NACA TN No. 1794

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GUST-TUNNEL INVESTIGATION OF A WING MODEL WITH SEMICHORD LINE SWEPT BACK 30°

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Washington
January 1949

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SUMMARY

Tests were made in the Langley gust tunnel of a 30° sweptback-wing model to provide information on some of the problems encountered in the prediction of gust loads for airplanes incorporating swept wings. The results indicate that within the scope of the data and the values of gradient distance investigated, the maximum acceleration increment depends on the slope of the lift curve of an equivalent straight wing multiplied by the cosine of the angle of sweep and on the effect of gradual penetration of the sweptback wing into the gust.

It was also found that an airplane with a 30° swept wing would show positive pitching motion in a gust, but that the acceleration increment would be approximately 15 percent lower than that for the equivalent straight wing.

INTRODUCTION

The use of swept wings has led to questions about the gust load factor for airplanes having wings of this type. The problems posed include the selection of the appropriate slope of the wing-lift curve and the determination of the effect of the gradual penetration of a swept wing into a gust. In order to provide information for the solution of these problems, gust-tunnel investigations and analyses were made on two related swept-wing models and the results reported in references 1 and 2. As a continuation of the investigation of the effect of sweep on the gust load factor, the results of gust-tunnel tests of a model having a 30° sweptback wing are presented. The experimental results are compared with the results of calculations made by the method of references 1 and 3.

APPARATUS AND TESTS

A photograph of the model used in the tests is shown as figure 1, and the plan-view line drawing is shown as figure 2. The characteristics of the model and the test conditions are as follows:

Weight, W, pounds	9.75
Wing area, S, square feet	6.05
Wing loading, W/S, pounds per square foot	1.61
Span, b, feet	5.2
Aspect ratio, b^2/S	4.44
Chord lengths measured parallel to plane of symmetry:	
Mean geometric chord, feet	1.16
Root chord, c_s, feet	1.55
Tip chord, c_t, feet	0.77
Taper ratio, c_t/c_s	0.5
Slope of lift curve determined by force tests, per radian	3.15
Slope of lift curve determined by multiplying lift-curve slope of equivalent straight wing by cosine of sweep angle, per radian	3.82
Center-of-gravity position, percent of mean geometric chord	23.0
Gust velocity, U, feet per second	10
Forward velocity, V, miles per hour	60

Force tests of the model were made in the Langley free-flight tunnel and the slope of the lift curve of the model with tail off is included in the preceding table. The center-of-gravity position of the model was adjusted to give the same static stability as that of the models in references 1 and 2.

The wing of the model was derived from that of the equivalent straight-wing model of reference 1 by rotating the straight wing about the half-chord point at the plane of symmetry so that the half-chord line, which was kept a constant length, moved back through an angle of 30°. The wing tip was modified to the form indicated in figure 2. In order to provide space for batteries and accelerometer in the wing of the model, the center section has smooth bulges projecting from the top and bottom surfaces. The thickness at the center section is therefore about double the thickness that the wing would have without the bulge.

The present Langley gust tunnel is the same in principle as the gust tunnel described in reference 4 and utilizes like instrumentation and techniques. The capacity of the gust-tunnel equipment now used is such that 6-foot-span models can be flown up to speeds of 100 miles per hour through gusts with velocities up to 20 feet per second. The gust of air provided is 8 feet wide and 14 feet long. The three gust velocity distributions for which the tests were made are shown in figure 3 as plots of the ratios of local gust velocity to average maximum gust velocity against the horizontal distance in chords from the leading edge of the gust tunnel. The gust velocity distributions were made to have gradient distances (distance from the start to the peak of the gust) of 0, 5.0, and 9.0 mean geometric chords.

Tests of the 30° sweptback wing consisted of flights of the model at a forward speed of about 60 miles per hour through three gust shapes having average maximum gust velocities of about 10 feet per second. A minimum of 8 flights was made for each of the three gust shapes. Measurements of forward velocity, gust velocity, normal-acceleration increment (recorded acceleration minus acceleration in steady flight), and pitch-angle increment were made during each flight.

PRECISION

The measured quantities are estimated to be accurate within the following limits for any single test or run:

Acceleration increment, Δn, g units	±0.05
Forward velocity, feet per second	±0.5
Gust velocity, feet per second	±0.1
Pitch-angle increment, $\Delta\theta$, degrees	±0.1

Results from repeat flights should have a maximum dispersion of not more than ±0.05g for a sharp-edge gust, ±0.07g for a gust with a gradient distance of 5 chords, and ±0.1g for a gust with a gradient distance of 9 chords. This dispersion is the result of minor variations in the test conditions, the effect of which cannot be eliminated by corrections to the data.

RESULTS

The records for all flights were evaluated to obtain histories of the normal-acceleration increment and pitch increment during the traverse of the gust. Representative test results are shown in figures 4(a), 4(b), and 4(c).

The maximum acceleration increment for each test flight was determined from the flight record and was corrected to a model weight of 9.25 pounds, a forward velocity of 60 miles per hour, and a gust velocity of 10 feet per second on the basis of the assumption that the increment is inversely proportional to the model weight and directly proportional to forward speed and gust velocity. This correction was made so that these results can be compared with those of reference 1 and so that the effect of minor variations in launching speed and gust velocity can be eliminated. The average of the corrected maximum acceleration increments for each gust shape is presented in table I.

Figure 4 shows that the model has appreciable pitching motion at the point of maximum acceleration in all three test gusts. In order that a comparison of the experimental values with the values calculated according to the method of reference 1 can be made, the effect of pitching motion was removed from the experimental data. This change was made by the approximate method reported in reference 1 and the resultant values of Δn_{max} are included in table I.

CALCULATIONS

Calculations to predict the response of the model to the test gusts were made according to the method presented in reference 1. Two slopes of the lift curve were used: that of the straight-wing model of reference 1 multiplied by the cosine of the angle of sweep and that determined from the force tests of the model without tail surfaces. The unsteady-lift functions C_{L_g} (for penetration of a sharp-edge gust) and C_{L_α} (for a sudden change of angle of attack) were derived from the functions for infinite aspect ratio given in reference 5. The curve for C_{L_g}, however, was modified by strip theory to include the effect of the gradual penetration of the swept wing into the gust. The curves for C_{L_g} and C_{L_α} modified and unmodified are shown in figure 5.

For comparative purposes calculations were made for the test gusts by the method of reference 3 using a slope of the lift curve derived by the cosine law. The equations of reference 3 are a solution of equation (1) of reference 1 using an unmodified curve for C_{L_g} and, in the case of gradient gusts, the additional assumption is made that the acceleration increment reaches a maximum value at the same time the gust reaches its maximum.

DISCUSSION

Table I indicates that the corrected experimental values of maximum acceleration increment Δn_{max} reduced to zero pitch are in excellent agreement with the calculated values obtained by the method of reference 1 when the slope of the lift curve used is that derived by the cosine law. The values of Δn_{max} obtained using the measured steady-flow of the lift curve, however, were approximately 13 percent lower than the cosine-law values. This result is in agreement with the finding of reference 1 for the 45° sweptback wing. The same conclusions, therefore, can be drawn for the wing of these tests; that is, within the scope of the data and the range of gradient distances investigated, the maximum acceleration increment experienced in a gust by a sweptback-wing airplane depends on the slope of the lift curve of the equivalent straight wing multiplied by the cosine of the angle of sweep rather than on the steady-flow slope of the lift curve.

In table I, comparison was made of the maximum acceleration increments obtained from calculations by the methods of references 1 and 3. Reference 1 uses a curve of C_{L_g} modified to account for the effects of penetration into the gust. Table I indicates that although the difference in the values determined by the two methods is small, the values determined by the method of reference 1 are in better agreement with the experimental results. This agreement is similar to the findings of reference 1. The maximum acceleration increment is believed, therefore, to depend partly on the effect on the unsteady-lift function of gradual penetration of a sweptback wing into a gust.

Table I shows that the pitching motion results in about a 9-percent increase in acceleration increment for the three gust shapes. This increase compares favorably with the results reported in reference 1 which states that the positive pitching motion of the 0° and 45° sweptback-wing models increases the acceleration increment 4 percent and 10 percent, respectively. This increase indicates that the effect of pitching motion on the value of Δn_{max} increases with the angle of sweep of the wing and is the result of gradual immersion of the wing into a gust.

The results in table I compared with table II in reference 1 show that, despite the adverse effect of pitching motion for a given gust, a net reduction in acceleration increment of approximately 15 percent of that for an equivalent straight wing is obtained by using a 30° sweptback wing.

CONCLUDING REMARKS

As in the investigation of a 45° sweptback-wing model, the results obtained from calculations and tests of the 30° sweptback-wing configuration indicated that, within the scope of the data and the values of gradient distance investigated, the maximum acceleration increment experienced in a gust by an airplane with a sweptback wing depends on (1) the slope of the lift curve of the equivalent straight wing multiplied by the cosine of the angle of sweep rather than on the steady-flow slope of the lift curve and on (2) the effect of the gradual penetration of the gust on the unsteady-lift function.

The data also indicated that the maximum acceleration increment experienced in a gust by a sweptback-wing airplane would be less than that experienced by an airplane with an equivalent straight wing despite the adverse effect of the pitching motion of the airplane.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Air Force Base, Va., November 24, 1948

REFERENCES

1. Pierce, Harold B.: Tests of a 45° Sweptback-Wing Model in the Langley Gust Tunnel. NACA TN No. 1528, 1948.

2. Pierce, Harold B.: Gust-Tunnel Investigation of a 45° Sweptforward-Wing Model. NACA TN No. 1717, 1948.

3. Rhode, Richard V.: Gust Loads on Airplanes. SAE Jour., vol. 40, no. 3, March 1937, pp 81-88.

4. Donely, Philip: An Experimental Investigation of the Normal Acceleration of an Airplane Model in a Gust. NACA TN No. 706, 1939.

5. Jones, Robert T.: The Unsteady Lift of a Wing of Finite Aspect Ratio. NACA Rep. No. 681, 1940.

TABLE I

COMPARISON OF EXPERIMENTAL AND CALCULATED MAXIMUM ACCELERATION INCREMENTS

Gradient distance (chords)	Corrected experimental Δn_{max} (g units)	Corrected experimental Δn_{max} reduced to zero pitch (g units)	Calculated Δn_{max} from reference 1 (g units)		Calculated Δn_{max} from reference 3 (g units)
			Cosine-law slope	Measured steady-flow slope	Cosine-law slope
0	1.91	1.72	1.72	1.42	1.78
5	1.73	1.59	1.55	1.28	1.60
9	1.49	1.37	1.46	1.20	1.56

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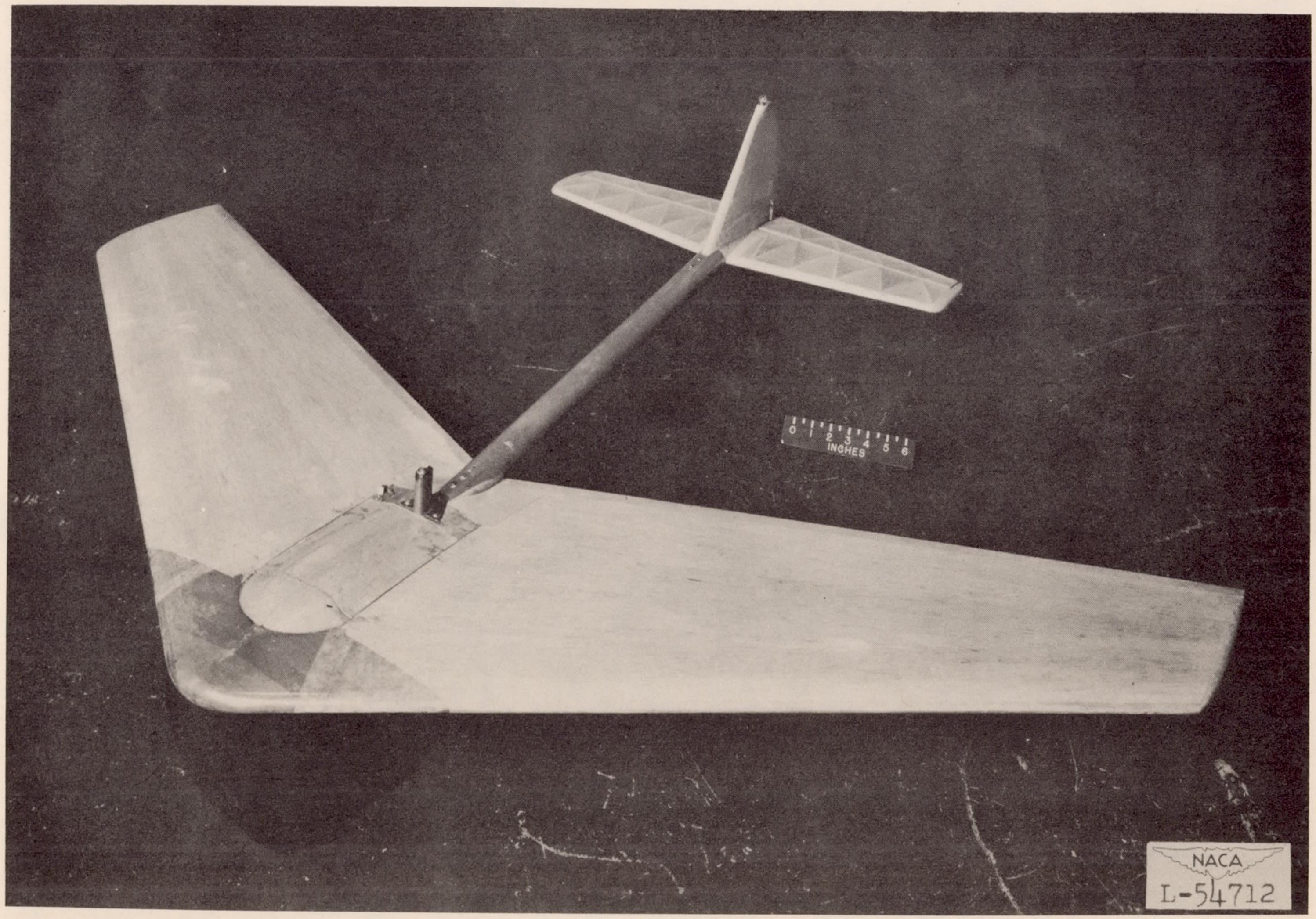

Figure 1.- Model with 30° sweptback wing.

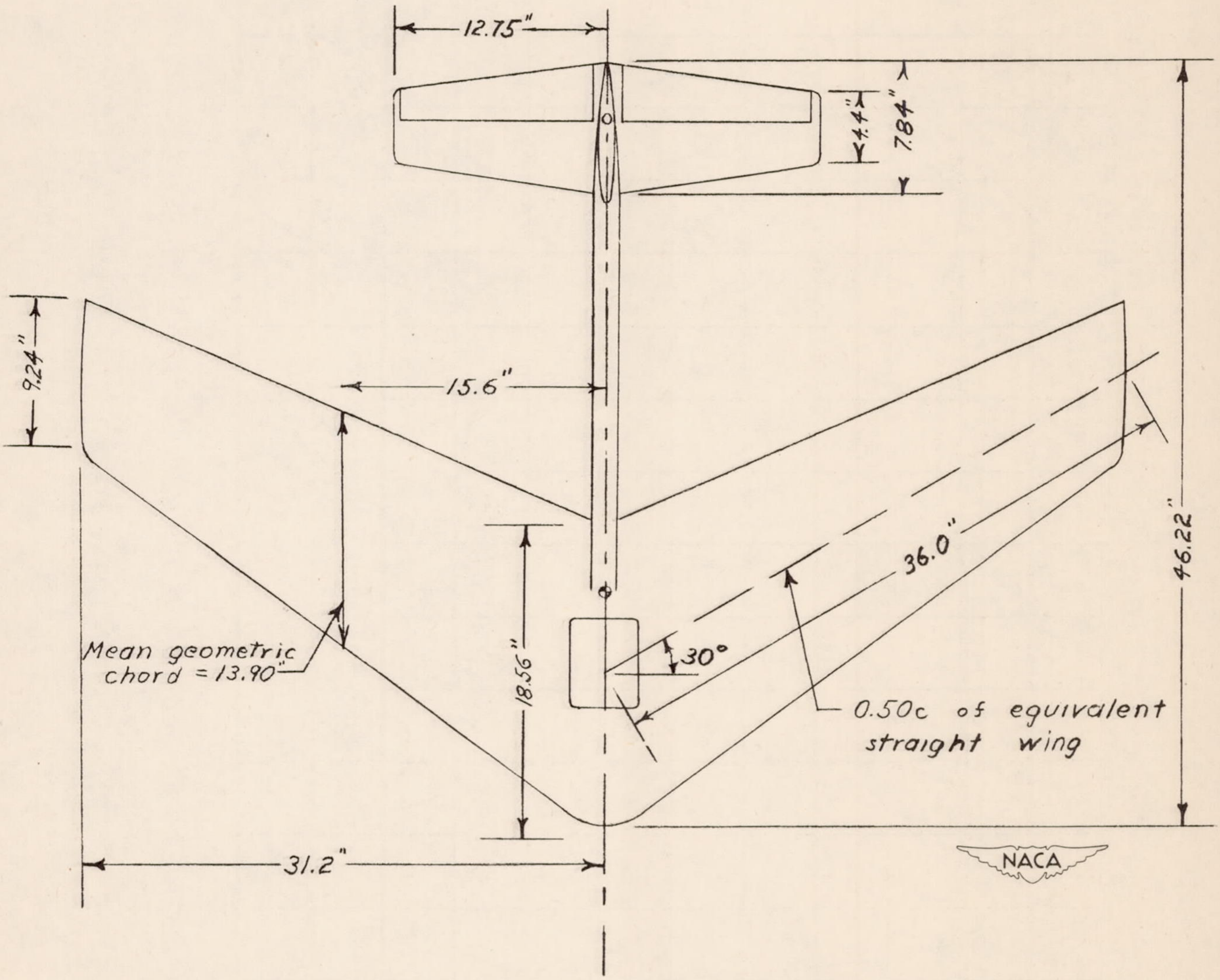

Figure 2.- Plan form of model with 30° sweptback wing.

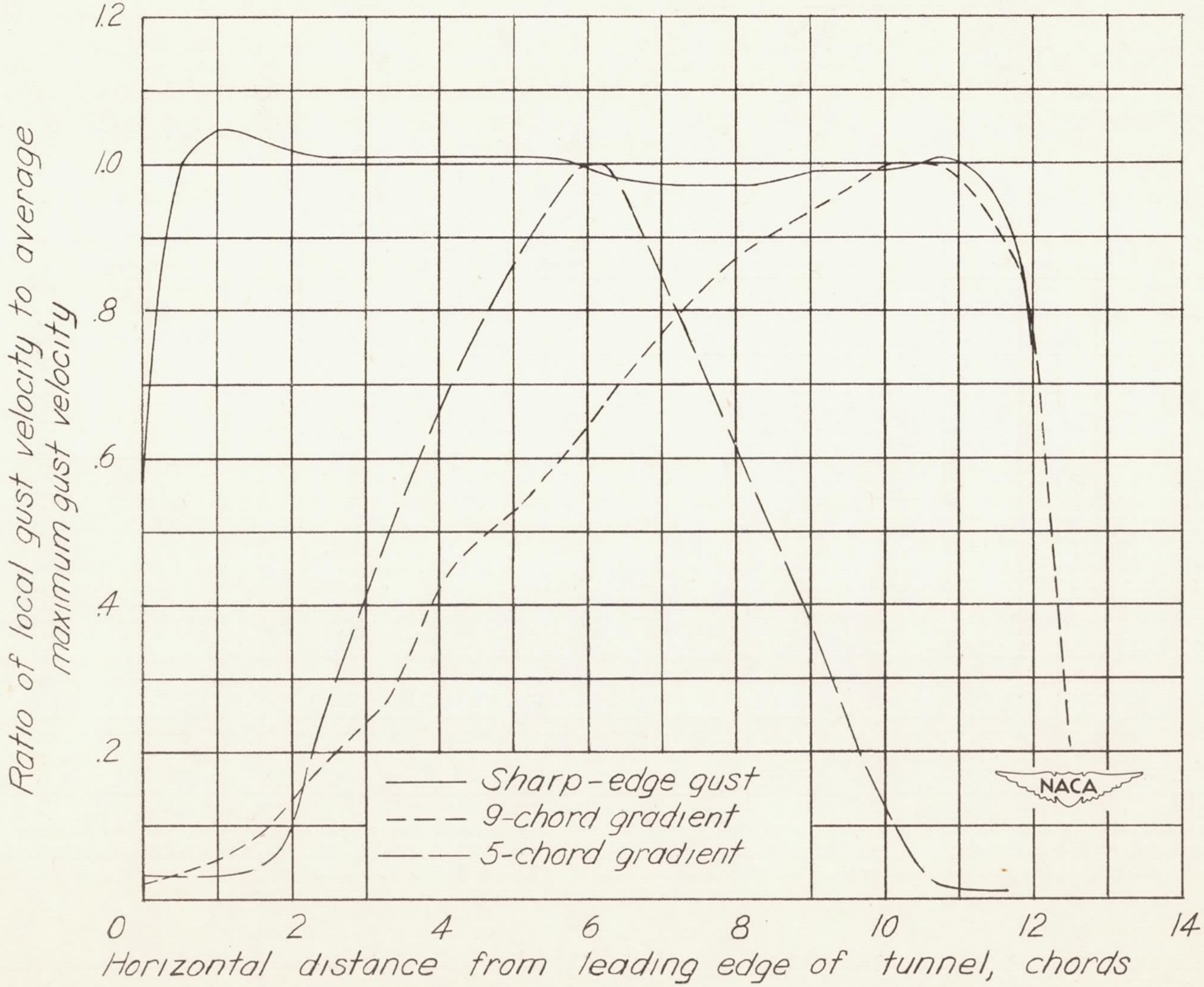

Figure 3.– Velocity distribution through jet.

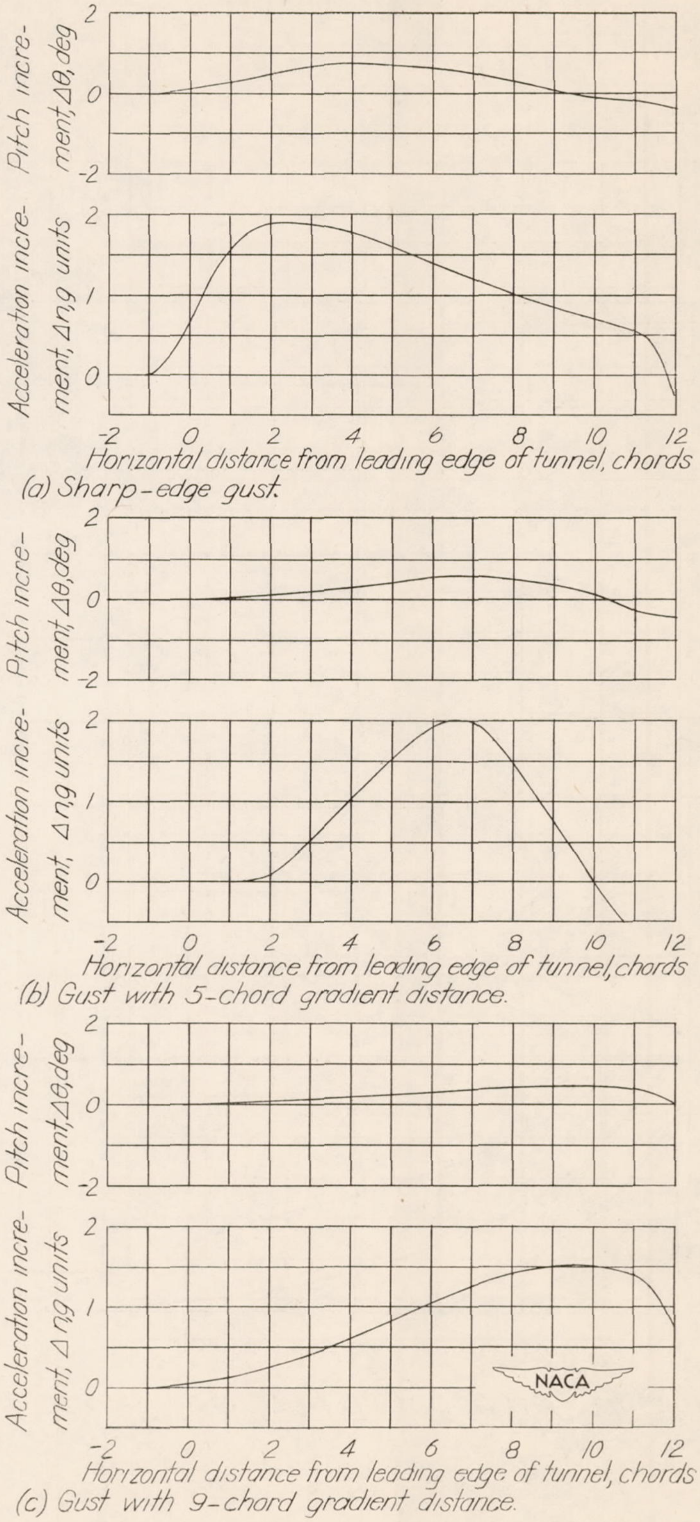

Figure 4.– Representative histories of events in test gusts.

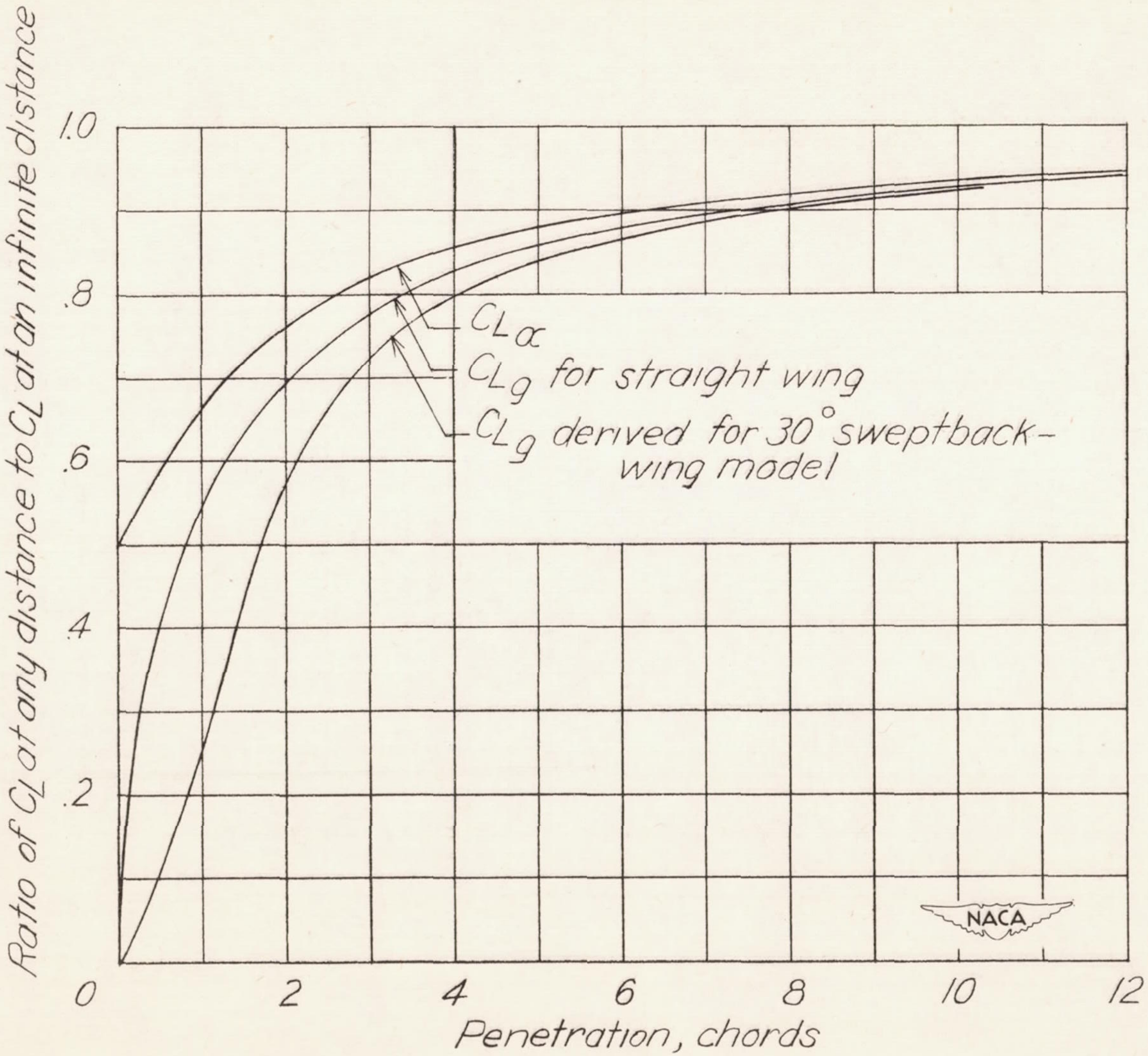

Figure 5.- Curves of C_{L_g} and C_{L_α} based on unsteady-lift functions for infinite aspect ratio.