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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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EXPERIMENTAL STUDY OF AN ANGLE-OF-ATTACK VANE MOUNTED AHEAD OF THE NOSE OF AN AIRPLANE FOR USE AS A SENSING DEVICE FOR AN ACCELERATION ALLEVIATOR

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SUMMARY

An investigation was made to determine the ability of a vane mounted ahead of the nose of an airplane to give an indication of the average angle of attack over the entire wing span during flight through rough air. These tests were performed to determine the suitability of such a vane as a sensing device for an acceleration alleviator. The results show that the vane gives a sufficiently accurate measure of the average angle of attack over the wing span to be of use for this purpose, though rapid fluctuations in angle of attack caused by small-scale turbulence would have to be filtered from its output.

INTRODUCTION

A recent theoretical investigation of some methods for increasing the smoothness of flight in rough air, reference 1, has considered the use of a vane mounted at the nose of an airplane for measuring the angle-of-attack change on the wing due to gusts. A vane mounted ahead of the nose gives a small amount of anticipation of the action of the gusts which would simplify the design of an acceleration alleviator by reducing the required rate of response of the control mechanism. The analysis of reference 1, however, assumed a constant vertical gust velocity across the wing span. In actual flight, the gust velocity would vary across the span, so that the question arises as to whether vanes measuring the angle of attack at relatively few points would give a sufficiently accurate measure of the average angle of attack caused by gusts over the entire wing span. This question is most critical when only a single gust detector located ahead of the nose is employed. Such an installation would, of course, be most convenient from structural considerations. The purpose of this investigation was to determine the ability of such a vane to measure the average angle of attack over the entire wing. A special vane capable of measuring high-frequency disturbances was used for these tests to obtain as accurately as possible the actual local angle-of-attack variations in the region of the vanes.

INSTRUMENTATION

Standard NACA photographically recording instruments were used to obtain the data presented in this paper with the exception of the angle-of-attack recorder. Measurements were made of the normal acceleration, indicated airspeed, inclination of the airplane thrust axis, and the angle of attack. A timer was also used to synchronize all of the records. The natural frequency of the normal accelerometer was 8.75 cycles per second and the damping of the accelerometer element was 0.7 of critical.

The angle-of-attack vanes used to make the angle-of-attack measurements presented in this paper were mounted on a rigid boom 5.8 feet long which was attached to the nose of the test airplane. The vanes were located near the nose of the boom at a distance of 2.3 chords ahead of the center of gravity of the airplane. The vanes were constructed of balsa wood to reduce their inertia and were mass-balanced. The axis of the vanes was mounted on frictionless bearings and rigidly attached to prevent lateral motion of the vanes. The angle of the vanes was measured by means of a small mirror attached to the shaft of the vanes. This mirror produced a continuous record on an optical recorder located in the boom. The natural frequency of the vanes at an airspeed of 150 miles per hour was estimated to be approximately 40 cycles per second and the damping resulting from air forces on the vanes was estimated to be 0.30 of critical. A schematic drawing of the vanes and boom is presented in figure 1 and a photograph of the test airplane with the boom installed is shown in figure 2.

The angle-of-attack vanes were calibrated during steady level flight in smooth air at various indicated airspeeds. At each airspeed, simultaneous records of the inclination of the thrust axis and the vane angle were obtained and the position of the vane was plotted as a function of the angle of attack of the thrust axis. This calibration is presented in figure 3. The results obtained from this calibration give an indication of the upwash at the vanes due to wing, fuselage, and boom. With zero upwash, the slope of the curve of vane angle as a function of angle of attack of the thrust axis would be 1.00. The flight test results show that the variation of these two values results in a slope of 2.03; therefore, the variation of upwash angle with angle of attack is 1.03. Theoretical calculations of the upwash produced by the wing in this region showed that the variation of upwash angle with angle of attack would be 0.09. The remainder of the upwash at the vanes can be attributed to the nose boom and fuselage. The variation of upwash angle with angle of attack resulting from the boom and fuselage therefore was 0.94. It should be noted that the greater portion of this upwash is a result of the flow field of the boom.

The angle of attack presented in this paper is the true angle of attack of the airplane during steady flight only. In order to obtain true angle of attack during unsteady flight conditions, a correction would have to be applied to the angles measured by the vane to account for the effect of pitching. This correction was small for the data presented, however, and was not applied inasmuch as only qualitative results were desired.

TESTS, RESULTS, AND DISCUSSION

Flight tests were made in the power-on clean condition at 150 miles per hour in smooth and moderately rough air. Typical records of angle of attack and normal acceleration obtained from these flights are shown in the time histories of figure 4. The record obtained in smooth air is included to show the level of the fluctuations picked up by the instruments as a result of engine vibration. These fluctuations are very small. The angle of attack presented in figure 4 was obtained from the vane-angle record by applying the calibration of figure 3 and adding the wing incidence of 2° to obtain the angle of attack of the wing rather than that of the thrust axis. The normal-acceleration record provides a measure of the average angle of attack which is effective in producing acceleration of the airplane.

The variations of normal acceleration appear to follow very closely the indications of the vane for oscillations with periods of about 1 second or more. There are many rapid fluctuations in angle of attack caused by small-scale turbulence which do not have any appreciable effect on the motion of the airplane. An analysis given in reference 1 indicates that the reason these rapid fluctuations do not affect the motion of the airplane appreciably is that they are not constant across the wing span. These fluctuations, however, are not so large as to obscure the angle-of-attack variations caused by the gusts of longer period, but they would have to be filtered out if the vane were used as a sensing device for an acceleration alleviator such as that analysed in reference 1. The indications of the vane, in general, precede the recorded accelerations by a small time interval, roughly 0.1 second; the time required for the airplane to travel the distance from the vane to the wing at 150 miles per hour is 0.12 second; the accelerometer introduces a lag of about 0.03 second in the recorded accelerations. The amount of "warning" given by the vane therefore appears to be about 0.07 second, slightly less than the time required for the air to travel from the vane to the wing. Therefore a small amount of lag probably exists in the angle of attack measured by the vanes. This difference in time interval (lag in the vanes) is probably due to the effect of changes in upwash ahead of the wing because the component of vane angle of attack due to upwash ahead of the wing occurs in phase with the changes in wing circulation resulting from gusts. The change in upwash ahead of the wing due to gusts would be reduced for an airplane having an acceleration alleviator since the changes in lift on the wing would be diminished.

CONCLUDING REMARKS

An angle-of-attack vane mounted ahead of the nose of an airplane has been shown to give a sufficiently accurate measure of the average angle of attack over the entire wing span to be of value as a sensing device for an acceleration alleviator. Rapid fluctuations in angle of attack measured by the vane as a result of small-scale turbulence would have to be filtered from the output of the vane.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., February 28, 1951

REFERENCE

1. Phillips, William H., and Kraft, Christopher C., Jr.: Theoretical Study of Some Methods for Increasing the Smoothness of Flight through Rough Air. NACA TN 2416, 1951.

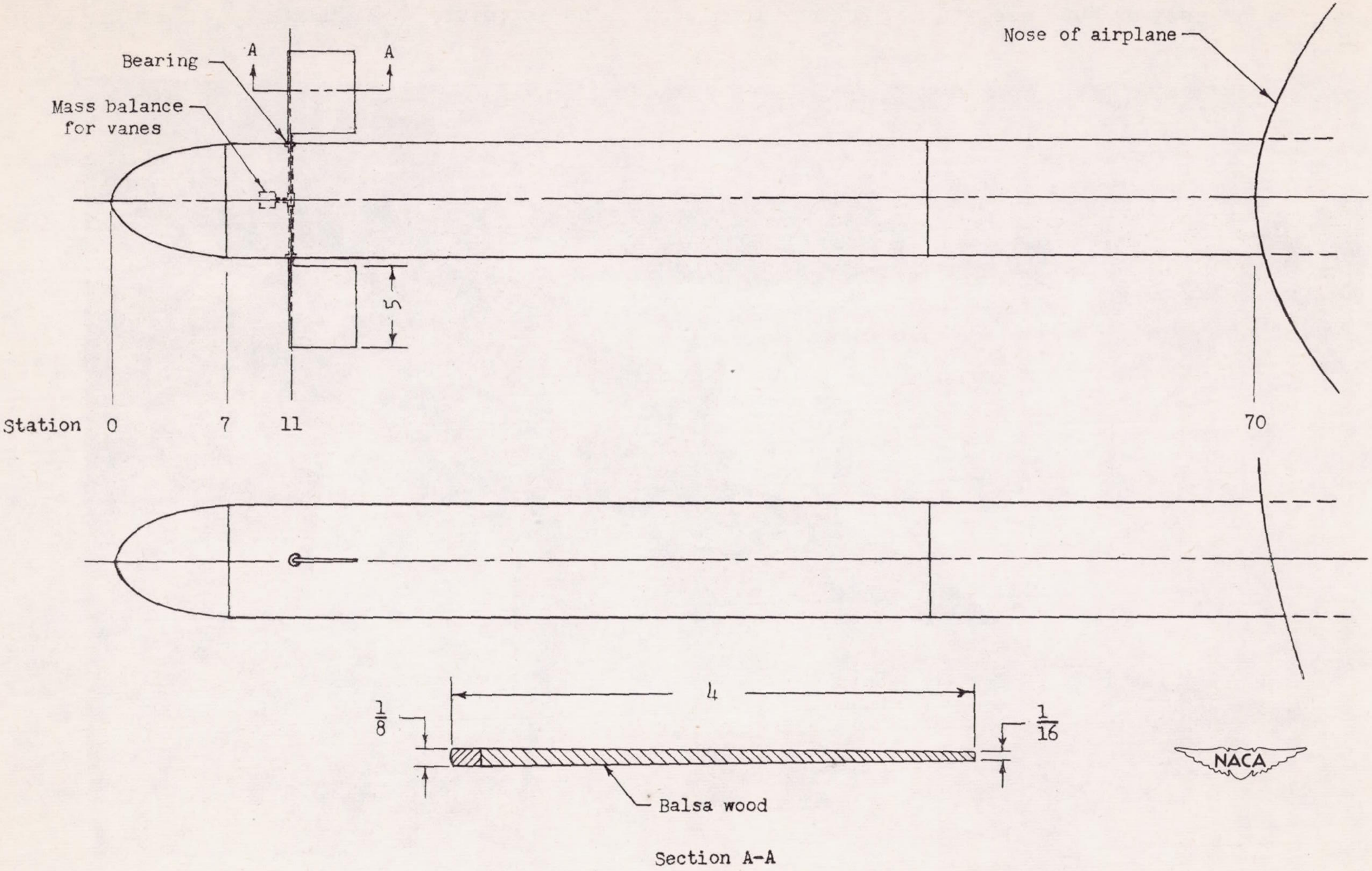

Figure 1.- Schematic drawing of the nose boom and angle-of-attack vanes. All dimensions are in inches.

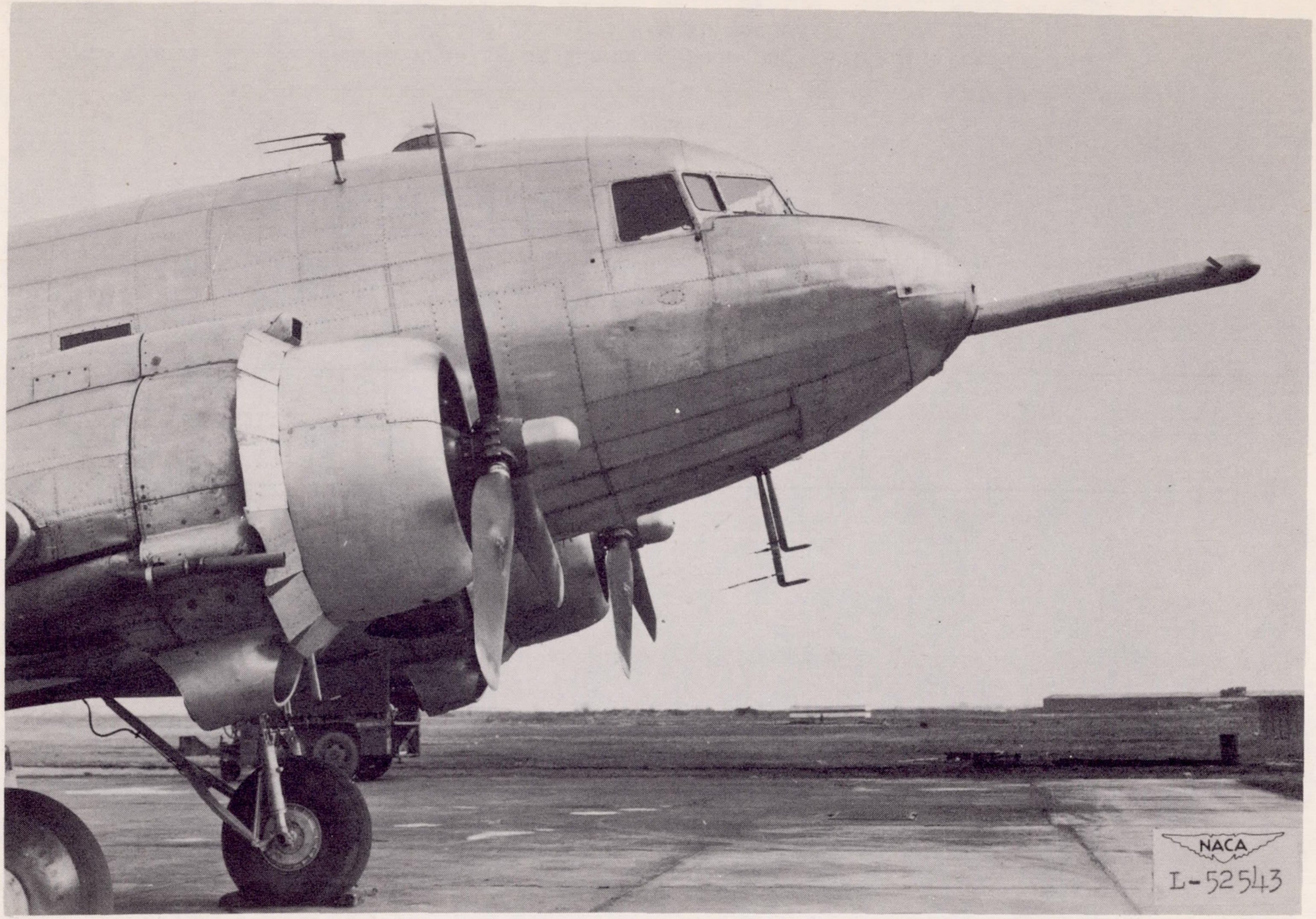

Figure 2.- Installation of nose boom and angle-of-attack vane in test airplane.

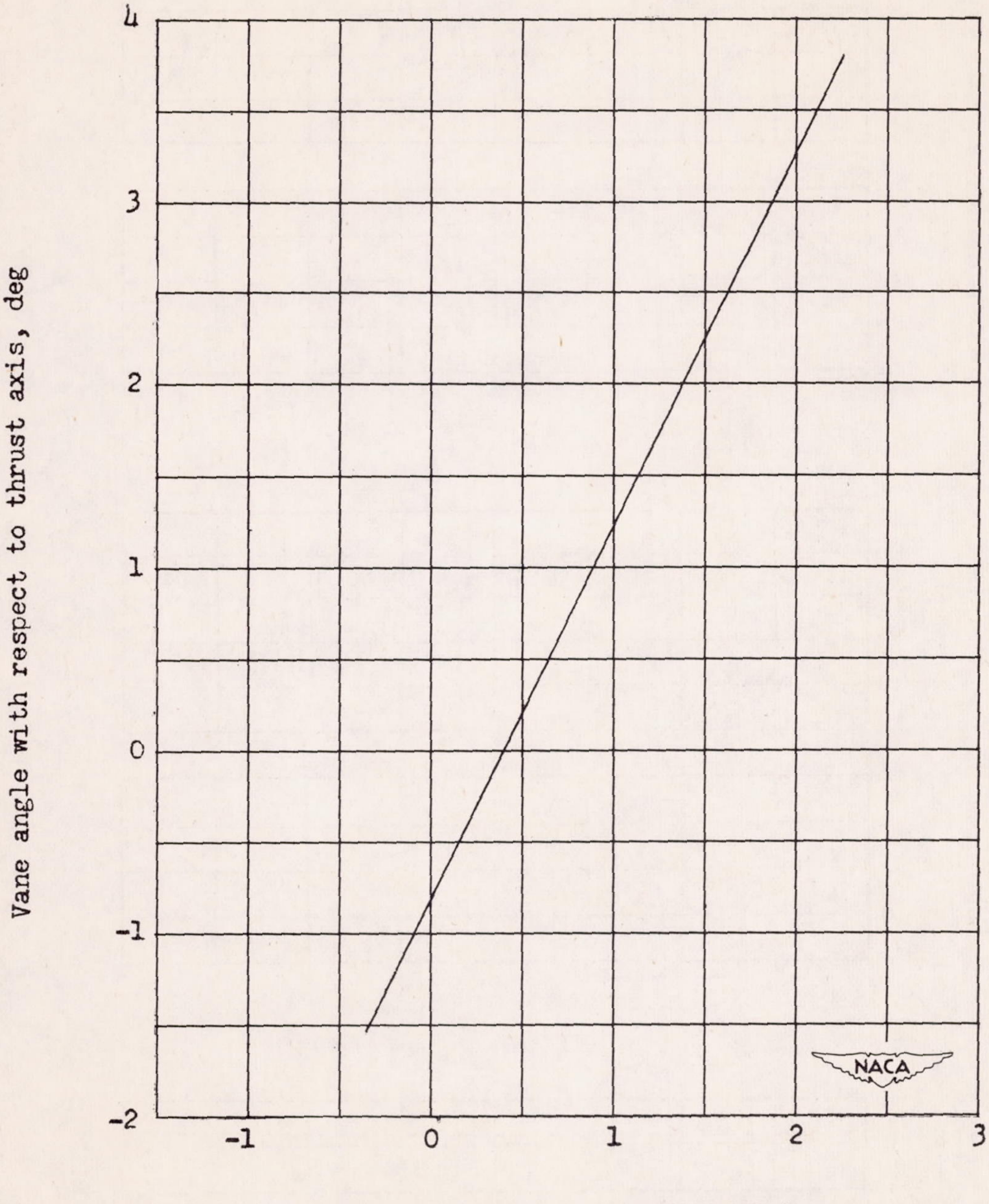

Figure 3.- Calibration of the angle-of-attack recorder in steady flight.

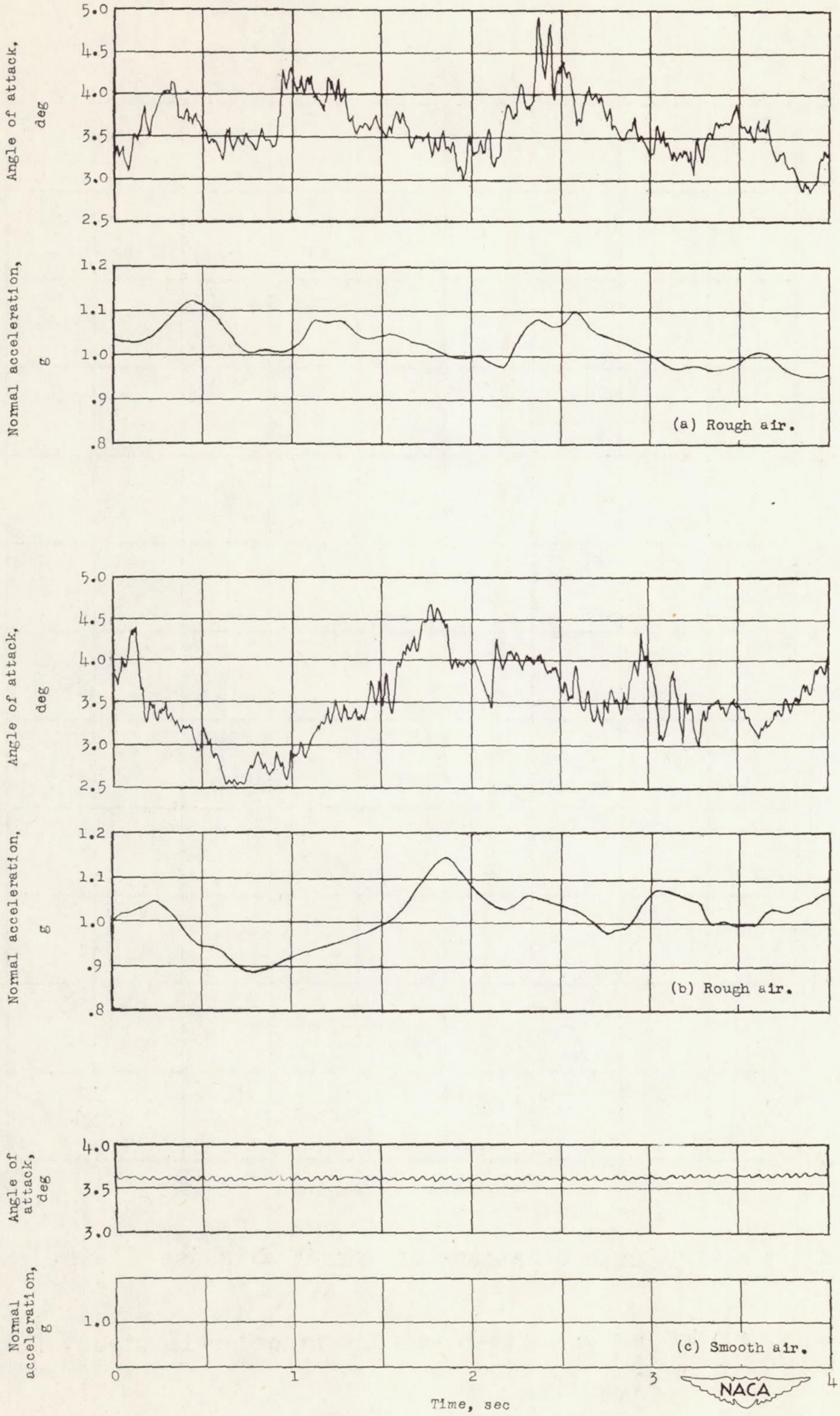

Figure 4.- Time histories of the normal acceleration and angle of attack obtained from flight through moderately rough air in the test airplane.

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