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TECHNICAL NOTE 2761

INSTRUMENT-FLIGHT RESULTS OBTAINED WITH A COMBINED-SIGNAL FLIGHT INDICATOR MODIFIED FOR HELICOPTER USE

By Almer D. Crim, John P. Reeder, and
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Langley Aeronautical Laboratory
Langley Field, Va.

Washington
August 1952

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INSTRUMENT-FLIGHT RESULTS OBTAINED WITH A COMBINED-SIGNAL FLIGHT INDICATOR MODIFIED FOR HELICOPTER USE

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SUMMARY

A commercially available flight indicator which combines heading, bank-angle, fuselage-pitch-attitude, and, if desired, altitude and radio-aid information was flight-tested in order to determine its suitability for helicopter instrument flying. The indicator was installed in the instrument panel of a single-rotor helicopter specially equipped for blind flying and was evaluated by performing prescribed maneuvers with conventional instruments and with the combined-signal flight indicator.

The instrument was then modified by adding a fuselage-rate-of-pitch signal and by decreasing the bank signal required for canceling a heading-deviation signal.

The use of the unmodified indicator for helicopter blind flying was found to result in less fatigue to the pilot and to require less concentration than the use of conventional instruments; also, the ability to maintain a given heading was greatly improved. The addition of the rate-of-pitch signal and increased bank sensitivity resulted in more precise control of heading, altitude, and airspeed, as well as a reduction in amplitude and frequency of control motion.

INTRODUCTION

The National Advisory Committee for Aeronautics is engaged in a study of problems associated with helicopter instrument flying in order to determine the flying qualities and flight aids that are necessary for all-weather operation. Preliminary results of this program were reported in reference 1, wherein the conclusion was reached that both the flying qualities of the helicopter and pilot's instruments would require improvement before satisfactory helicopter instrument flight would be possible throughout the

speed range. In view of these results, an investigation of the instrument problems appeared desirable before the determination of satisfactory stability and control characteristics for instrument flight is attempted.

One approach to the problem of providing more suitable instruments is to combine on a single indicator information that is usually obtained from several different instruments and to present this information in a manner easily interpreted by the pilot. A commercially available instrument employing such a presentation was obtained and modified along lines suggested by the problems reported in reference 1. Some results of flight tests obtained with this instrument, which for convenience is referred to as a combined-signal flight indicator, are given in the present paper.

DESCRIPTION OF FLIGHT INDICATOR

Basic Instrument

The combined-signal flight indicator is a gyroscopic flight and navigation instrument which combines heading, bank-angle, fuselage-pitch-attitude, and, if desired, altitude and radio-aid information and presents it to the pilot on a two-element indicator. As may be seen in figure 1, the face of the indicator consists of a horizontal bar and a vertical bar which move at right angles to each other and a fixed background reference marked with suitable scales. The vertical bar is actuated by heading signals from a gyroscopic compass, bank signals from a vertical gyro, and, at the discretion of the pilot, radio track signals. The horizontal bar is actuated by fuselage-pitch-attitude signals and, if desired, by a constant-altitude or radio glide-path signal. Figure 2 illustrates the sensing of the indicator bars for various conditions.

Flight by means of the indicator is accomplished, once the desired flight path has been selected, by keeping the two crossbars centered, or zeroed, over the reference marker of the instrument. Displacement of the vertical bar due to bank angle, heading, or radio-track deviations may be canceled by banking the aircraft in the proper direction. Similarly, the indications of deviation in pitch attitude, altitude, or radio glide path, as shown on the horizontal bar, may be canceled by nosing the aircraft up or down. In any case, as long as the indicator remains zeroed the aircraft is either on or is approaching the desired flight path.

As an example of the principle of the combined-signal flight indicator, a deviation from an established heading will cause a displacement

of the vertical pointer, but by banking the aircraft in the proper direction, the pilot can return the bar to center immediately. Because the bank angle required to cancel the heading signal is proportional to the heading deviation, the pilot must gradually reduce the amount of bank, as he approaches the desired course, in order to keep the indicator bar zeroed. The heading correction is thus made smoothly and without overshoot. In order to maintain altitude or follow a radio glide path a similar technique is employed, that of nosing the aircraft up or down in response to indications of the horizontal pointer.

In order to avoid the possibility of overcontrolling, the constant-altitude and glide-path signals to the indicator are limited so that in no case will more than 6° of pitch-attitude change be required to cancel the deviation signal, whereas the sum of the heading and radio track signals are limited to a value that will never require more than 20° of bank to cancel the deviation signal.

Modifications

Inasmuch as the flight indicator just described was designed for use in airplanes, certain modifications to the instrument were made in order to evaluate its usefulness for helicopters. These modifications consisted of adding a fuselage-rate-of-pitch signal to the horizontal bar and reducing the bank angle required to cancel a given heading-deviation signal.

As a means for enabling the pilot to anticipate changes in attitude of the helicopter, indication of rate of change of attitude about all three axes of the machine would seem desirable. However, the difficulty of maintaining low airspeeds and the large and frequent longitudinal control motions sometimes necessary suggested the possibility of significant improvement by simply adding a fuselage-rate-of-pitch signal to the combined-signal flight indicator. Accordingly, an electrical signal proportional to the rate of fuselage pitch was added to the horizontal bar of the indicator, the instrument thus providing the pilot with information about both attitude and rate of change of attitude. Means were provided whereby the pilot could vary this fuselage-rate-of-pitch signal from zero to its maximum value, the maximum value giving full-scale deflection of the bar for a rate of pitch of 17 degrees per second.

As noted in reference 1, the helicopter, because of its relatively low speed, experiences very high rates of turn at bank angles considered normal for airplanes. The flight indicator was therefore further modified by increasing the sensitivity of the instrument in roll and thus reducing the bank angle required to cancel a given heading-deviation signal. Since the bank angle necessary for a given rate of turn is a function

of forward speed, means were provided whereby the pilot could select different values of instrument sensitivity. These values ranged from the normal setting for an airplane, which required a bank angle of 20° to cancel a maximum heading-deviation signal, to one which required only 5° of bank to accomplish the same purpose.

TEST METHODS

The combined-signal flight indicator was installed in the rear instrument panel of a single-rotor helicopter (fig. 3) equipped with dual controls and a hood, or curtain, which permitted the rear pilot to fly without outside visual reference. The instrument was evaluated by comparing results of a series of prescribed maneuvers flown with conventional instruments, with the unmodified flight indicator, and with the indicator after modification. The conventional instruments used for this evaluation consisted of an artificial horizon, directional gyro, altimeter, and airspeed, turn-and-bank, and rate-of-climb indicators (fig. 4).

Since the combined-signal flight indicator shows only deviation from a desired flight path or changes from trim attitude, other instruments are still necessary for cross-checking and for establishing desired flight conditions. However, when flight records were desired by using only conventional instruments, the combined-signal flight indicator was covered. In most of the cases, records of a given maneuver made with the various instrument combinations were obtained during the same flight.

Two pilots, both experienced in visual and instrument helicopter flying, performed the flight tests. The evaluation was based on the opinions of the pilots and records, obtained with standard NACA recording instruments, of heading, airspeed, altitude, control position, pitching velocity, and rolling velocity.

The radio-aid channels of the flight indicator were not used in the present investigation, since the necessary receivers were not available in the test helicopter.

RESULTS AND DISCUSSION

Unmodified Flight Indicator

A comparison of flight records of maneuvers performed with conventional instruments and with the unmodified flight indicator reveals that

the most outstanding difference is in heading deviation. As noted in reference 1, precise control of helicopter heading is difficult under instrument conditions, particularly at low speeds. Figures 5(a) and 5(b) show records of heading, altitude, and airspeed made during a maneuver involving straight and level flight while changing airspeed from 65 to 25 knots. The record made with conventional instruments shows large, inadvertent heading variations, at one point exceeding 20°. In comparison, headings are held within very close limits when the same maneuver is flown with the combined-signal flight indicator. Examination of the records showed no significant change in frequency or amplitude of control motion between the two maneuvers and little difference in altitude and airspeed. The opinion of the pilots was, however, that the flight indicator made instrument flying less fatiguing and required less concentration than with conventional instruments alone.

As previously mentioned, a constant-altitude signal is available, at the discretion of the pilot, in the flight indicator. Any deviation from an established altitude causes a displacement of the horizontal bar, which may be returned to zero by a pitch signal produced by nosing the aircraft up or down. If changes in airspeed are not objectionable, this procedure normally provides an easy method for correcting small altitude deviations. However, at speeds below that for minimum power (about 45 knots for the test helicopter), a decrease in airspeed requires more power to maintain level flight, and any attempt to correct an altitude loss simply by raising the nose of the helicopter results in decreased speed and further loss of altitude. The pilots concluded that the constant-altitude signal, in its present form, was useful only above 45 knots and could lead to control difficulties at lower speeds. For this reason, the constant-altitude signal was not used when comparing the combined-signal flight indicator with standard instruments; however, the horizontal bar of the indicator still provided fuselage-pitch information.

Modified Flight Indicator

The addition of a fuselage-rate-of-pitch signal to the combined-signal flight indicator enabled the pilot to maintain more precise control of the helicopter under instrument conditions. Figures 5(b) and 5(c) show the flight records of heading, altitude, and airspeed made with the unmodified flight indicator and with the same instrument after a rate-of-pitch signal was added. Although the previous comparison of conventional instruments and the unmodified flight indicator (figs. 5(a) and 5(b)) showed little difference in airspeed and altitude variations, such variations are noticeably reduced after addition of the rate-of-pitch signal. Also of interest is the improvement in heading control when the rate-of-pitch signal is used. This improvement apparently results from the fact that, when less difficulty is experienced

with longitudinal control, more time is available for the pilot to devote to directional control.

The rate-of-pitch signal could be varied in flight from the maximum available, which produced full-scale deflection of the horizontal bar for a rate of pitch of 17 degrees per second, to zero. The magnitude of the rate-of-pitch signal did not appear to be critical and a value which produced half-scale deflection for a pitching rate of 17 degrees per second was found to be satisfactory (this was the value used in obtaining the records shown in fig. 5(c)). Full-scale deflection of the horizontal bar of the indicator may also be obtained by a 15° pitch-attitude change.

The second modification to the flight indicator, that of increasing the bank sensitivity and thus reducing the bank angle required to cancel a given heading deviation, resulted in improvement in the ease and accuracy of turning to and establishing a desired heading. Figure 6 shows typical time histories at 25 knots of turns to selected headings using the combined-signal flight indicator. Figure 6(a) illustrates the high rate of turn (about 14 degrees per second) involved and the consequent overshooting of the desired heading for an instrument sensitivity which required 20° of bank to cancel a maximum heading-deviation signal. In contrast, figure 6(b) shows the better control resulting from a lower rate of turn when the required bank angle was reduced to 6°. Although the instrument was noticeably sensitive to small disturbances at the latter setting, flight records indicate that the frequency and magnitude of control motion was reduced, particularly at low speeds, by using the smaller bank angles.

Inasmuch as the most satisfactory value of instrument sensitivity in bank is a function of forward speed, some compromise is necessary if a fixed value is used. In the present tests an instrument setting of 10° bank to cancel a maximum heading-deviation signal was found to be satisfactory over the speed range from 25 to 75 knots.

CONCLUSIONS

A flight indicator which combines heading, altitude, bank-angle, and pitch information was evaluated by means of instrument flight in a single-rotor helicopter, and the following conclusions were reached:

1. The use of the unmodified combined-signal flight indicator for helicopter blind flying resulted in less fatigue to the pilot and required less concentration than with the use of conventional instruments alone. In particular, the ability to establish and maintain a given heading was greatly improved.

2. The addition of a fuselage-rate-of-pitch signal to the original instrument resulted in more precise control of airspeed, altitude, and heading.

3. The bank angle required to cancel a given heading-deviation signal of the instrument should be smaller for the helicopter than the airplane. Bank angles considered satisfactory for airplanes resulted in excessive rates of turn for the test helicopter.

4. A constant-altitude signal, as used in the test instrument, is undesirable for the helicopter at low speeds, although helpful at high speeds. At speeds below that for minimum power, maintenance of constant altitude by means of simple attitude changes is not feasible.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 23, 1952.

REFERENCE

1. Crim, Almer D., Reeder, John P., and Whitten, James B.: Initial Results of Instrument-Flying Trials Conducted in a Single-Rotor Helicopter. NACA TN 2721, 1952.

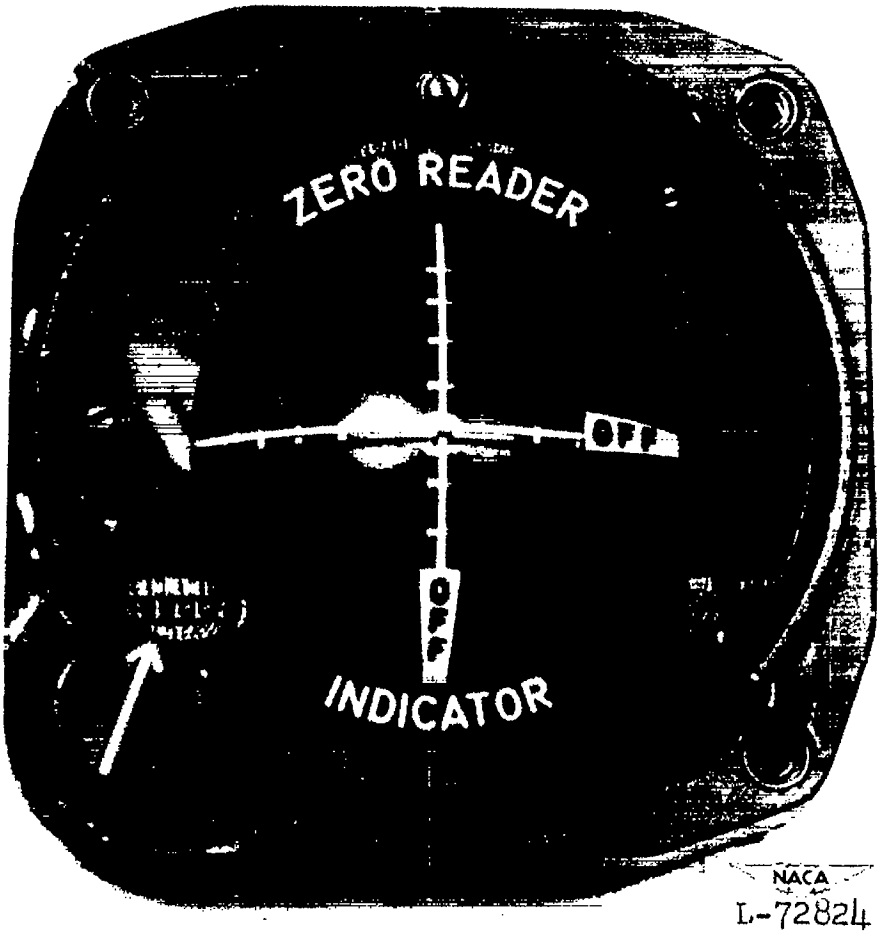


Figure 1.- Combined-signal flight indicator.

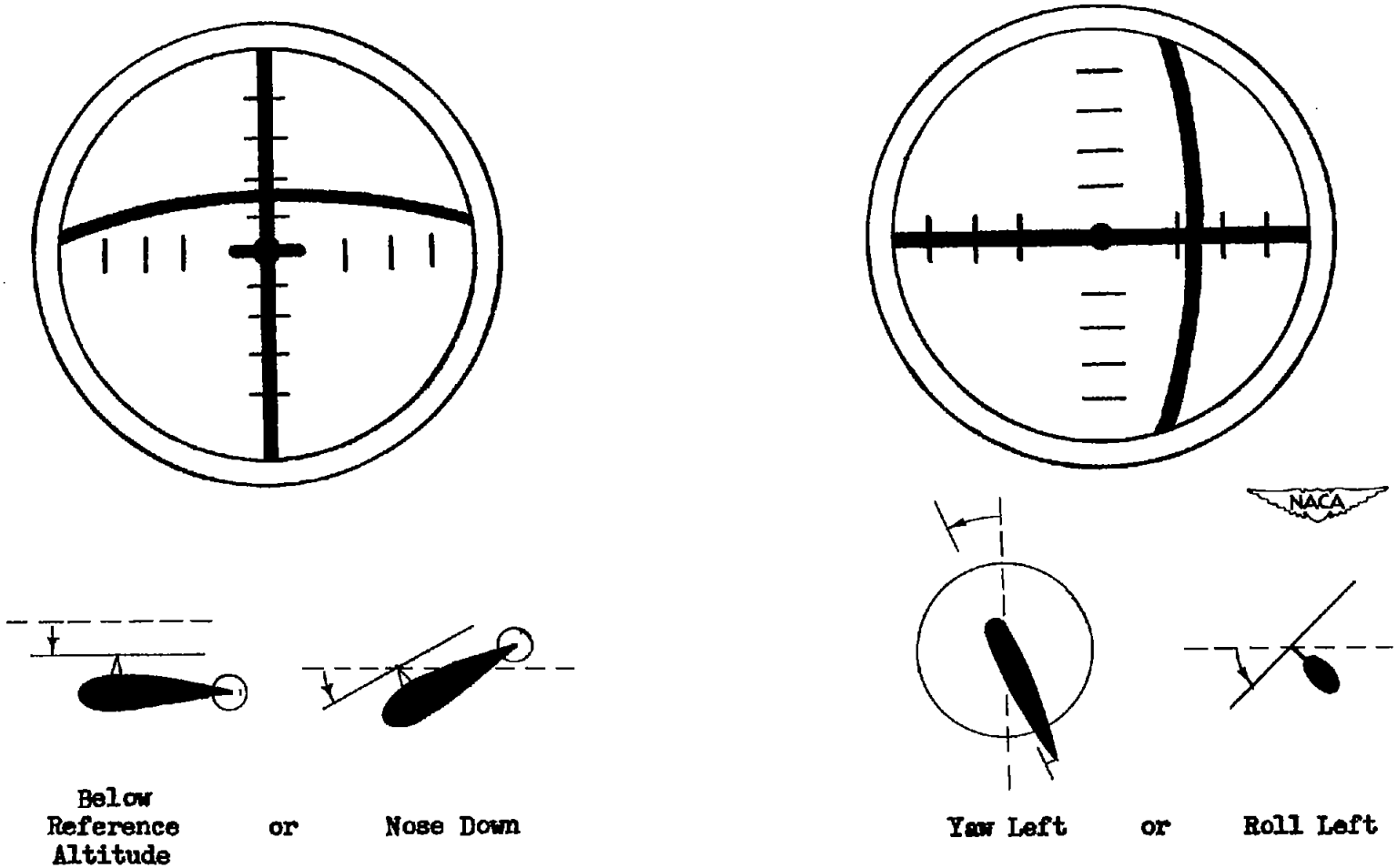


Figure 2.- Sensing of flight indicator for various conditions.

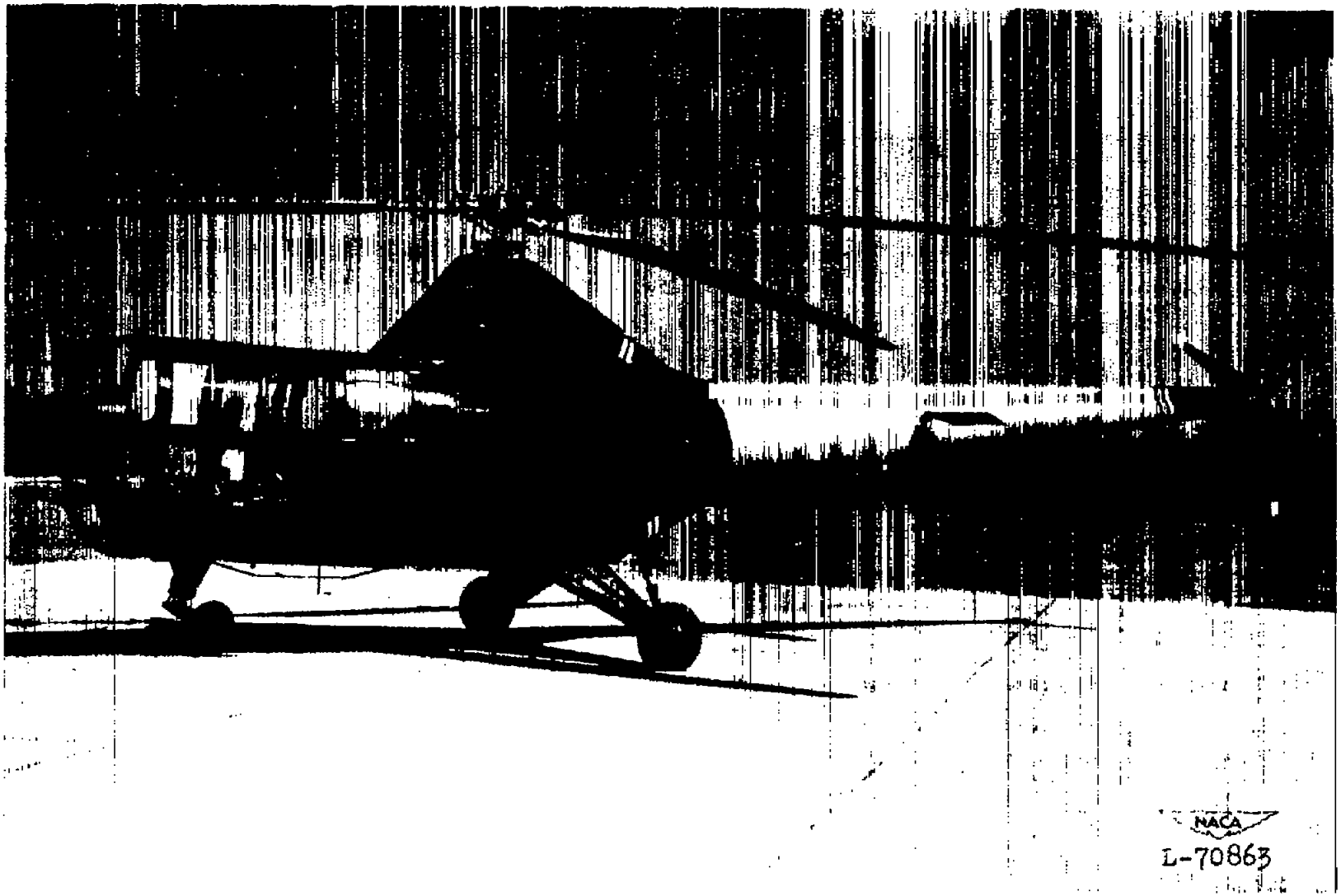


Figure 3.- General view of test helicopter.

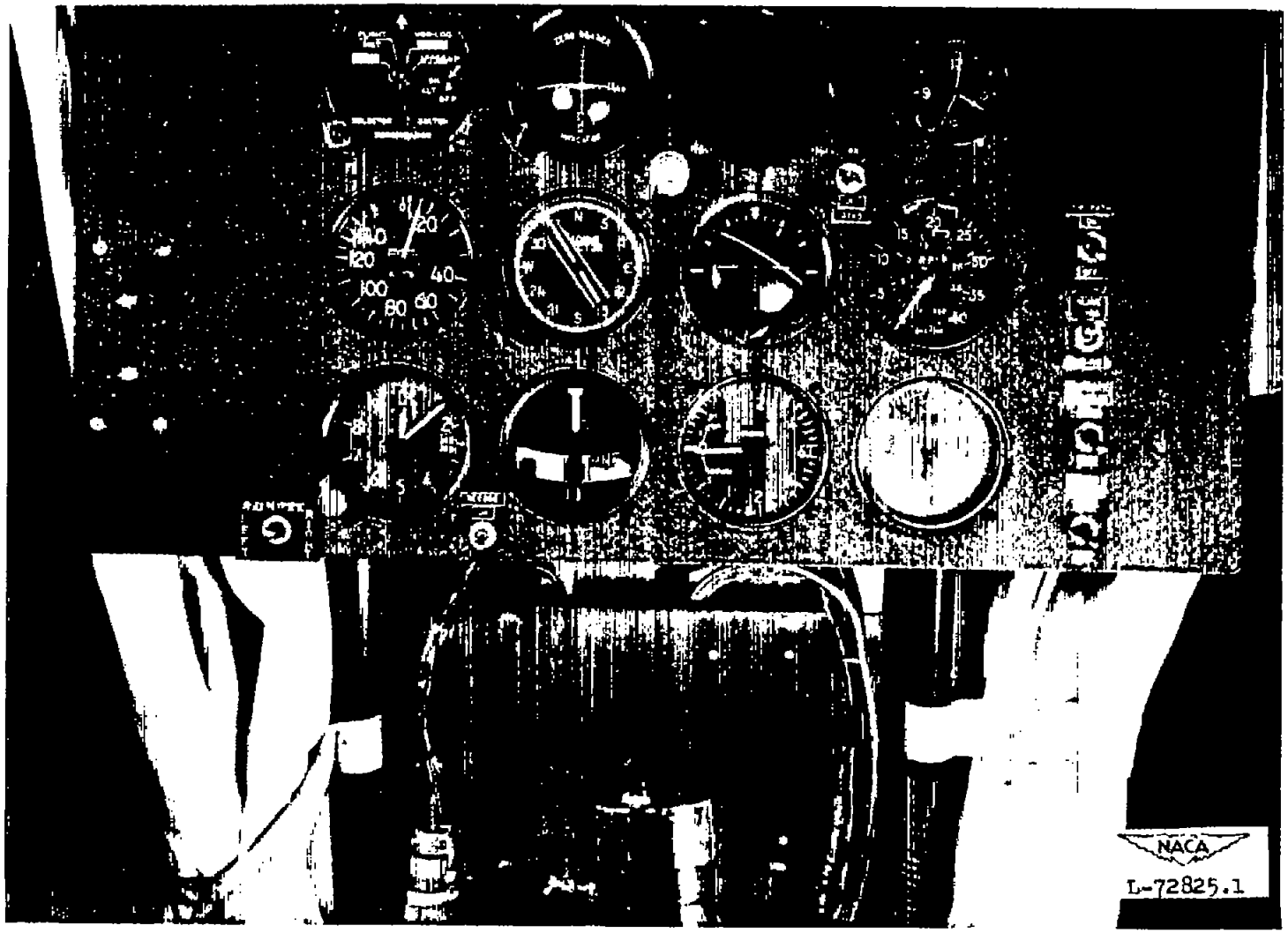
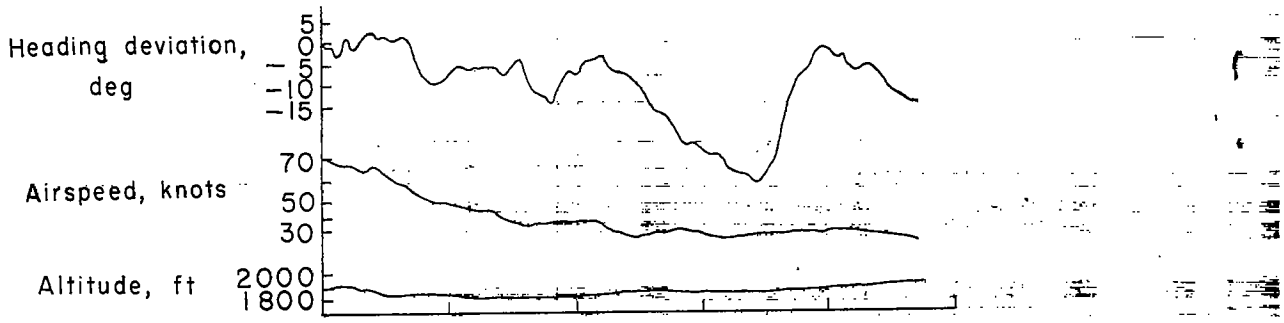
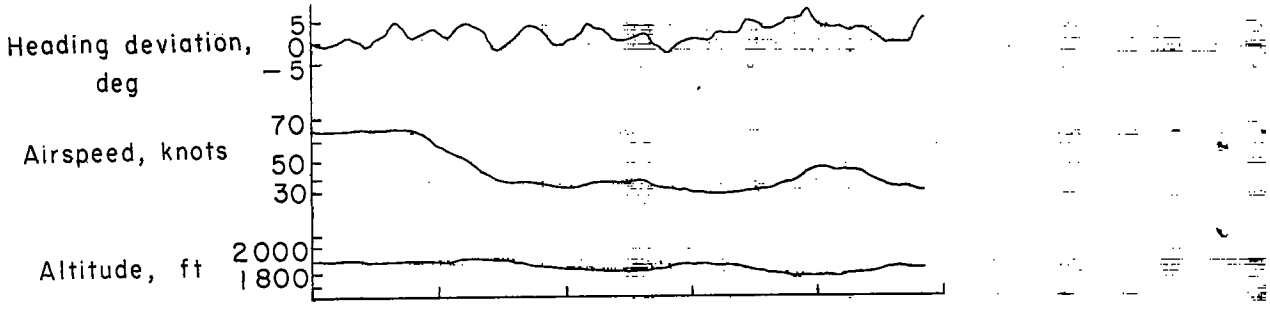


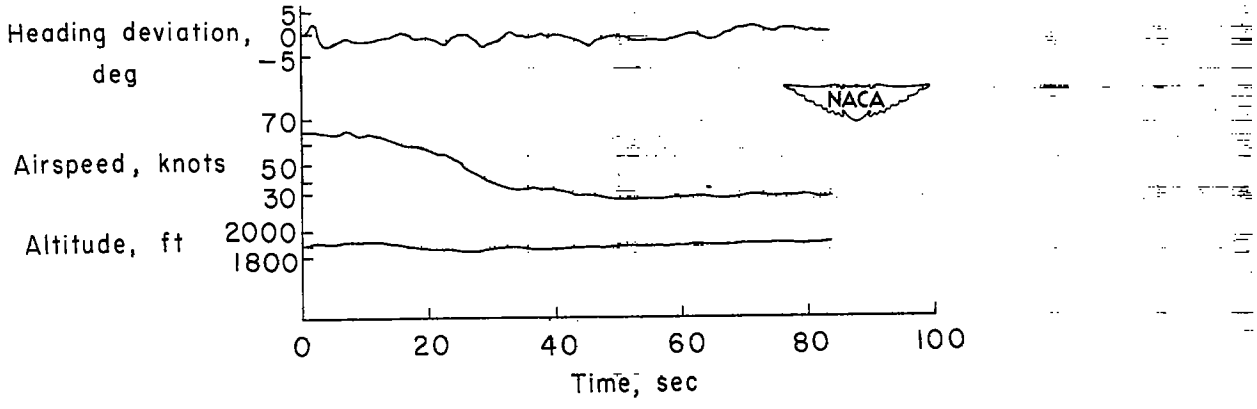
Figure 4.- Instrument panel used in evaluating combined-signal flight indicator.



(a) Standard instruments.

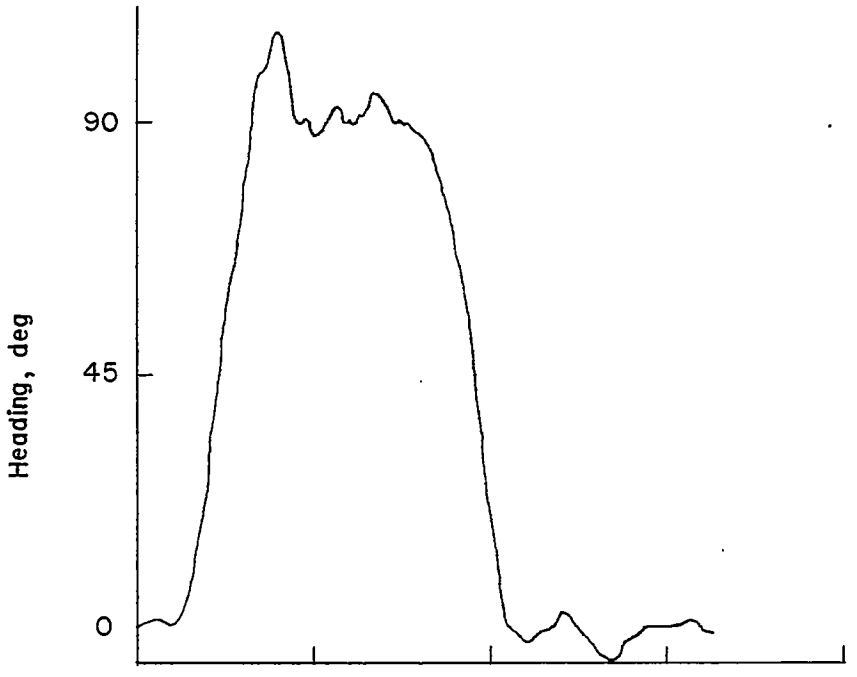


(b) Unmodified flight indicator.

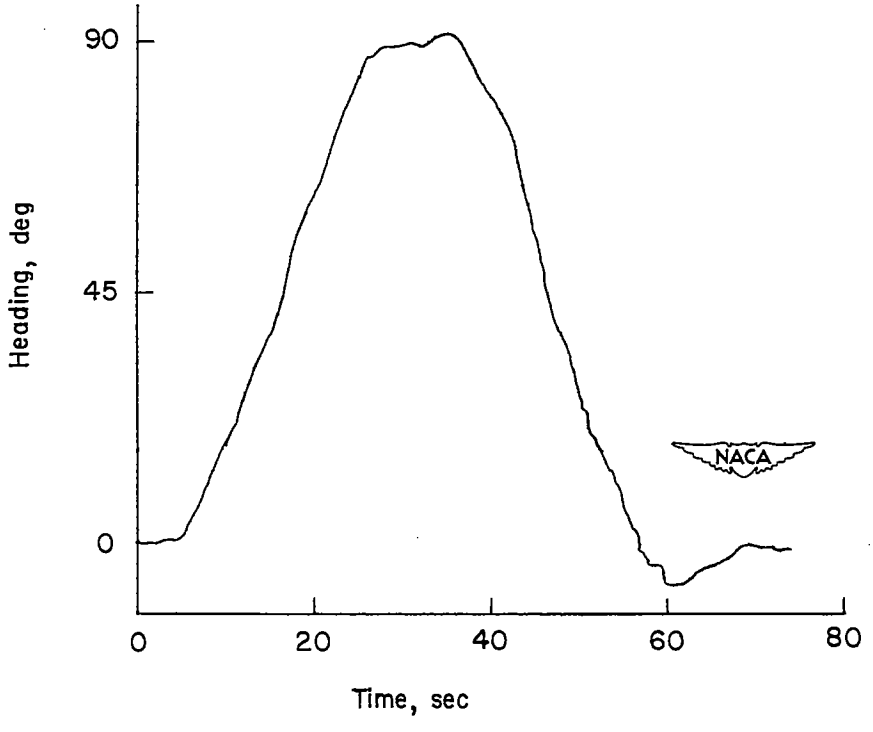


(c) Flight indicator with pitch rate.

Figure 5.- Comparison of maneuver (straight and level flight with change in airspeed from 65 to 25 knots) flown with standard instruments and combined-signal flight indicator.



(a) 20° bank cancels maximum heading-deviation signal.



(b) 6° bank cancels maximum heading-deviation signal.

Figure 6.- Heading records obtained during 90° turns. Airspeed approximately 25 knots.

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