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# RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

## HIGH-SPEED WIND-TUNNEL TESTS OF A $\frac{1}{16}$-SCALE MODEL OF THE D-558 RESEARCH AIRPLANE

## AIR-STREAM FLUCTUATIONS AT THE TAIL OF THE D-558-1 AIRPLANE

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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# HIGH-SPEED WIND-TUNNEL TESTS OF A $\frac{1}{16}$-SCALE MODEL OF THE D-558 RESEARCH AIRPLANE

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## SUMMARY

An investigation of the air-stream fluctuations at the tail of the D-558-1 airplane has been made at high speed for the purpose of determining the vertical region in which the horizontal tail may be placed without becoming subject to tail buffeting. The investigation was made for a range of Mach numbers from 0.775 to 0.907, and a range of vertical positions at the tail to include two proposed horizontal-tail positions. The tests were made at two angles of attack, 0.2° and 4.2°, representative, respectively, of the angles of attack for high-speed level flight and a pull-out condition.

The air-stream fluctuations recorded are not considered serious throughout the speed and lift range of the tests. It was concluded further that insofar as tail buffeting is concerned, little is to be gained by raising the horizontal tail above the two proposed horizontal-tail positions, but tail positions below the lower proposed position are believed to be dangerous under a pull-up condition at high speed.

## INTRODUCTION

The problem of tail buffeting in the design of aircraft to fly in the high-speed range of the D-558-1 airplane is associated with the large turbulent wake of the wing arising from the presence of compression shocks and attendant separation. This turbulent wake occurs in the normal high-speed operating lift range as well as in the pull-up condition for modern aircraft designed to fly at supercritical speeds. As discussed in reference 1, tail buffeting can occur at these speeds with a tail located outside as well as within the boundaries of the wake as defined by total-pressure measurements.

As part of the research program of the National Advisory Committee for Aeronautics for the D-558 airplane, the present tests have been conducted to investigate the flow fluctuations at high speeds in the region of possible horizontal-tail positions, since knowledge of the amplitude and frequency of the flow fluctuations in this region is necessary in order to avoid placing the horizontal tail where it will be subject to buffeting.

## APPARATUS AND METHODS

The investigation was conducted in the Langley 8-foot high-speed tunnel with the $\frac{1}{16}$-scale model of the Douglas D-558-1 airplane described in reference 2, in which the tunnel configuration of the Langley 8-foot high-speed tunnel used for the D-558 research program is also described. The present tests were made without the horizontal tail and with some modifications to the support system. A schematic diagram of the model support system for the air-stream fluctuation tests is given as figure 1.

The air-stream fluctuation instrument used was the same as that used in the investigation of reference 3, which reports the details of the construction, function, and operation of the instrument. The recording system used, however, was not as sensitive as that employed in the tests of reference 3.

Since the fluctuations of the air stream were nonperiodic and irregular, a statistical method of analysis was adopted for the purpose of predicting tail buffeting by which the average of the maximum amplitude of angular fluctuation is determined for samples of frequency ranges that predominate. The analysis of the records thus depends to some degree upon individual judgement.

Air-stream fluctuations were recorded at five vertical positions at the tail to provide a vertical range including the two proposed horizontal-tail positions. The longitudinal and lateral positions of the instrument were such as to measure the fluctuations at the quarter-chord line of the horizontal tail and approximately on the midsection of the horizontal-tail semispan. The tests were made at Mach numbers of 0.775, 0.8, 0.85, 0.875, 0.9 and 0.907 at angles of attack measured with respect to the airplane thrust line of 0.2° and 4.2°. These angles of attack correspond respectively to those for high-speed level-flight and a pull-up condition.

Following the fluctuation measurements, the wake position was determined at the same Mach numbers and angles of attack with a total-pressure rake located 1.92-wing-root chords behind the quarter-chord point of the wing mean aerodynamic chord (corresponding to the longitudinal location of the fluctuation survey) and 0.41 tail semispan from the plane of symmetry.

## SYMBOLS

$\alpha$ angle of attack of airplane thrust line, degrees

$\beta$ average of the maximum amplitude of angular fluctuation of the air stream for samples of fluctuations of a specific frequency range, degrees (The amplitude of a fluctuation is herein taken as the total angular deviation of the flow during a cycle.)

$\Delta H$ free-stream total pressure minus local total pressure, pounds per square foot

M free-stream Mach number

q free-stream dynamic pressure, $\frac{1}{2}\rho V^2$, pounds per square foot

V free-stream velocity, feet per second

$\rho$ free-stream density, slugs per cubic foot

F frequency of air-stream fluctuations, cycles per second

d vertical projection of airfoil profile on a plane perpendicular to the direction of the flow, feet

## RESULTS AND DISCUSSION

The results of the tests are presented in figures 2 and 3 as the vertical variation of $\beta$ and the total-pressure loss in the wing wake, where the vertical distance is given as percent of wing-root chord above the wing chord line extended. The two proposed horizontal-tail positions of the D-558-1 airplane are indicated. The three frequency ranges for which $\beta$ is presented are those in which fluctuations predominated; the flow fluctuations that occurred at frequencies outside of these ranges were negligible in amplitude and number. The scatter of the test points is due in part to instrumentation difficulties which resulted in low sensitivity, and in part to the irregular and nonperiodic nature of the flow. The accuracy of the data for the low-frequency range is best, with the possible error of the order of $\pm 0.15^{\circ}$. The fluctuations of the higher frequency ranges were the most difficult to read with possible errors ranging from approximately $\pm 0.15^{\circ}$ to $\pm 0.3^{\circ}$. No attempt has been made to fair the curves in some parts of the figures because of the scatter.

Throughout the Mach number range the fluctuations with the model at the angle of attack of $0.2^{\circ}$ (fig. 2) were found to be small with no significant changes in $\beta$. A trend toward diminution of the angle of fluctuation with increase in vertical distance from the wing wake is indicated. At an angle of attack of $4.2^{\circ}$ (fig. 3), the air-stream fluctuations were approximately the same for Mach numbers of 0.8 and 0.85, but as the Mach number was increased above 0.85 and the normal-shock loss from the upper surface of the wing spread upward into the zone investigated, the angle of fluctuation increased rapidly at points nearest the wake. For both angles of attack and throughout the Mach number range, however, the maximum fluctuations of the air stream over the range of vertical position investigated are not considered serious and, therefore, the two proposed horizontal-tail positions should be satisfactory from the standpoint of tail buffeting.

Data from the high-speed-bomber wing tests of reference 3 are presented in figure 4 at approximately the same lift coefficients and Mach number with the data of the present tests for the design maximum level-flight Mach number of the D-558-1 airplane. The high-speed-bomber wing data illustrate the magnitude to which fluctuations grow in the central part of the turbulent wake, and the data suggest that for the D-558-1, the fluctuations can be expected to increase severely as the wake is approached more closely than the lowest point of the fluctuation survey. The fluctuations in the wake of the D-558-1 wing, however, will probably not be as severe as those in the wake of the high-speed-bomber wing, owing to the smaller aspect ratio (4.17 as compared to 9.0).

Insofar as tail buffeting is concerned, the figures show that for the range of lift and Mach number of these tests, little is to be gained by raising the horizontal tail above either of the two proposed horizontal tail positions. Tail positions below the lower proposed position are believed to be dangerous under pull-up conditions at high speed as represented by the data for the high angle of attack (fig. 3), because of an expected abrupt increase in the angle of fluctuation as the wake is approached a small distance beyond the lower tail position.

The law of similitude by which the results may be corrected to the full-scale conditions is not known, as there is no theory defining the frequency of wake disturbances for any type of wake other than a double row of vortices. An approximation to full-scale conditions may be made by assuming the Strouhal number $Fd/V$ to be a constant, as suggested from the tests of reference 4. Essentially, this was the assumption of the analysis of reference 3. The velocities of the present tests correspond to full-scale velocities; thus, the frequencies at the tail of the full-scale airplane will vary inversely as the size or will be one-sixteenth of the test frequencies. The physical meaning of the assumption of constant Strouhal number is simply that the geometry of the wake disturbances increases in scale directly as the airfoil. The amplitude of the angular air-stream fluctuations in the wake would on the basis of constant Strouhal number experience no effect of scale.

## CONCLUSIONS

From the tests and analysis of this report, the following conclusions are made:

1. The fluctuations of the air stream at the two proposed positions for the horizontal tail are not considered serious throughout the speed and lift range of these tests.

2. Insofar as tail buffeting is concerned, little is to be gained by raising the horizontal tail above the two proposed horizontal tail positions.

3. Tail positions below the lower proposed position are believed to be dangerous under a pull-up condition at high speed.

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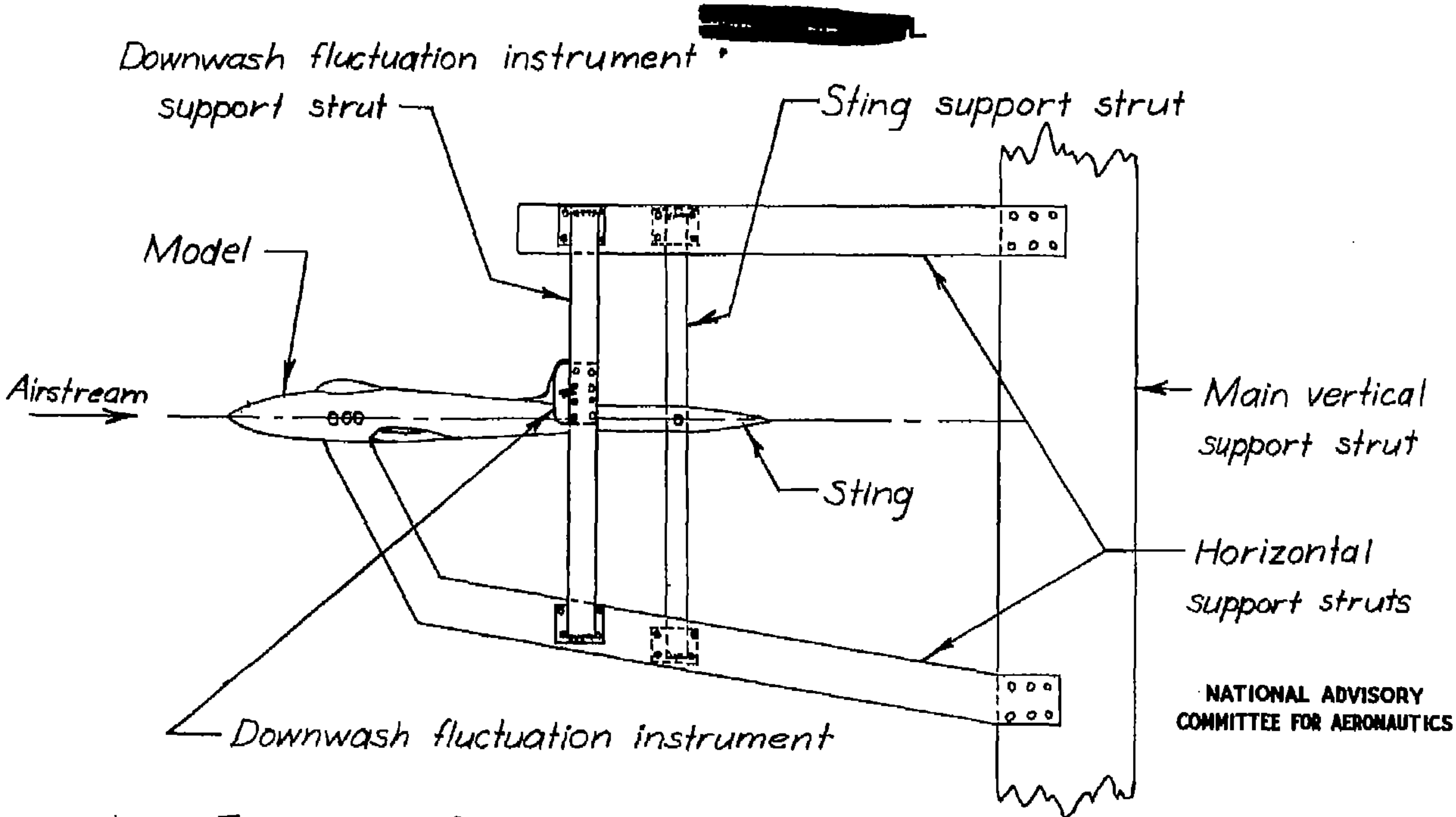


Figure 1.- Schematic diagram of downwash fluctuation test set-up. [redacted]

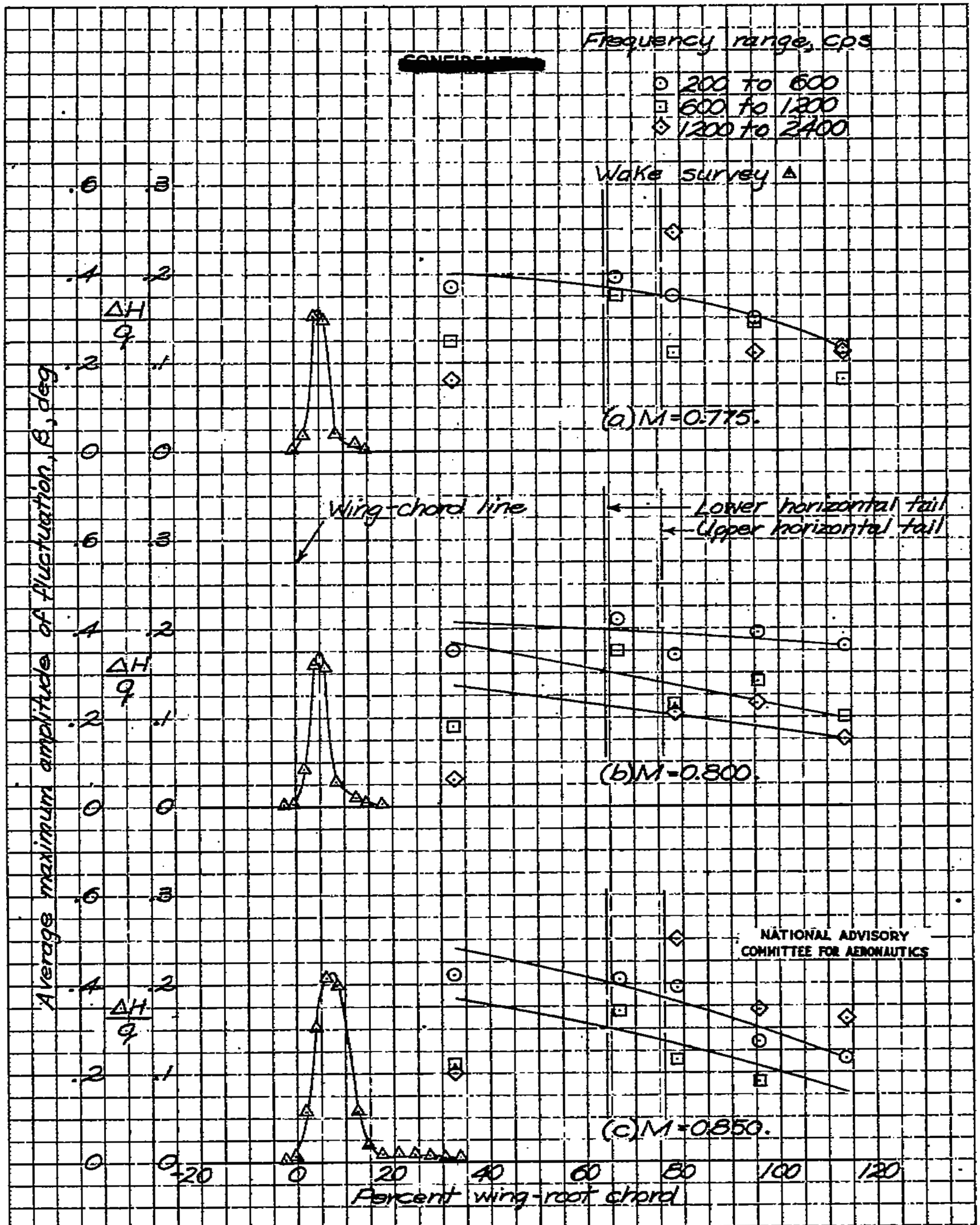


Figure 2.—Vertical variation of the maximum amplitude of fluctuation at the tail. α = 0.2°

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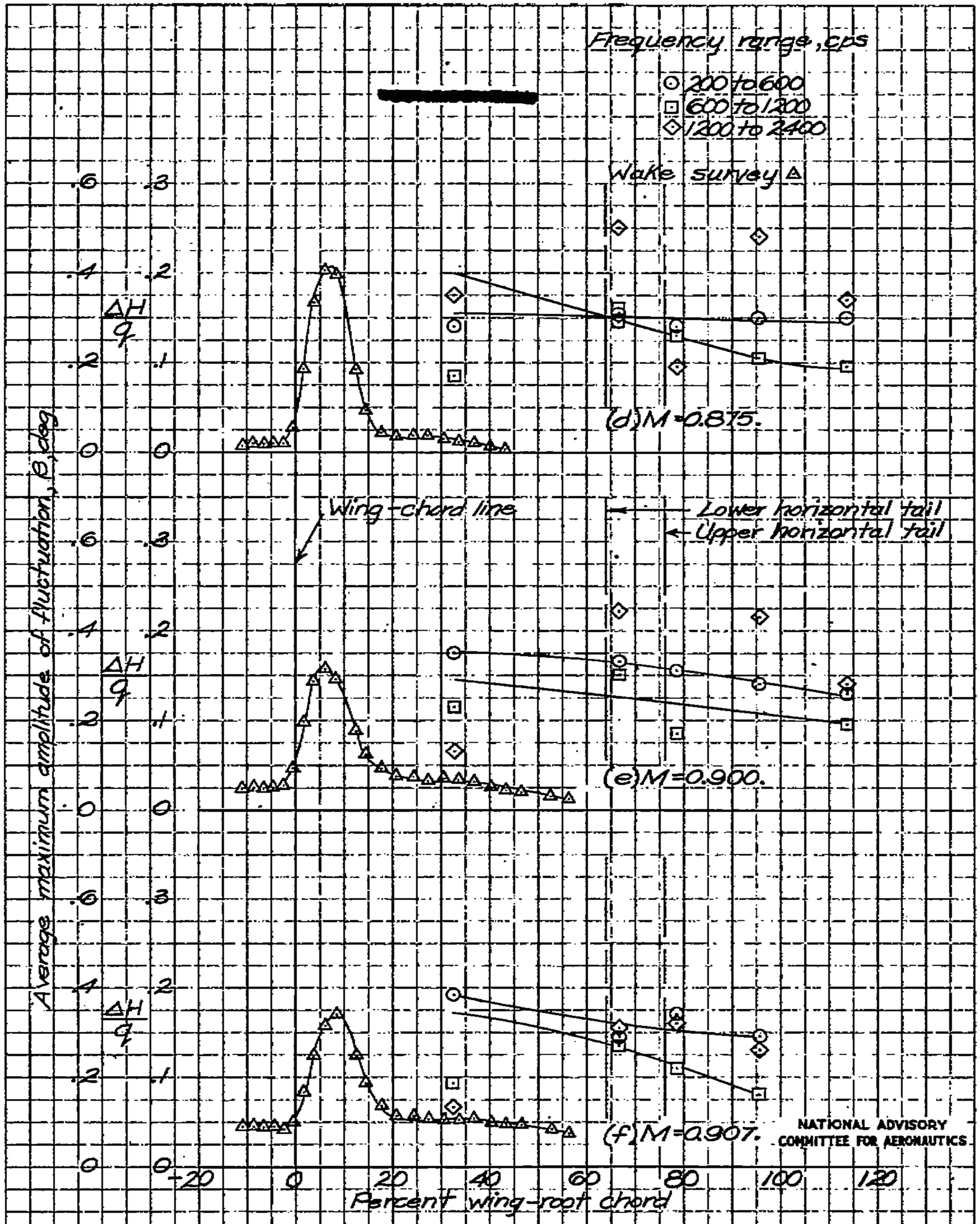


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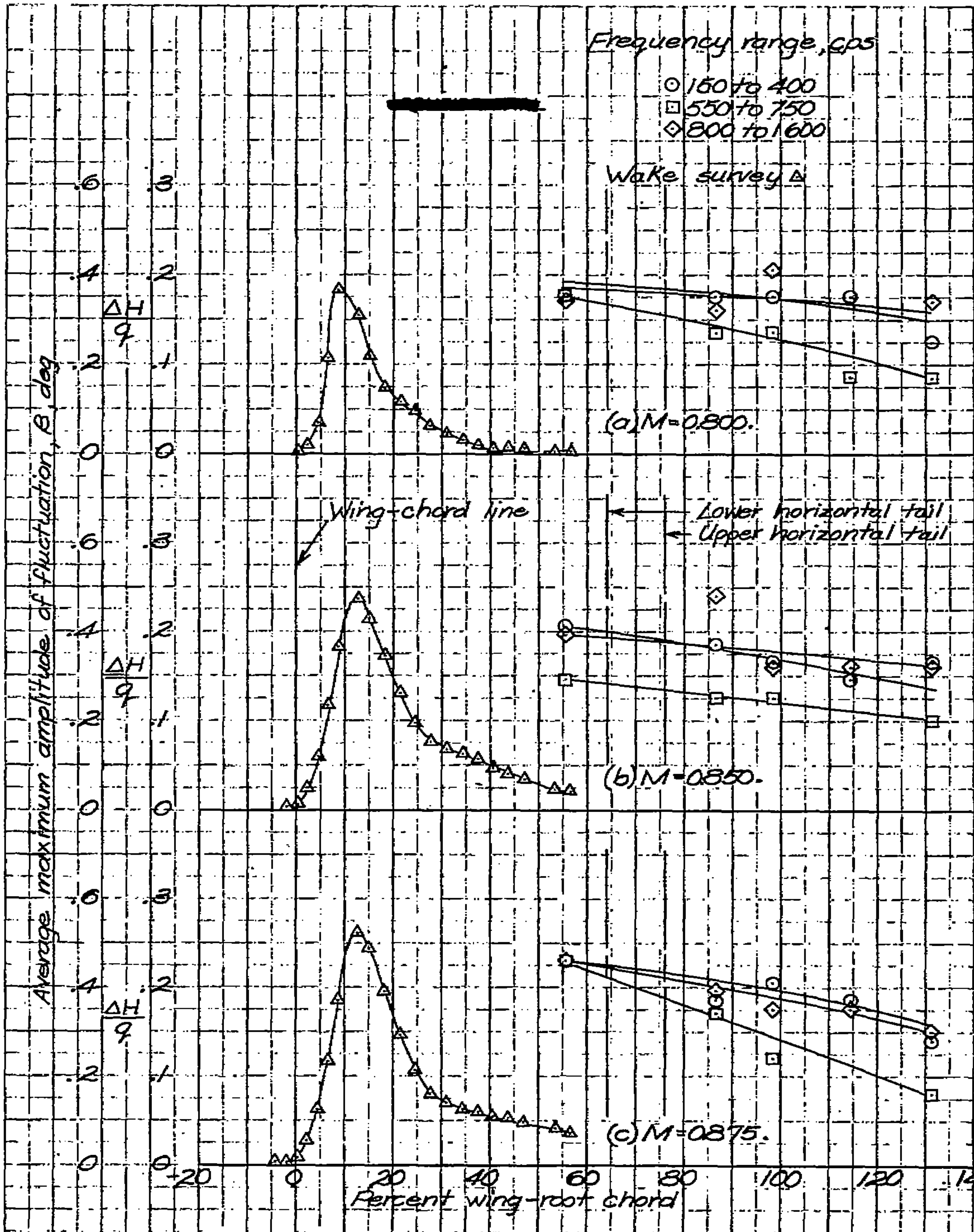


Figure 3.- Vertical variation of the maximum amplitude of fluctuation at the tail. α = 4.2°.

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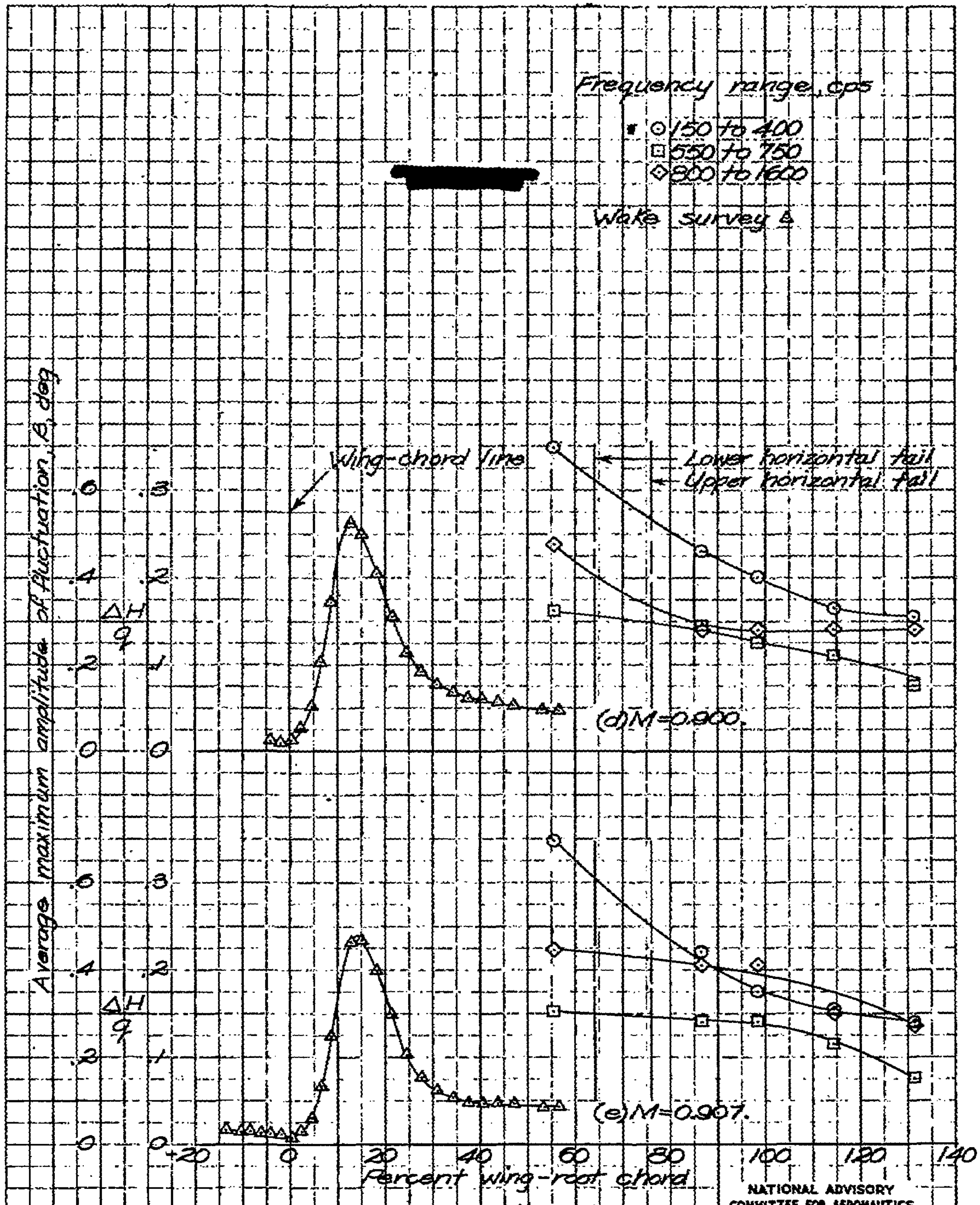


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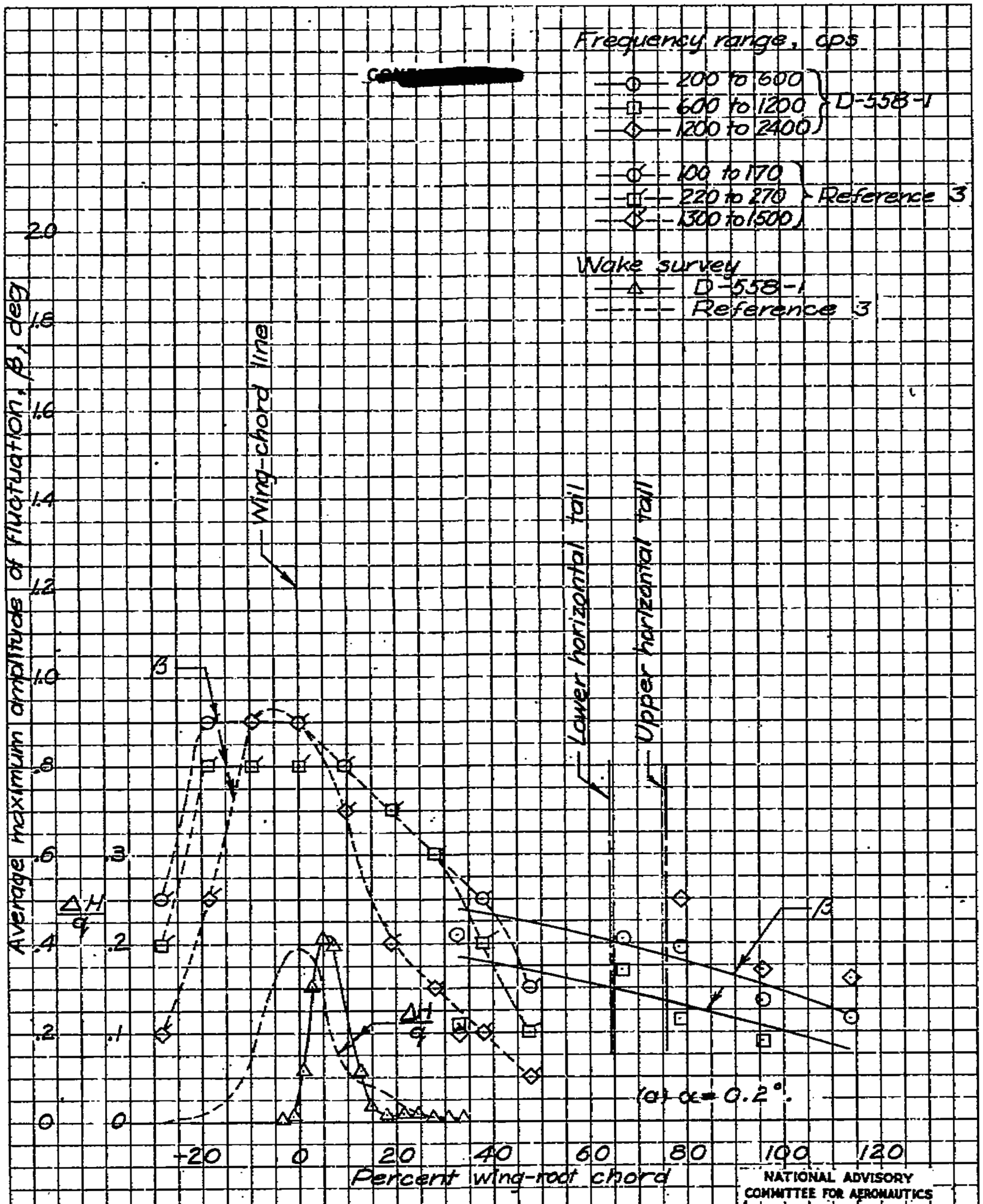


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Figure 4.- Comparison of air-stream fluctuations in the wake from data of reference 3 with air-stream fluctuations measured above the wing-wake of the D-558-I. M=0.85.

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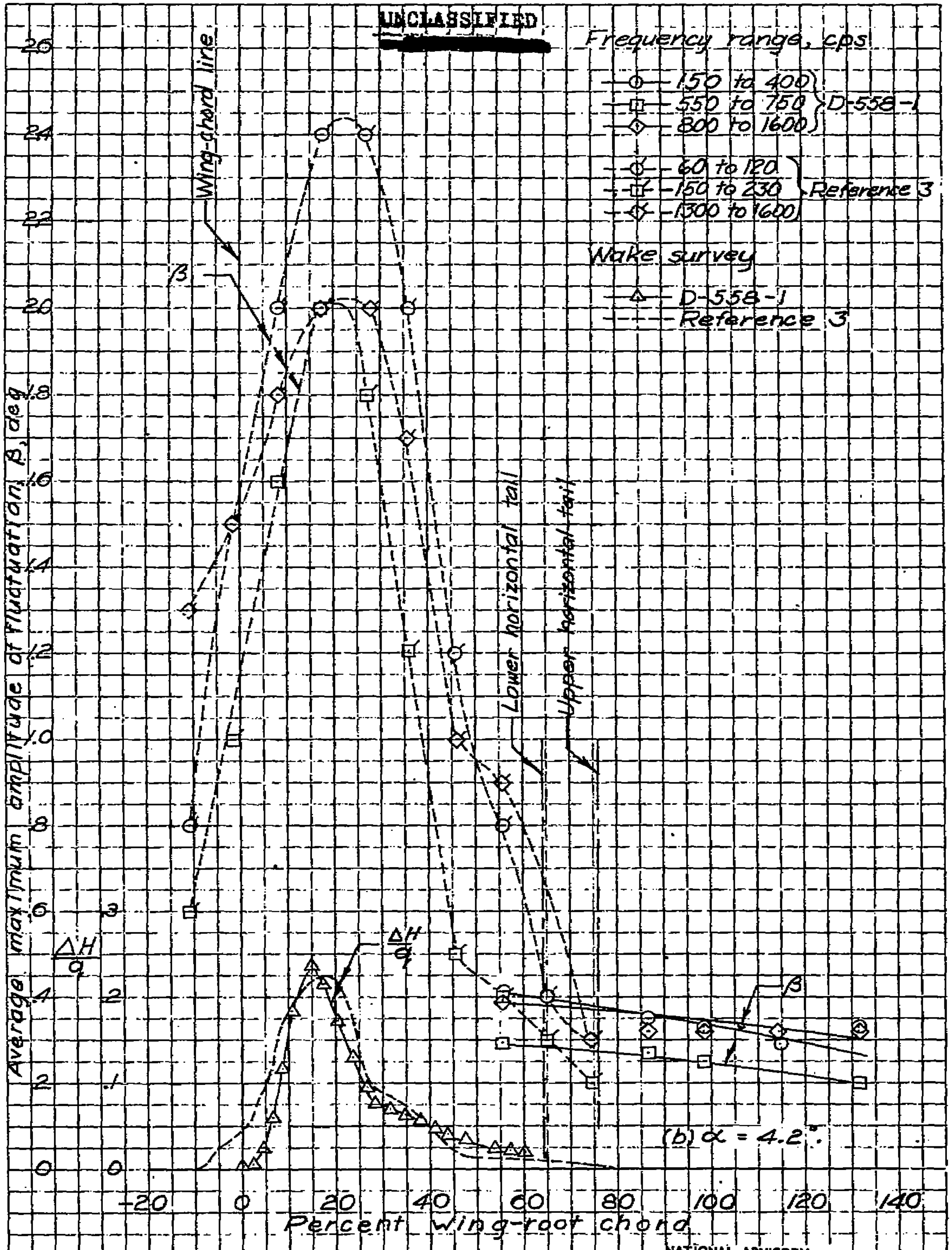


Figure 4.- Concluded.

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