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LONGITUDINAL TRIM CHARACTERISTICS OF A DEFLECTED SLIPSTREAM V/STOL AIRCRAFT DURING LEVEL FLIGHT AT TRANSITION FLIGHT SPEEDS

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SUMMARY

Flight tests were conducted on a deflected slipstream V/STOL aircraft to determine the longitudinal trim characteristics in level flight at transition flight speeds between 80 and 24 knots. No abrupt or major changes in trim were noted as a result of flap deflections and airspeed reductions, and no serious trim limitations were encountered. It was found that elevator angles required for trim were relatively small and that transitions to low speeds in level flight could be readily accomplished. No adverse or favorable ground effects were noted for the airspeed range tested for altitudes from a few inches to approximately 50 feet off the ground.

In horizontal transitions, it was observed that decelerations more rapid than the chase helicopter was able to follow were possible without encountering any longitudinal trim limitations.

INTRODUCTION

As part of an integrated study of various V/STOL aircraft in wind tunnels, on flight-motion simulators, and in flight, the NASA at Ames Research Center is currently investigating the aerodynamic characteristics of a deflected-slipstream type aircraft. The test vehicle used in this investigation, the Ryan VZ-3RY, was developed under the auspices of the Office of Naval Research and the U. S. Army Transportation Research and Engineering Command. Since the initial wind-tunnel and simulator studies (ref. 1), the test vehicle has undergone several major changes to improve its flight safety and research utility. Preliminary flight studies (ref. 2) indicated that the vehicle had the capability of flying at zero airspeed, out of ground effect, but was severely limited in ability to cope with power, flap, and airspeed changes. The present investigation was conducted with the thrust axis and center-of-gravity locations selected to minimize these longitudinal trim restrictions.

Since the longitudinal trim characteristics in the transition speed range are felt to be of concern to designers of V/STOL vehicles, it was felt desirable to expedite the publication of flight-derived longitudinal trim data in level flight at this time rather than to wait for a complete investigation of flight characteristics. Hence, this report will be confined to the longitudinal trim characteristics in the transition speed range. This report also includes a comparison of the longitudinal trim requirements, estimated from static trim data, with the longitudinal trim requirements encountered in a typical dynamic flight transition.

AIRCRAFT AND LONGITUDINAL CONTROL SYSTEM

The Ryan VZ-3RY deflected slipstream test vehicle, shown in figure 1 with fully deflected flaps, is a single-place high-wing monoplane powered by a single Lycoming YT-53 "free" turbine engine that drives two counter-rotating propellers through connecting drive shafts. Since the aircraft was designed to fly at airspeeds both above and below the region where pure aerodynamic controls are effective, dual flight control systems were provided. The lateral and directional control systems are described in reference 1. In the longitudinal control system, an adjustable horizontal stabilizer and a conventional elevator, incorporating a geared tab, provided the aerodynamic control. A thrust diverter mechanically linked to the elevator utilized residual thrust from the turbine engine exhaust (see fig. 2). A maximum of 2800 ft-lb pitching moment was provided by the diverter at maximum power and at zero airspeed. During flight both aerodynamic and reaction control systems were operating thereby relieving the pilot of having to switch control systems during the critical flight regimes. The relative moment contribution of each mode of longitudinal control is given in figure 14 of reference 1 for the usable range of airspeeds.

Thrust control was obtained through manipulation of a conventional throttle or, if more rapid thrust changes were required, through changes in propeller collective pitch at the maximum throttle position.

Pertinent dimensions of the aircraft are given in table I. A photograph of the pilot's instrument panel is shown in figure 3. Unique indicating instruments, not usually found in conventional aircraft, are the linear sideslip-angle and angle-of-attack indicators (which have vane sensors) and the low-speed airspeed indicator (0 - 15 mph). The sensor for this instrument is a balanced thermocouple hot wire anemometer.

FLIGHT TEST TECHNIQUE

All data presented in this report were obtained at flight altitudes less than 50 feet over the runway surface. This somewhat unorthodox

technique insured that perfectly horizontal flight paths were achieved by providing the pilot with good visual position references. The technique did somewhat limit the climbing or diving attitudes in which the aircraft could be flown, but this was not considered a serious limitation in the transition speed range. It was believed that the restriction on altitude changes during the test maneuvers placed more stringent conditions on the trim capability of this wing-lift vehicle than if altitude changes were permitted.

Data were obtained over the maximum allowable speed range for each flap setting, δ_f, by trimming for zero stick force in level flight with the horizontal stabilizer and then obtaining higher or lower airspeeds by adjusting engine power while holding level flight with the elevator deflection required at the fixed stabilizer position.

Transition data were obtained under similar altitude limitations with the pilot continuously varying thrust and flap angle to achieve the desired reduction in airspeed. Full flap travel from 0° to 70° was utilized in this maneuver.

RESULTS AND DISCUSSION

Longitudinal Trim Characteristics

The longitudinal trim characteristics of the test aircraft during level flight in the transition speed range are shown in figures 4 and 5. The elevator angles and forces required for trim are shown in figures 4(a) and 4(b), respectively; the power and angles of attack required for level flight are shown in figures 4(c) and 4(d); and the trim horizontal stabilizer incidence angles used at each flap setting are shown in figure 5.

In general, no major or abrupt changes in trim were noted with flap deflection and speed reduction and no serious trim limitations were encountered. It is noted in figure 5 that a maximum of 15.4° of horizontal stabilizer incidence was used for trim whereas the full travel[1] of 23° was required in previous flight tests with this aircraft (ref. 2). This difference is primarily due to the reduction of engine thrust axis inclination from the 22° used in reference 2 to the 13° used in reference 1.

Elevator angles and forces required for trim were relatively small and were not greatly influenced by reducing speed for flap deflections above 40°. Power changes required for any given flap deflection were small and throttle management to fly on the back side of the power-required curve did not constitute a problem; hence, high thrust response

[1]Horizontal-tail incidence is adjustable in flight between 13° and 23° with respect to the fuselage reference line.

was not required. It should be noted that the airspeed ranges for each flap deflection were small because of the structural limitation on the maximum airspeeds allowed for flap-deflected configurations.

The elevator force data of figure 4(b) indicate that trim conditions, that is, zero force at trim airspeed, were not always achieved. Early in the flight program the aircraft exhibited a lateral unbalance that required the pilot to hold a lateral stick force; hence, his judgment of longitudinal trim was difficult, particularly, at the larger flap deflections, where changes in stick force with airspeed were negligible. The lateral unbalance was corrected in later flights but it was not deemed necessary to repeat the data of figure 4.

Minimum speed limitations.- The fuselage angle-of-attack variations with airspeed for each flap deflection are shown in figure 4(c). It was inferred from these data that the minimum airspeed obtainable for each flap deflection up to 50° was being limited by a wing stalling condition at the given power setting and airspeed. Further reductions in airspeed caused the aircraft to descend. Increasing power to provide additional slipstream lift could not be accomplished without causing the aircraft to climb. The maximum altitude change limitation in the testing technique precluded climbing or descending flight conditions influencing the effective angle of attack on the wing. Airspeeds below 24 knots were not covered in this investigation, for they are considered to be in the hovering region where the aircraft is supported solely by thrust and slipstream generated lift.

Ground effects.- Over the airspeed range used in transition no adverse or favorable ground effects were found, even though the aircraft was flown at times with the wheels only inches away from the runway. It is believed that the adverse ground effects (abrupt loss in lift and turbulent flow through the propellers) noted in the flight investigation of reference 2 resulted from effects of recirculation of the slipstream through the propellers at airspeeds less than 17 knots (in calm air) where the propeller slipstream wake, deflected by the flaps, can proceed ahead of the aircraft. The characteristics of the aircraft in these lower speed ranges were not studied in this investigation. It is believed that the hovering characteristics close to the ground are important enough to be the subject of a separate investigation since the adverse nature of a self-disturbing slipstream on a hovering or near hovering vehicle should be applicable to deflected-slipstream, tilt-wing, or flapped tilt-wing VTOL concepts.

HORIZONTAL TRANSITION

It can be inferred from the static trim data that, with this aircraft configuration, a variety of horizontal transition techniques can be followed that will result in relatively small changes in longitudinal trim.

One technique, a hypothetical constant -6° angle-of-attack horizontal transition, based on pseudostatic conditions derived from the data of figure 4 and an assumed constant 14° horizontal-tail incidence, is plotted in figure 6(a) as a function of indicated airspeed. Another technique, a constant horsepower (270) horizontal transition, similarly derived is plotted in figure 6(b). Although the constant angle-of-attack transition appears less critical, the amount of longitudinal control required for trim in either case appears to be small and well within the pilot's capabilities.

An example of an actual flight transition from 73 to 27 knots is shown in figure 7. Airspeed was to be reduced at a slow rate to simulate the quasistatic case. As was expected, changes in the horizontal stabilizer incidence were not required for trim and the elevator motions and power changes required were small. The pilot was instructed to fly the transition maneuver at a constant altitude of 30 feet and attempt to hold a constant -6° angle of attack to duplicate the maneuver of figure 6(a). It was not possible, however, to accomplish this maneuver. Angle-of-attack changes were necessary to reduce speed without changing altitude. Power changes required were not considered excessive and were accomplished by changing the engine throttle position. The more responsive power changing technique of controlling propeller collective pitch at a constant throttle setting, available in the test vehicle, was not required.

It is of interest to observe that transitions at various deceleration rates have been accomplished including decelerations at higher rates than the accompanying chase helicopter can follow. In all cases the longitudinal trim requirements were similar to those shown in figure 7 and were considered small.

CONCLUDING REMARKS

Flight tests of the longitudinal characteristics of the Ryan VZ-3RY deflected-slipstream V/STOL aircraft in the transition speed range (80 to 24 knots) with power for level flights at a constant altitude disclosed no serious longitudinal trim problems. No abrupt or major changes in trim were noted for flap deflections and airspeed reductions.

No adverse or favorable ground effects were noted for airspeeds down to the lowest test speed of 24 knots. Horizontal transitions from 73 to 25 knots were accomplished with only minor longitudinal control motions and easily controlled changes in power. It was observed that decelerations more rapid than the chase helicopter was able to follow were obtained without encountering any longitudinal trim limitations.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif., June 21, 1962

REFERENCES

1. James, Harry A., Wingrove, Rodney C., and Holzhauser, Curt A.: Wind-Tunnel and Piloted Flight Simulator Investigation of a Deflected-Slipstream VTOL Airplane, the Ryan VZ-3RY. NASA TN D-89, 1959.

2. Tuttle, Donald T.: Final Flight Test Report, VZ-3RY (Ryan Model 92) Airplane, Contract NONR 2139(00). Ryan Aeronautical Co., Rep. 9269-2, 1 March 1960.

TABLE I.- GEOMETRIC DATA, RYAN VZ-3RY

Wing	
Area (flaps up), sq ft	125
Span, ft	23.4
Aspect ratio	4.4
Taper ratio	1.0
Mean aerodynamic chord, $\bar{c}$, ft	5.34
Incidence (relative to fuselage reference line), deg	22
Airfoil	NACA 4418
Flap	
Area (four flaps), sq ft	126.8
Span (each flap), ft	10.0
Chord, ft	
Upper flap	3.29
Lower flap	3.05
Horizontal tail	
Area, sq ft	64.4
Span, ft	15.4
Aspect ratio	3.7
Taper ratio	1.0
Mean aerodynamic chord, $\bar{c}$, ft	4.18
Elevator area aft of hinge line, sq ft	11.86
Tab area aft of hinge line, sq ft	2.56
Tab gear ratio, deg tab/deg elev	1.43:1
Length (wing $\bar{c}/4$ to horizontal tail $\bar{c}/4$), ft	13.76
Incidence change available for trim (Incidence reference line inclined 13° nose up with respect to fuselage reference line), deg	10
Vertical tail	
Area, sq ft	21.2
Rudder area aft of hinge line, sq ft	4.1
Span, ft	4.7
Fuselage	
Length (including thrust diverter), ft	29.88
Height (maximum), ft	5.15
Width (maximum), ft	2.5
Cockpit	open
Ejection seat (rocket-catapult with zero-zero capability)	North American LW-1A
Ejection seat weight (including parachute and catapult), lb	71.5
Engine	Lycoming YT-53
Power rating, hp	785

TABLE I.- GEOMETRIC DATA, RYAN VZ-3RY - Concluded

Propellers - Hartzell, three-blade, wood, Model HC-93Z20-1C	
Diameter, ft	9.17
Thrust axis relative to fuselage reference line, deg	13
Thrust axis toe-out, deg	1.5
Thrust axis inclination relative to wing chord line, deg	-9.0
Weight and balance	
Gross weight, maximum lb	2925
Center of gravity (at maximum gross weight), inches aft of leading-edge $\bar{c}$	21.10
Vertical center of gravity (above fuselage reference line), in.	46.40

NOTE: Thrust axis passes 1.87 in. below center of gravity at longitudinal center-of-gravity position.

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Figure 1.- Ryan VZ-3RY deflected slipstream test vehicle; flaps full down.

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Figure 2.- Rear view Ryan VZ-3RY showing exhaust gas thrust diverter.

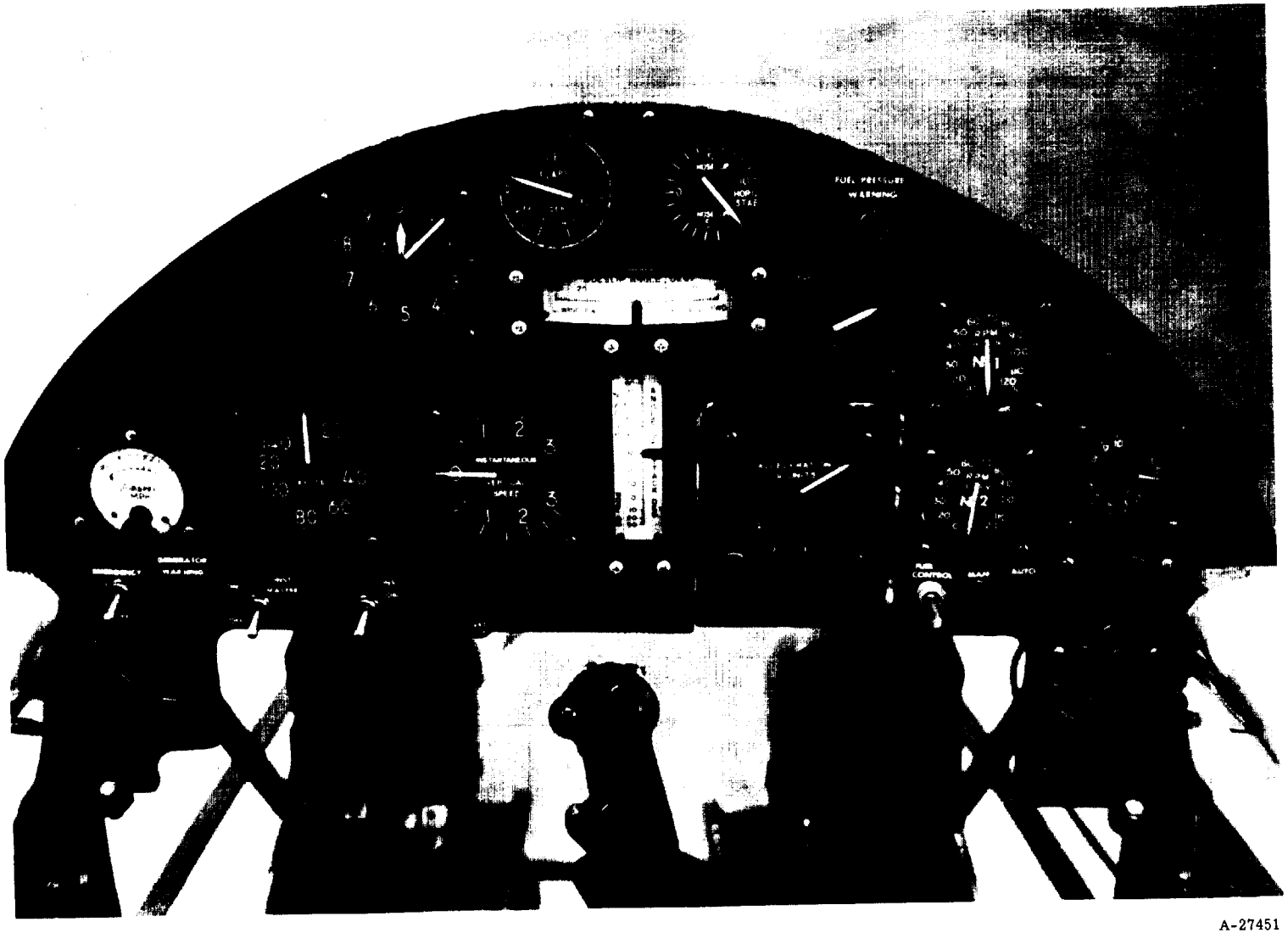

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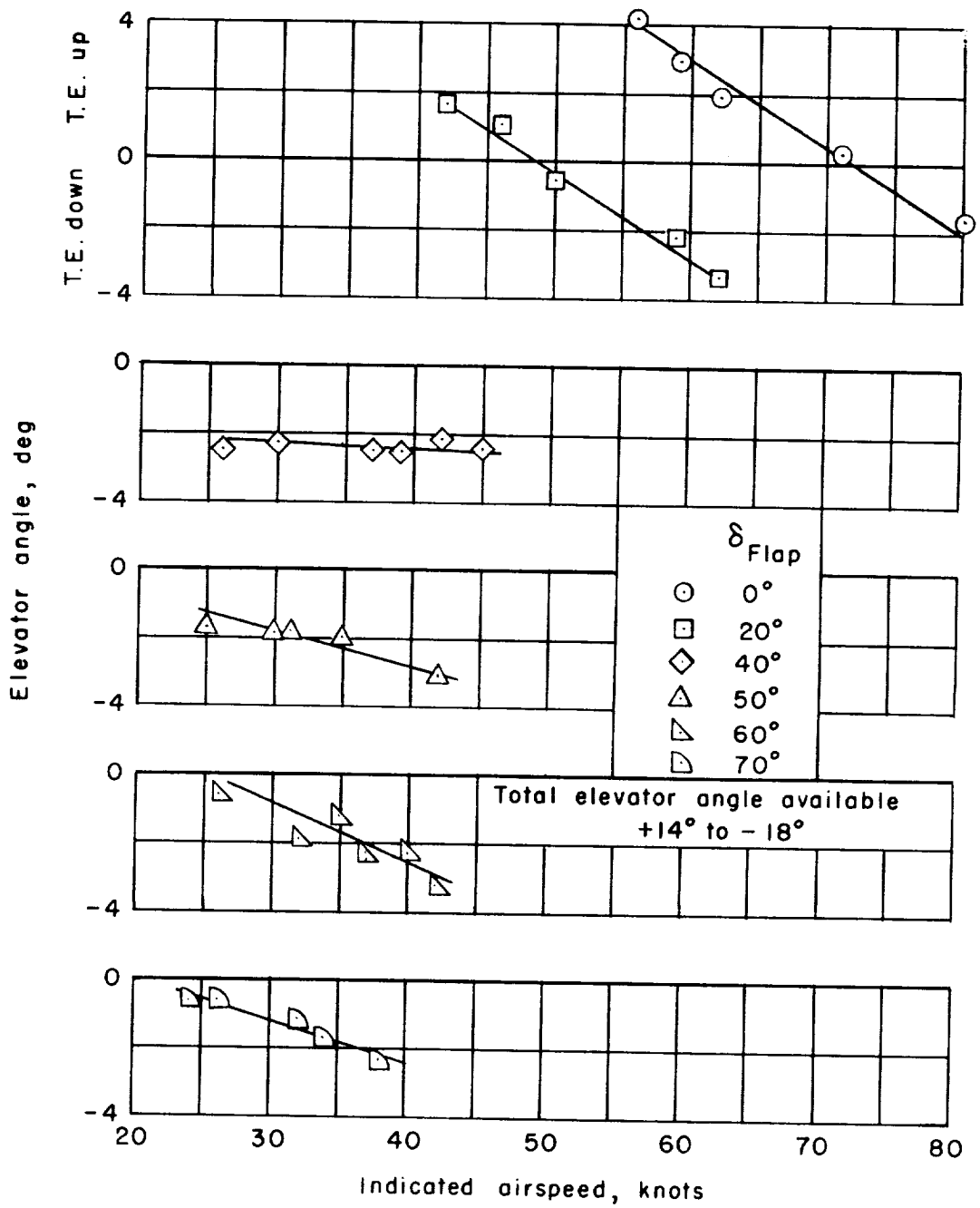
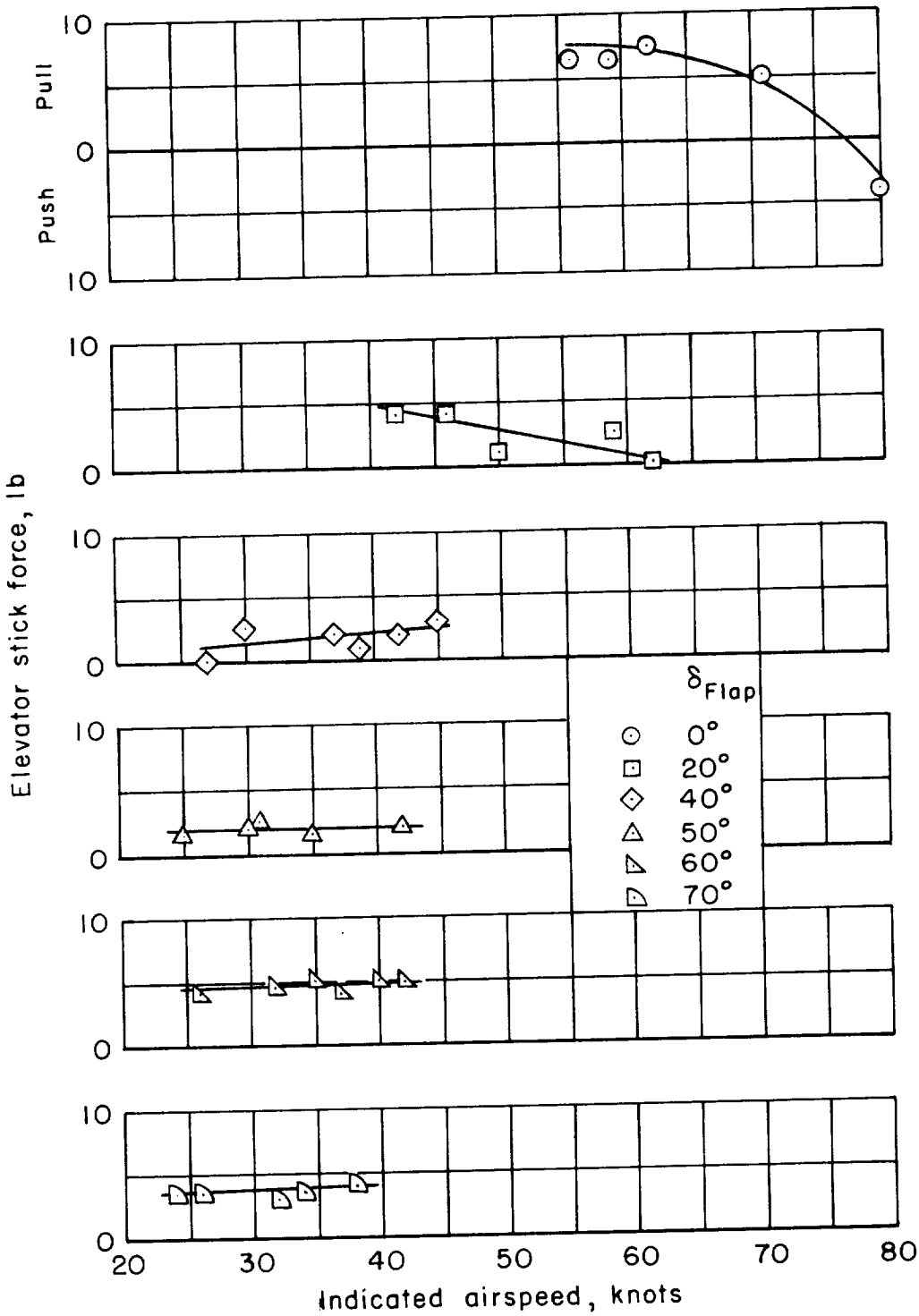
Figure 3.- Flight instrument panel, Ryan VZ-3RY.



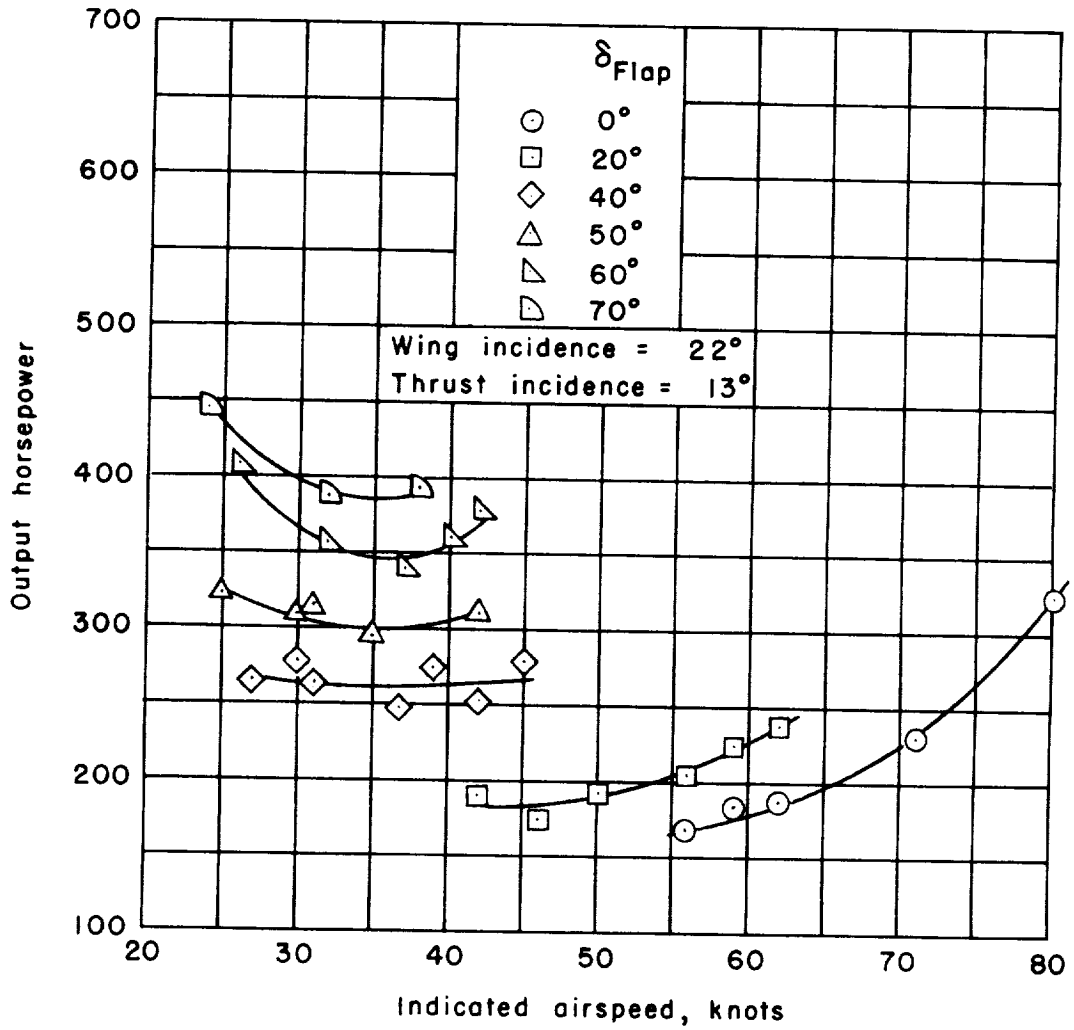
(a) Elevator angle required for trim; reaction control on.

Figure 4.- Longitudinal trim characteristics; power for level flight; VZ-3RY deflected slipstream test vehicle.



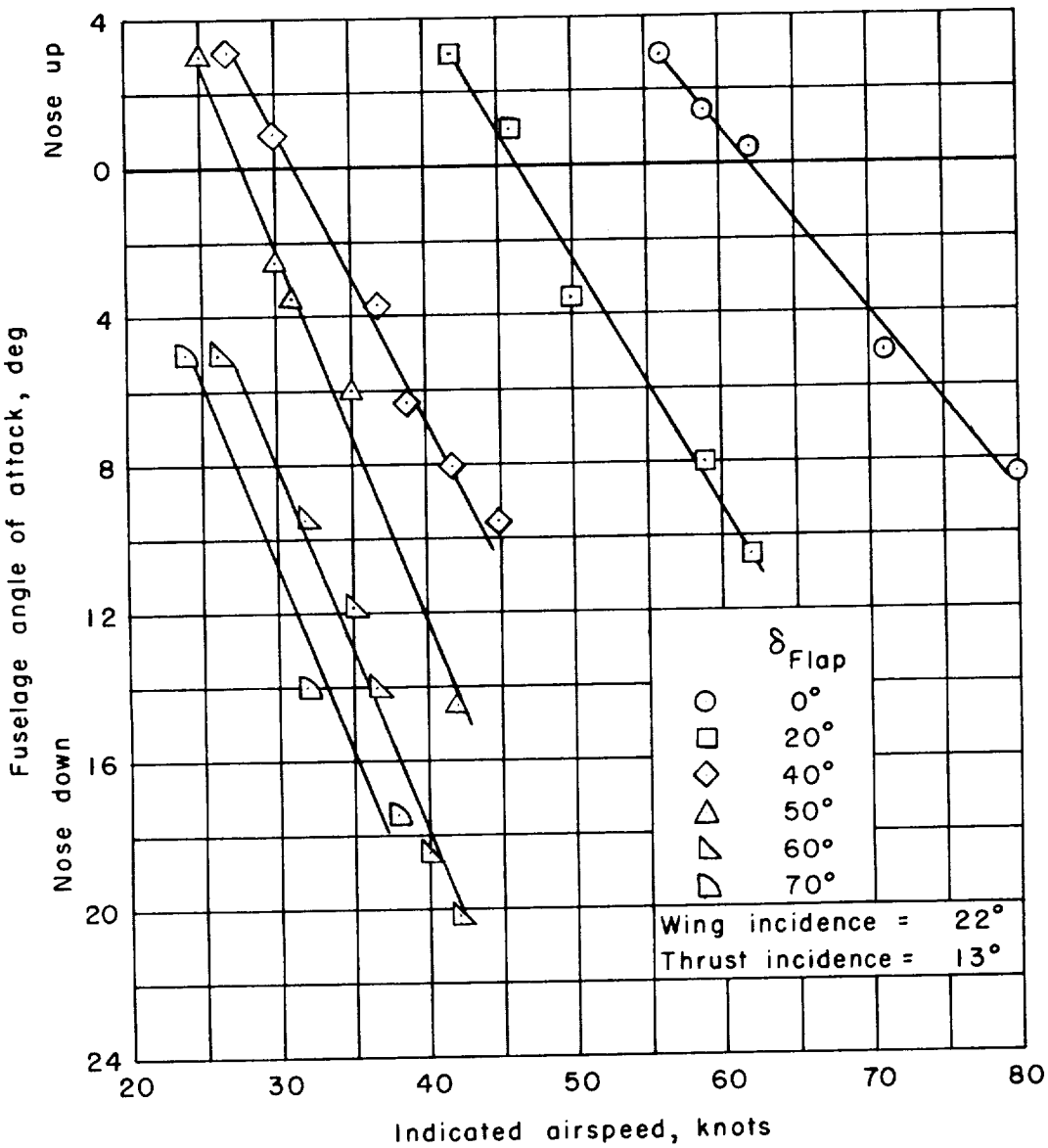
(b) Elevator stick force required for trim.

Figure 4.- Continued.



(c) Power required for trim.

Figure 4.- Continued.



(d) Fuselage angle of attack required for trim.

Figure 4.- Concluded.

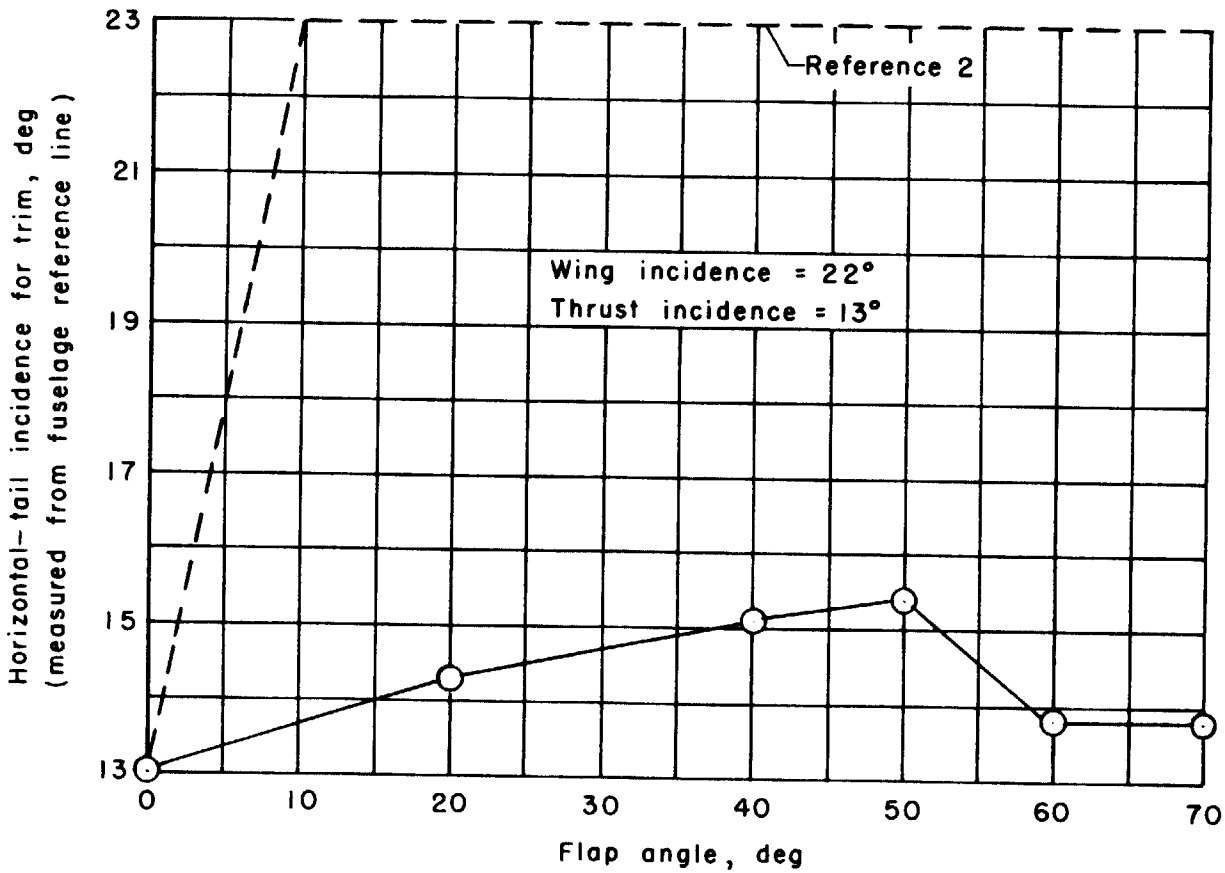
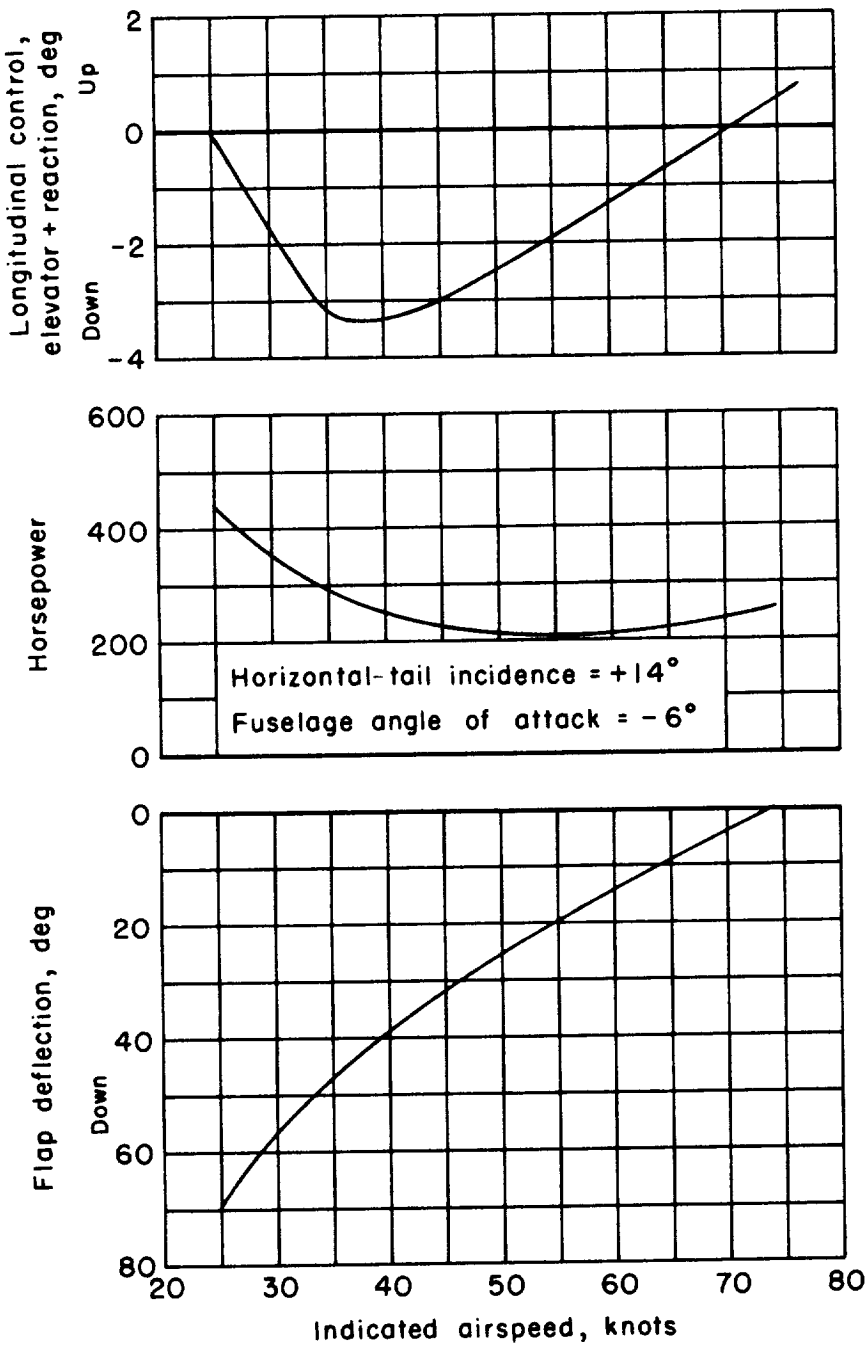
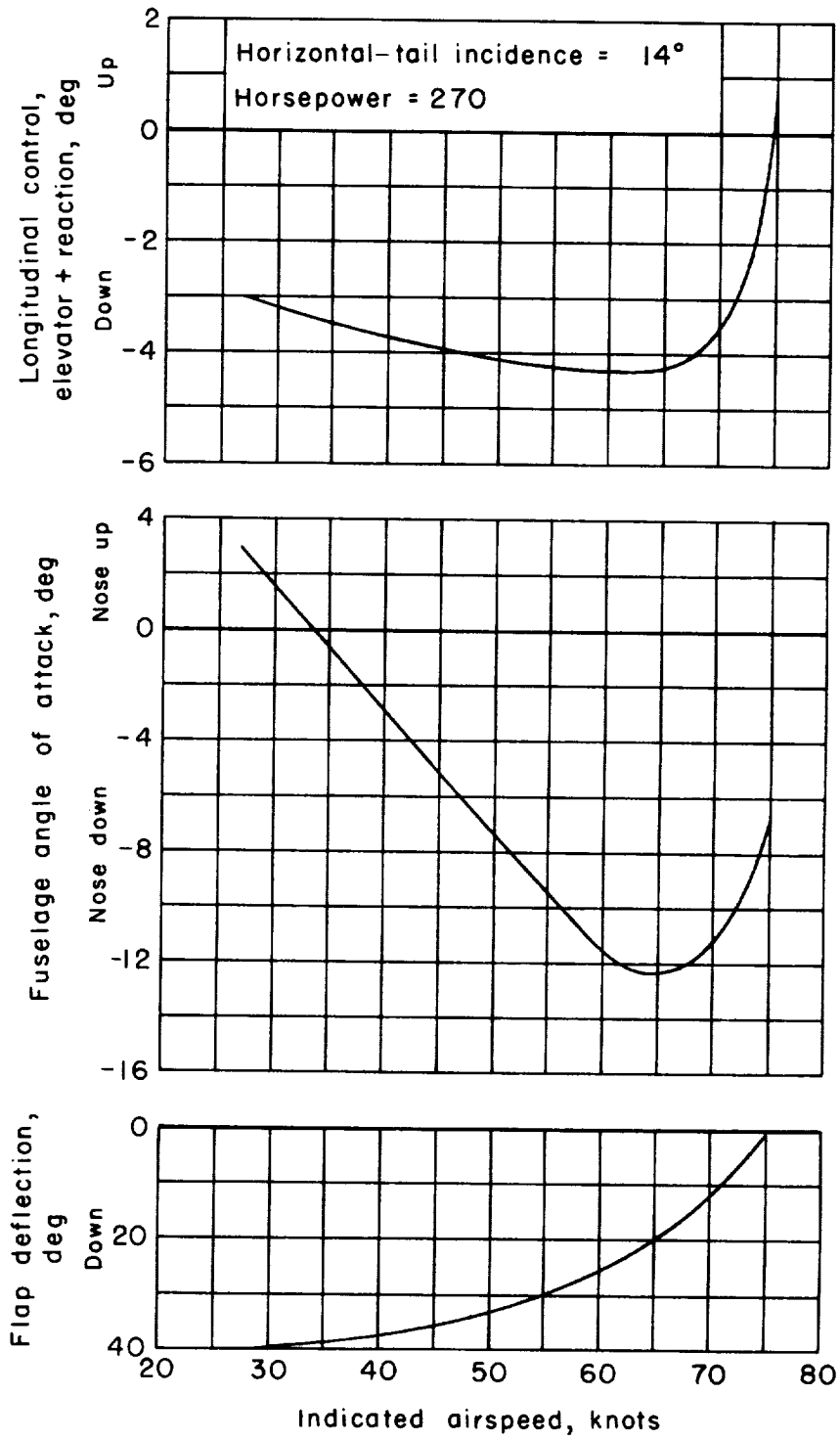


Figure 5.- Horizontal-tail incidence required for trim at trim airspeed, power, and flap deflection; VZ-3RY deflected slipstream test vehicle.



(a) Constant angle of attack.

Figure 6.- Hypothetical horizontal transition.



(b) Constant horsepower.

Figure 6.- Concluded.

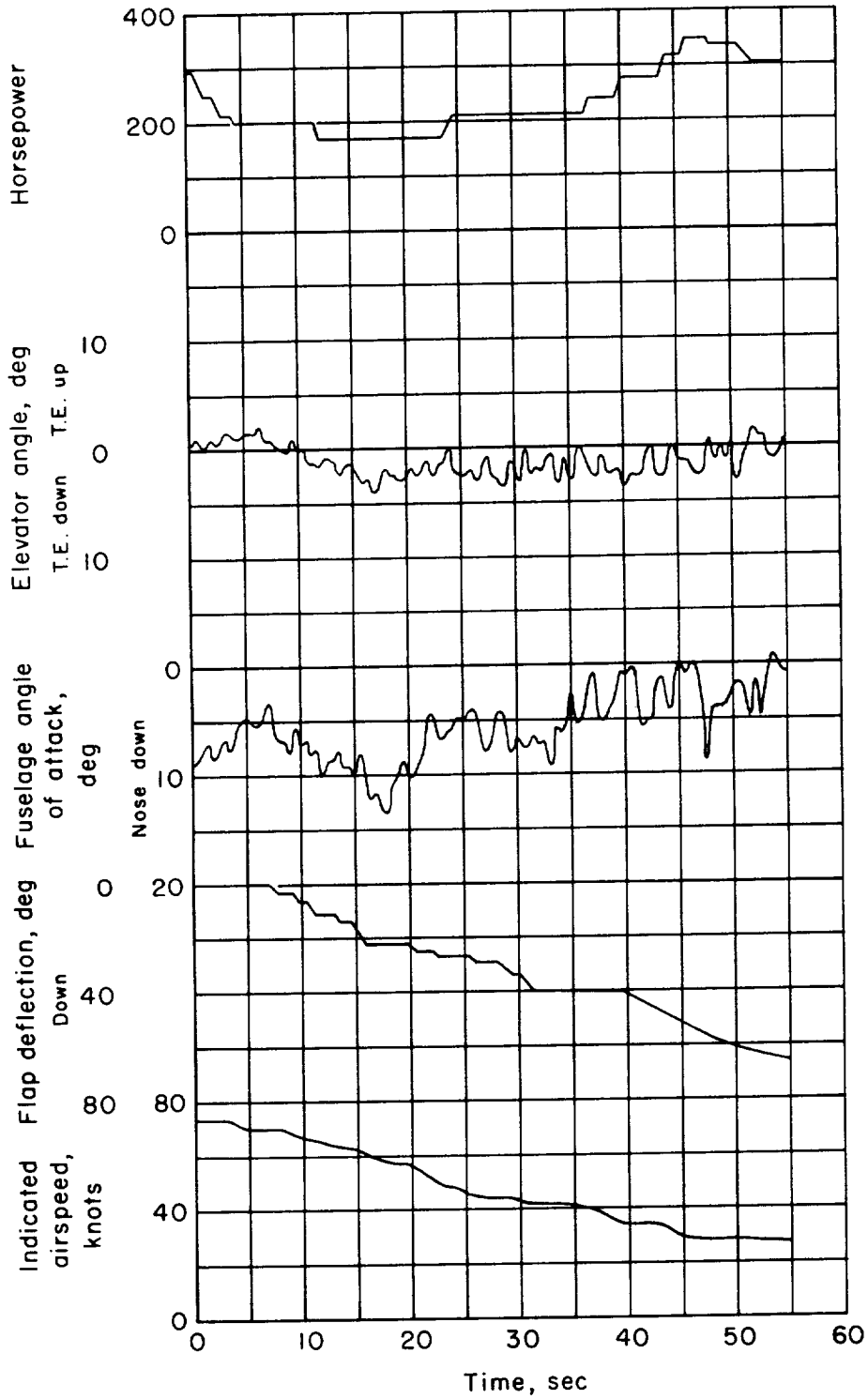


Figure 7.- Typical time history of an in-flight constant attitude transition.

NASA-Langley, 1962 A-680