N 62 70996
NASA TN D-422

/N-02
387 889
18p

NASA TN D-422

TECHNICAL NOTE

D-422

A WIND-TUNNEL INVESTIGATION OF THE DEVELOPMENT OF LIFT

ON WINGS IN ACCELERATED LONGITUDINAL MOTION

By Thomas R. Turner

Langley Research Center
Langley Field, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON August 1960

IY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL NOTE D-422

A WIND-TUNNEL INVESTIGATION OF THE DEVELOPMENT OF LIFT ON WINGS IN ACCELERATED LONGITUDINAL MOTION*

By Thomas R. Turner

L-1027

SUMMARY

An investigation was made in the Langley 300 MPH 7- by 10-foot tunnel to determine the development of lift on a wing during a simulated constant-acceleration catapult take-off. The investigation included models of a two-dimensional wing, an unswept wing having an aspect ratio of 6, a 35° swept wing having an aspect ratio of 3.05, and a 60° delta wing having an aspect ratio of 2.31.

All the wings investigated developed at least 90 percent of their steady-state lift in the first 7 chord lengths of travel. The development of lift was essentially independent of the acceleration when based on chord lengths traveled, and was in qualitative agreement with theory.

INTRODUCTION

There has been considerable interest in the effect of acceleration on the development of lift as encountered in carrier-deck catapult take-offs. This problem has taken on greater significance with the increase of acceleration capabilities of catapults and with the take-off coming at fewer chord lengths of deck run as a result of the large chords associated with the low-aspect-ratio swept and delta wings.

Several available theoretical papers exist on the development of lift (refs. 1 to 4); however, scarcely any experimental data are available in the range of accelerations obtainable with present and design-stage catapults. Therefore, the present investigation was made to determine to what extent the lift might be affected by accelerations encountered in catapult take-offs for several wings of different aspect ratios.

A two-dimensional wing, an unswept wing having an aspect ratio of 6, a 35° swept wing having an aspect ratio of 3.05, and a 60° delta wing

*Supersedes recently declassified NACA RM L56H28a by Thomas R. Turner, 1956.

having an aspect ratio of 2.31 were investigated at several angles of attack and several accelerations.

MODEL AND APPARATUS

Geometric characteristics of the four models used in this investigation are given in figure 1. The two-dimensional and unswept-wing models had NACA 0012 airfoil sections, the delta-wing model had NACA 65A003 airfoil sections, and the swept-wing model had a symmetrical 10.5-percent-thick airfoil section with the maximum thickness at 39 percent of the chord. The coordinates for the swept-wing section are given in reference 5.

L-1027

The investigation was made in a special test section constructed within the regular test section of the Langley 300 MPH 7- by 10-foot tunnel. This special test section was a rectangular tube 16 feet long with a $3\frac{1}{2}$- by 5-foot rectangular cross section (see fig. 2(a)). The downstream end of the special test section was equipped with pneumatically operated doors (see fig. 2(b)). A schematic sketch of the test section is presented in figure 3. This particular test section was developed as a result of considerable preliminary testing to obtain the type of flow desired for this investigation.

The semispan models were mounted on a one-component (lift) electrical strain-gage type of balance having a natural frequency of approximately 500 cycles per second. The dynamic pressure of the test section was obtained from an electrical pressure pickup several chord lengths ahead of the model and on the opposite wall. The output of both the lift balance and the dynamic-pressure pickup were recorded on an oscillograph.

TEST TECHNIQUE

In operation the tunnel was brought up to a given velocity with the doors held closed by air pressure in the cylinder. In this condition the tunnel airstream would pass around the four sides of the special test section and leave the tube filled with still air. When the doors were opened, the air in the tube started moving and the acceleration depended on the tunnel airstream velocity and the rate at which the doors were opened. A two-way valve was used for cutting the air supply to the door-closing piston and bleeding the piston so that the doors could be made to open at the desired rate. Figure 4 gives the variation of velocity with time for several tests and shows that essentially constant accelerations were obtained.

The test procedure used consisted of setting the model at a given angle of attack and making simultaneous oscillograms of model lift and dynamic pressure for a range of constant velocities (with doors open) and then for several rates of acceleration of the airstream. Sample oscillograms for these two types of tests are given in figure 5. The data are presented as the ratio of the lift in accelerated flow to the lift at the same dynamic pressure for the steady-state condition as a function of chord lengths traveled.

Jet-boundary corrections are believed to have a negligible effect on the lift ratios presented and were, therefore, not applied.

RESULTS AND DISCUSSION

The results of this investigation are presented in figures 6 to 10. The data presented in figures 6 to 9 are for angles of attack of about 10° and are representative of data obtained for other angles of attack below the stall.

The variation of the lift ratio with chord lengths traveled for various constant accelerations for the unswept wing (fig. 6) indicates that the development of lift at a constant acceleration is practically independent of acceleration which is in agreement with theory. Since the variation of the lift ratio with chord lengths traveled for the unswept wing (fig. 6) is typical of the variation for the other wings tested, only one of the higher acceleration runs is presented for the remaining wings. Each of the different plan-form wings developed 90 percent of its steady-state lift within 7 chord lengths of travel and 100 percent within about 14 chord lengths. (See figs. 6 and 7.)

The experimental two-dimensional data of this investigation are compared with the theoretical two-dimensional values of references 1 and 2 in figure 8. The theory of reference 2 varies from the theory of reference 1 in that it includes a noncirculatory or virtual mass term. This term is powerful in determining the value of the lift ratio for the first few chord lengths of the accelerated test run, and gives a starting lift-ratio value of more than 1.00; however, this term becomes insignificant after 5 or 6 chord lengths of travel. The experimental curve is in very good agreement with the theoretical curve of reference 2 for approximately the first three chord lengths; however, above three chord lengths the experimental curve approaches a lift-ratio value of 1.00 faster than the theoretical curves. Part of this discrepancy can probably be attributed to the fact that it is almost impossible to get an experimental two-dimensional setup because of end effects.

The delta plan-form wing had a ratio of accelerated lift to steady-state lift always equal to or greater than 1.00. This fact seems reasonable considering that the theory for the constant velocity case predicts that finite wings develop steady-state lift at fewer chord lengths traveled as the aspect ratio is decreased (fig. 9). The finite theoretical curves are an extension by Jones (ref. 3) of the constant-velocity infinite-aspect-ratio case developed by Wagner in reference 1.

The investigation on the unswept wing was also made at 16° angle of attack which was considerably above the stall angle. The data for this condition at an acceleration of 410 feet per second per second are presented in figure 10. The lift value for approximately the first 6 chord lengths traveled was approximately twice the steady-state-lift value, the value obtained by extending the unstalled lift curve to an angle of attack of 16°, and decreased to the steady-state value at approximately 15 chord lengths. This is in qualitative agreement with results from a similar investigation in reference 6.

CONCLUSIONS

The results of a wind-tunnel investigation to determine the effect of acceleration on the development of lift indicated the following conclusions:

1. The wings investigated developed 90 percent of steady-state lift in 7 or fewer chord lengths travel and developed steady-state lift within 14 chord lengths of travel.

2. The results were in qualitative agreement with theory.

3. For constant acceleration the development of lift was practically independent of acceleration when based on chord lengths traveled.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 15, 1956.

REFERENCES

1. Wagner, Herbert: Über die Entstehung des dynamischen Auftriebes von Tragflügeln. Z.a.M.M., Bd. 5, Heft 1, Feb. 1925, pp. 17-35.

2. Ashley, Holt, Dugundji, John, and Neilson, Donald O.: Two Methods for Predicting Air Loads on a Wing in Accelerated Motion. Jour. Aero. Sci., vol. 19, no. 8, Aug. 1952, pp. 543-552.

3. Jones, Robert T.: The Unsteady Lift of a Wing of Finite Aspect Ratio. NACA Rep. 681, 1940.

4. Walker, P. B.: Experiments on the Growth of Circulation About a Wing With a Description of an Apparatus for Measuring Fluid Motion. R. & M. No. 1402, British A.R.C., 1932.

5. Donlan, Charles J., and Kuhn, Richard E.: Estimated Transonic Flying Qualities of a Tailless Airplane Based on a Model Investigation. NACA RM L9D08, 1949.

6. Aeronautics Laboratory, Cambridge: The Flow Near a Wing Which Starts Suddenly From Rest and Then Stalls. R. & M. No. 1561, British A.R.C., 1934.

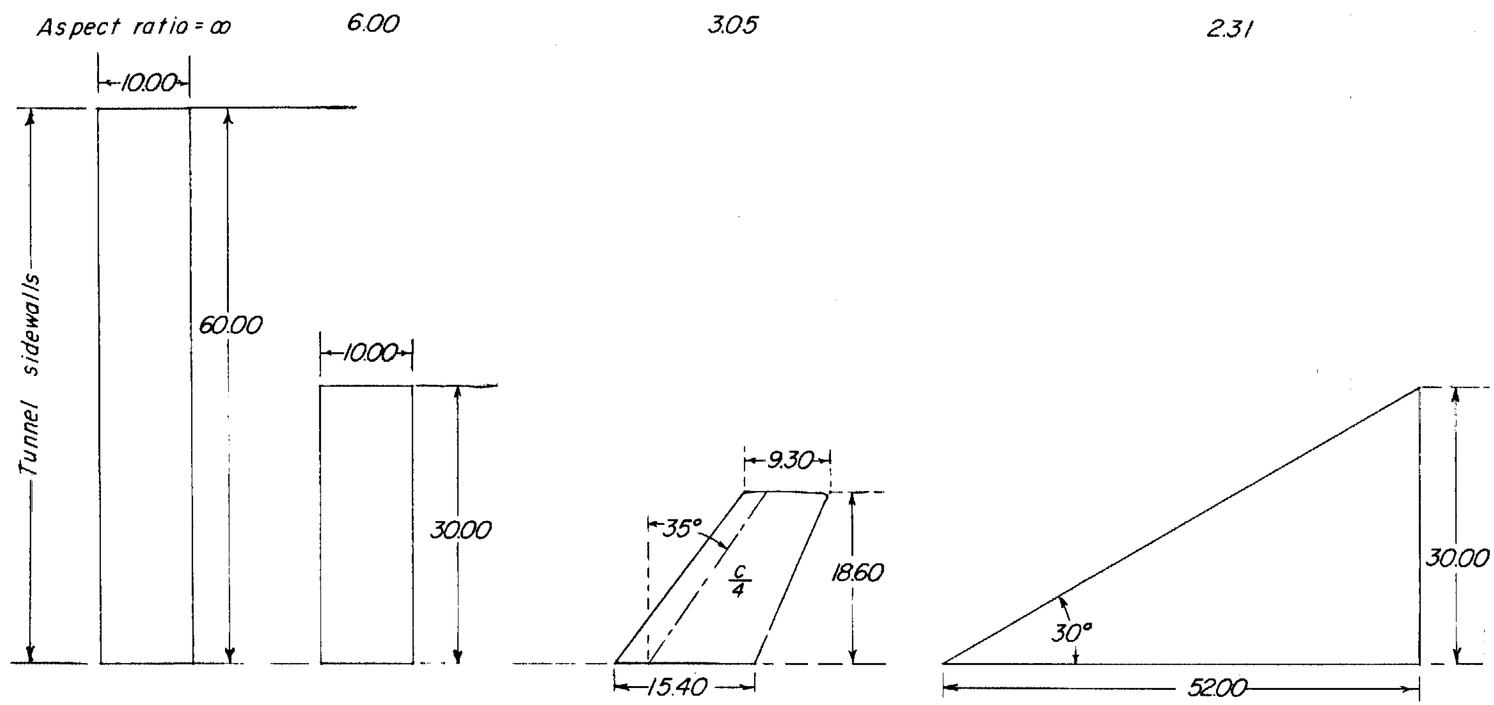
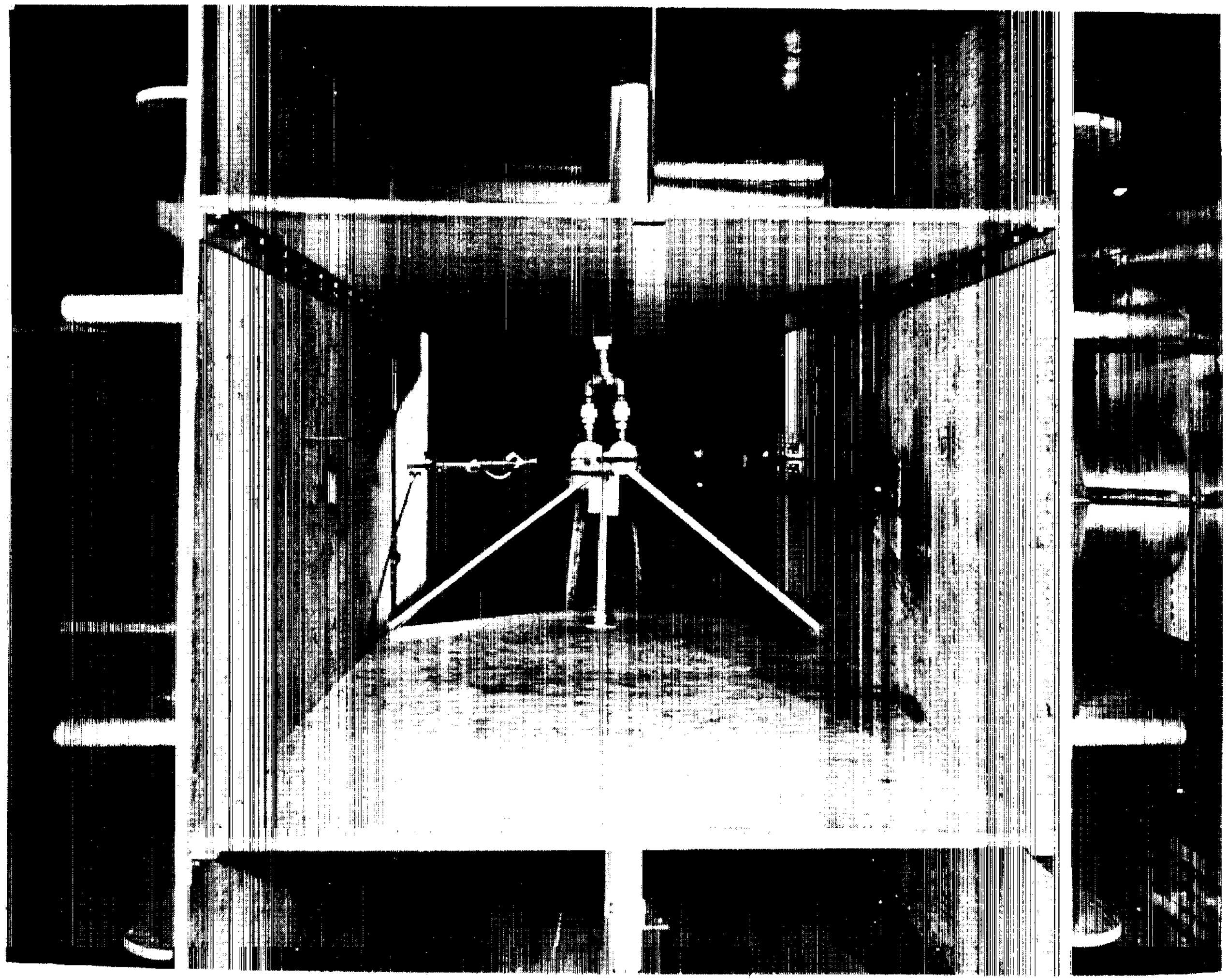
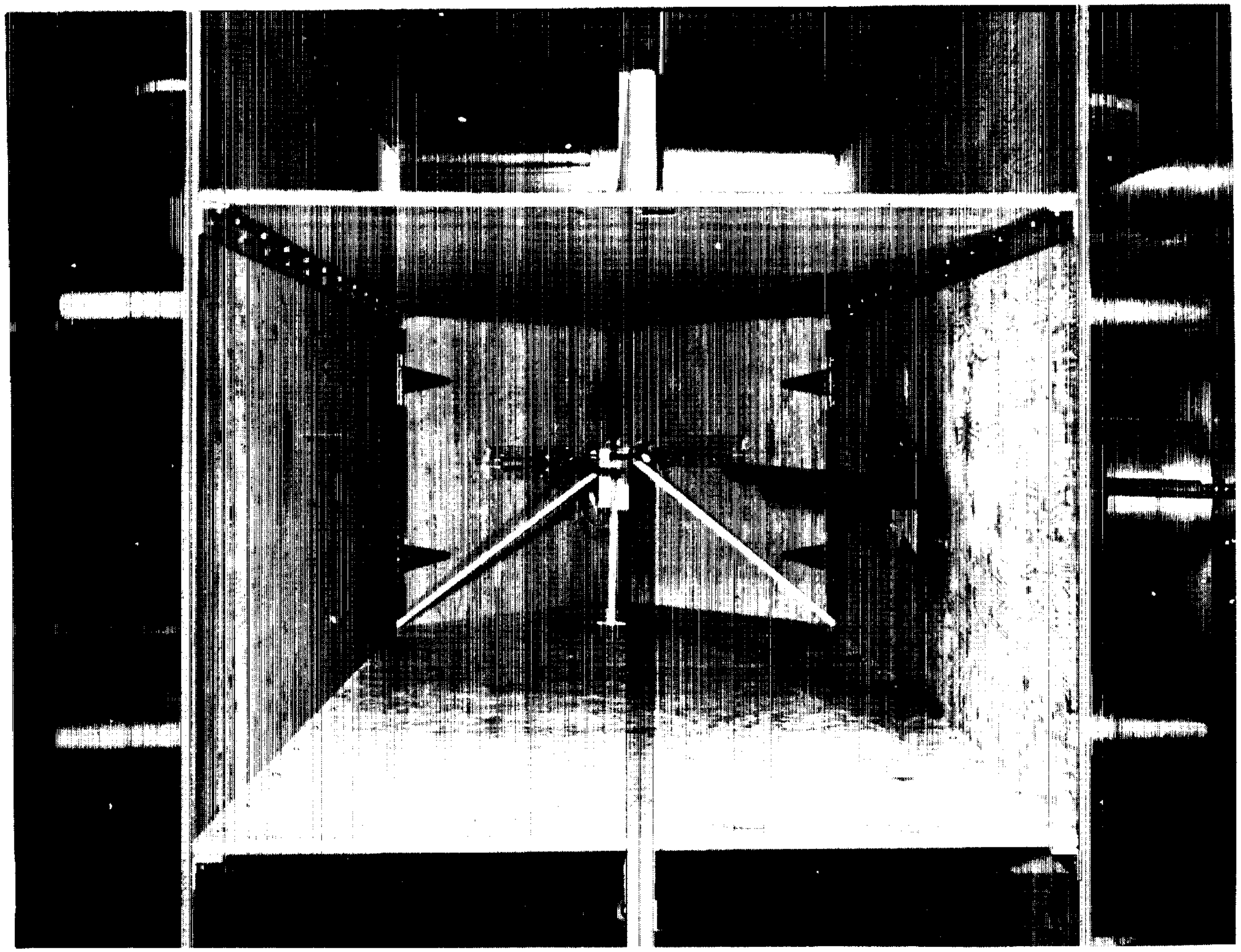


Figure 1.- Plan form of wings tested. All dimensions are in inches.



(a) Door open. L-81724

Figure 2.- Photograph of test setup.



(b) Door closed. L-81725

Figure 2.- Concluded.

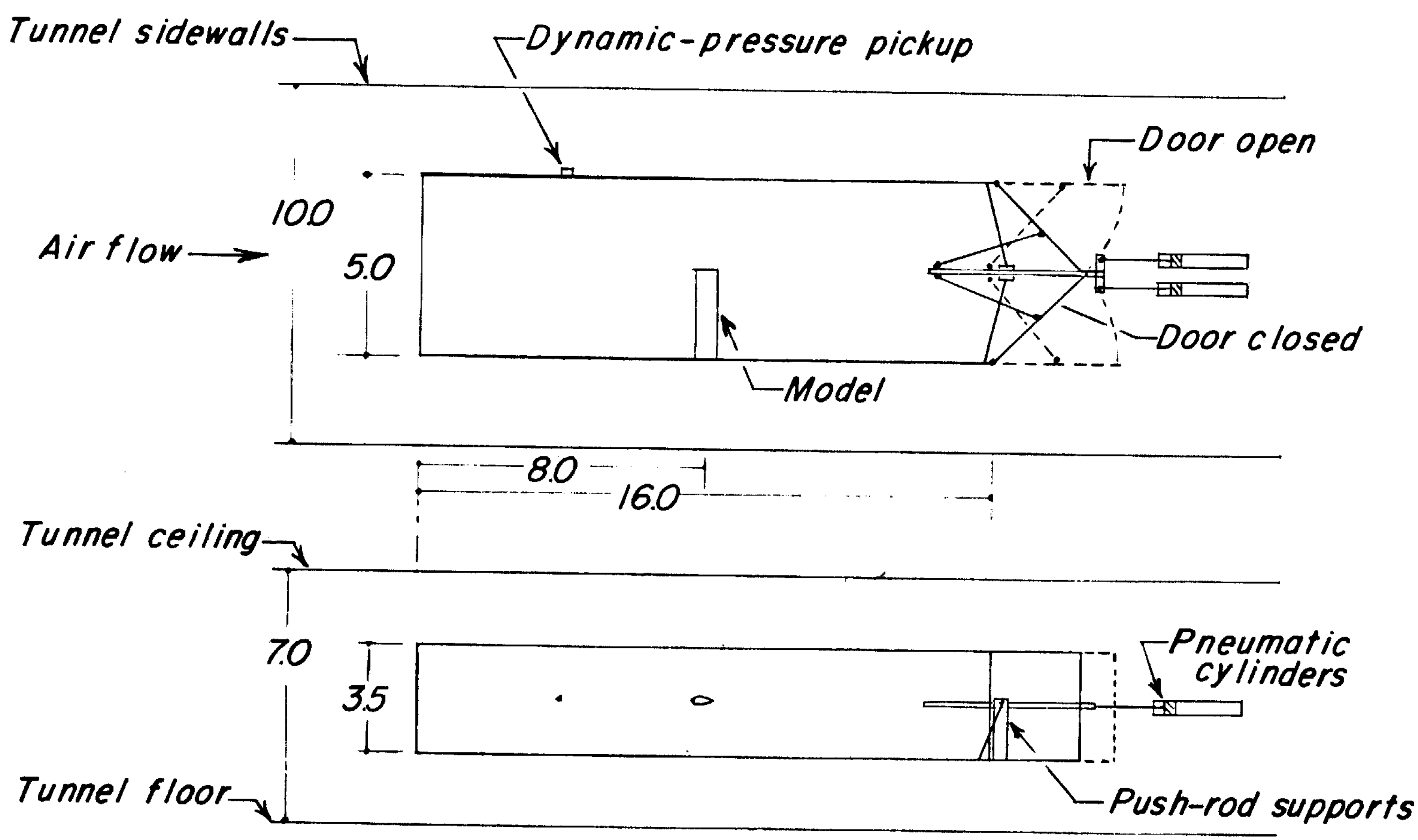


Figure 3.- Schematic diagram of test section. All dimensions are in feet.

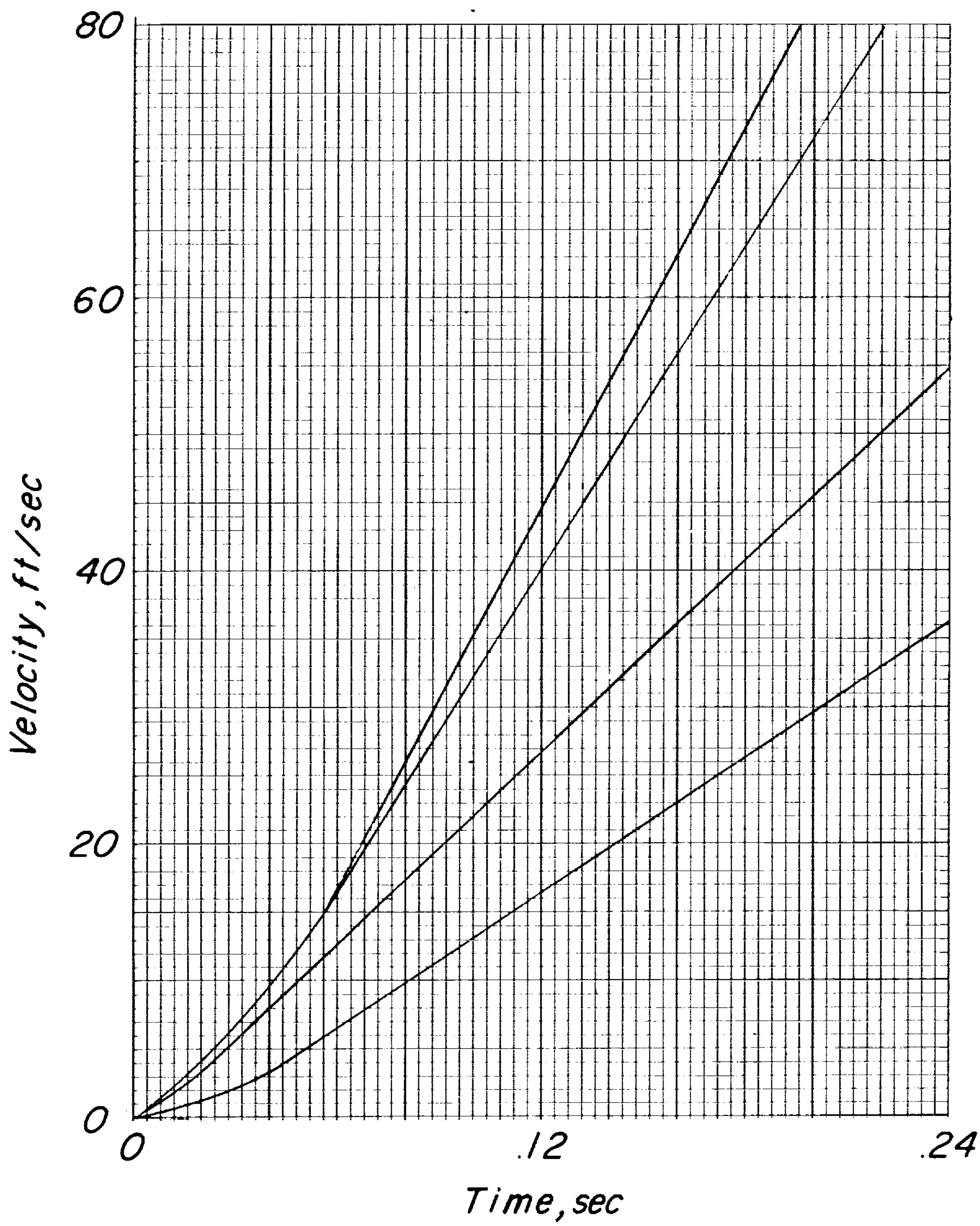


Figure 4.- Typical variation of velocity with time for several accelerations.

L-1027

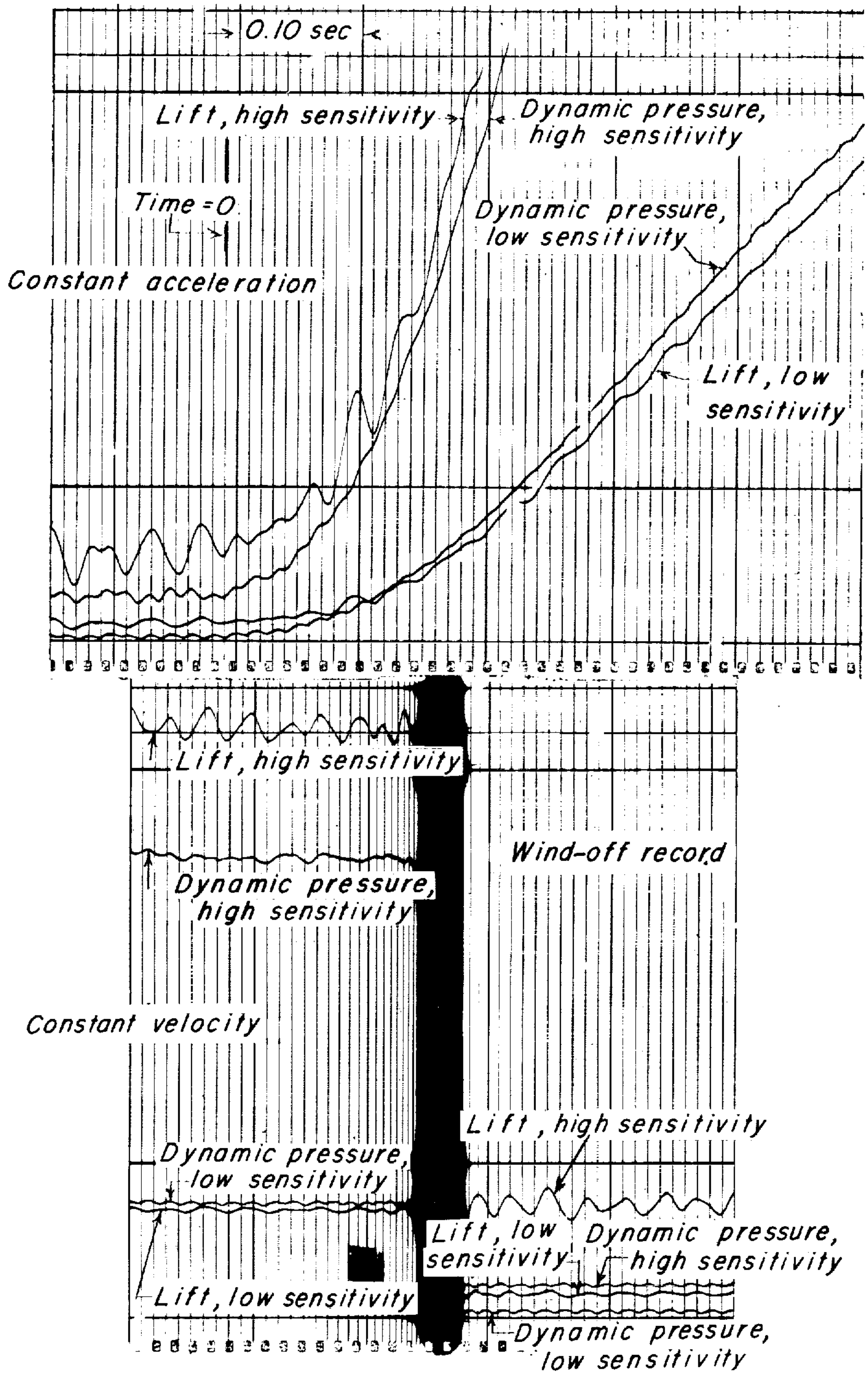


Figure 5.- Typical time history.

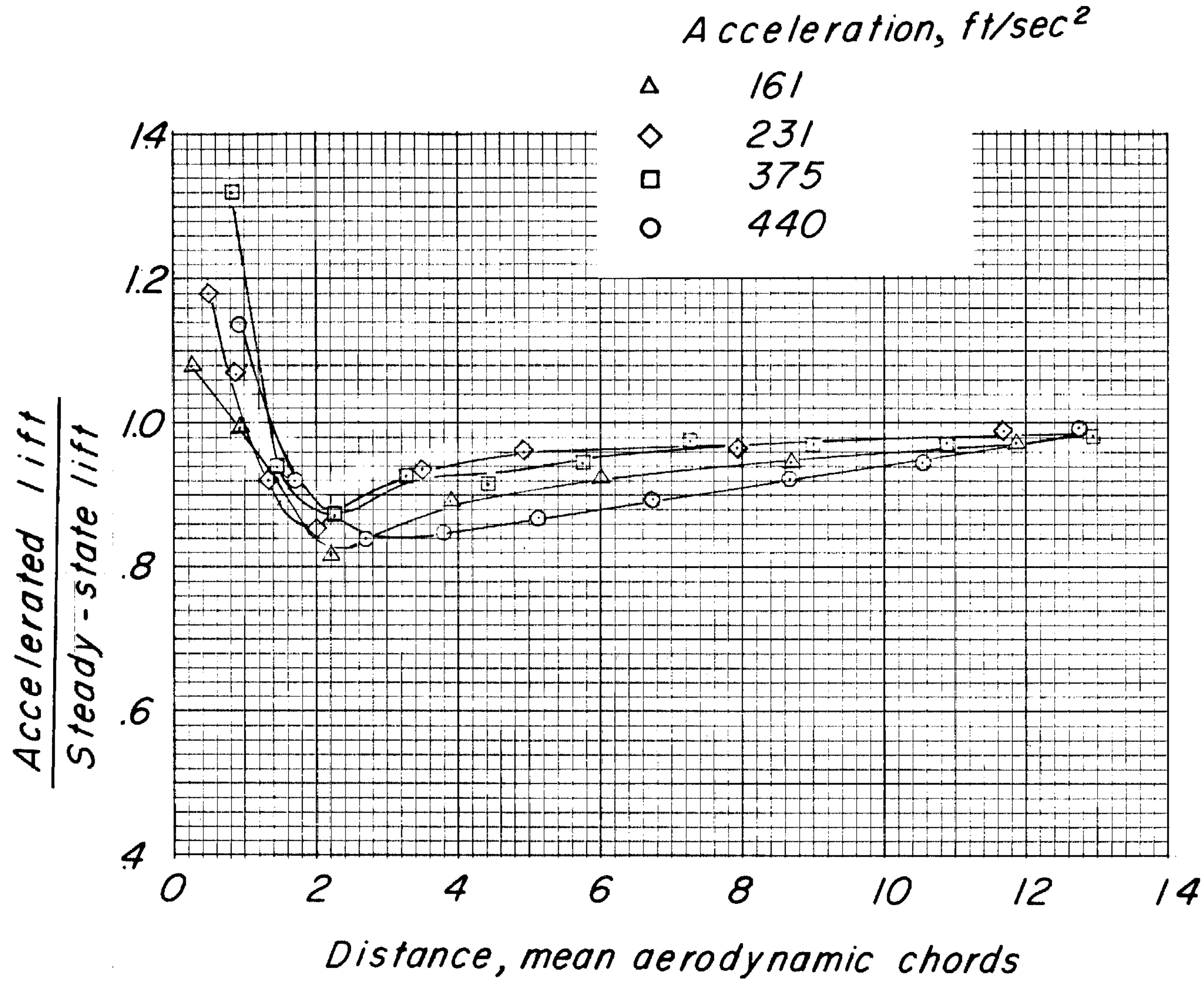


Figure 6.- Variation of ratio of accelerated lift to steady-state lift with distance for the unswept wing.

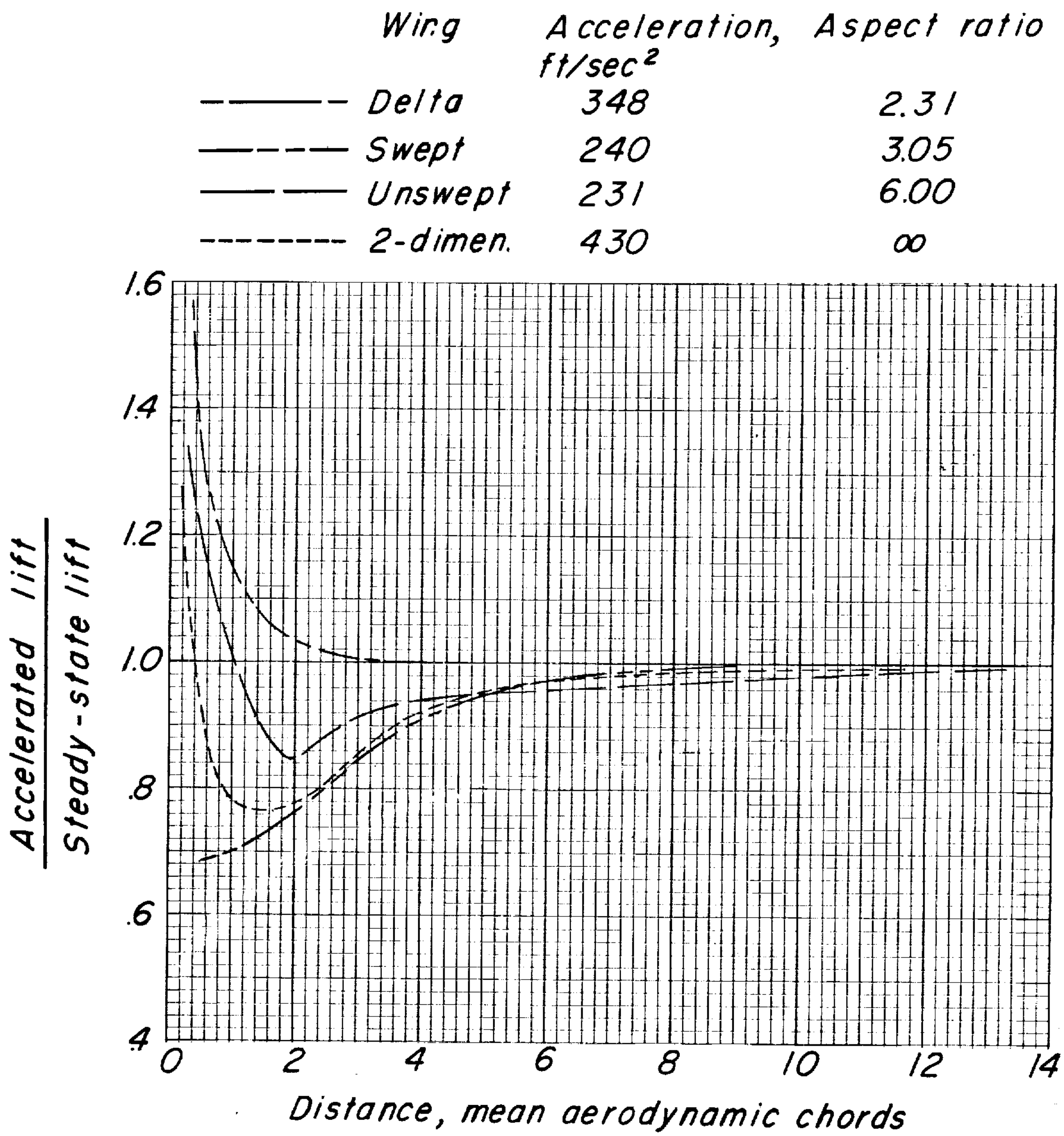


Figure 7.- Variation of ratio of accelerated lift to steady-state lift with distance.

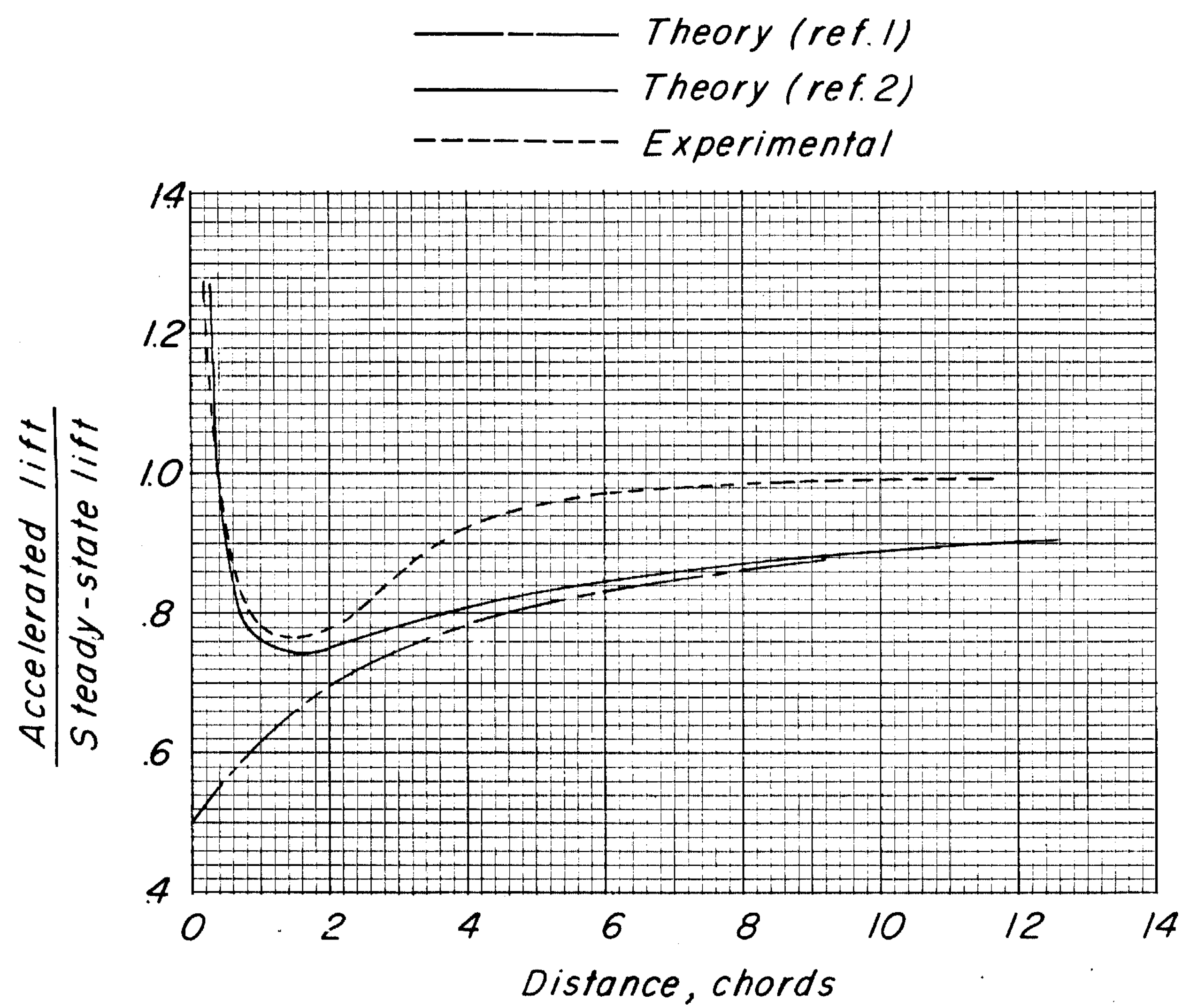


Figure 8.- Variation of lift-ratio with chords for constant acceleration. Aspect ratio, ∞.

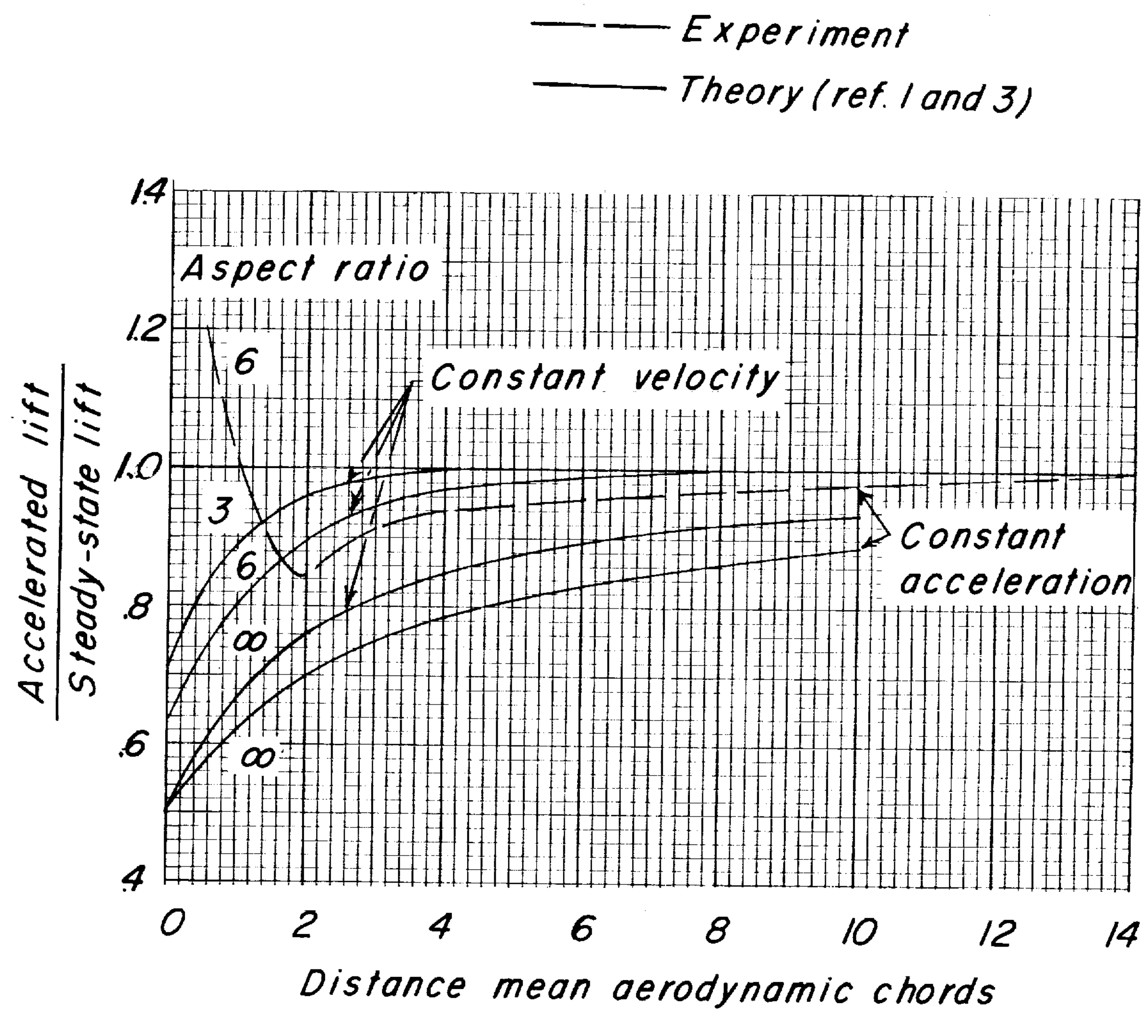


Figure 9.- Effect of aspect ratio on buildup of lift.

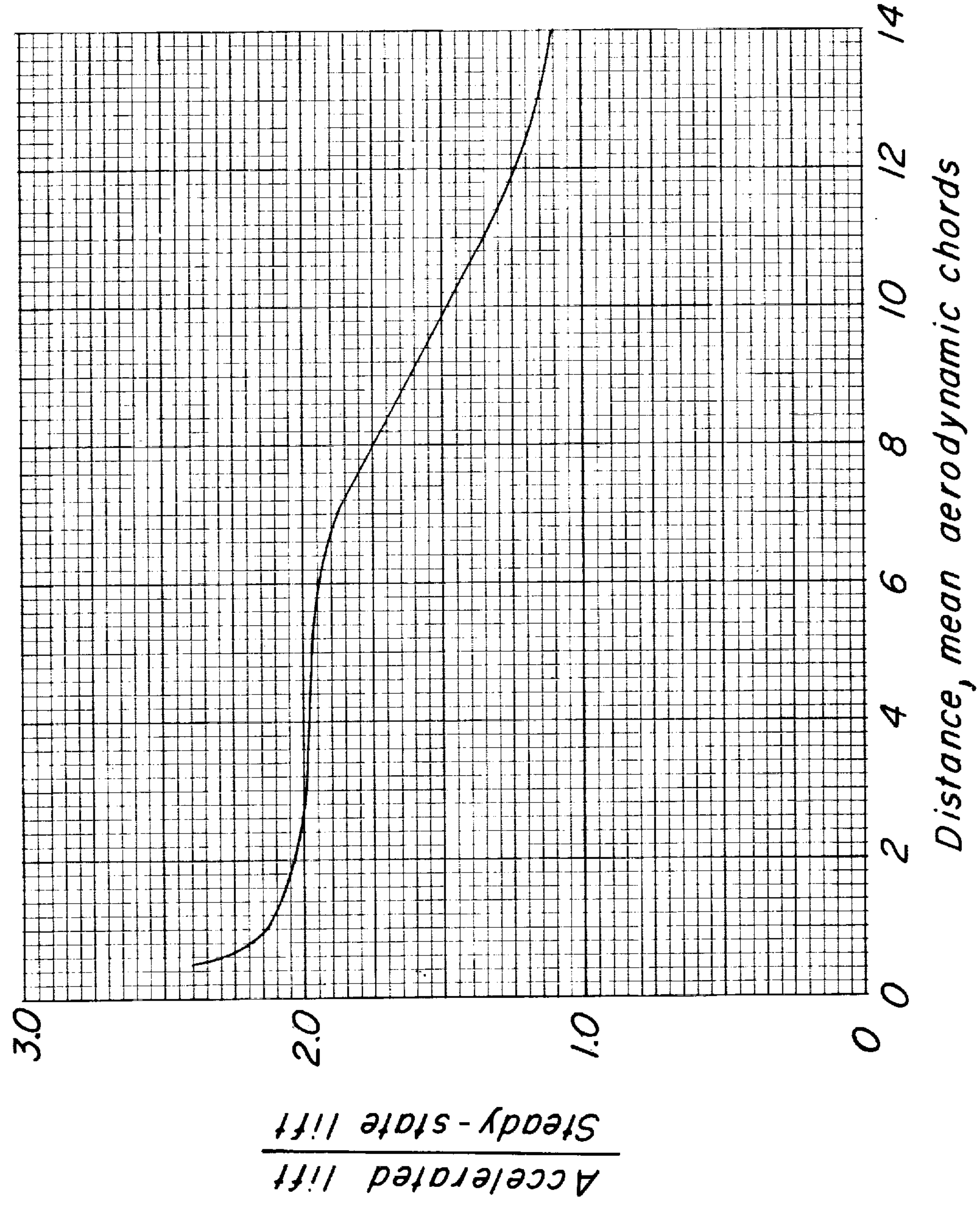


Figure 10.- Variation of ratio of accelerated lift to steady-state lift for an angle of attack above steady-state stall. Acceleration, 410 feet per second per second.