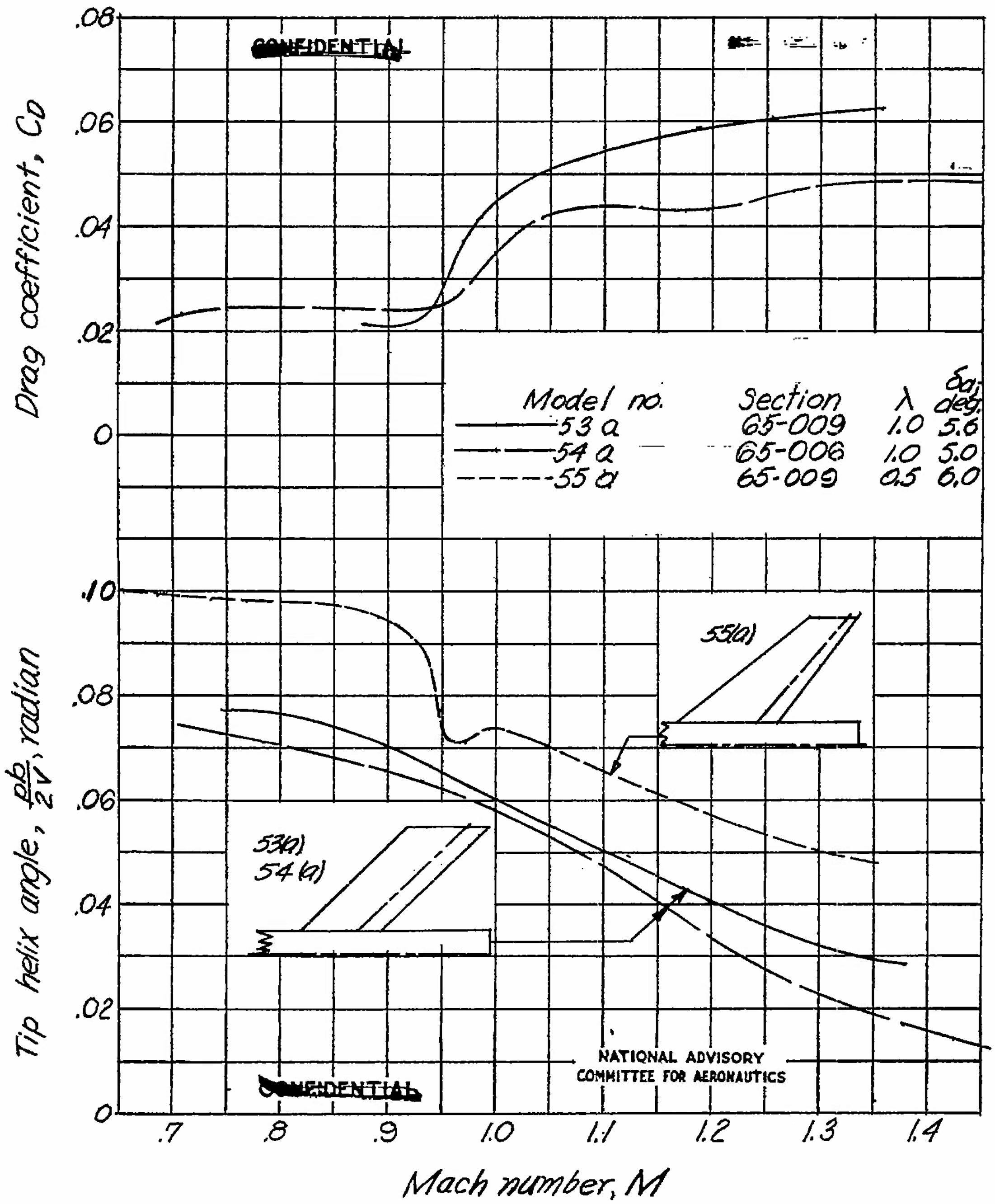

Figure 6.- Effect of thickness and taper on the variation of tip helix angle and drag coefficient with Mach number. A = 3.0; Λ = 45 deg. Data for model 53a from reference 1.

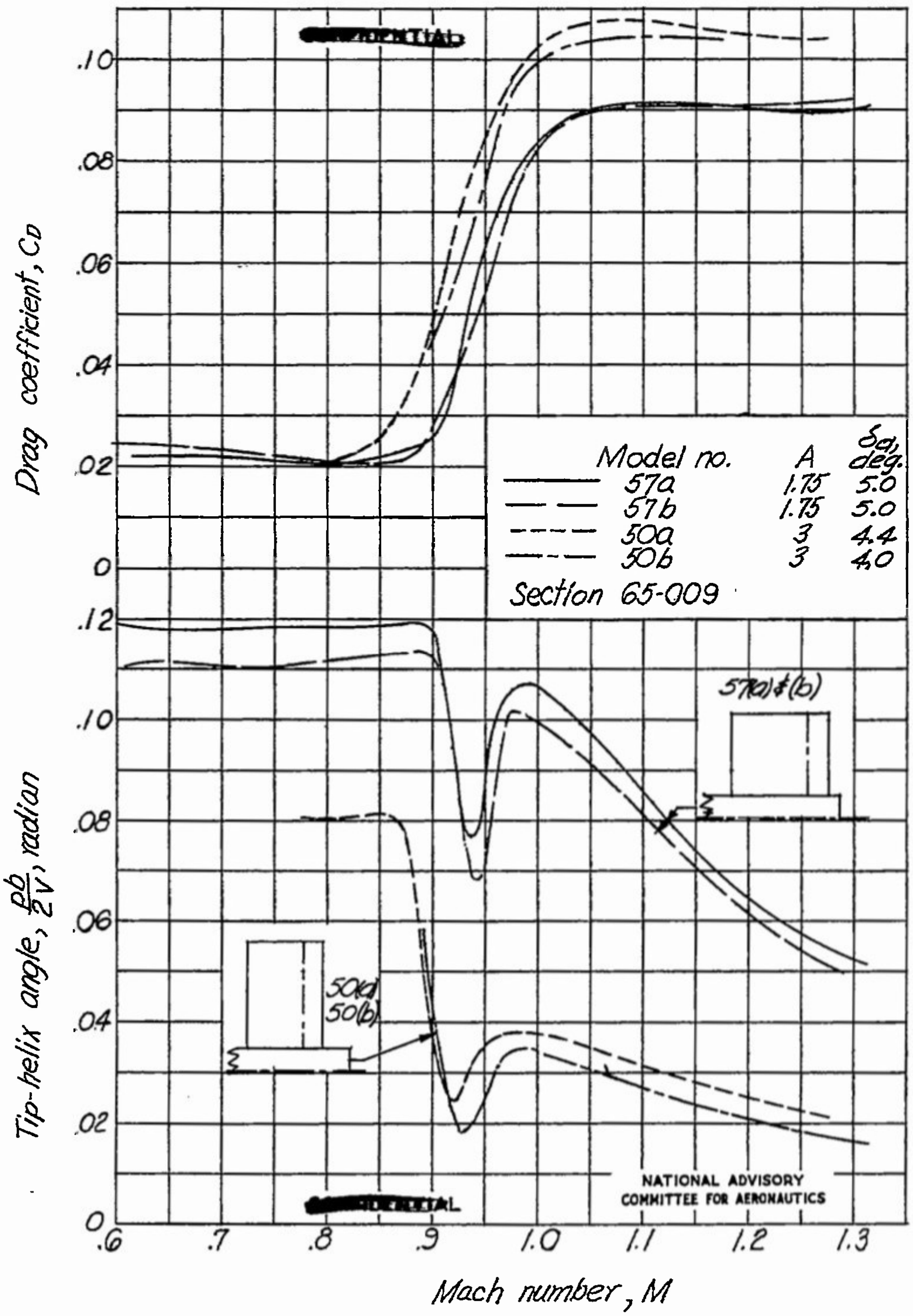

Figure 7.- Effect of aspect ratio on the variation of tip-helix angle and drag coefficient with Mach number. $\Lambda = 0^\circ$; $\lambda = 1.0$. Data for models 50(a) and 50(b) from reference 1.

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ABSTRACT:

Aerodynamic-control-effectiveness investigation was conducted using free-flight rocket-propelled RM-5 test vehicles. Aileron control characteristics of untapered 45° swept-back wings of aspect ratio 3.0 were found to be generally the same for NACA 65-006 and NACA 65-009 airfoil sections. The latter exhibited small abrupt change in rolling effectiveness in Mach number range from 0.92 to 1.00 which was not characteristic of untapered wings tested. Reduction in aspect ratio from 3.0 to 1.75 for unswept, untapered wings resulted in appreciable increase in rolling effectiveness.

* Effects of Wing Sweepback, Taper, Aspect Ratio, and Section-thickness Ratio

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