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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 731

TESTS IN THE GUST TUNNEL OF A MODEL OF THE XBM-1 AIRPLANE

By Philip Donely and C. C. Shufflebarger
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SUMMARY

A dynamically scaled model of a Navy XBM-1 biplane was tested in the gust tunnel to provide data for use in determining the structure of atmospheric gusts from measurements of the motions of the full-scale airplane in rough air.

The agreement of the test results with values computed by means of the theory of unsteady lift of monoplanes was good for gust gradient distances up to 12 chord lengths when the computations were based on the assumption that the wings of a biplane act independently in unsteady flow and when the mean slope of the lift curves of the two wings and the mean chord of the cellule were used in conjunction with data on the unsteady lift of finite wings.

INTRODUCTION

In connection with a general investigation of the flight loads imposed by atmospheric gusts on airplane structures, flight tests have been made at Langley Field for the purpose of obtaining detailed information regarding the characteristics of gusts in thermal conditions at various altitudes. A Navy XBM-1 biplane was utilized for this purpose, the characteristics of the gusts to be determined from measurements of the motions of the airplane.

As available theoretical relationships between gust shape and airplane motion could not with confidence be applied to the case of a biplane to determine the gust characteristics, these relationships for the XBM-1 airplane had to be experimentally determined by testing a dynamically scaled model of the airplane in the gust tunnel with several gust shapes.

In this paper, the experimental results of the gust-tunnel tests of the XBM-1 model are presented and compared with computed results based on the theory of the unsteady lift of monoplanes.

APPARATUS

The gust tunnel and its related equipment are described in reference 1.

The model is shown in figures 1 and 2. Its pertinent characteristics, as well as those of the full-size airplane, are given in table I. Although the principal aerodynamic features of the airplane were faithfully represented in the model, no attempt was made to reproduce small excrescences such as engine cylinders, windshields, etc., in view of their small importance in these tests. The fuselage diameter was also slightly enlarged to accommodate the accelerometer.

The wings were made as rigid as practicable in order to eliminate effects due to their deflection in the steepest gust gradient. The natural period of the wings is given in table I and the deflection curve for a load factor of 1.0 is given in figure 3.

The three gust velocity distributions or profiles in which the tests were made were approximately linear and are shown in figure 4 as plots of the ratio of local gust velocity, U, to the average maximum gust velocity $U_{max_{av}}$, against the distance, in chord lengths, in the direction of flight.

TESTS

The tests consisted of flights over the gust tunnel at fixed values of the forward velocity and of the average maximum gust velocity. A minimum of five flights was made for each of the three gust gradients. Measurements were made of flight velocity, gust velocity, normal acceleration, vertical displacement, and pitch.

PRECISION

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

Acceleration - - - - - - - - ±0.1g

Forward velocity - - - - - - ±1.0 foot per second

Gust velocity - - - - - - - ±0.1 foot per second

Pitch - - - - - - - - - - - - ±0.2°

Vertical displacement - - - ±0.01 foot

Approximate computations of the effect of wing flexibility indicated an error of 2 percent in the acceleration in a sharp-edge gust and smaller errors in the gradient gusts. The error due to wing flexibility is thus within the limits of accuracy of the rest of the data.

RESULTS

Records of two flights for each gradient were evaluated to give histories of events during passage through the gust. These results are shown in the uncorrected form in figures 5, 6, and 7. The oscillations superimposed on the acceleration curve for the sharp-edge gust (fig. 5) were due to the flexing of the wings as a result of the gust.

In order to eliminate the effects of slight departures from the nominal values of air speed and gust velocity, the maximum acceleration increments were corrected to a forward velocity of 60 feet per second (40.9 miles per hour) and a gust velocity of 6.0 feet per second. These results are shown in figure 8 plotted against the gradient distance H.

Two methods of computing the acceleration increments are available: namely, the method presented in reference 2; and a method which is based on the unsteady lift functions of reference 3, and which results in formulas corresponding to equations (3) and (4) of reference 2. Computations were made by both methods on the assumption that the biplane cellule could be represented by an equivalent monoplane

having the same slope of the lift curve and a chord equal to the mean chord of the cellule. For these computations, a measured value of the slope of the lift curve was used. The theoretical curves are shown in figure 8 together with the experimental curve. Inspection of figure 8 shows that the theoretical curves are lower than the experimental for gradient distances from 0 to 16 chord lengths, the values computed by the method of reference 2 and the method based on reference 3 being 80 percent and 92 percent of the experimental values, respectively.

In an attempt to arrive at better agreement, the wings of a biplane were assumed to act independently; i.e., there is no interference between the wings in unsteady flow. Accordingly, the mean of the slopes of the lift curves of the individual wings and the mean chord were used to define the biplane cellule, and calculations based on the theory of reference 3 were made. The computed curve for this case is shown in figure 8 and is in almost perfect agreement with the experimental curve for gradient distances up to 12 chord lengths.

As would be expected, the theoretical curve for the case in which there were assumed to be no interference effects does not apply for the longer gradient distances because of the fact that the interference effects were approaching their steady-flow values and because of the pitch of the model. Calculations indicated that approximately 30 percent of the discrepancy for the gust gradient distance of 20 chord lengths was due to the effect of pitch.

CONCLUDING REMARKS

For a model of the XBM-1 airplane, the theoretical acceleration increments, computed by the use of data on the unsteady lift of finite wings under the assumption that the wings of a biplane act independently in unsteady flow, were in good agreement with experiment for gradient distances up to 12 chord lengths. Beyond 12 chord lengths, the rapid decrease of the experimental values of the acceleration increment in the longer gradient distances is probably accounted for by the pitch of the model and by the fact that the interference effects were approaching their steady-flow values.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 19, 1939.

REFERENCES

1. Donely, Philip: An Experimental Investigation of the Normal Acceleration of an Airplane Model in a Gust. T.N. No. 706, N.A.C.A., 1939.

2. Rhode, Richard V.: Gust Loads on Airplanes. S.A.E. Trans., vol. 32, 1937, pp. 81-88.

3. Jones, Robert T.: The Unsteady Lift of a Finite Wing. T.N. No. 682, N.A.C.A., 1939.

TABLE I

Characteristics of the XBM-1 Model

	Model	Corresponding values for XBM-1 airplane
Weight, lb.	2.029	5,200
Wing area, sq. ft.	2.195	412
Wing loading, lb. per sq. ft.	.924	12.6
Span, ft.	3.0	41
Mean aerodynamic chord, ft.	.414	5.66
Center of gravity, percent m.a.c.	27.1	27.1
Natural wing period, sec.	.019	--
Moment of inertia mk_Y^2, lb.-ft.^{2}	.368	180,000
Slope of lift curve, per radian	4.16	4.16
Gust velocity, f.p.s.	6.0	22.2
Forward velocity, m.p.h.	40.9	152

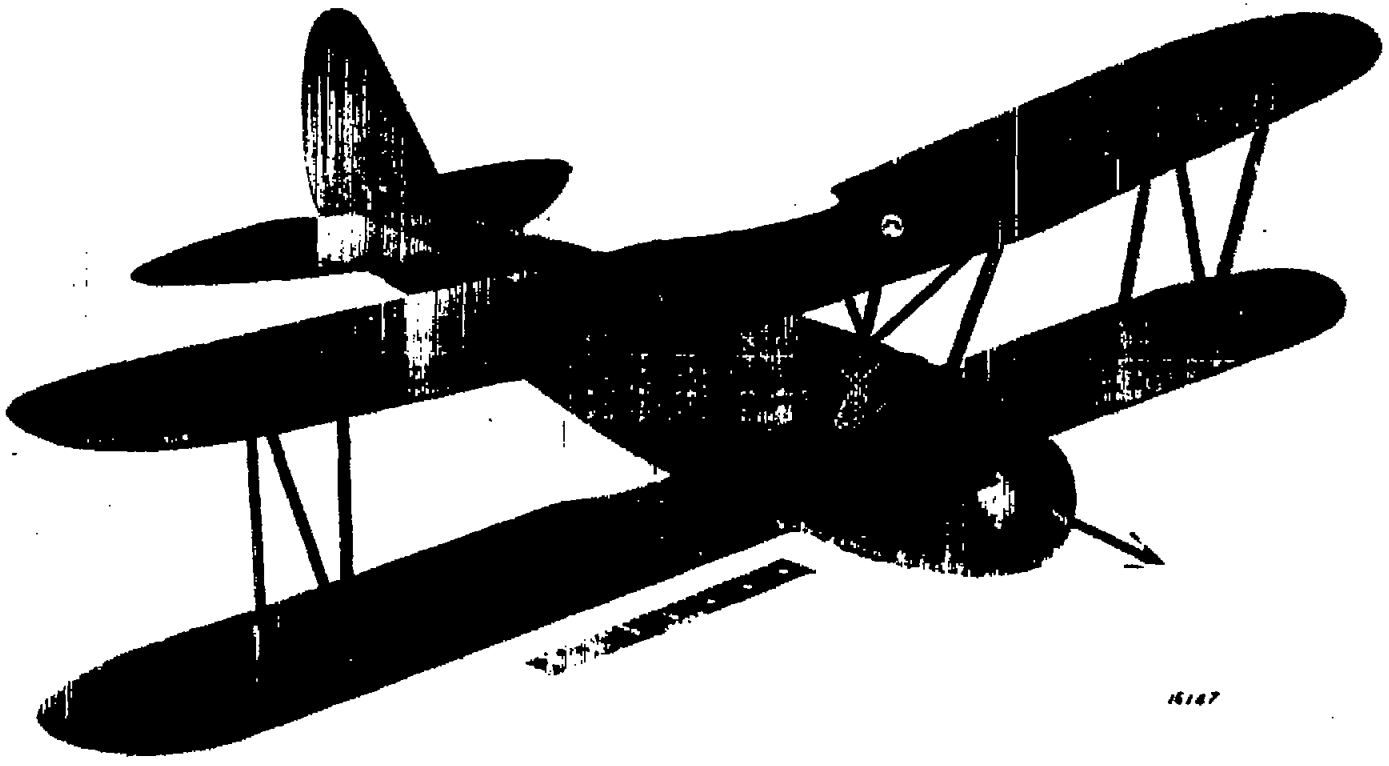

Figure 1.- The 1/13.7 scale model of the XBM-1 biplane.

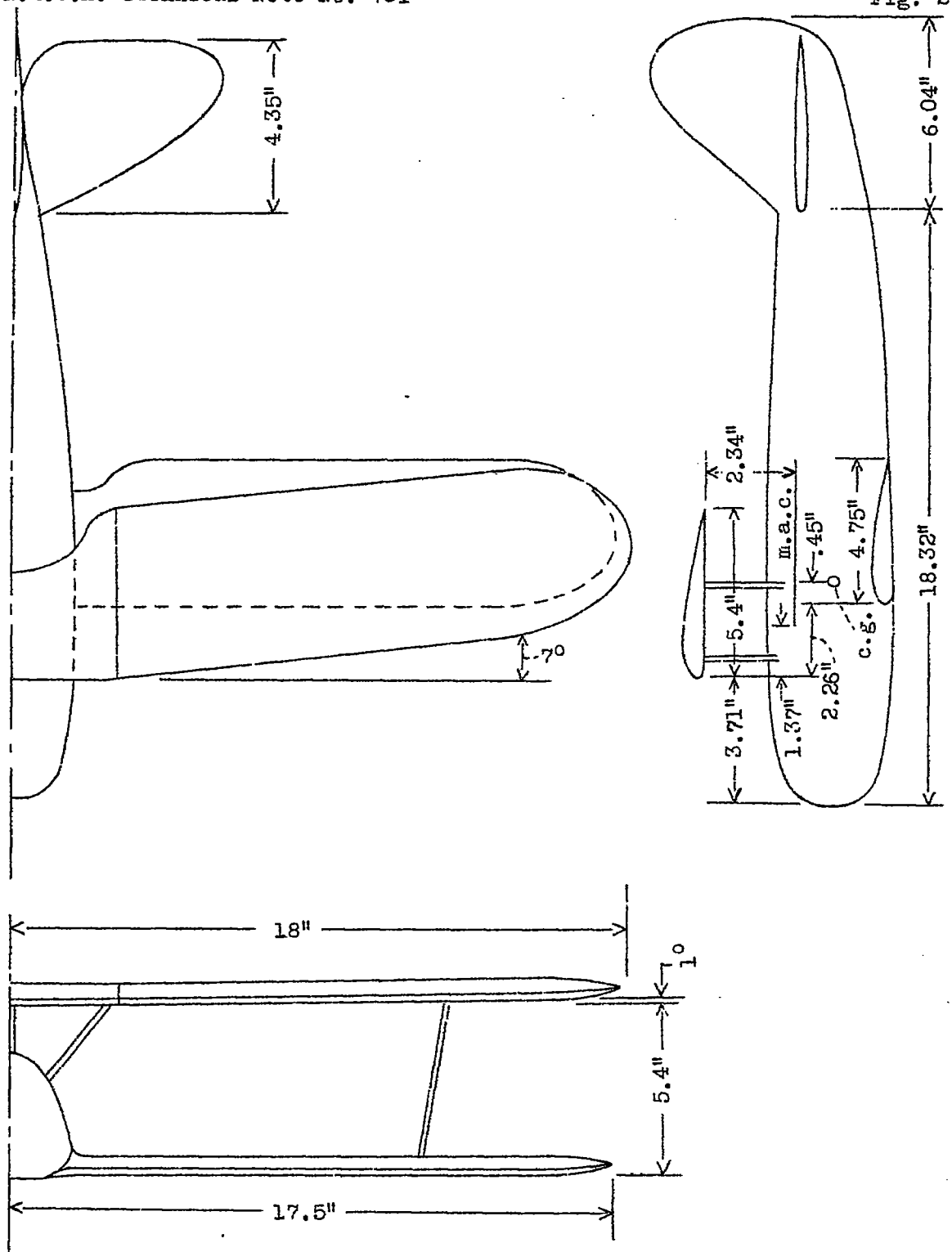

Figure 2.- Line drawing of the 1/13.7 scale model of the XBM-1 airplane.

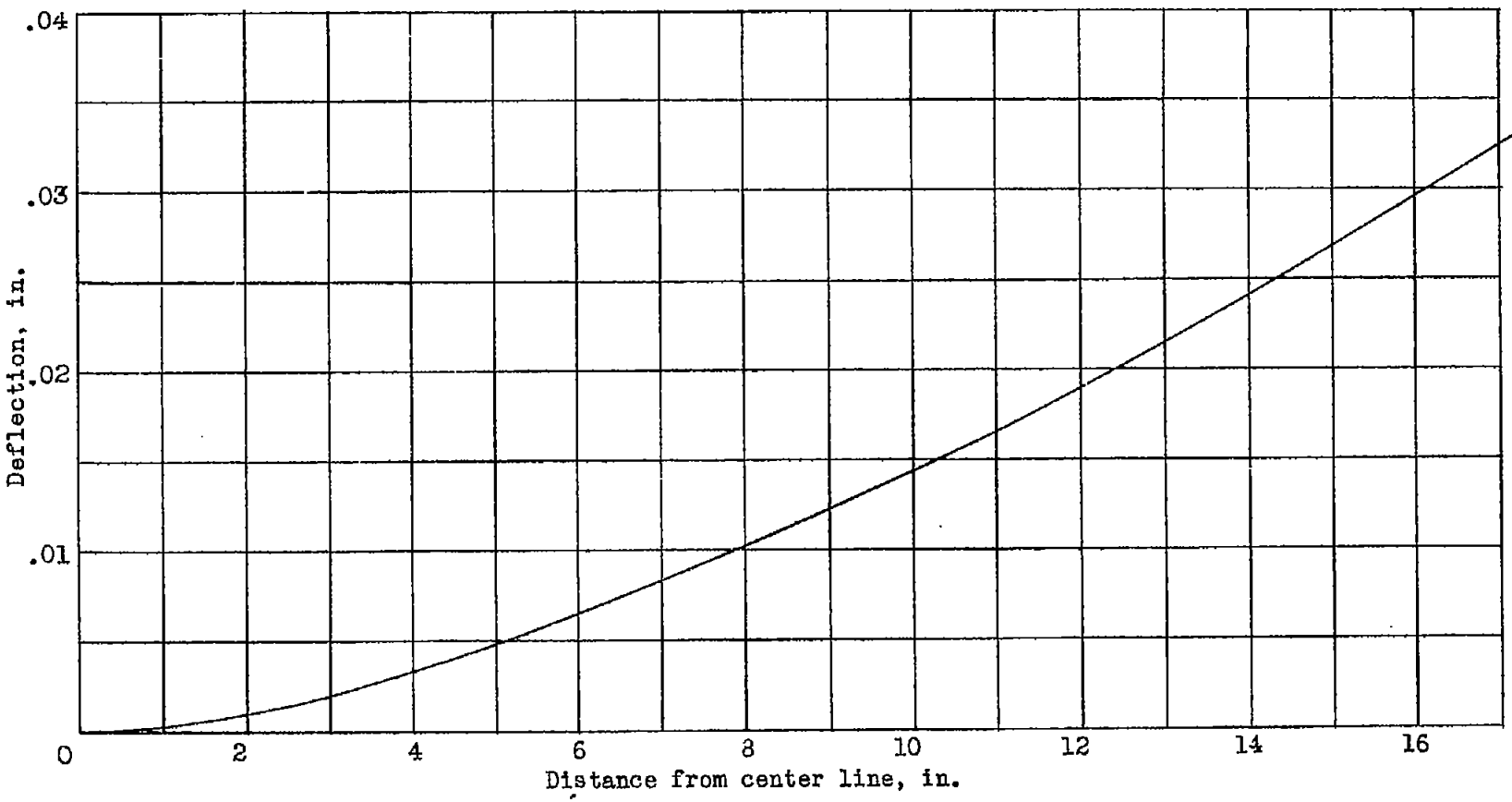

Figure 3.- Wing-deflection curve for a load factor of 1.0

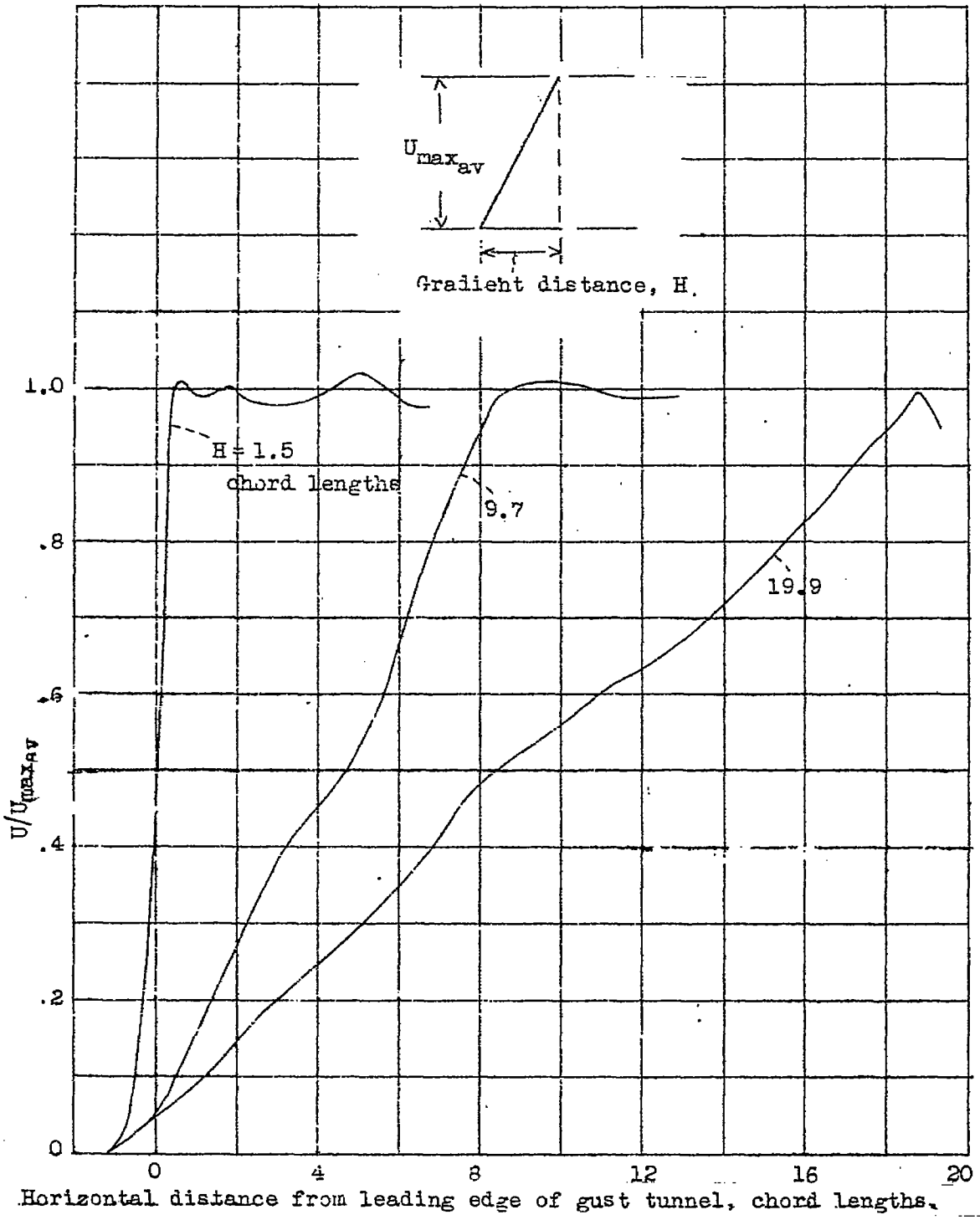

Figure 4.- Velocity distributions of the gusts.

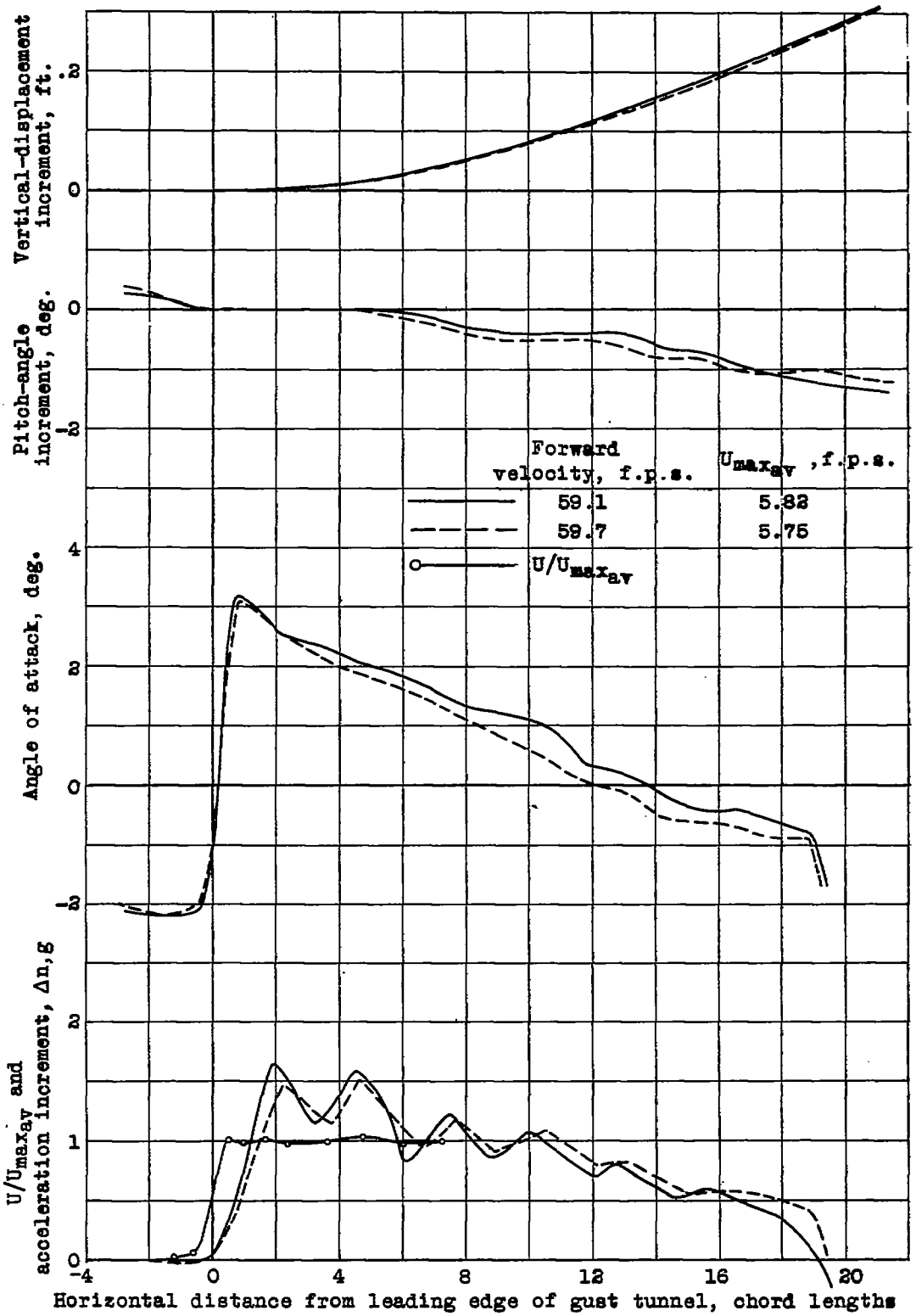

Figure 5.- History of events in the 1.5 chord-length sharp-edge gust.

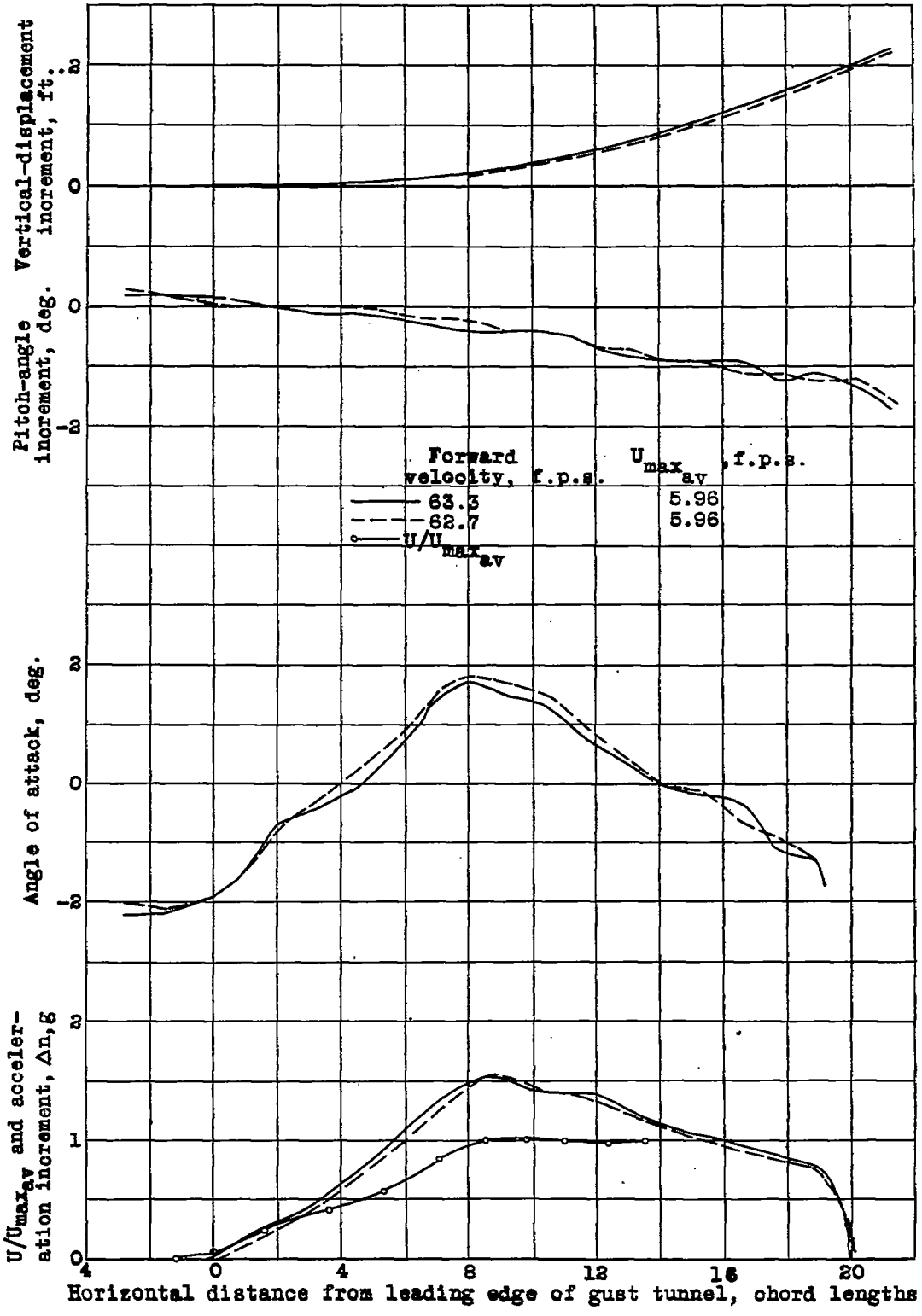

Figure 6.- History of events in the 9.7 chord-length gradient gust.

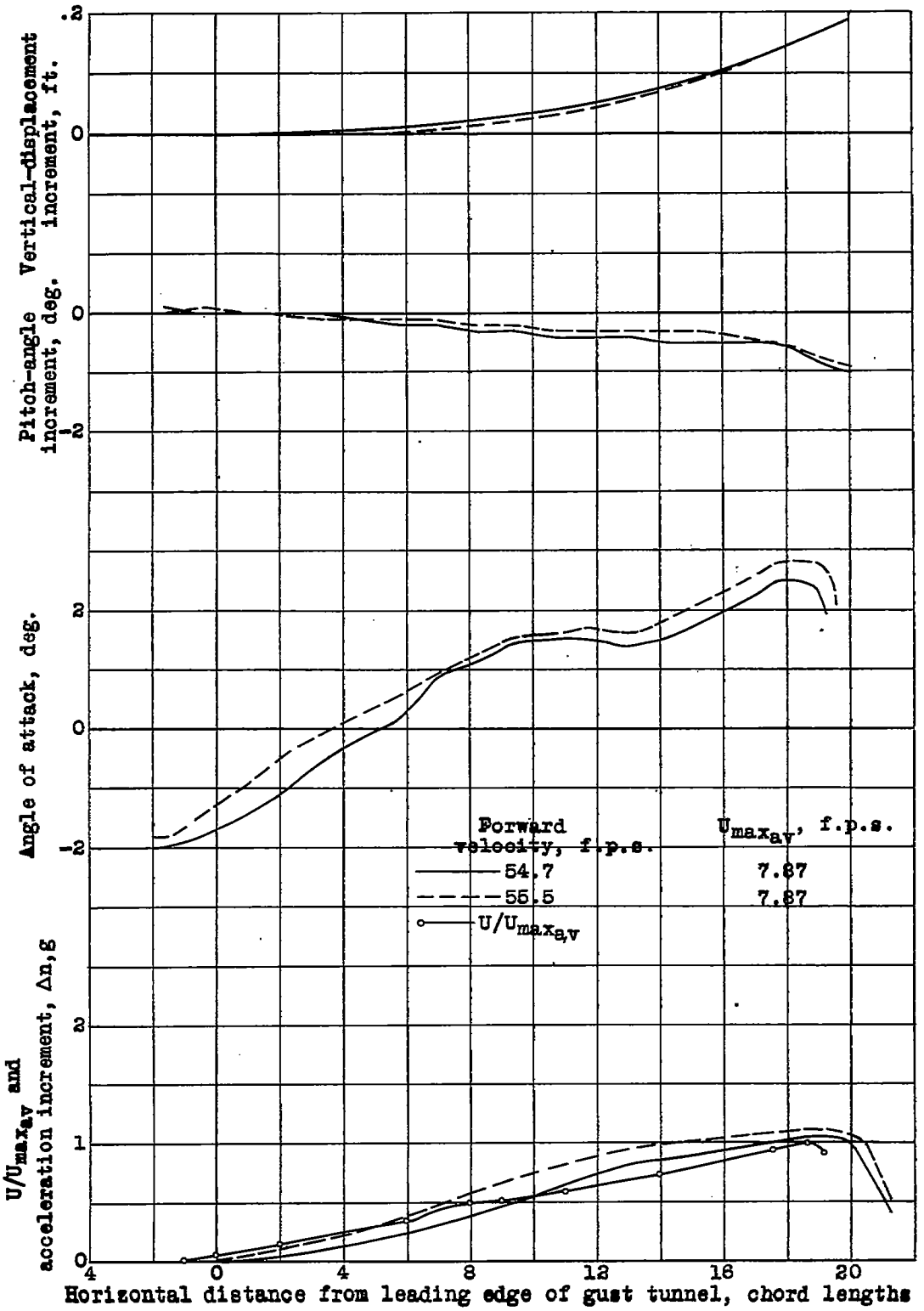

Figure 7.- History of events in the 19.9 chord-length gradient gust.

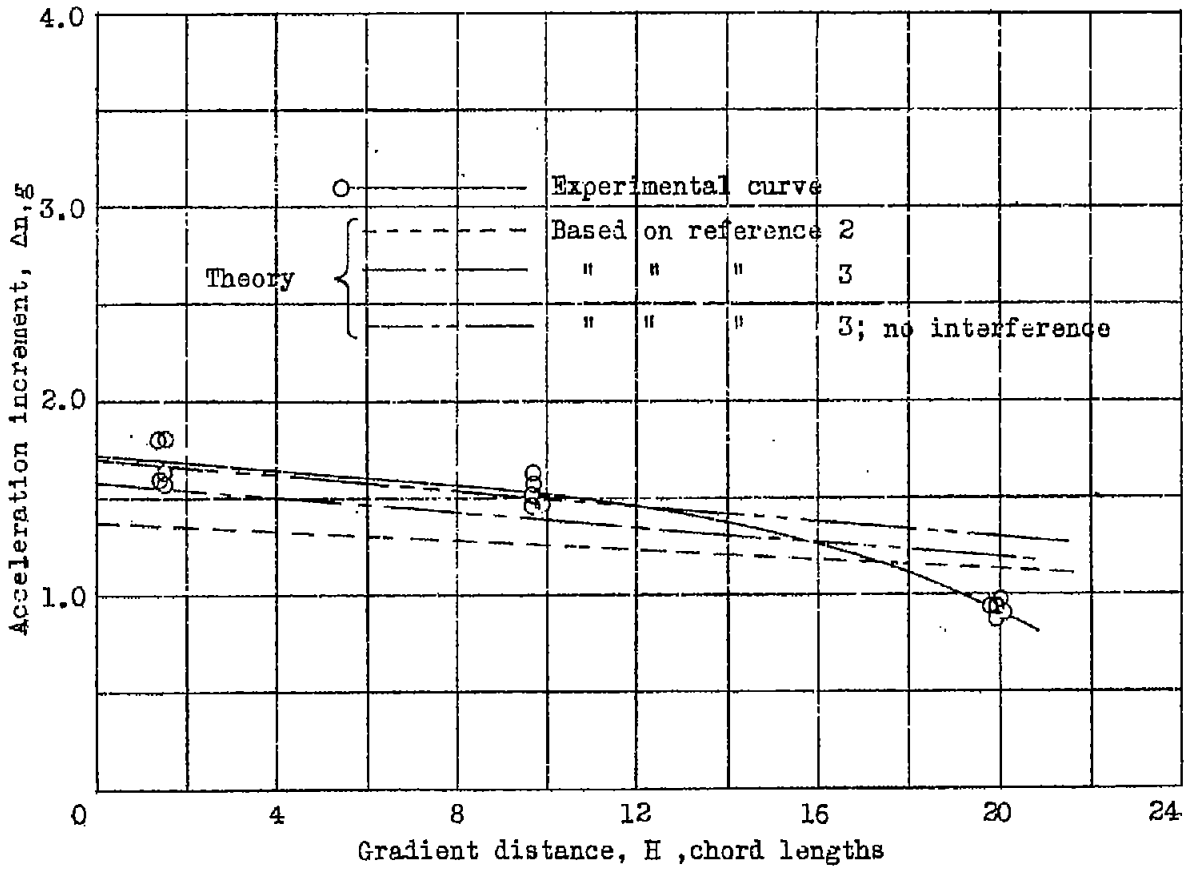

Figure 8.- Comparison of theory and experiment.