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RESEARCH MEMORANDUM

BUFFETING INFORMATION OBTAINED FROM ROCKET-PROPELLED AIRPLANE MODELS HAVING THIN UNSWEPT WINGS

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BUFFETING INFORMATION OBTAINED FROM ROCKET-PROPELLED AIRPLANE MODELS HAVING THIN UNSWEPT WINGS

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SUMMARY

Some buffeting information has been obtained from flights of rocket-propelled models of an airplane configuration having an unswept low-aspect-ratio wing with 4.5-percent thick-hexagonal airfoil sections. The flights covered a fairly large positive lift-coefficient range in the Mach number range from 0.75 to 1.35.

In the Mach number region below 0.90 the buffeting, as indicated by vibrations in the normal-acceleration record, occurred at a lift coefficient about 0.1 below the maximum. At Mach numbers above 0.90, both the maximum lift coefficients and the buffeting boundary increased. In the Mach number range from 1.00 to 1.35 no evidence of buffeting was obtained up to the highest lift coefficients reached in the tests, which were 0.84 and 0.45 at Mach numbers of 1.00 and 1.35, respectively. The frequency of the buffeting vibrations corresponded to the probable frequency of the model wings in the first bending mode.

INTRODUCTION

Buffeting at high subsonic or transonic Mach numbers is one of the factors causing concern about some airplanes at the present time. The type of buffeting to be discussed in this paper is that arising from unsteady flow over the wing and causing fluctuations of the normal accelerations of the airplane. Flight-test information for conventional subsonic airplanes having unswept wings of moderate aspect ratio and thickness (reference 1 and unpublished data) indicates that, at low speeds, this type of buffeting starts near the maximum lift coefficient but at speeds above that corresponding to the force-break Mach number, the lift coefficient at which buffeting starts decreases to very low values. The latter phenomenon thus appears to be a compressibility effect, associated with the aerodynamic characteristics of the wing at supercritical Mach numbers.

The experimental data on buffeting presented herein were obtained from the flights of two rocket-propelled models of an airplane configuration having wings of aspect ratio 3 and hexagonal airfoil sections of 4.5-percent thickness. This thin low-aspect-ratio wing illustrates one approach to the problem of minimizing changes in wing characteristics in the transition from subcritical to supercritical flow conditions.

The Mach number range covered in the tests was 0.75 to 1.35. The models were flown primarily to determine the stability, control, and drag characteristics of the configuration and some of this information has been presented in reference 2, which briefly mentioned the buffeting phenomenon. The buffeting information was incidental to the stability investigation and is described in detail in this paper. The models were flown at the Langley Pilotless Aircraft Research Station, Wallops Island, Va.

SYMBOLS

a_n	normal acceleration
α	angle of attack, degrees
δ	elevator deflection
M	Mach number
C_L	lift coefficient

MODELS AND APPARATUS

The model configuration investigated is shown in figures 1 and 2. Two geometrically similar models were flown. Model A had a solid-steel wing and model B had a solid aluminum wing. The airfoils were 4.5-percent-thick hexagonal sections as shown in figure 1 and had no radii at the contour changes of the section. Variations in angle of attack and lift coefficient were obtained by rapid deflections of the all-moveable horizontal tail as an elevator control. The information contained herein was obtained from telemetered measurements of normal acceleration, angle of attack, elevator deflection, total pressure, and a reference static pressure. The angle of attack was measured by a vane-type instrument located on the nose of the models (figs. 1 and 2). A more complete description of the models and the test and analysis procedures are contained in reference 2.

The models were boosted to Mach numbers of about 1.4 by 6-inch-diameter dry-fuel Deacon rocket motors and then separated from the boosters by reason of the different drag-weight ratios of the models and boosters. The models contained no sustaining rockets. The data used in the analysis were those recorded during the decelerating part of the flight following booster separation.

RESULTS AND DISCUSSION

Parts of the telemeter records which illustrate the buffeting phenomena are reproduced in figures 3 and 4. The parts of the records at $M = 1.05$ and $M = 1.00$ for models A and B, respectively, are included to illustrate the general quality of the telemeter signal which existed throughout the entire duration of the flights and to show the appearance of the records when no buffeting was present. The portions of the records at Mach numbers of 0.75 and 0.90 show the vibrations indicative of the unsteady air flow existing at high lift coefficients. These normal-acceleration records are very similar to those shown in figure 2 of reference 1, which describes maximum lift and buffeting tests on a full-size airplane.

The amplitudes of the buffeting oscillations were larger than indicated by the records shown (by a factor of approximately 2) because of the reduced amplitude response characteristics of the telemeter recording equipment at the frequencies encountered here (110 to 130 cycles per second). The severity of the buffeting for a full-size airplane cannot be predicted from these data because the instrumentation was not designed for this purpose and because of the different mass and stiffness characteristics of the model and airplane. The departure of the normal-acceleration curve from a sine-wave shape at the first oscillation peak following a negative control deflection (fig. 3(b)) appears to indicate that the maximum lift coefficient was reached (reference 2). This effect also occurred in the normal-acceleration records shown in reference 1.

Figure 5 shows the variation with Mach number of the lift coefficient for constant angle of attack. Only the positive lift range for model A is shown. Model B did not cover so great a lift-coefficient range. On this plot are also shown curves of the maximum lift coefficients and the lift coefficients at which buffeting starts, as obtained from both models, over the subsonic speed range for which these quantities were measured. Model B entered the buffeting region at only one point ($M = 0.90$, fig. 4(b)). At this point the agreement between models A and B as to the lift coefficient at which the buffeting starts was excellent. At Mach numbers above 0.90 the maximum lift coefficients were not reached, although the lift coefficients attained at a Mach number of 1.0 were greater than the maximum values occurring at lower Mach numbers. Apparently the maximum lift coefficients increased above a Mach number of 0.90. This same effect is shown in reference 3 for an unswept wing of aspect ratio 4.

Buffeting appeared to start at approximately 0.1 lift coefficient below the maximum (fig. 5) in the Mach number range where both were measured and is in a region where the lift-curve slope is decreasing prior to the stall. At Mach numbers above 0.85 the buffet boundary increased, and above $M = 0.97$ no evidence of buffeting appeared in the records at any lift coefficient obtained during the flights.

A criterion for determining the probable buffet boundary is described in reference 4. The criterion was derived from wind-tunnel and flight tests of airplanes having wings with relatively thick conventional airfoil sections. Application of this criterion to the wing of the configuration described herein indicates that the buffet boundary should decrease very rapidly from $C_L = 0.7$ at $M = 0.76$ to about $C_L = 0.3$ at $M = 0.85$. Figure 5 indicates that this decrease did not occur during the model flights and it is thus concluded that the criterion of reference 4 does not apply to wings of the type used on these models.

Referring again to the telemeter records in figures 3 and 4 it is evident that, as the angle of attack decreases following the appearance of the buffeting, the vibration persists to a lower lift coefficient than that at which it starts. This effect may be an aerodynamic phenomena or may represent the structural damping characteristics of the wings. Although the frequency of vibration in figures 3 and 4 is nearly the same for models A and B, the time required for the oscillation to damp out is much less for model B which had the aluminum wing. The vibration characteristics of the models were not checked prior to flight. Subsequent to the flights of these models vibration tests were made of an aluminum wing similar in plan form and airfoil section to those discussed herein but somewhat larger in size and having a different form of root attachment imposing less bending restraint. If the measured natural frequency of this wing in the first bending mode is modified by the scale factor, a frequency of 105 cycles per second is obtained for wings the size of those used on these models. The vibration frequency in figures 3 and 4 is about 110 cycles per second for model B and 120 cycles per second for model A. Thus it appears that the vibrations appearing in the records probably represent the bending frequency of the wings.

In comparing the rocket-model results presented herein with those of reference 1 the difference in configuration should be kept in mind, particularly the difference in the wing airfoil sections, which were thin, sharp-nosed, and had sharp surface breaks for the rocket models and were relatively thick and round-nosed for the airplane of reference 1. Both sets of data show that above a Mach number of about 0.7 the buffeting starts before maximum lift is reached. The data of reference 1 show a rapid decrease of the buffeting boundary above a Mach number of about 0.6 approaching zero lift coefficient above a Mach number of approximately 0.8. No evidence of this latter effect occurred on the rocket models.

CONCLUSIONS

Flight tests at transonic speeds and high lift coefficients of rocket-propelled models of an airplane configuration having an unswept low-aspect-ratio wing with 4.5-percent-thick hexagonal airfoil sections indicated the following conclusions with respect to the buffeting characteristics:

1. At Mach numbers between 0.75 to 0.90, the buffeting, as indicated by the fluctuations in normal acceleration, began at lift coefficients about 0.1 below the maximum, where decreases in lift-curve slope prior to the stall were evident.

2. At Mach numbers above about 0.90 both the maximum lift coefficients and the buffeting boundary increased.

3. At Mach numbers between 1.00 and 1.35 no evidence of buffeting was obtained up to the test limit of 0.84 lift coefficient at a Mach number of 1.00 and 0.45 lift coefficient at a Mach number of 1.35.

4. The frequency of the vibrations that were indicative of buffeting corresponded to the probable frequency of the wings in the first bending mode.

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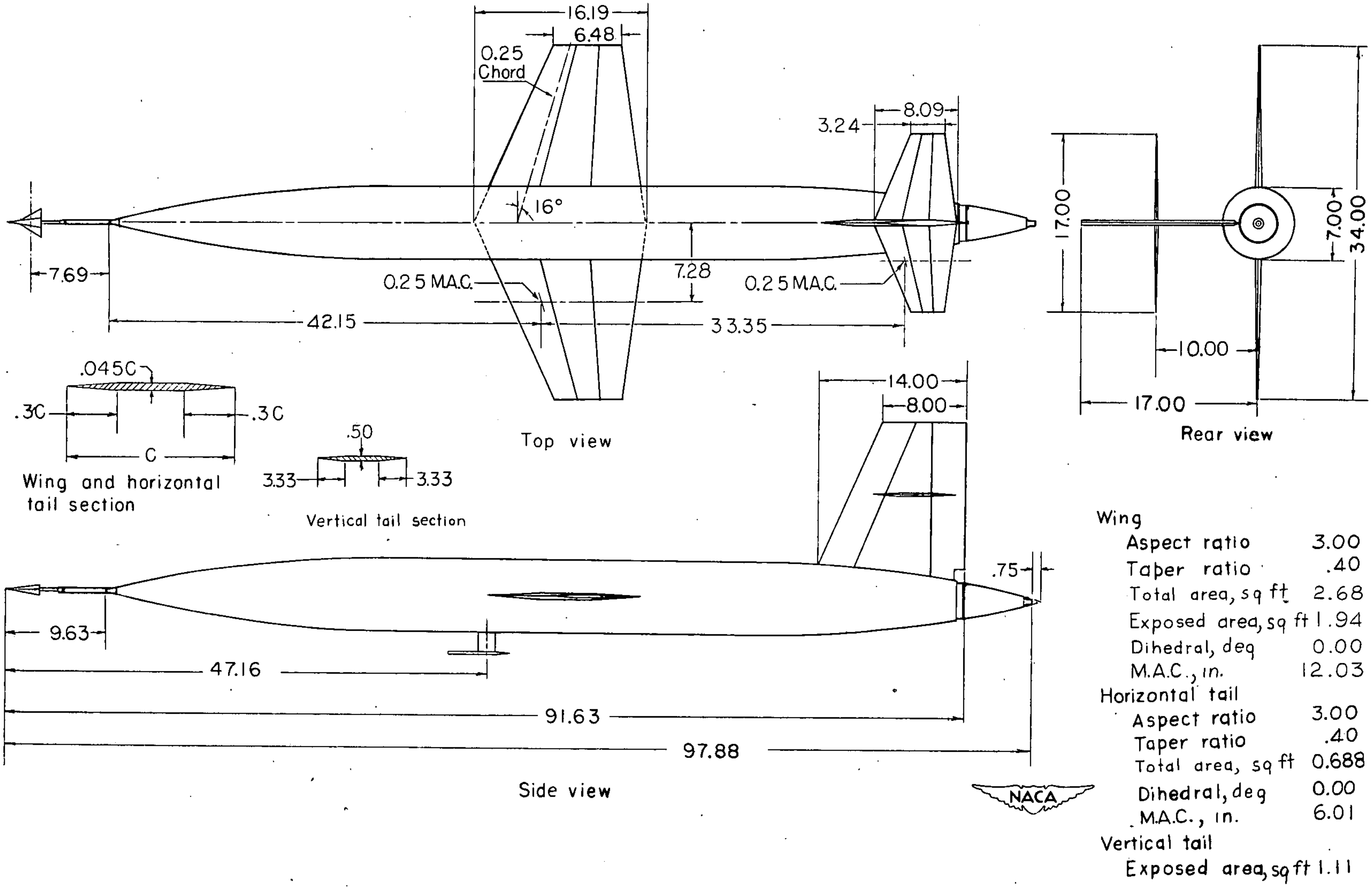

Wing	
Aspect ratio	3.00
Taper ratio	.40
Total area, sq ft	2.68
Exposed area, sq ft	1.94
Dihedral, deg	0.00
M.A.C., in.	12.03
Horizontal tail	
Aspect ratio	3.00
Taper ratio	.40
Total area, sq ft	0.688
Dihedral, deg	0.00
M.A.C., in.	6.01
Vertical tail	
Exposed area, sq ft	1.11

Figure 1.- General arrangement of models A and B. All dimensions in inches.

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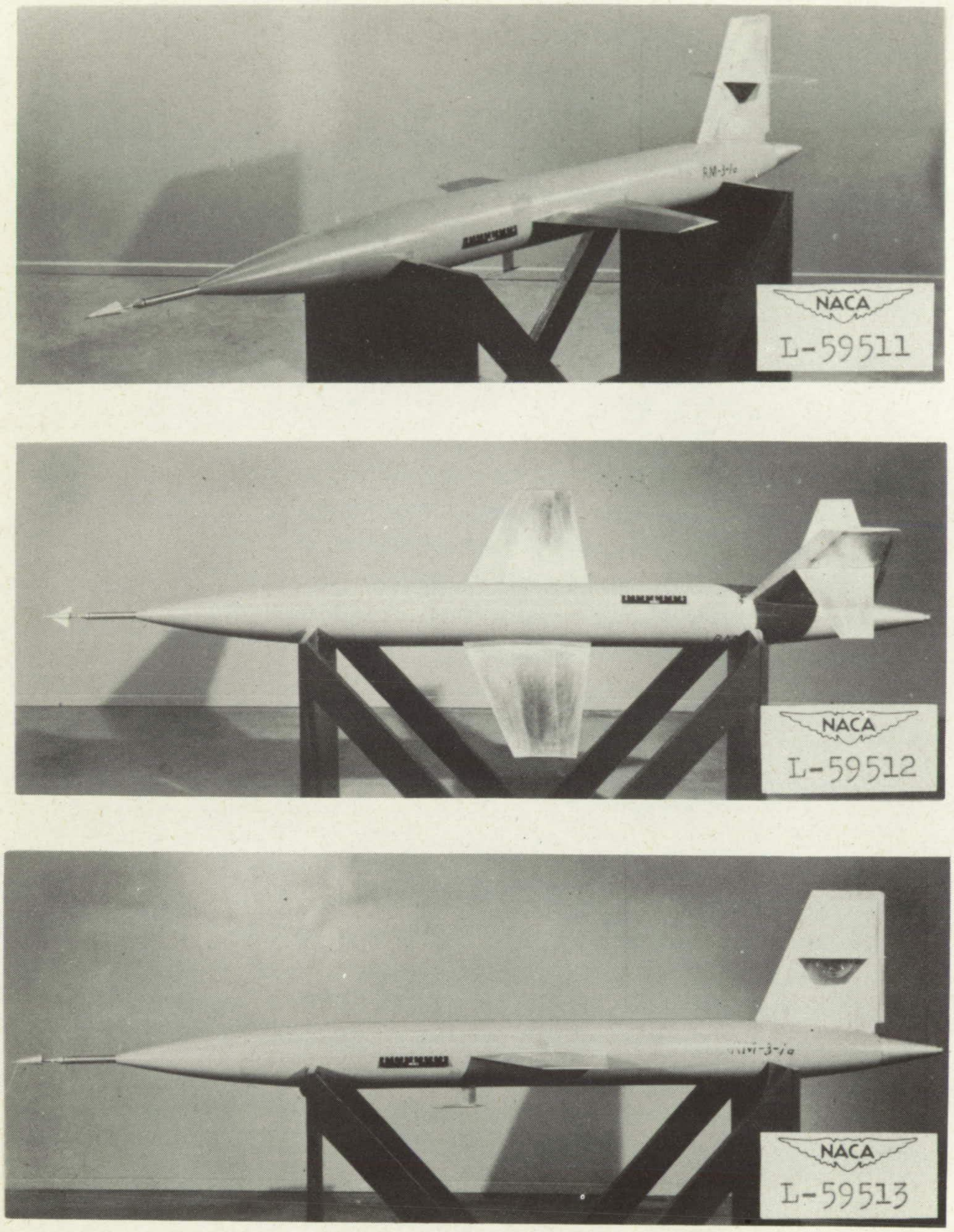

Figure 2.- Model A.

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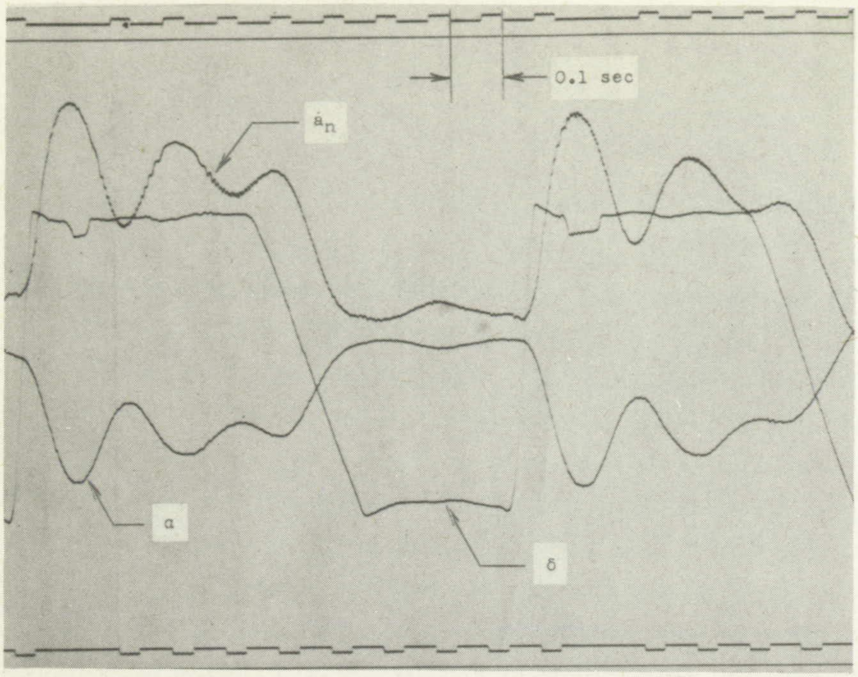
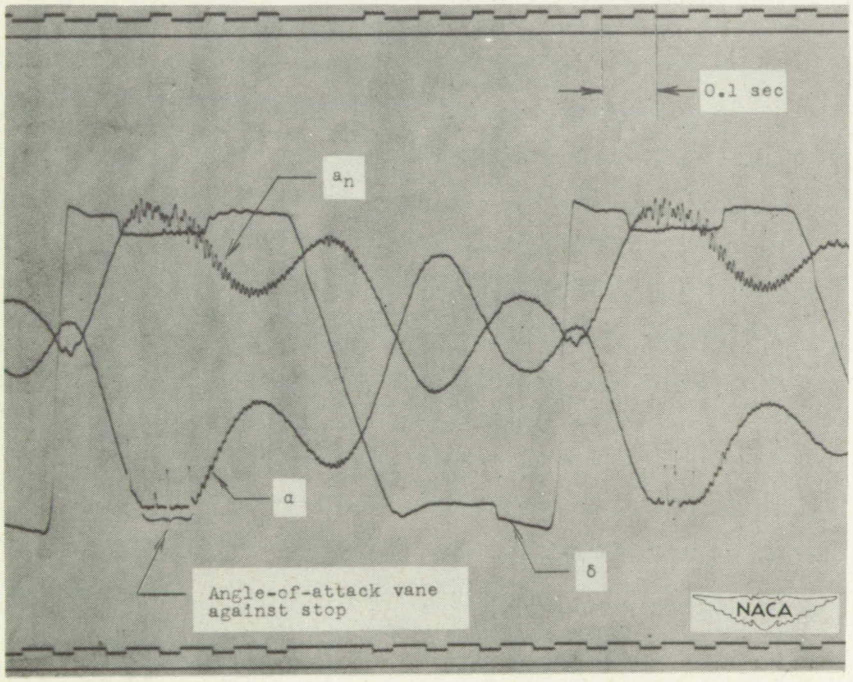


(a) M = 1.05, no buffeting, maximum $C_L \approx 0.81$.



(b) M = 0.75, with buffeting, maximum $C_L \approx 0.78$.

Figure 3.- Typical portions of telemeter record. Model A.

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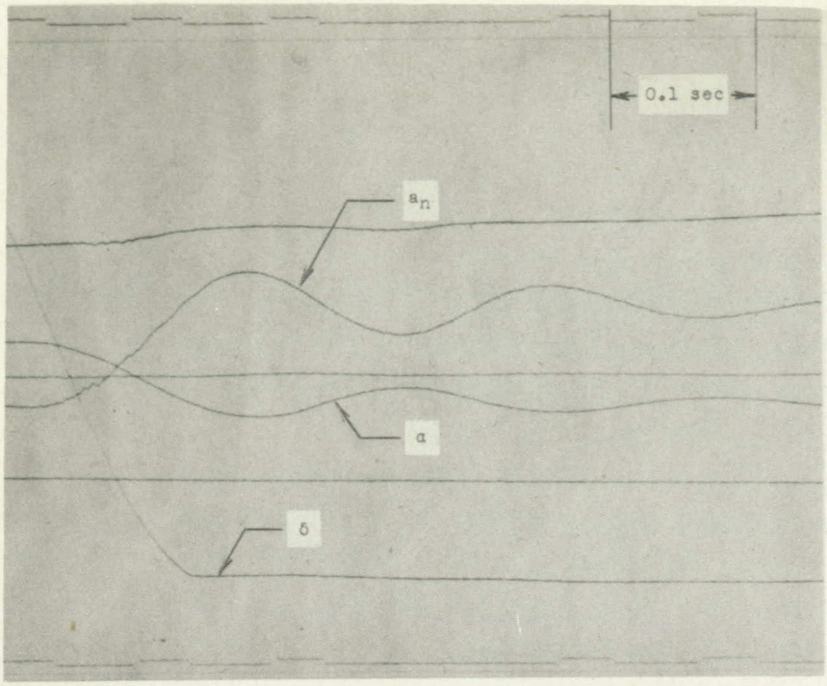
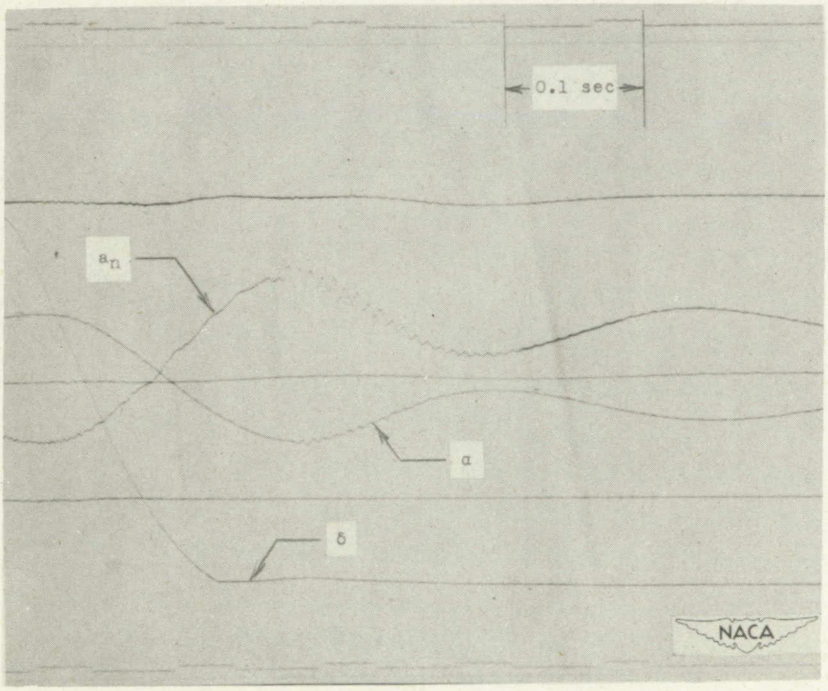


(a) M = 1.00, no buffeting, maximum $C_L \approx 0.52$.



(b) M = 0.90, with buffeting, maximum $C_L \approx 0.70$.

Figure 4.- Typical portions of telemeter record. Model B.

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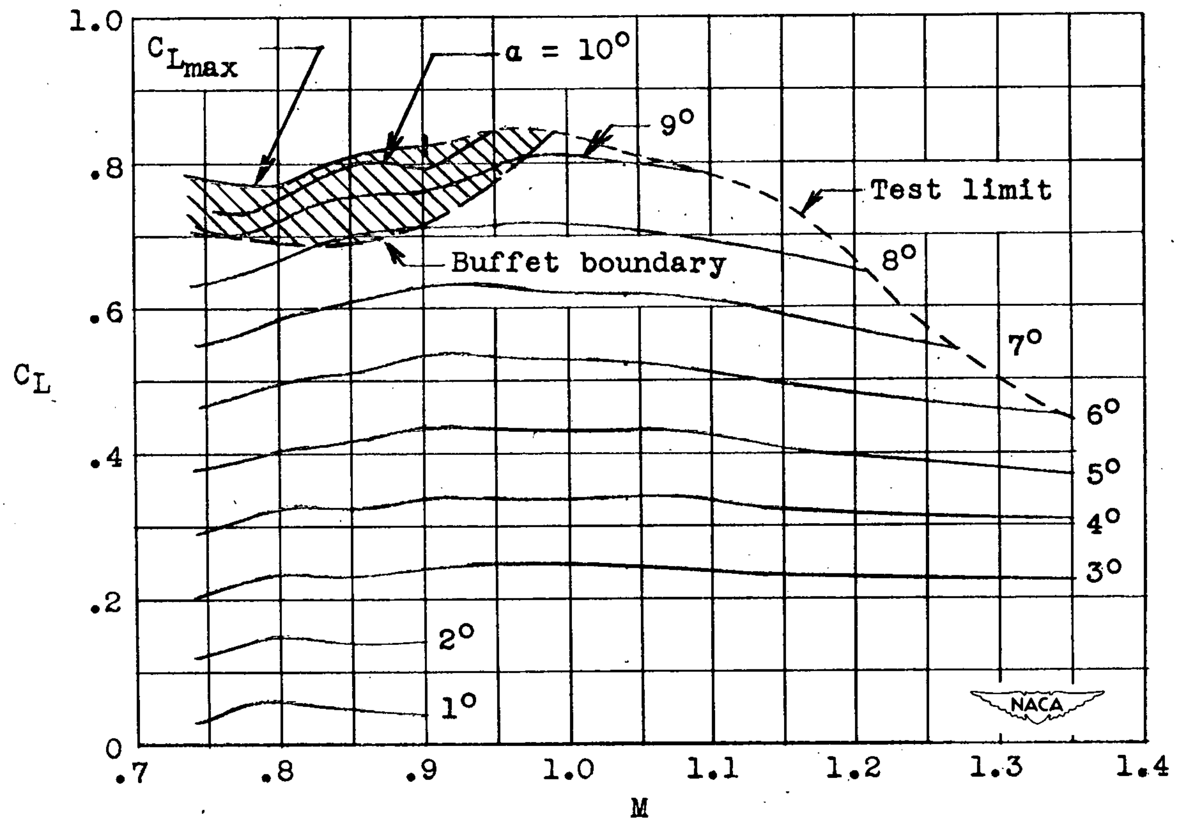

Figure 5.- Summary of buffet and maximum lift information.

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