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RESEARCH MEMORANDUM

AN NACA VANE-TYPE ANGLE-OF-ATTACK INDICATOR FOR USE AT SUBSONIC AND SUPERSONIC SPEEDS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

August 16, 1949

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RESEARCH MEMORANDUM

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SUMMARY

A vane-type angle-of-attack indicator suitable for measurements at both subsonic and supersonic speeds has been developed by the National Advisory Committee for Aeronautics. A brief history is given of the development, and a wind-tunnel calibration of the indicator is presented, together with a discussion of the corrections to be applied to the indicated readings.

INTRODUCTION

The purpose of this paper is to present a description of an angle-of-attack indicator developed by the NACA for recording angles of attack at subsonic and supersonic speeds. The instrument was designed by the cooperative efforts of the Langley Pilotless Aircraft Research Division and the Langley Instrument Research Division. Use of the indicator has been limited mainly to experiments on rocket-propelled models. No basic limitations are inherent in the design, however, which would prohibit its use for other testing techniques.

DESCRIPTION

A sketch of the NACA vane-type angle-of-attack indicator is shown as figure 1. This indicator consists of a conical body with a flat-plate triangular vane mounted at the rearward part. The vane is pivoted about a point ahead of the aerodynamic center and is statically balanced about this pivot axis so that the air forces and moments will cause the vane to float at zero angle relative to the wind. Rotation of the vane about the pivot axis is converted by means of push rods to translation of an iron core (also counter-balanced) which moves inside an inductance coil. The angular position of the vane relative to the sting is then obtained as a function of inductance. The stops shown in the sketch limit the range of the instrument. With no stops the maximum angle-of-attack range of this instrument is about $\pm 15^{\circ}$. Figure 2 is a photograph of the angle-of-attack indicator mounted on the nose of a rocket-propelled research model.

DISCUSSION

Some of the early flight tests of this angle-of-attack indicator mounted in the high-speed flow over the wing of a P-51 airplane and on rocket-propelled models gave evidence of a flutter or buzzing phenomenon occurring in some cases near a Mach number of 1.0 and in one case near a Mach number of 2.0. An investigation of this buzzing phenomenon conducted in the Langley 8-foot high-speed tunnel indicated that the buzzing was due to a mechanical failure of the ball or pivot-type bearings. Since these tests, all indicators have been equipped with plain sleeve-type bearings and no further trouble has been encountered with flutter.

After the investigation of the buzzing phenomenon, one of tbe indicators was tested at zero angle of yaw through an angle-of-attack range of -4° to 12° at Mach numbers of 0.85, 0.95, and 1.20. The results are given in figure 3 as a plot of the angle of attack of the sting against the angle measured by the indicator. The agreement between the two angles of attack is best at a Mach number of 1.2. In any case, however, with due consideration given to the accuracy of the measurements, the data indicate that the instrument has a calibration factor of 1.0.

Measurements obtained with this angle-of-attack indicator, first on special rocket-propelled test vehicles and then on actual research models, indicate that, with a symmetrical and carefully balanced instrument, reliable data can be obtained. Great care must be taken in the construction, surface finishing, alinement, and positioning of the indicator if it is to read absolute angles of attack correctly. In any case, the indicated variations of angle of attack are believed to be very good.

Figure 4 presents a reproduction of a section of a telemetered record of some angle-of-attack data obtained on the rocket-propelled research model shown in figure 2. The trace of angle of attack follows the normal acceleration with no apparent time lag.

CORRECTIONS

Small corrections for flight-path curvature and rate of pitch about the center of gravity must be made to the indicated angles of attack to convert them to angles of attack at the center of gravity of the model. The angle of attack at the center of gravity can be shown to be given to a good approximation by the following formula:

$$\alpha_{c.g.} = \alpha_i + \frac{X}{V}\left[\frac{360g}{2\pi}\left(\frac{\frac{a_n}{g} - \cos\theta\cos\phi}{V}\right) + \frac{d\alpha_i}{dt}\right]$$

where

$\alpha_{c.g.}$ angle of attack at center of gravity of model, degrees

α_i angle of attack measured by indicator, degrees

X distance between aerodynamic center of vane and center of gravity of model (positive when the vane is ahead of the center of gravity), feet

V model velocity, feet per second

a_n normal acceleration, feet per second per second

g acceleration of gravity, feet per second per second

θ angle which longitudinal axis of model makes with the horizontal

ϕ angle of roll of model

$\frac{d\alpha_i}{dt}$ indicated rate of pitch about center of gravity, degrees per second

If the angles θ and ϕ are unknown, and, in addition, the normal acceleration is high, it can be assumed that $\cos\theta\cos\phi = 0$ and the angle of attack at the center of gravity is approximately

$$\alpha_{c.g.} = \alpha_i + \frac{X}{V}\left[\frac{360g}{2\pi}\frac{\frac{a_n}{g}}{V} + \frac{d\alpha_i}{dt}\right]$$

In the usual installation with the vane mounted ahead of the wing, a correction should also be made for the effect of upwash at subsonic speeds. This correction will be very small if the vane is mounted several mean wing chords ahead of the wing. For any fixed location ahead of a wing, the upwash is a function of the aspect ratio of the wing and the flight Mach number such that the correction to the indicated angle of attack decreases with decreasing aspect ratio and with increasing Mach number. As the Mach number increases to 1.0, the upwash should decrease to zero, as no disturbances can exist ahead of the wing at or above sonic velocity. Atpresent, no data are available on the variation of upwash angle with angle of attack and Mach number, but theoretical methods are available (reference 1) which apply the Glauert-Prandtl compressibility correction to the induced-flow field around a lifting line. Calculations based on this theory for a wing of aspect ratio 4 at a Mach number of 0.8 indicate that the upwash angle on the center line of the wing at a point 2.5 mean wing chords ahead of the wing is about 2.5 percent of the angle of attack. Until data become available to substantiate the theory, it is recommended that, for subsonic installations of the angle-of-attack indicator, the vane be mounted as far ahead of the wing as is feasible.

CONCLUDING REMARKS

A vane-type angle-of-attack indicator suitable for measurements at both subsonic and supersonic speeds has been developed by the NACA. Measurements made with the indicator mounted on rocket-propelled models indicate that, if the following precautions are observed, the vane will give reliable results:

1. The vane should be mounted as far forward of the wing as is feasible to minimize errors due to upwash at subsonic speeds.

2. Care should be used in the manufacture and installation of the vane so that absolute angles of attack will be correct.

3. Corrections should be applied for flight-path curvature and rate of pitch to the indicated readings.

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

REFERENCE

1. Tsien, Hsue-Shen, and Lees, Lester: The Glauert-Prandtl Approximation for Subsonic Flows of a Compressible Fluid. Jour. Aero. Sci., vol. 12, no. 2, April 1945, pp 173-187, 202.

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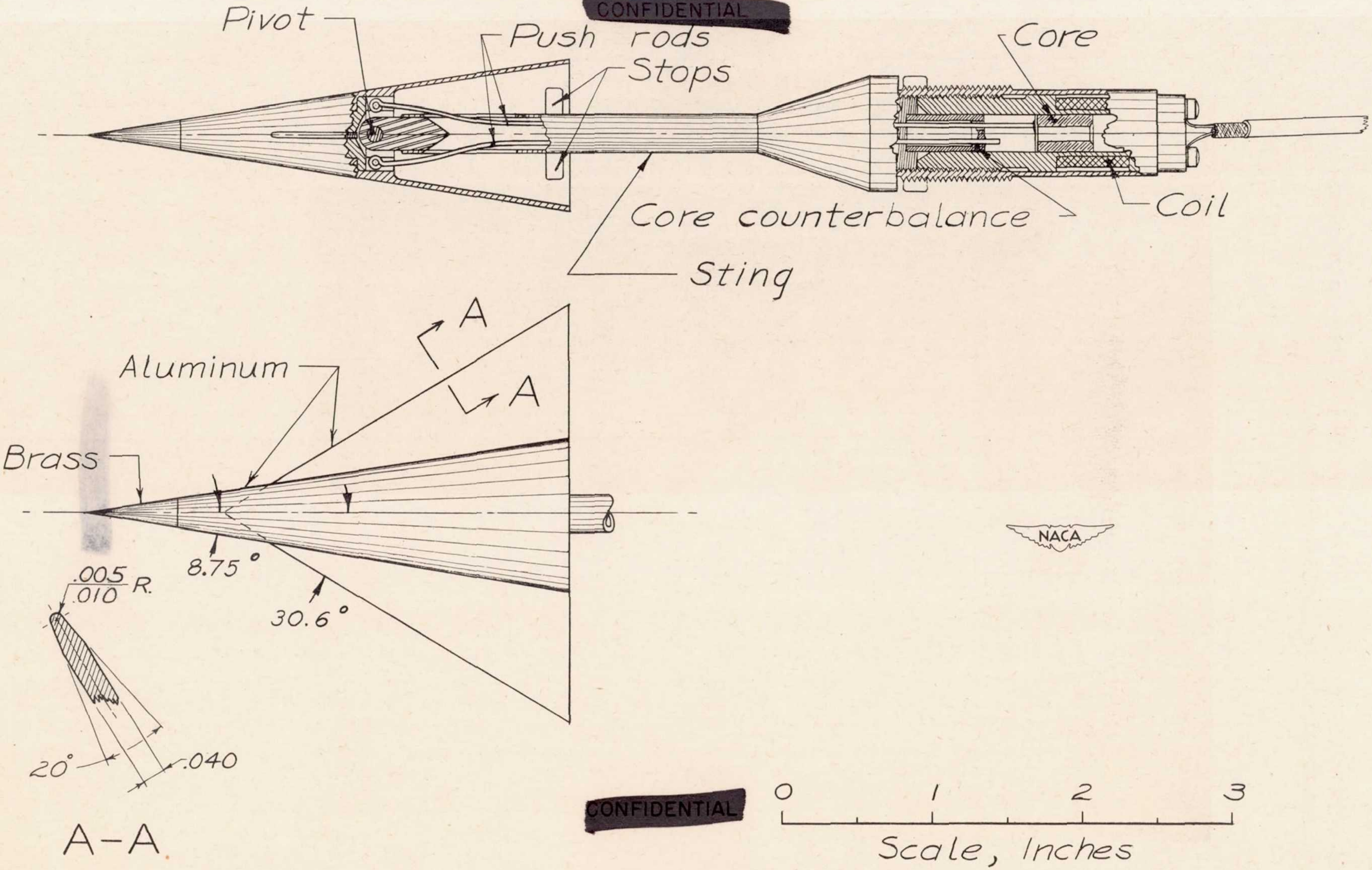

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Figure 1.- NACA vane-type angle-of-attack indicator.

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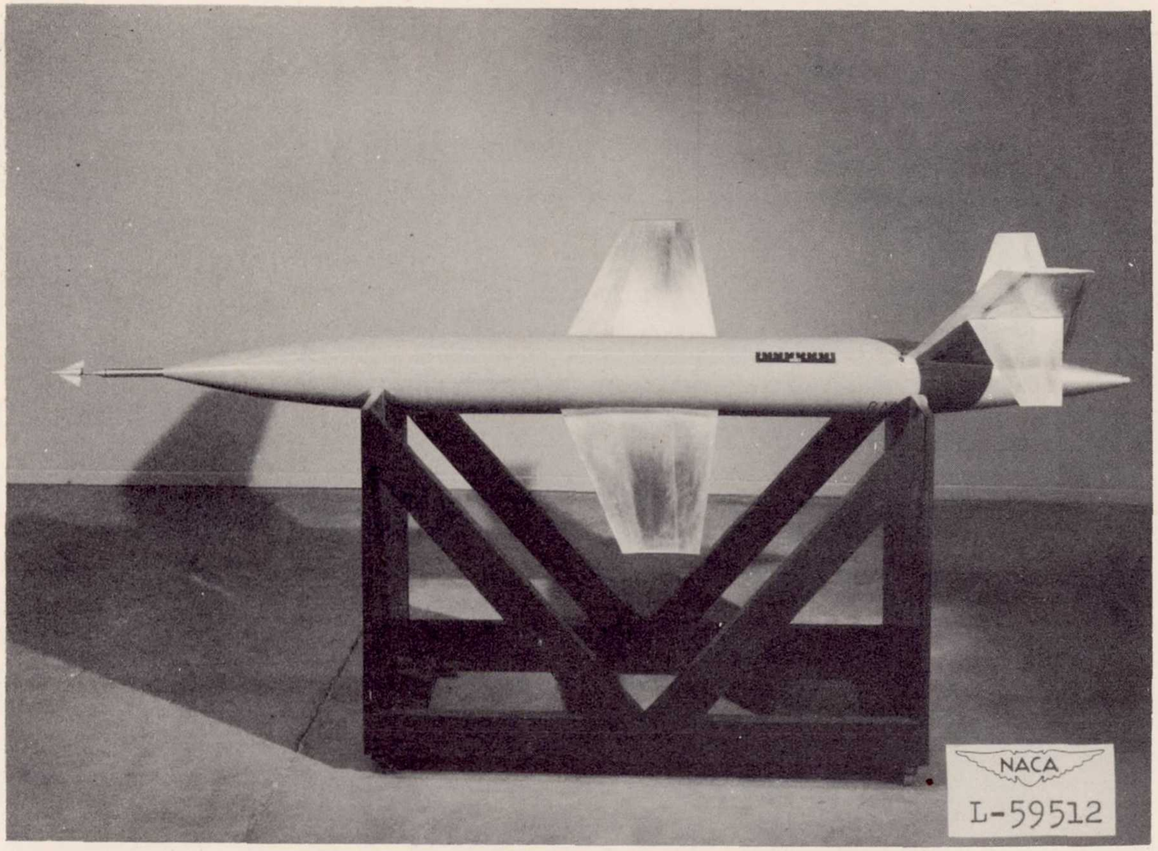

Figure 2.– Typical installation of an angle-of-attack indicator on a rocket-propelled model.

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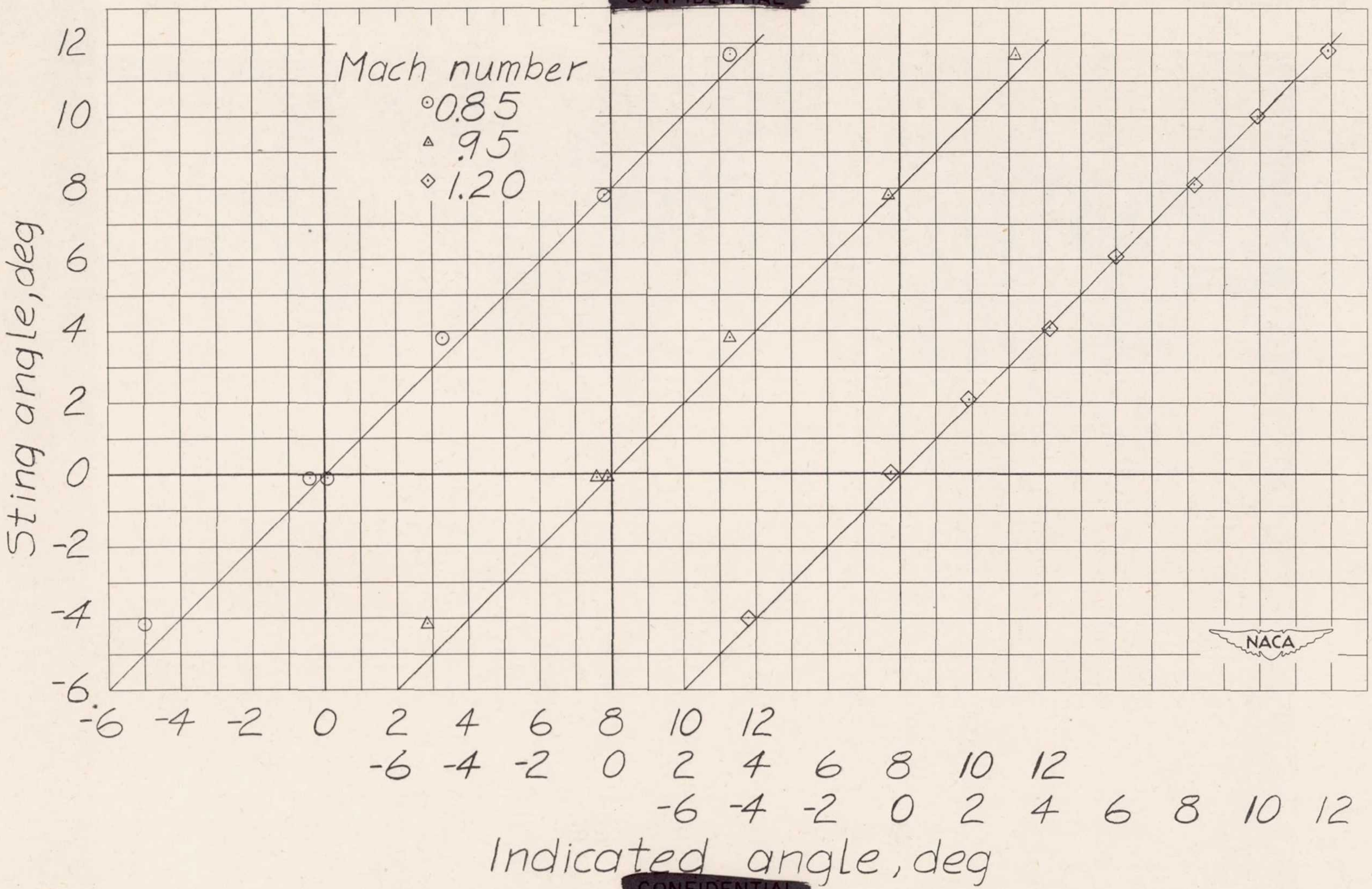

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Figure 3.— Calibration of NACA vane-type angle-of-attack indicator in Langley 8-foot high-speed tunnel.

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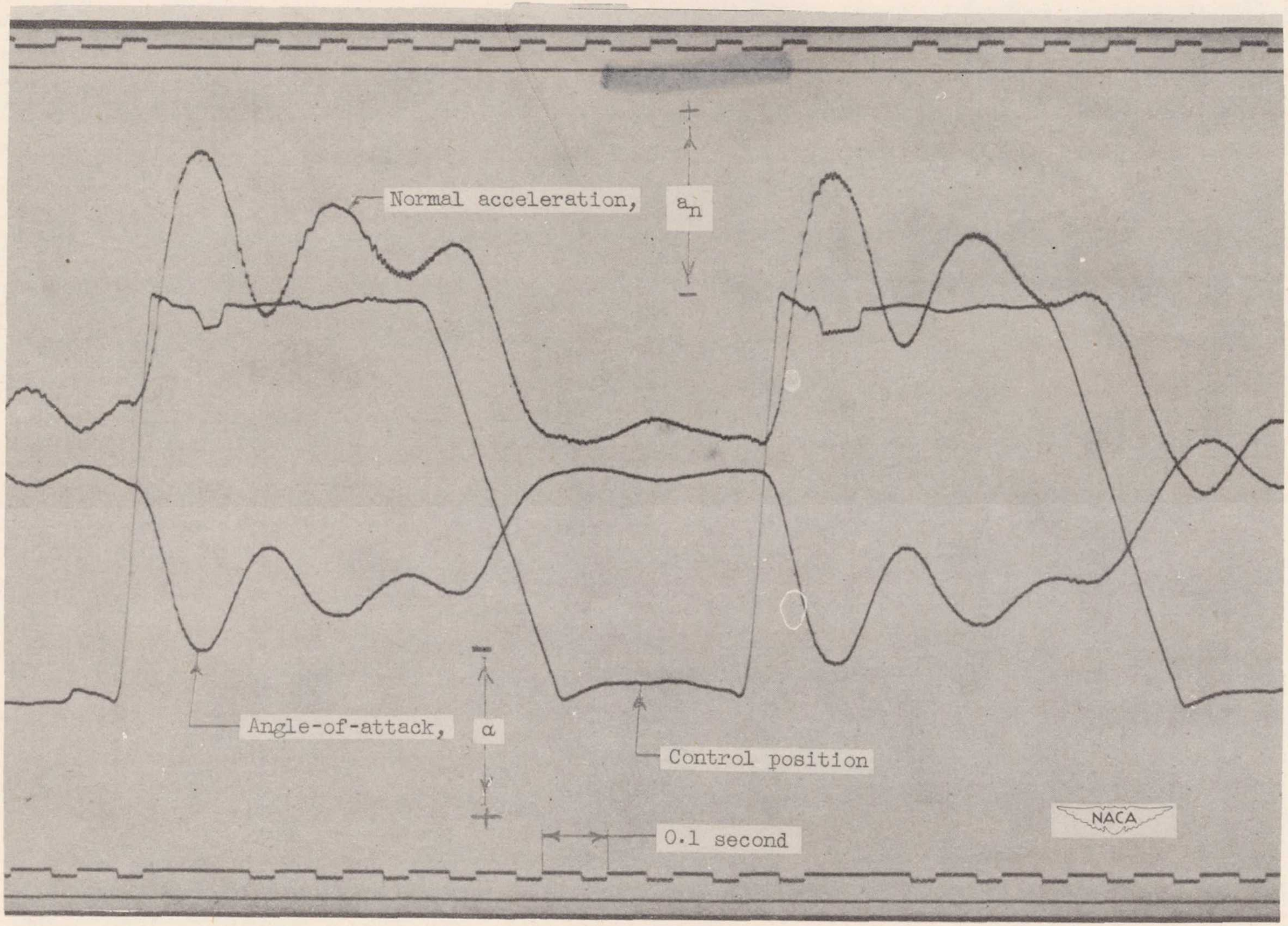

Figure 4.- Typical telemetered trace of angle of attack obtained with NACA vane-type angle-of-attack indicator.

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