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MEMORANDUM

FLIGHT INVESTIGATION OF AN AUTOMATIC THROTTLE

CONTROL IN LANDING APPROACHES

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FLIGHT INVESTIGATION OF AN AUTOMATIC THROTTLE CONTROL IN LANDING APPROACHES

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SUMMARY

A flight investigation of an automatic throttle control in landing approaches has been made. It was found that airspeed could be maintained satisfactorily by the automatic throttle control. Turbulent air caused undesirably large variations of engine power which were uncomfortable and disconcerting; nevertheless, the pilot felt that he could make approaches 5 knots slower with equal assurance when the automatic control was in operation.

INTRODUCTION

Several previous flight investigations of landing approaches have been made in an effort to determine the factors influencing the pilot's choice of minimum approach speed. A number of factors affect this choice. The determining factors are not always the same. Inability to control altitude was, however, most often found to be the reason given by pilots for the choice of minimum approach speed. There are several aerodynamic characteristics of an airplane that influence this ability to control height, but one of the most important is the variation of drag with airspeed at a constant flight-path angle. In landing approaches, when the pilot is holding the airplane to a fixed glide slope, the airplane is unstable in speed if the approach is being made at a speed less than the minimum-drag speed. For example, if a disturbance causes a small decrease in speed, the drag will increase and the speed will continue to decrease until the pilot advances the throttle. At speeds higher than the minimum-drag speed, the drag slope is stable and the airplane, if disturbed in speed, will tend to return to the selected speed without corrective throttle application. Approaches for landing on short runways and aircraft carriers are usually made at the minimum speed compatible with good handling qualities of the airplane.

In an attempt to aid the pilot in these critical landing conditions, an automatic throttle control was designed and installed in a Navy swept-wing jet fighter in the belief that reducing the workload on the pilot might enable him to fly the airplane at a lower approach speed.

DESCRIPTION OF AUTOMATIC THROTTLE CONTROL

A block diagram of the throttle control is shown in figure 1. The throttle control provides automatic stabilization of speed for approaches on the back side of the drag curve. The control consists of an inner-loop servomechanism which positions the throttle and an outer loop which includes the engine, the airplane characteristics, and the airspeed pickup. Adjustment of the manual-throttle position, therefore, is, in effect, a speed-selection setting by virtue of the outer-loop feedback. A certain selected position of the manual throttle results in a particular electrical input signal. This signal is summed with the airspeed signal at the first summing point and will be canceled by only one particular value of airspeed. An error in airspeed from the selected value will result in a signal at the second summing point which will then command a new throttle position. This new throttle position will change the thrust and therefore the airspeed until the airplane is flying at the selected speed.

The airspeed-gain setting for the tests presented provides a stabilization of about 0.05g per knot of airspeed deviation. For the test airplane, the stabilization was about 740 pounds of thrust change per knot of airspeed error. A throttle limiter (see fig. 1) reduces the rate of throttle movement for rapid thrust changes greater than about 1,200 pounds of thrust on either side of the drag curve.

FLIGHT-TEST METHOD

Flight tests with the automatic throttle control were conducted using the Navy mirror landing system to provide a constant-angle glide slope. Figure 2 will aid in explaining the mirror landing system. In operation, the pilot looks at the light which appears in the mirror from the source lights. If the airplane is above the 4° glide slope, the image will appear above the reference lights. If the airplane is below the 4° glide slope, the image will appear below the reference lights.

RESULTS AND DISCUSSION

The variation of drag with airspeed for the airplane has been determined in a flight investigation at the Langley Research Center. This plot is presented in figure 3 to show the slope of the drag curve for each landing approach that will be presented. Mirror landing approaches using manual throttle control are marked "A" and "B" and approaches with the automatic throttle control are marked "C" and "D."

A comparison will first be made of the two approaches in which manual throttle control is used. Approach A was made at a speed about normal for the test airplane, whereas approach B was at a speed less than normal. It should be noted that the slope of the drag curve is positive for approach A and negative for approach B. Figures 4 and 5 are time histories of these two approaches. The measurements shown are elevator deflection δ_e, engine thrust F_n, airspeed corrected to a constant weight V_e, and altitude h. The time scale is in seconds before touchdown. Although the pilot was able to maintain speed and flight-path angle almost equally well for both approaches, the greater difficulty of making the lower speed approach is apparent from the larger amount of throttle movement and elevator movement required.

The effectiveness of the automatic throttle control in relieving the pilot of the task of maintaining a selected speed is shown by comparing the time histories of approach B (fig. 5) and approach C (fig. 6). It can be seen in figure 3 that approach C is at a lower airspeed and has a more negative slope than approach B. The comparison shows that the pilot was able to maintain the proper flight path about as well with the manual throttle control (fig. 5) as with the automatic throttle control (fig. 6) and the speed was kept constant within about the same limits. However, the automatic control relieved the pilot of the task of keeping the speed constant and he was able to make the approach at a lower speed. It should be noted that the automatic control made more frequent throttle adjustments than the pilot. Combined effects of other factors such as buffeting, lateral control, longitudinal stability, and attitude angle prevented further reduction of the approach speed. In the pilot's opinion, landing approaches with the automatic throttle control at low speeds were easier and were made with less apprehension than those made with the manual throttle control at the same speed.

The approaches shown so far were in relatively smooth air. Approaches were also made in very turbulent air. One of these approaches is presented and is shown at point D on the drag curve (fig. 3). A comparison of this approach with approach C shows that it was made at a higher speed with less airspeed instability. The time histories of these two approaches (figs. 6 and 7) show a comparison of the operation of the automatic throttle control in smooth air and in very turbulent air. It can be seen that again the flight path was flown about equally well and the speed was held nearly constant for both approaches, but large and frequent throttle adjustments were made by the automatic control in response to the gusts. The pilot found that engine surging was very uncomfortable and disconcerting, but preferred to make approaches, even in rough air, with the automatic throttle control operating. The pilot felt that he could make approaches 5 knots slower with equal assurance when the automatic control was in operation.

CONCLUDING REMARKS

A flight investigation of an automatic throttle control in landing approaches showed that airspeed could be maintained satisfactorily. Turbulent air caused undesirably large variations of engine power which were uncomfortable and disconcerting; nevertheless, the pilot felt that he could make approaches 5 knots slower with equal assurance when the automatic control was in operation.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., November 5, 1958.

AUTOMATIC THROTTLE CONTROL

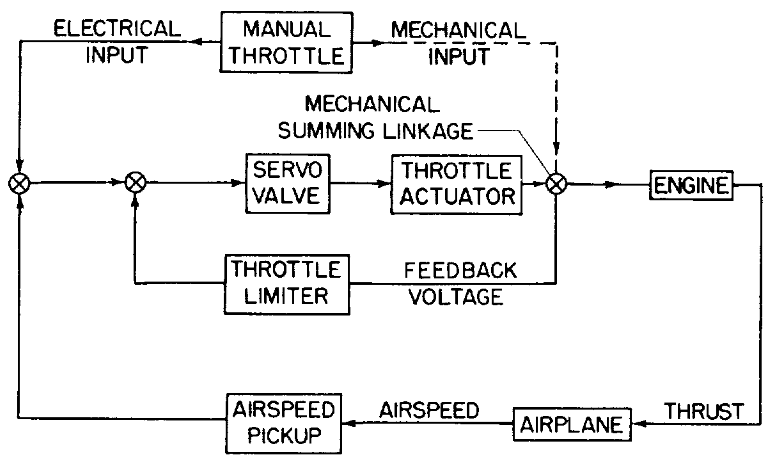

Figure 1

SKETCH OF NAVY MIRROR LANDING SYSTEM

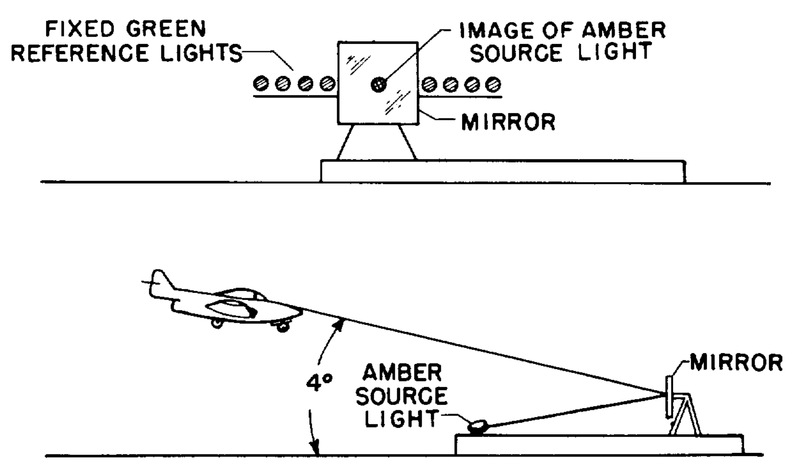

Figure 2

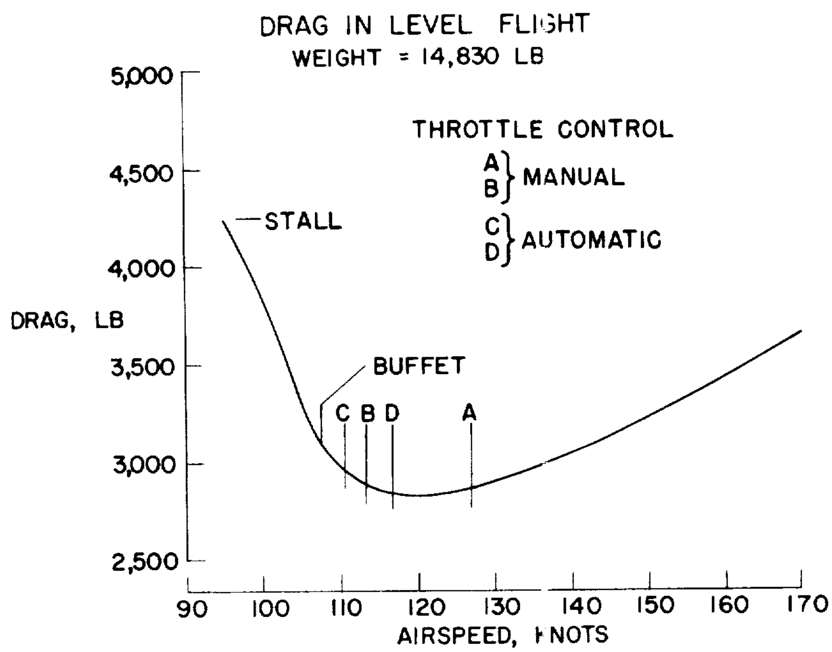

Figure 3

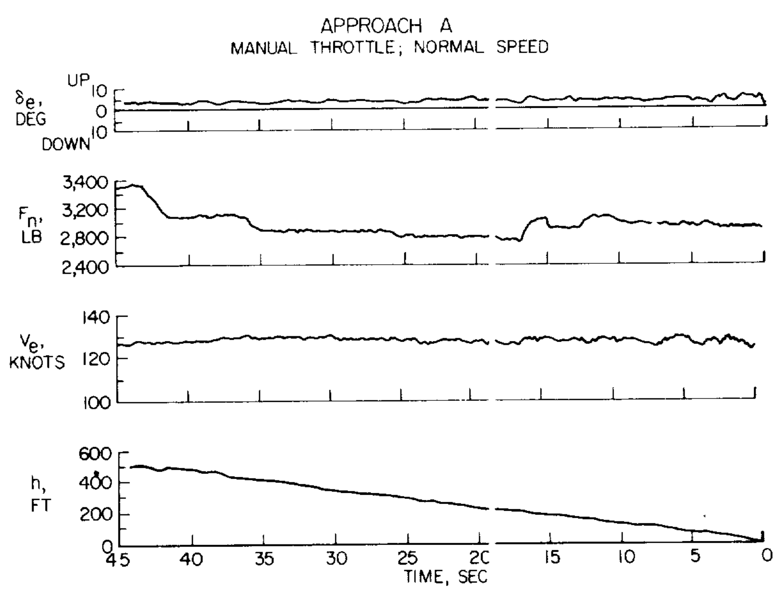

Figure 4

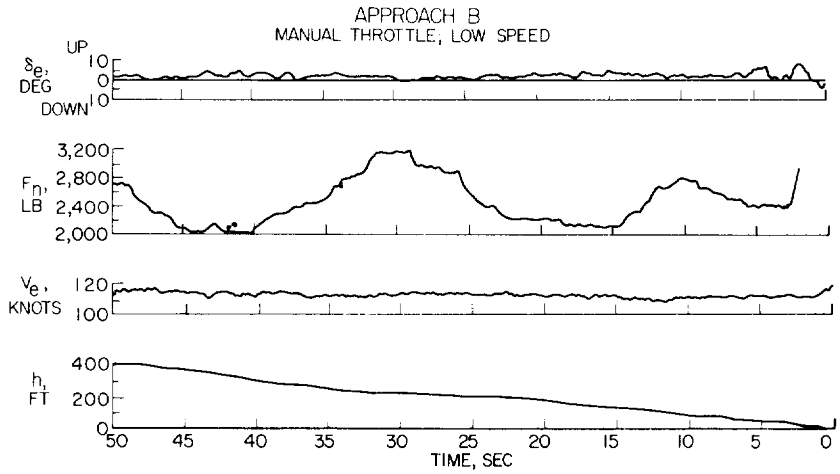

Figure 5

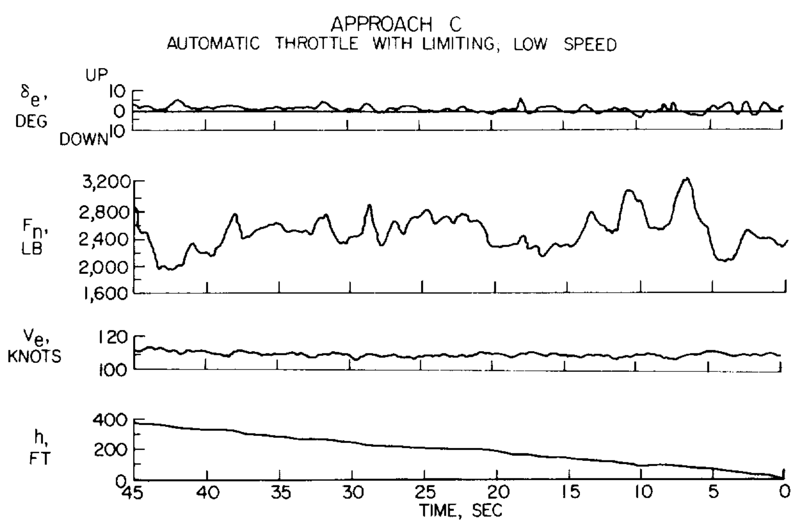

Figure 6

APPROACH D
AUTOMATIC THROTTLE WITHOUT LIMITING; NORMAL SPEED; TURBULENT AIR

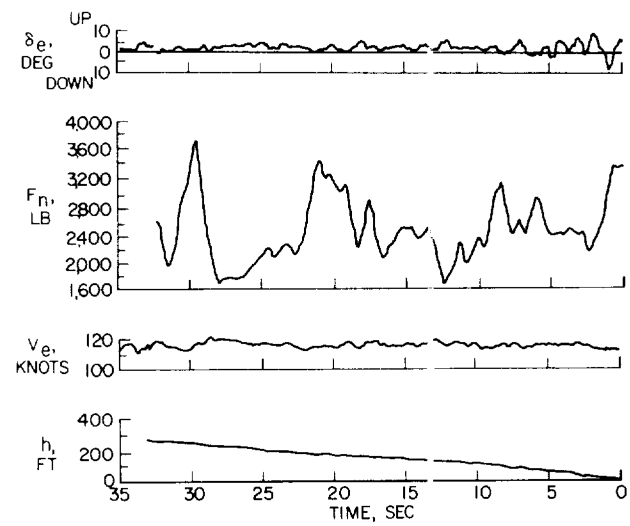

Figure 7

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