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FLIGHT EVALUATION OF VARIOUS PHUGOID DYNAMICS AND $1/T_{h_1}$ VALUES FOR THE LANDING-APPROACH TASK

Charles Chalk

FOREWORD

This report was prepared for the United States Air Force by Cornell Aeronautical Laboratory, Inc., Buffalo, New York, in partial fulfillment of Contract AF33(615)-1253; Exhibit (A) and (A-1), Item V.

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The work reported in this document represents the efforts of a group of skilled individuals: Mr. R. Harper, the evaluation pilot; Messrs. N. Infanti and J. Meeker, the safety pilots and in-flight test conductors; and Mr. R. Huber, who was responsible for the modifications, calibration, and maintenance of the variable stability and variable drag systems.

This report was submitted by the author December 1965.

This technical report has been reviewed and is approved.

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ABSTRACT

This is the second in a series of two reports dealing with longitudinal handling qualities in the landing approach. The T-33 variable stability and variable drag airplane was used in a flight program to evaluate various short-period dynamics, phugoid dynamics, drag characteristics and elevator control authority levels. The first phase of the flight program was directed mainly at longitudinal short-period dynamics, drag variation with angle of attack and elevator control authority. This work was reported in FDL-TDR-64-60. The second phase of the flight program was directed at phugoid dynamics, short-period frequency, elevator control authority and drag characteristics. Drag variations with angle of attack, airspeed and elevator deflection were considered. Pilot ratings and comments are related to the airplane characteristics tested.

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Cont.)

SYMBOLS AND DEFINITIONS

The basic symbols used in this report are defined below. In a few cases symbols are used which relate only to the immediate text in which they appear, these are defined when they are introduced.

Dimensional Units

Distance	-	feet
Time	-	seconds
Angle	-	radians (unless otherwise stated)
Force	-	pounds
Moment	-	foot-pounds
Mass	-	slugs

Aerodynamic Notation

a_z	component of acceleration of airplane cg along Z stability axis
b	wing span
c	wing chord
z_i	thrust line offset, positive when cg above thrust line
C_ℓ	rolling moment coefficient, $L/q_0 Sb$
C_m	pitching moment coefficient, $M/q_0 Sc$
C_n	yawing moment coefficient, $N/q_0 Sb$
C_D	drag coefficient, $D/q_0 S$
C_L	lift coefficient, $L/q_0 S$
C_Y	side force coefficient, $Y/q_0 S$
C_T	thrust coefficient, $T/q_0 S$
D	drag, force in plane of symmetry and parallel to component of relative wind in plane of symmetry, positive aft
F_{ES}	elevator stick force
F_{AS}	aileron stick force
g	acceleration of gravity (i.e., 32.2 ft/sec^2)

Aerodynamic Notation (Cont.)

h	altitude
I_{xx}, I_{yy} I_{zz}, I_{xz}	airplane moments of inertia about body axes
$\mathcal{L}$	lift, force in plane of symmetry and normal to component of relative wind in the plane of symmetry, positive up
L	rolling moment about X body axis, positive right wing down
M	pitching moment about Y body axis, positive nose up
N	yawing moment about Z body axis, positive nose right
m	mass
n_z	normal accelerometer reading in g units, positive in pullup
p, q, r	angular velocities about X, Y, Z body axes, respectively
T	thrust force along X body axis
$\hat{q}$	dynamic pressure, $1/2\ \rho U^2$
S	wing area
u, v, w	incremental velocity along the X, Y, Z reference axes respectively
U	airspeed
W	weight
X_S	aerodynamic force along X stability axis, positive forward
Y_S	aerodynamic force along Y stability axis, positive to right
Z_S	aerodynamic force along Z stability axis, positive down
α	angle of attack
α_V	angle of attack measured by vane
β	angle of sideslip
γ	flight path angle, positive up
γ_{DES}	desired flight path, defined by landing aid
ξ	angle between X axis and thrust line
δ_a	aileron angle, positive right aileron down
δ_{AS}	aileron stick deflection, positive right
δ_e	elevator angle, positive trailing edge down
δ_{ES}	elevator stick deflection, positive back

Aerodynamic Notation (Cont.)

δ_r	rudder angle, positive trailing edge left
δ_{RP}	rudder pedal deflection, positive right pedal forward
δ_p	drag pedal deflection, $\frac{1}{2}$ included angle
θ	attitude angle, angle between X body axis and the horizontal plane
ρ	air density
ϕ	bank angle, angle between Y body axis and a horizontal line in the Y-Z plane
ψ	heading angle, angle between reference azimuth (North) and the projection of the X body axis in the horizontal plane

The following stability derivative notation is used:

$$C_{D_\alpha} = \frac{\partial C_D}{\partial \alpha} \qquad C_{m_q} = \frac{2U}{c}\frac{\partial C_m}{\partial q} \qquad C_{m_u} = \frac{U}{2}\frac{\partial C_m}{\partial u}$$

$$C_{L_\alpha} = \frac{\partial C_L}{\partial \alpha} \qquad C_{m_\alpha} = \frac{\partial C_m}{\partial \alpha} \qquad C_{m_{\delta e}} = \frac{\partial C_m}{\partial \delta e}$$

$$C_{L_{\delta e}} = \frac{\partial C_L}{\partial \delta e} \qquad C_{m_{\dot\alpha}} = \frac{2U}{c}\frac{\partial C_m}{\partial \dot\alpha} \qquad C_{T_u} = \frac{U}{2}\frac{\partial C_T}{\partial u}$$

$$C_{L_u} = \frac{U}{2}\frac{\partial C_L}{\partial u} \qquad C_{D_u} = \frac{U}{2}\frac{\partial C_D}{\partial u}$$

The following dimensional stability derivative notation is used:

$$M_q = \frac{q_0 S c}{I_{YY}}\frac{c}{2U} C_{m_q} \qquad T_u = \frac{\rho S U}{m}(C_{T_u} + C_T) \qquad M_{\delta_{ES}} = \frac{\delta_e}{\delta_{ES}} M_{\delta_e}$$

$$M_\alpha = \frac{q_0 S c}{I_{YY}} C_{m_\alpha} \qquad X_u = -\frac{\rho S U}{m}(C_{D_u} + C_D)$$

$$M_{\dot\alpha} = \frac{q_0 S c}{I_{YY}}\frac{c}{2U} C_{m_{\dot\alpha}} \qquad X_w = \frac{\rho S U}{2m}(C_L - C_{D_\alpha})$$

$$Z_u = -\frac{\rho S U}{m}(C_L + C_{L_u})$$

$$M_u = \frac{\rho S U c}{I_{YY}}(C_{m_u} + C_m) \qquad Z_w = -\frac{\rho S U}{2m}(C_{L_\alpha} + C_D)$$

$$M_{\delta_e} = \frac{\rho S U^2 c}{2 I_{YY}} C_{m_{\delta e}} \qquad Z_{\delta_e} = -\frac{\rho S U^2}{2m} C_{L_{\delta e}}$$

Transfer Function Notation

f	frequency, cycles/second
f_n	undamped natural frequency, cycles/second
K	gain factor
N	transfer function numerator
S	Laplace operator
T	time constant
ζ	damping ratio
τ	time constant
λ	real root
ω	frequency, radians/second
ω_n	undamped natural frequency, radians/second
ω_p''	closed-loop phugoid frequency, θ controlled by δ_e, h by throttle
$G(j\omega)$	transfer function of filter
$\Phi(f)$	power spectral density
$R(\tau)$	autocorrelation function

Subscripts

sp	short period
p	phugoid
θ_1, θ_2	identifies factors of numerator of θ/δ_e transfer function
T	throttle, as in throttle deflection δ_T, also as in factor of numerator of h/δ_T transfer function $1/T_{h_T}$
h_1, h_2, h_3	identifies factors of numerator of h/δ_e transfer function $\frac{1}{T_{h_1}}, \frac{1}{T_{h_2}}, \frac{1}{T_{h_3}}$

Axes

The following axes are right-hand orthogonal sets with origin at the center of gravity.

X	in the plane of symmetry, directed toward the nose and initially along the projection of the wind vector in that plane
Y	normal to the plane of symmetry, directed along the right wing
Z	in the plane of symmetry, directed "down"

These axes are fixed in the airplane.

General

a_n	coefficient of polynomial
$E\{\ \}$	expected value or statistical average
P.R.	pilot rating
$\ln$	natural logarithm
Δ	incremental value

SECTION I
INTRODUCTION

1.1 BACKGROUND

In the flight program described in Reference 46, the T-33 variable stability airplane was used to study longitudinal flying qualities for the landing-approach task. The factors studied were short-period dynamics, longitudinal control gain, and drag variation with angle of attack; the work was conducted during the summer and fall of 1963.

The study of longitudinal flying qualities for the landing approach was extended during the summer and fall of 1964 to include the effects of phugoid dynamics, drag variation with airspeed, and drag variation with elevator control. The results of this latter program are the subject of this report. The same airplane, evaluation pilot, and test crew were used for both test programs.

References 1 through 45 form the background information for Reference 46, and are, therefore, equally valid for the present study.

1.2 APPROACH

In the program conducted, selected configurations of drag, short-period and phugoid configurations were established through the T-33 variable drag and variable stability systems. The piloting task was to fly a constant speed approach consisting of a straight-in IFR portion, followed by transition to a visual glide path defined by an arrangement of lights. The approach was then terminated by a waveoff, which was followed by a visual circuit of the airfield and a second visual approach on the glide path with the same configuration. The pilot then commented on the control difficulties experienced, answered a list of specific questions (designed to determine how he used the information and controls available to him), and assigned a rating to the configuration.

1.3 ARRANGEMENT OF REPORT

The experimental procedure is described in Section II. The equipment used to perform the experiment is described, the evaluation task is defined, and the selection of configurations to be evaluated is discussed.

The results of the experiment are discussed in detail in Section III. These consist of pilot rating and comment data, optimum longitudinal gains selected by the pilot, and typical time-histories of the approaches.

The major conclusions drawn from the results of the experiment are listed in Section IV.

SECTION II
EXPERIMENTAL PROCEDURE

2.1 VARIABLE STABILITY AND VARIABLE DRAG EQUIPMENT

2.1.1 General Description

The design and installation of the variable stability and control system in the T-33 airplane are described in Reference 31. The design, installation, and calibration of the variable drag system are described in Reference 32. Figure 1 illustrates the T-33 airplane with variable drag petals on the tip tanks.

Briefly, the airplane has been equipped with electro-hydraulic servos to position the elevator, rudder, aileron and drag surfaces in response to combinations of pilot commands and airplane response parameters. Airplane angle of attack, angle of sideslip, angular rates, linear and angular accelerations, dynamic pressure and random noise generator are available as inputs to the servos. In addition, the front cockpit controls have been mechanically disconnected from the airplane control surfaces and connected instead to hydraulic feel servos. In this manner, the control system characteristics and the airplane characteristics can be varied independently.

The T-33 variable stability, variable-drag airplane is described and illustrated in a 25-minute color movie listed as Reference 33.

2.1.2 Lateral-Directional Dynamics

The primary purpose of the flight program was to study longitudinal handling qualities in the landing-approach task. Therefore, it was considered desirable to have sufficiently good lateral-directional handling qualities to avoid compression of the rating scale. It was also considered desirable to use a minimum number of lateral-directional feedback signals to simplify flight operations.

Figure 1. VARIABLE STABILITY T-33 WITH DRAG PETALS EXTENDED

With the exception of the Dutch-roll damping ratio, the evaluation pilot considered the unaugmented T-33 flown through the CAL power-control system to be adequate for the landing approach task. The Dutch-roll damping ratio was increased to a satisfactory level through yaw-rate feedback to the rudder.

2.1.3 Control System Characteristics

For the landing-approach flight program, the control surface servos were commanded by signals proportional to control stick and rudder pedal position. The aileron and rudder control gains and feel characteristics were maintained constant throughout the program at values initially selected by the pilot as being satisfactory. The elevator stick force per unit stick displacement was also maintained constant throughout the program; however, the gain between the control stick displacement and the commanded elevator angle was selected by the evaluation pilot for each configuration at the beginning of each evaluation. This technique was used because it seemed more logical to assume the spring rate known and fixed, and to let the pilot select the control gain.

The feel system static stiffness or spring rate and the longitudinal control gains used in the program are listed in Tables I and II.

The response of the elevator feel servo to a step input is shown in Figure 2. It should be noted that the response time of this servo has been significantly reduced from what it was during the Reference 46 program. This was accomplished by the use of stick rate feedback to reduce the servo damping ratio.

Figure 3 illustrates the net engine thrust as a function of engine rpm for U = 160 kts IAS at $h_p \cong 2400$ ft pressure altitude and temperature, $OAT = 22°C$. Data were taken with landing gear down and various drag petal settings from $\delta_p = 0$ to $\delta_p = 60°$. The net thrust was calculated using drag coefficient data (for the airplane and drag petals) from Reference 32.

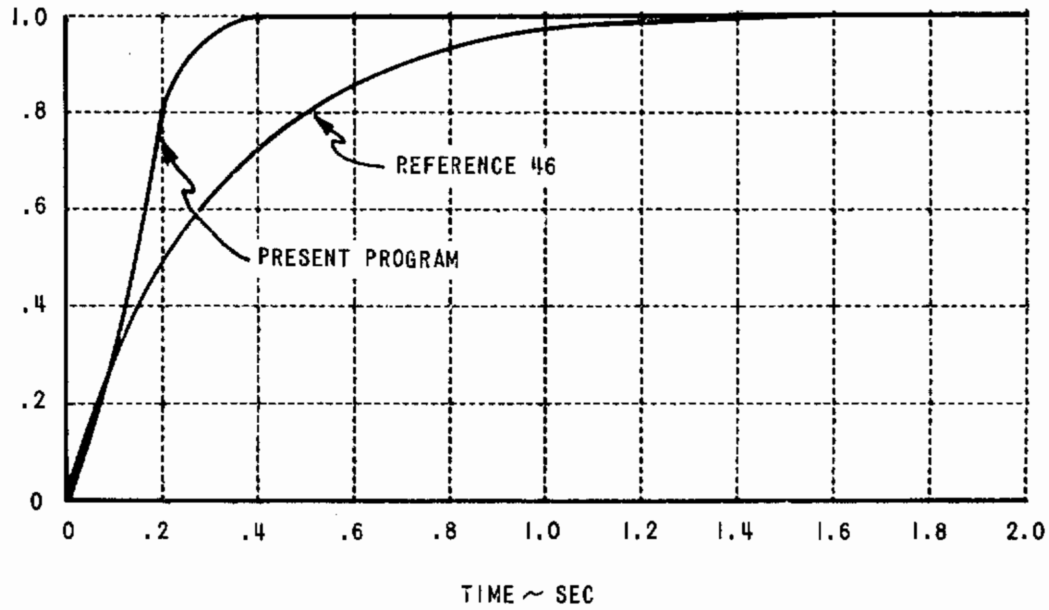


Figure 2. STEP RESPONSE OF ELEVATOR FEEL SERVO

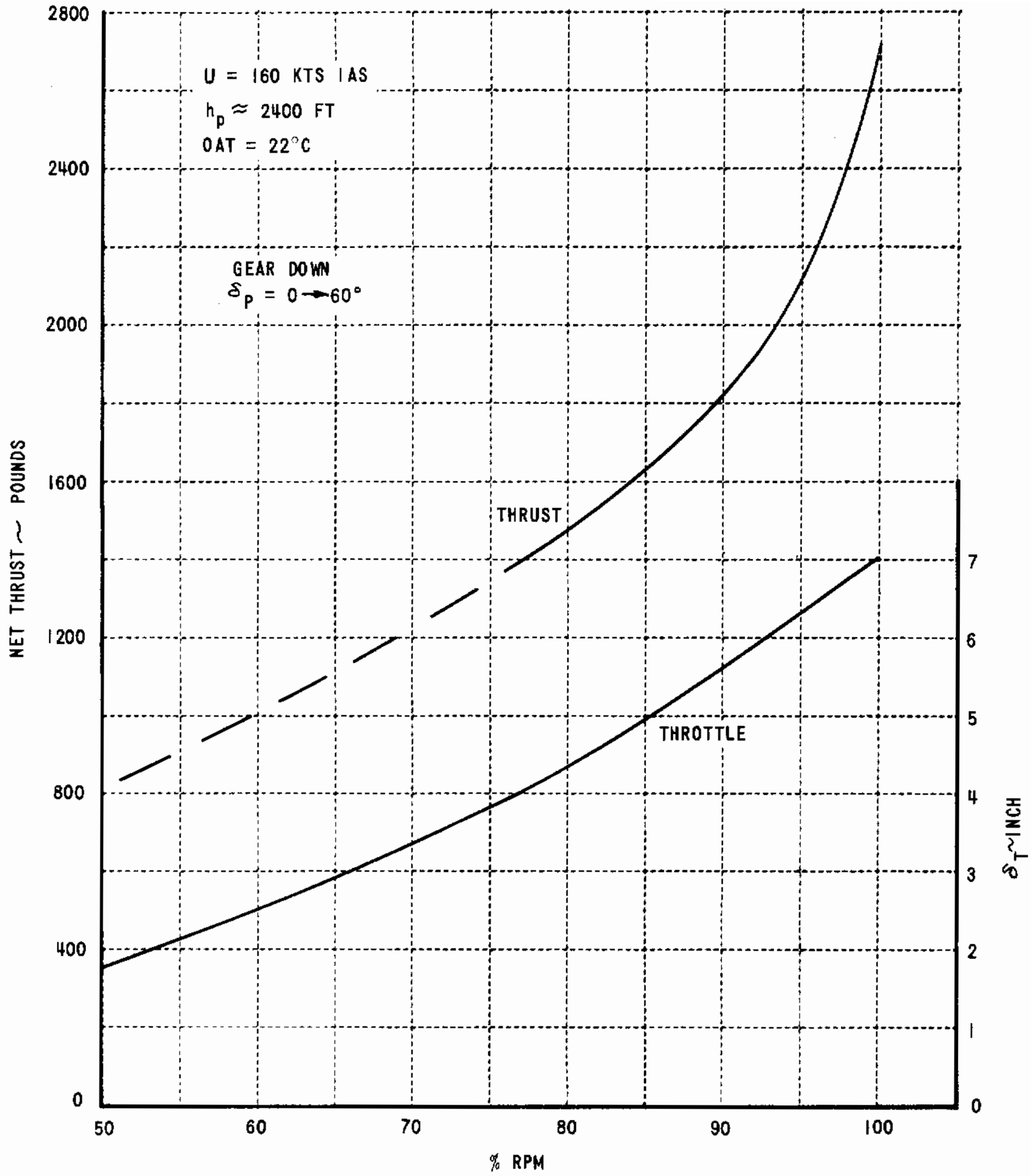


Figure 3. NET ENGINE THRUST AND THROTTLE POSITION AS FUNCTION OF ENGINE RPM

Figure 3 also shows the relation between throttle position and engine rpm. From these curves it can be seen that over the range 70 percent to 100 percent, the engine thrust is a nonlinear function of throttle position. The pilot was aware of this fact and commented about it on several occasions.

2.1.4 Longitudinal System Setup

Figure 4 illustrates the longitudinal setup of the T-33 variable stability, control, and drag system used in the test program.

The short-period dynamics were varied primarily through δ_e/α and $\delta_e/\dot{\alpha}$ feedback gains which affect the stability derivatives M_α and $M_{\dot{\alpha}}$.

The phugoid dynamics were varied primarily through $\delta_e/\Delta\hat{q}$, $\delta_e/\dot{\hat{q}}$, δ_p/u and δ_p/α feedback gains which affect the stability derivatives M_u, $M_{\dot{u}}$, X_u and X_w.

The degree of "backside operation" or value of the low-frequency factor in the numerator of the altitude-to-elevator transfer function was varied through the feedback gains δ_p/u, δ_p/α and the command gain δ_p/δ_{ES}. These gains affect the stability derivatives X_u, X_w, and $X_{\delta_{ES}}$.

The elevator control gain δ_e/δ_{ES} was also a variable in the experiment. The function generator interconnect between the petal servo and the elevator servo was required to cancel the pitching moments of the drag petals.

Frequency response data and equivalent time lags for various dynamic components of the system are documented in Reference 47.

The low-pass filter in the $\delta_e/\Delta\hat{q}$ and $\delta_e/\dot{\hat{q}}$ channels and the one in the δ_p/δ_{ES} channel are of particular significance to the results of the experiment. Figure 5 contains frequency response data for these filters.

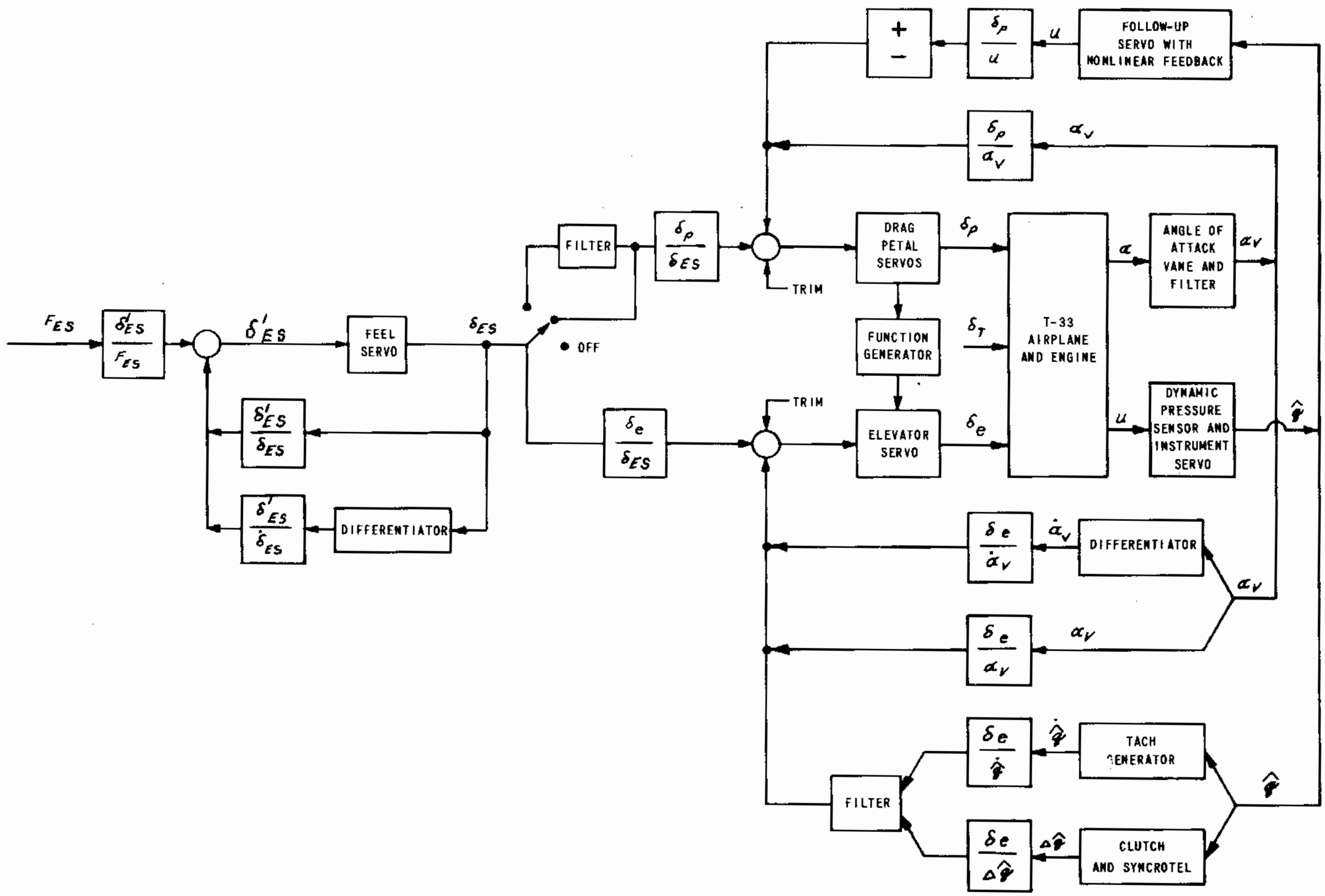


Figure 4. BLOCK DIAGRAM OF LONGITUDINAL SYSTEM

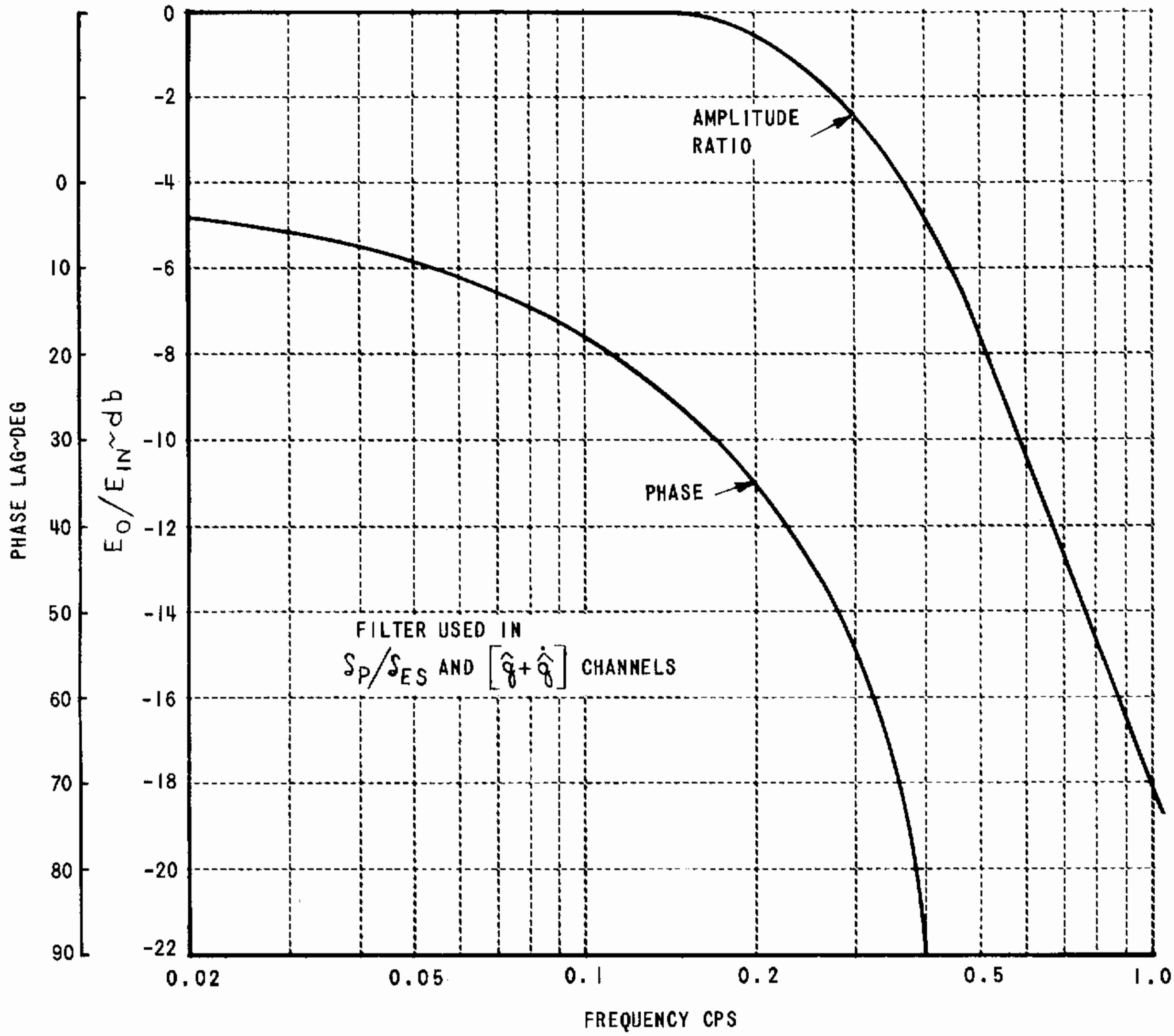


Figure 5. FILTER FREQUENCY RESPONSE

2.2 EVALUATION TASK

2.2.1 Flight Path

The flight path used for the evaluation task is sketched in Figure 6. The straight-in instrument approach started twelve miles out at 5000 ft above ground level. Track over the ground was maintained by reference to either the radio magnetic indicator or to the vertical needle of the VOR/ILS cross pointer which displayed course deviations from the Niagara Falls ILS course. The initial rate of descent was approximately 2300 ft/min. This rate of descent was maintained down to 1600 ft altitude, at which point it was decreased to 700 ft/min. This rate was held down to 600 ft altitude. Arrival at 600 ft altitude occurred prior to reaching the outer marker (4.2 miles). The 600 ft altitude was maintained until 2 miles from the end of the runway. When the safety pilot called the 2-mile point, the evaluation pilot raised the instrument hood (masked helmet visor), and the final approach to the runway was made with visual reference. Visual glide slope information was obtained from the light glide-path indicating system illustrated in Figure 7. At approximately 25 to 100 ft, waveoff was initiated at the pilot's discretion.

A closed-traffic left turn to downwind was followed by a second visual approach and waveoff. After waveoff, a climbing turn to the right completed the landing-approach maneuver. The pilot climbed back to 5000 ft altitude and recorded his comments and ratings. He also performed level turns at this time when sufficient fuel was available. Generally, two configurations were evaluated on each flight.

2.2.2 Glide Slope Equipment

The glide slope indicating system was developed by the Navy for Marine use at advanced airfields. The approach angle is obtained by placing a single light bar (source light) behind and between a pair of light bars (datum lights) adjusted vertically to present the desired approach angle. To maintain the proper glide path, the pilot lines up the source light bar with the datum light bars in a single horizontal line and keeps them lined up. If he is

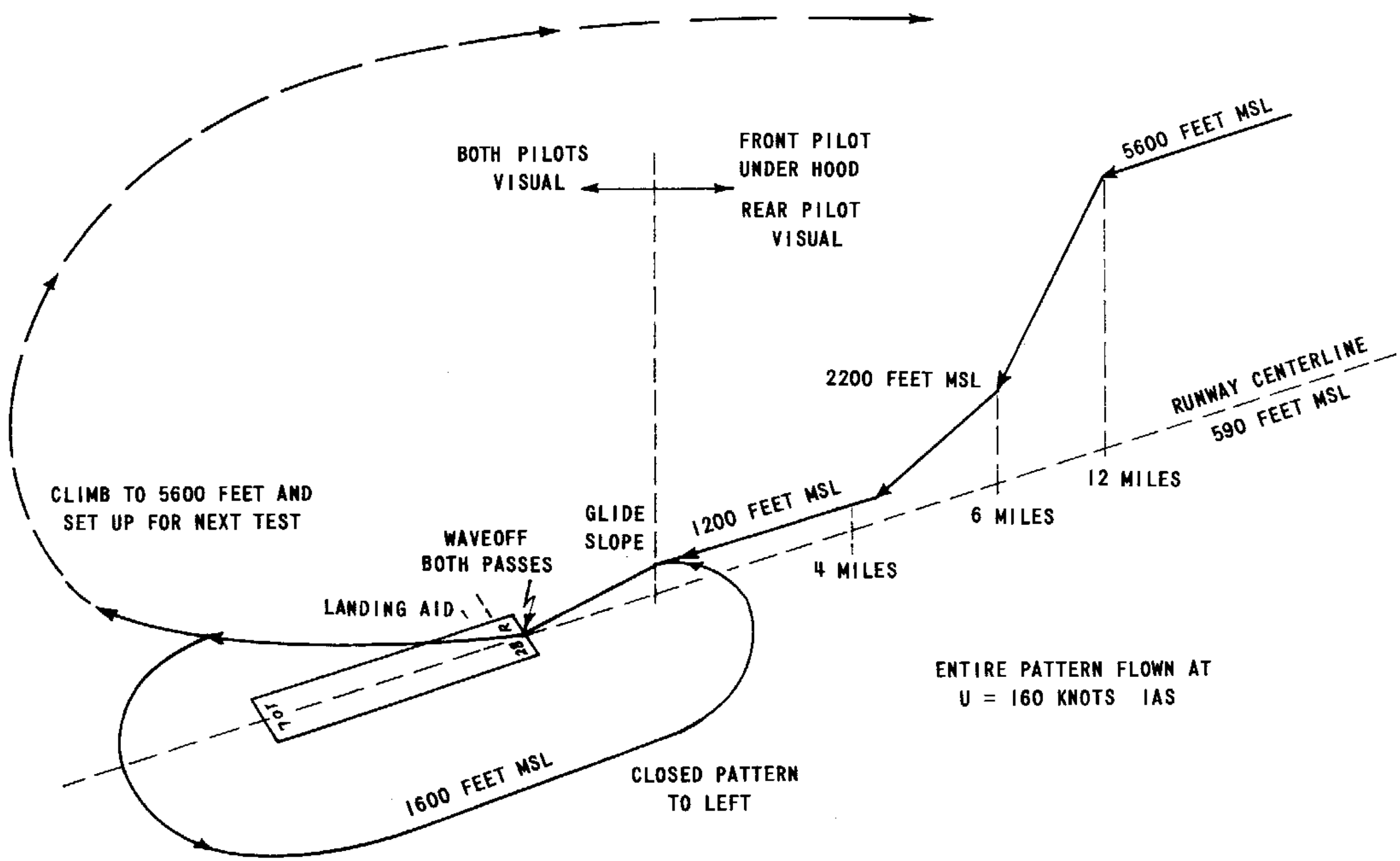
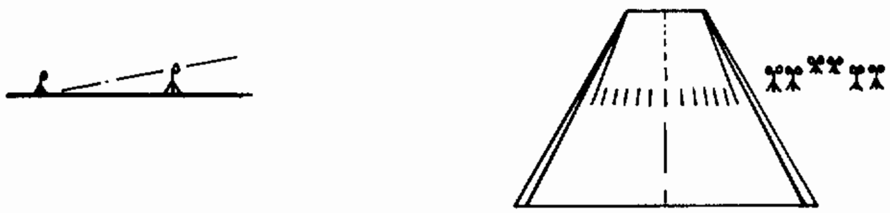


Figure 6. LANDING APPROACH EVALUATION FLIGHT CONTROL TASK



ABOVE GLIDE SLOPE

ON GLIDE SLOPE

BELOW GLIDE SLOPE

Figure 7. GLIDE PATH PRESENTATION

low, the source light bar appears below the datum bars. If he is high, the source bar appears above the datum bars (see Figure 7). The system does not provide lateral guidance.

The gain of this system (i.e., the magnitude of the vertical displacement between light bars for a given altitude error) is proportional to the horizontal separation between the source lights and the datum lights and inversely proportional to the distance from the airplane to the source light. The system was designed for 50 ft horizontal separation between source and datum lights. This separation, however, results in a very low gain. For the landing-approach program, the light system was modified by extending the supports of the datum lights and moving the source light back to 135 ft. These modifications resulted in a gain approaching that of the Navy Mirror System which has a source to datum distance of 150 ft. The glide path angle was 3.6°. The glide slope thus defined intersected the runway approximately 1100 ft from the threshold.

2.2.3 Flight Instruments

The front-cockpit instrument panel arrangement is shown in Figure 8. Grouped on the left side of the panel are altimeter, rate of climb, normal acceleration, airspeed and angle of attack. A Lear remote attitude indicator (Model 4005) displays pitch and roll attitude, sideslip angle, yaw rate and side acceleration. The remote magnetic indicator (RMI) with compass heading and ADF bearing is located on the right side of the panel along with the ILS cross pointer, engine rpm and tail pipe temperature. The scale on the angle-of-attack indicator was quite compressed, so this instrument was of limited utility. A set of three colored lights to indicate airspeed errors were installed in the pilot's field of view above the right corner of the instrument panel. The green center light is lit for ±5 kts from the reference, the red top light is lit when the speed is more than 2.5 kts low and the amber bottom light is lit when the speed is more than 2.5 kts high. From the combination of lights, the pilot has five indications of his airspeed error state:

1. Green only: Within ±2.5 kts of reference.
2. Green and red: Low 2.5 - 5.0 kts

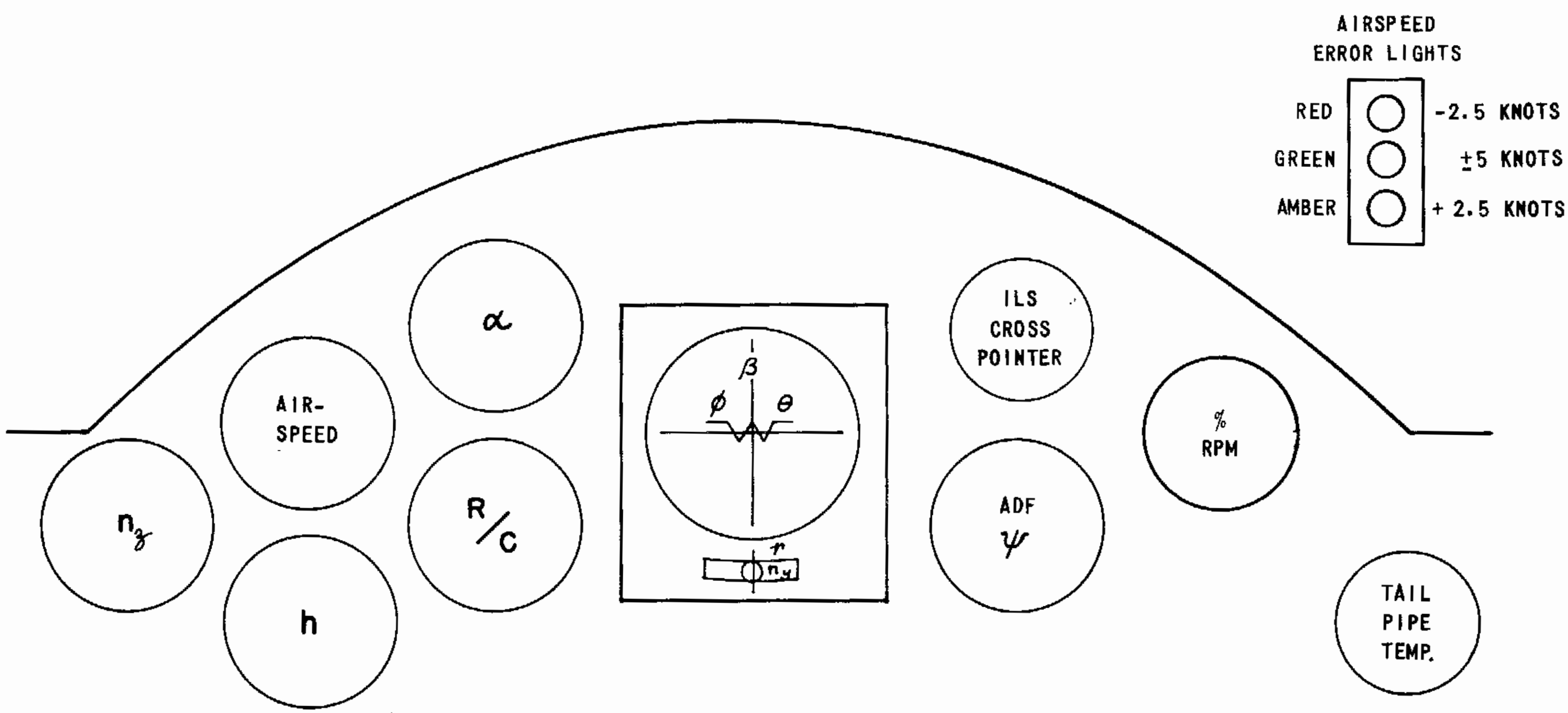


Figure 8. T-33 PANEL ARRANGEMENT

3. Red only: Low > 5 kts
4. Green and amber: High 2.5 - 5.0 kts
5. Amber only: High > 5 kts

This system presents airspeed information similar to that presented by the α indexer in Naval aircraft.

2.2.4 Pilot Comment List and Rating Scale

When the pilot had completed the approach maneuver, he wire-recorded his observations and described the control difficulties he had experienced. In each case, he answered the following questions:

1. Is the airplane difficult to trim?
2. Is the elevator control gain satisfactory?
3. Is attitude control satisfactory?
4. Is maintaining altitude a problem?
   a. straight and level
   b. turns
5. Can you establish a specific rate of descent?
6. Is maintaining airspeed a problem?
7. What instruments are you using most?
8. Is a special control technique required?
9. Are throttle adjustments necessary?
   Are they used to control:
   Attitude? Rate of climb? Other?
   Altitude? Airspeed?
10. Is elevator used to control:
   Attitude? Rate of climb? Other?
   Altitude? Airspeed? Normal Acceleration?
11. Could you make an instrument landing approach with this configuration at this speed?
12. What happens when you transition to visual flight? How do you fly the visual approach, particularly regarding glide slope control? Are you checking

airspeed and/or angle-of-attack on final?

If so, when do you quit?

13. Comment on waveoff.

14. Comment on the visual circling approach.

The following rating scale was used to rate the suitability of each configuration for the landing-approach task:

CATEGORY	ADJECTIVE DESCRIPTION WITHIN CATEGORY	NUMERICAL RATING
ACCEPTABLE AND SATISFACTORY	EXCELLENT	1
	GOOD	2
	FAIR	3
ACCEPTABLE BUT UNSATISFACTORY	FAIR	4
	POOR	5
	BAD	6
UNACCEPTABLE	BAD[a]	7
	VERY BAD[b]	8
	DANGEROUS[c]	9
UNFLYABLE	UNFLYABLE	10

[a]REQUIRES MAJOR PORTION OF PILOT'S ATTENTION.

[b]CONTROLLABLE ONLY WITH A MINIMUM OF COCKPIT DUTIES.

[c]AIRCRAFT JUST CONTROLLABLE WITH COMPLETE ATTENTION.

2.3 SELECTION OF CONFIGURATIONS TO BE EVALUATED

2.3.1 Short-Period Configurations

The results of the investigation of short-period dynamic requirements conducted in Reference 46 indicate which combinations of short-period frequency and damping ratio were satisfactory for the landing-approach task and which combinations were not. Based on these results, it was decided to use two nominal values of short-period dynamics for the tests to be made of phugoid dynamics and backside operation.

The nominal values chosen were:

ω_{sp}	ζ_{sp}	Comments
2.46 rad/sec	.45	Good
1.46 rad/sec	.45	Poor -- frequency low

Configurations evaluated with the higher short-period frequency are listed in Table I, and configurations evaluated with the lower short-period frequency are listed in Table II.

2.3.2 Phugoid Configurations

The results of the investigation of the importance of phugoid damping on en route instrument flying reported in Reference 48 indicated that the phugoid damping ratio should be positive and of the order of $\zeta_p = .30$. Since en route instrument flying implies long time periods and consists mainly of correcting for effects of external disturbances, it seems logical that the pilot would be most happy with an airplane that had a high level of inherent damping.

In Reference 49 a study was made of several hundred GCA approaches in an attempt to identify significant effects of the phugoid mode on altitude errors during this type of landing approach. It was concluded from this study that the phugoid is normally kept from having any large effect on the flight path during GCA approaches because the pilot maintains tight control over pitch attitude and airspeed.

It has been hypothesized by the authors of References 11 and 12, however, that airplane phugoid dynamics are of primary importance to handling qualities in the landing approach. In these references, systems analysis of the closed-loop pilot-airplane combination is based on phugoid equations of motion to represent the airplane. Minimum approach speed criteria are then devised which are based on the closed-loop phugoid bandwidth.

Thus, it is of interest to experimentally explore the effect of airplane phugoid dynamics on the pilot's ratings and comments for the landing-approach task, so as to provide experimental data to either support this simplified analysis or to form the basis of a more adequate one.

Flight evaluations were planned for three values of phugoid frequency for each of the previously described short-period poles; the normal T-33 value and phugoid frequencies twice and three times as high. The effect of the $\delta_e / \Delta\hat{\theta}$ feedback gain on the phugoid roots is to increase the frequency and reduce the damping, as illustrated by the root locus sketch in Figure 9. The short-period roots are essentially unchanged for practical values of the $\delta_e / \Delta\hat{\theta}$ gain.

The phugoid damping is effectively changed by the use of $\delta_e / \dot{\hat{\theta}}$ and δ_p / u feedback gains, also illustrated in Figure 9. Thus, at each of the three phugoid frequencies, it was planned to vary the phugoid damping ratio through combinations of $\delta_e / \dot{\hat{\theta}}$ and δ_p / u feedback gains.

2.3.3 Drag Characteristics

In References 5, 6, 9, 11, 12 and 13, it is shown that airspeed behavior, when the elevator is used to control attitude and altitude, is characterized by a first-order root which is stable for trim speeds higher than the minimum drag speed, but unstable for trim speeds below the minimum drag speed. Reference 11 shows that as the pilot increases the elevator gain for altitude errors, this first-order root approaches a limiting value (assuming linearized small perturbation equations) which is determined by the value of the low-frequency factor $1/T_{h_1}$ of the open-loop altitude-to-elevator transfer function numerator.

In the appendices of Reference 11, a systems analysis is made of multiple loop longitudinal control in the landing approach. It is assumed that the pilot uses the elevator to control attitude and that both the throttle and the elevator are used to correct errors in airspeed and altitude. The closed-loop transfer functions are derived for this pilot-airplane system in Appendix A of Reference 11. (However, there are several typographical errors in the summary equations A-28, A-29 and A-30, which may cause the reader some confusion.) In Appendix C of Reference 11, the somewhat simplified situation of attitude and altitude control with elevator and airspeed control with throttle is analyzed and a numerical example is presented which again identifies $1/T_{h_1}$ as a parameter important to system stability and

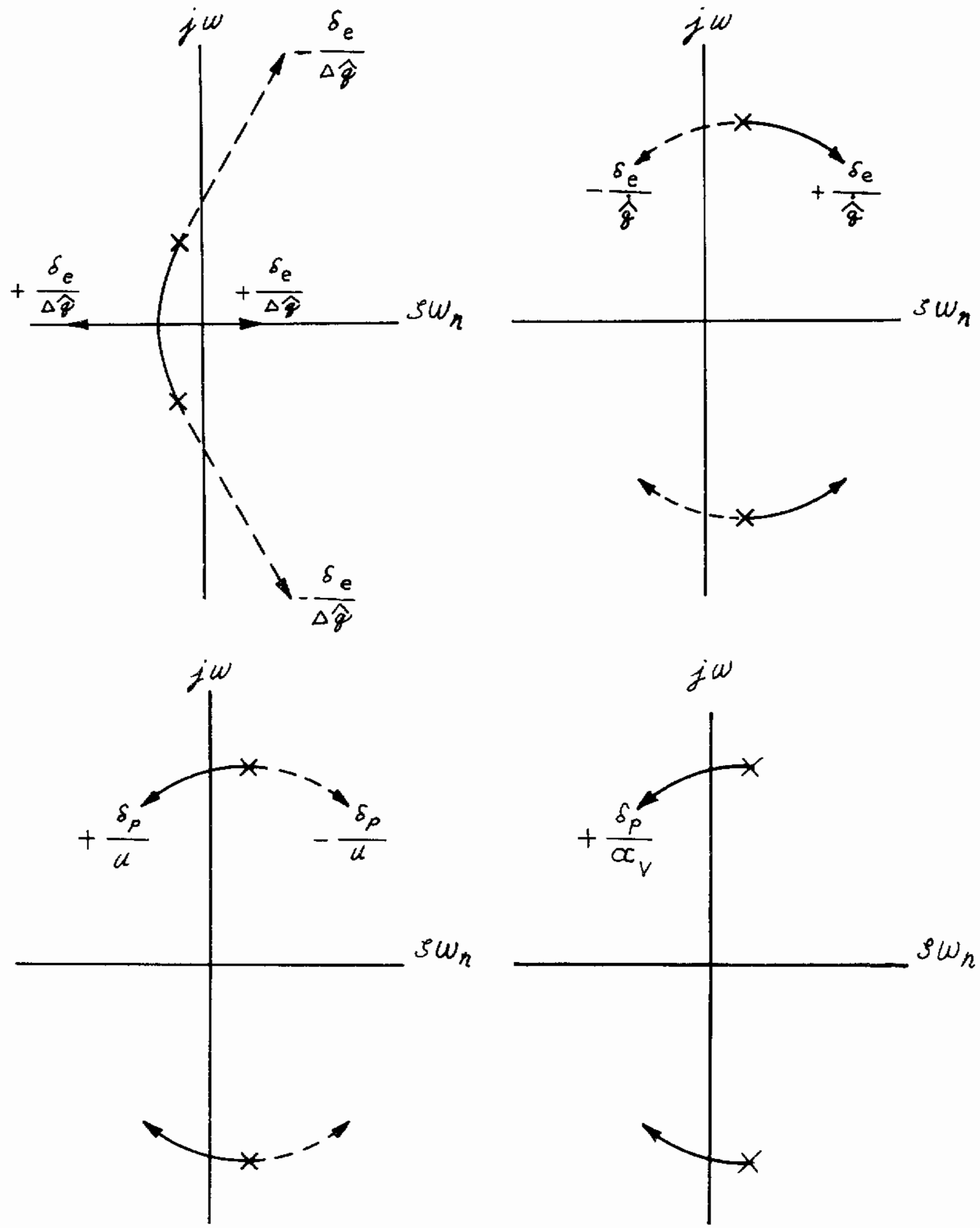


Figure 9. EFFECT OF $\frac{\delta_e}{\Delta\hat{q}}$, $\frac{\delta_e}{\dot{\hat{q}}}$ $\frac{\delta_p}{\alpha_V}$ AND $\frac{\delta_p}{u}$ FEEDBACK GAINS ON PHUGOID ROOTS

pilot work load. This analysis shows that stable flight on the backside of the power-required curve is possible if a certain minimum gain is maintained in the throttle-to-airspeed error loop. The magnitude of this throttle gain is directly related to the value of $1/T_{h_1}$.

In view of this theoretical background and the experimental results of References 40 and 46, it was decided to use $1/T_{h_1}$ as the open-loop airplane parameter to be systematically investigated in the flight program.

Since the parameter $\frac{d\left(\frac{T}{W}\right)}{dU} \sim \frac{1}{Kts}$ has been used to describe the results of other flight-test programs, it is desirable to relate $1/T_{h_1}$ to this parameter. In Reference 46, the following equation is developed:

$$\frac{1}{T_{h_1}} \doteq \frac{g}{1.69} \frac{d\left(\frac{T}{W}\right)}{dU} \sim \frac{1}{sec} \qquad (1)$$

Computing equations will now be derived for $1/T_{h_1}$, including the stability derivatives which were parameters in the flight program. The derivation assumes the equations of motion used in Reference 46 with the addition of a term for $M_{\dot{u}}$. The numerator to be factored is a cubic:

$$AS^3 + BS^2 + CS + D = 0 \qquad (2)$$

The coefficients can also be written in terms of the roots of the equation:

$$AS^3 + BS^2 + CS + D = S^3 + (\lambda_1 + \lambda_2 + \lambda_3)S^2 + (\lambda_1\lambda_2 + \lambda_1\lambda_3 + \lambda_2\lambda_3)S + \lambda_1\lambda_2\lambda_3 = 0 \qquad (3)$$

Assume $\lambda_2 \cong -\lambda_3$, (which is valid for aft-tailed configurations such as the T-33) and that the relative magnitude of the roots is:

$$|\lambda_2| \approx |\lambda_3| >> |\lambda_1| \qquad (4)$$

Then

$$\lambda_1 \approx \frac{\lambda_1 \lambda_2 \lambda_3}{\underbrace{\lambda_1 \lambda_2 + \lambda_1 \lambda_3}_{\approx 0} + \lambda_2 \lambda_3} = \frac{D}{C} \tag{5}$$

If stability derivatives are substituted for D and C, and the expression is simplified by eliminating terms involving ($M_q + M_{\dot{\alpha}}$), then the following expression for λ_1 or $1/T_{h_1}$ is obtained:

$$\frac{1}{T_{h_1}} \cong \frac{-\left(M_w Z_{\delta_{ES}} - M_{\delta_{ES}} Z_w\right) X_u' + \left(M_u' Z_{\delta_{ES}} - Z_u' M_{\delta_{ES}}\right)\left(X_u - \frac{g}{V}\right) + \left(M_w Z_u' - M_u' Z_w\right) X_{\delta_{ES}}}{\left(M_w Z_{\delta_{ES}} - M_{\delta_{ES}} Z_w\right) + \left[\left(X_w - \frac{g}{V}\right) Z_{\delta_{ES}} - Z_w X_{\delta_{ES}}\right] M_{\dot{u}}'} \tag{6}$$

where the primed derivatives represent both the aerodynamic and the engine effects:

$$X_u' = X_u + T_u \cos \xi \qquad M_u' = M_u + \frac{\partial i^m}{I_{YY}} T_u$$

$$Z_u' = Z_u - T_u \sin \xi \qquad M_{\dot{u}}' = M_{\dot{u}} + \frac{\partial i^m}{I_{YY}} T_{\dot{u}} \tag{7}$$

For the configurations where $M_{\dot{u}}'$ is zero, Equation (6) simplifies to:

$$\frac{1}{T_{h_1}} \approx -X_u' + \left(X_w - \frac{g}{V}\right) \frac{\left(M_u' Z_{\delta_{ES}} - M_{\delta_{ES}} Z_u'\right)}{\left(M_w Z_{\delta_{ES}} - M_{\delta_{ES}} Z_w\right)} + X_{\delta_{ES}} \frac{\left(M_w Z_u' - M_u' Z_w\right)}{\left(M_w Z_{\delta_{ES}} - M_{\delta_{ES}} Z_w\right)} \tag{8}$$

If M_u' is assumed zero and $M_{\delta_{ES}} Z_w \gg M_w Z_{\delta_{ES}}$, then Equation (8) simplifies to:

$$\frac{1}{T_{h_1}} \approx -X_u' + \left(X_w - \frac{g}{V}\right) \frac{Z_u'}{Z_w} + X_{\delta_{ES}} \frac{M_w}{M_{\delta_{ES}}} \frac{Z_u'}{Z_w} \tag{9}$$

From these computing equations and the root locus sketches of Figure 9, it is evident that the stability derivative X_u' has a direct effect on both $1/T_{h_1}$ and the phugoid damping ratio. Values of X_u' that make $1/T_{h_1}$

negative (i.e., backside operation) also cause the phugoid damping ratio to be less stable. Since both the phugoid damping ratio and $1/T_{h_1}$ are of possible significance to longitudinal handling qualities, it was considered desirable to make independent variations of each of these parameters.

Essentially independent control of the phugoid damping ratio is possible through use of the stability derivative $M'_{\dot{u}}$. Note that although $M'_{\dot{u}}$ appears in Equation (6) for $1/T_{h_1}$, it is not very effective in changing $1/T_{h_1}$ unless $X_{\delta_{ES}}$ is large.

The experimental procedure adopted for part of the program was to vary X'_u with the δ_p/u gain for each of three values of $M'_{\dot{u}}$ obtained through the $\delta_e/\hat{\dot{q}}$ gain. In this way, essentially the same values of $1/T_{h_1}$ were evaluated for three different values of phugoid damping ratio.

Independent control of $1/T_{h_1}$ was possible through the control derivative $X_{\delta_{ES}}$. The control derivatives do not affect the roots of the system characteristic equation; thus, $1/T_{h_1}$ can be changed independently of the phugoid damping ratio through the δ_p/δ_{ES} gain. It should be noted from Equation (8) that the effect of $X_{\delta_{ES}}$ on $1/T_{h_1}$ is weighted by $(M_w Z'_{\dot{u}} - M'_{\dot{u}} Z_w) \doteq \frac{1}{g}\omega_{sp}^2 \omega_p^2$. Thus, $X_{\delta_{ES}}$ causes the largest changes in $1/T_{h_1}$ when both the short-period and phugoid frequencies are high.

The experimental procedure adopted for the second part of the program was to use the δ_p/u gain to establish certain reference values of phugoid damping ratio and $1/T_{h_1}$, and then to both increase and decrease $1/T_{h_1}$ from each of these reference values through use of the δ_p/δ_{ES} gain.

In the flight program of Reference 46, $1/T_{h_1}$ was varied through X_w or the δ_p/α feedback gain. The pilot's comments indicated that, when $1/T_{h_1}$ was made negative through X_w, he had to use particular care in coordinating throttle inputs during turns and on the glide slope, in order to maintain constant airspeed. It occurred to the author that if this situation should occur on a production aircraft it might be improved through the use of a stick-to-throttle interconnect. The effect would be to make $1/T_{h_1}$ positive by augmenting $X_{\delta_{ES}}$. If the time lag between pilot-initiated stick inputs and the engine thrust response could be matched to the equivalent time lag of the airplane angle-of-attack response, then, with proper gain, such a system would automatically compensate for drag changes resulting from pilot-commanded angle-of-attack changes and the longitudinal forces would be kept in balance during maneuvers. The normal engine time lag could be used to advantage to match the airplane short-period lag, instead of serving as a destabilizing factor, as in auto-throttle systems.

The low-pass filter described in Figure 5 was fabricated and installed in the T-33 system as shown in Figure 4, so that the elevator stick command to the drag petals could be filtered and thus permit simulation of a filtered stick-to-throttle interconnect. A limited number of tests were conducted of combinations of δ_p / α and filtered δ_p / δ_{ES} gain to explore the feasibility of this system.

SECTION III
EXPERIMENTAL RESULTS

3.1 IDENTIFICATION OF CONFIGURATIONS EVALUATED

At the beginning of each evaluation, oscillograph records were taken to facilitate measurement of the following parameters used to identify the configurations.

1. Short-period frequency and damping ratio; ω_{SP}, ζ_{SP}
2. Phugoid frequency and damping ratio; ω_P, ζ_P
3. Elevator feel system gradient; F_{ES}/δ_{ES}
4. Elevator control gain; δ_e/δ_{ES}
5. Drag system gains; δ_P/u, δ_P/α, δ_P/δ_{ES}

The records were taken at 160 kts indicated airspeed at 5500 ft pressure altitude, and consisted of elevator stick force pulses and doublets, and stick position steps.

The free responses to elevator stick force doublets and pulses were analyzed by the transient peak or time-ratio methods of Reference 35. The resulting frequency and damping ratio measurements represent the best second-order fit to the angle-of-attack response in the short-period mode, and the best second-order fit to the incremental dynamic pressure response in the phugoid mode. The stick doublet input has most of its energy at high frequency and so was used to excite the short-period mode while causing a minimum of disturbance to the phugoid mode. Stick-force pulse inputs of 2-3 sec pulse duration were used to excite the phugoid mode through small airspeed and attitude perturbations. The airplane would then oscillate in the phugoid mode without causing a change in the steady state or trim speed. The phugoid frequency and damping ratio measurements thus obtained are presented in Tables I and II. It should be appreciated that these measurements are subject to variability caused by turbulence on particular records. The short-period measurements were made to verify that the nominal values were being maintained.

The ratios F_{ES}/δ_{ES} and δ_e/δ_{ES} were measured from the responses to elevator stick step inputs.

The values of the variable stability and variable drag system gains were determined from the step and pulse records, together with special ground and flight calibration records.

The values of $1/T_{h_1}$ listed in Tables I and II were calculated by substituting augmented stability derivatives into the computing equations defined in Paragraph 2.3.3. The augmented stability derivatives were calculated from basic T-33 stability derivatives, plus increments equal to the feedback gains multiplied by the appropriate control derivatives.

A total of 100 configurations were evaluated, of which 63 were at the high short-period frequency and 37 were at the low short-period frequency. (See Tables I and II, respectively.) The configurations are arranged in lettered groups according to phugoid frequency and the feedback gain combinations. In a given group, the configurations are arranged in the order of the δ_p/u gain values. In several cases, there is only one configuration in a group. These configurations represent special cases and will be discussed individually. To facilitate reference to the various groups, they are labeled alphabetically, starting with Table I and continuing through Table II. Groups A - M are contained in Table I, and groups N - V are contained in Table II. The key (located on page 29 and repeated on page 30) will identify the configurations in each group.

TABLE I

IDENTIFICATION OF CONFIGURATIONS TESTED

SHORT PERIOD: ω_{SP} = 2.46 RAD/SEC

ζ_{SP} = 0.45

NOTE:

NUMBERS IN PARENTHESES ARE $M_{\delta_{ES}}$ AVERAGES FOR EACH GROUP.
UNDERLINED VALUES NOT INCLUDED IN AVERAGES.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
FLT. NO. CONFIG.	PILOT RATING	SAFETY PILOT RATING	ω_{n_p} RAD/SEC	ζ_p	$\delta_e/\Delta\dot{\psi}$ RAD/FT/SEC	$\delta_e/\dot{\psi}$ RAD/FT/SEC	δ_p/u RAD/FT/SEC	δ_p/δ_{ES} RAD/INCH	δ_p/α RAD/RAD	$1/T_{h_1}$ 1/SEC	F_{ES}/δ_{ES} LB/INCH	$M_{\delta_{ES}}$ RAD/SEC²/IN	DATE
GROUP A												(0.221)	
404-2	2.0	2.5	0.185	0.49	0	0	0.036	0	0	0.1580	7.25	0.243	8-19-64
400-1	3.5	4-3	0.146	0.29	0	0	0.026	0	0	0.0990	7.95	0.128	7-31-64
405-1	2.5	2.5	0.157	0.40	0	0	0.026	0	0	0.1030	7.09	0.269	8-19-64
404-1	2.0	2.0	0.147	0.35	0	0	0.0175	0	0	0.0740	7.28	0.234	8-19-64
424-1	2.0	3-2	0.185	0.40	0	0	0.0175	0	0	0.0751	7.60	0.269	9-4-64
403-2	2.0	4.0	0.139	0.26	0	0	0.0095	0	0	0.0541	7.06	0.243	8-18-64
402-1	4.5	3.5	0.150	-0.037	0	0	-0.0098	0	0	-0.0215	7.00	0.164	8-18-64
394-1	4.0	-	0.155	-0.016	0	0	-0.0122	0	0	-0.0261	13.90	0.164	7-27-64
403-1	6.5	5.0	0.143	-0.12	0	0	-0.0223	0	0	-0.0627	6.88	0.234	8-18-64
400-2	9.0	8-9	0.170	-0.25	0	0	-0.0262	0	0	-0.0860	7.94	0.170	7-31-64
405-2	8.0	7.0	0.145	-0.15	0	0	-0.0262	0	0	-0.0872	7.06	0.280	8-19-64
402-2	10.0	9.0	0.183	-0.27	0	0	-0.0379	0	0	-0.131	7.10	0.243	8-18-64
406-1	10.0	10.0	0.180	-0.38	0	0	-0.054	0	0	-0.170	7.11	0.234	8-20-64
GROUP B												(0.257)	
420-1	2.5	2.5	0.185	0.046	0	0.00277	0.0175	0	0	0.0737	6.79	0.234	9-2-64
422-1	3.0	3.5	0.164	0.074	0	0.00277	0.0175	0	0	0.0737	7.36	0.234	9-2-64
419-2	5.5	7.0	0.138	-0.15	0	0.00277	-0.0052	0	0	-0.00419	6.88	0.280	9-1-64
418-1	8.0	8-9	0.149	-0.35	0	0.00277	-0.0182	0	0	-0.0482	7.15	0.305	8-31-64
421-1	8.5	9-8	0.171	-0.40	0	0.00277	-0.0279	0	0	-0.0826	7.28	0.234	9-2-64
GROUP C												(0.272)	
420-2	4.0	3-4	0.167	0.57	0	-0.00277	0.0 75	0	0	0.0859	6.58	0.243	9-2-64
424-2	3.0	8-9	0.164	0.58	0	-0.00277	0.0175	0	0	0.0860	7.00	0.280	9-4-64
419-1	4.0	4-3	0.177	0.32	0	-0.00277	-0.0052	0	0	-0.00405	7.11	0.269	9-1-64
418-2	5.0	6.0	0.157	0.07	0	-0.00277	-0.0182	0	0	-0.0554	6.89	0.317	8-31-64
422-2	4.0	3.5-4	0.155	0.17	0	-0.00277	-0.0182	0	0	-0.0557	7.30	0.280	9-2-64
421-2	7.0	7-8	0.163	0	0	-0.00277	-0.0279	0	0	-0.0841	6.87	0.243	9-2-64
GROUP D												(0.253)	
416-1	5.0	5-6	0.155	-0.	0	0	-0.0142	-0.243	0	-0.0228	7.49	0.305	8-28-64
416-2	7.0	5.0	0.152	-0.09	0	0	-0.0142	0.243	0	-0.0487	7.30	0.465	8-28-64
429-1	5.5	5-6	0.172	-0.	0	0	-0.0142	-0.180	0	-0.0234	7.15	0.234	9-14-64
429-2	4.5	4.5	0.153	-0.069	0	0	-0.0142	0.162	0	-0.0484	6.83	0.317	9-14-64
460-2	8.0	7.0	0.161	-0.28	0	0	-0.0311	-0.192	0	-0.0911	6.97	0.207	10-15-64
GROUP E												(0.253)	
431-1	3.5	2.5-3	0.343	0.14	-0.00420	0	0.036	0	0	0.136	6.80	0.283	9-15-64
428-2	5-8	7.5-8	0.330	0	-0.00420	0	0.0175	0	0	0.0858	7.20	0.317	9-14-64
430-2	2.5	3.0	0.331	0.11	-0.00420	0	0.0175	0	0	0.0857	6.87	0.317	9-15-64
446-1	4.0	4-5	0.340	-0.012	-0.00420	0	0.0095	0	0	0.0403	6.51	0.305	9-30-64
396-2	2.0	-	0.325	-0.005	-0.00420	0	0	0	0	0.0164	7.86	0.170	7-28-64
414-1	4.0	3.5	0.326	-0.06	-0.00420	0	0	0	0	0.0137	7.55	0.269	8-27-64
425-2	4.5	4.5	0.321	-0.06	-0.00420	0	0	0	0	0.0162	6.80	0.317	9-11-64
452-1	4.0	2.0	0.324	0.01	-0.00420	0	0	0	0	0.0133	6.80	0.340	10-7-64
441-1	4.0	4.0	0.306	-0.05	-0.00420	0	-0.008	0	0	-0.0140	6.16	0.375	9-28-64
430-1	6.5	5.5	0.335	-0.14	-0.00420	0	-0.0182	0	0	-0.0480	7.05	0.269	9-15-64
431-2	10.0	10.0	0.340	-0.22	-0.00420	0	-0.031	0	0	-0.106	6.94	0.317	9-15-64

TABLE I (Cont.)

IDENTIFICATION OF CONFIGURATIONS TESTED

SHORT PERIOD: ω_{SP} = 2.46 RAD/SEC

ζ_{SP} = 0.45

1	2	3	4	5	6	7	8	9	10	11	12	13	14
FLT. NO. CONFIG.	PILOT RATING	SAFETY PILOT RATING	ω_{n_p} RAD/SEC	ζ_p	$\delta_e/\Delta\hat{q}$ RAD/FT/SEC	$\delta_e/\hat{\dot{q}}$ RAD/FT/SEC	δ_p/u RAD/FT/SEC	δ_p/δ_{FS} RAD/INCH	δ_p/α RAD/RAD	$1/T_{h_1}$ 1/SEC	F_{ES}/δ_{ES} LB/INCH	$M_{\delta_{ES}}$ $\frac{\text{RAD/SEC}^2}{\text{IN}}$	DATE
GROUP F													
437-2	6.5	5-6	0.346	0.086	-0.00420	-0.00560	0	0	0	0.0163	6.66	0.243	9-22-64
GROUP G												(0.281)	
458-2	8.0	6.0	0.342	0.05	-0.00420	0	0.0175	0.275	0	-0.0156	6.97	0.280	10-14-64
458-1	2.5	3.0	0.296	0.09	-0.00420	0	0.0175	-0.313	0	0.170	6.90	0.269	10-14-64
399-1	10.0	-	0.319	0.037	-0.00420	0	0	0.243	0	-0.151	7.43	0.128	7-30-64
439-2	5.5	5.5	0.315	-0.037	-0.00420	0	0	0.154	0	-0.0333	6.91	0.317	9-23-64
439-1	4.0	4-3	0.312	-0.035	-0.00420	0	0	-0.137	0	0.0573	6.96	0.269	9-23-64
399-2	5.0	-	0.318	0.01	-0.00420	0	0	-0.243	0	0.165	7.76	0.170	7-30-64
438-1	9.0	9.0	0.313	-0.13	-0.00420	0	-0.0182	0.178	0	-0.105	7.21	0.269	9-22-64
438-2	3.0	3.5	0.322	-0.18	-0.00420	0	-0.0182	-0.10	0	-0.0193	6.95	0.280	9-22-64
441-2	5.5	5-6	0.343	-0.16	-0.00420	0	-0.0182	-0.10	0	-0.0191	6.47	0.280	9-28-64
460-1	9.0	7-8	0.340	-0.18	-0.00420	0	-0.0311	-0.313	0	0.0108	7.18	0.269	10-15-64
GROUP H												(0.281)	
452-2	5.0	3.0	0.352	0.08	-0.00420	0	0	0	4.54	-0.0038	7.00	0.317	10-7-64
454-1	5.0	8.0	0.340	0.15	-0.00420	0	0	0	7.00	-0.0128	7.20	0.269	10-8-64
455-1	6.0	5.0	0.340	0.15	-0.00420	0	0	-0.152[F]	6.62	0.0348	7.14	0.269	10-8-64
461-2	10.0	10.0	0.348	0.13	-0.00420	0	0	0.400[F]	7.00	-0.222	6.58	0.200	10-16-64
454-2	4.0	6.0	0.340	0.15	-0.00420	0	0	-0.152	7.00	0.0422	7.20	0.280	10-8-64
461-1	4.0	2-3	0.348	0.18	-0.00420	0	0	-0.394[F]	7.00	0.159	6.40	0.192	10-16-64
462-1	2.0	3.0	0.346	0.15	-0.00420	0	0	-0.394[F]	6.97	0.151	7.28	0.192	10-16-64
GROUP I												(0.284)	
434-2	6.5	3.5-4	0.480	0.024	-0.0090	0	0.036	0	0	0.160	7.14	0.243	9-18-64
427-1	7.0	5-6	0.411	-0.03	-0.0090	0	0.0175	0	0	0.0725	7.14	0.276	9-14-64
414-2	7.0	5-10	0.521	0.017	-0.0090	0	0	0	0	0.0165	7.04	0.280	8-27-64
425-1	7.0	4-5	0.421	-0.034	-0.0090	0	0	0	0	0.0131	6.80	0.305	9-11-64
394-2	9.0	-	0.431	-0.012	-0.0090	0	-0.0122	0	0	-0.0314	17.60	0.317	7-27-64
GROUP J												(0.284)	
445-1	8.0	6.5	DIVERGENT $\lambda_1 = .194$	CONVERGENT $\lambda_2 = -.194$	0.00276	0	0	0	0	0.0133	6.81	0.234	9-30-64
GROUP K													
398-1	3.0	-	0.104	0.27	0.000750	0	0	0	0	0.0134	8.15	0.135	7-28-64
GROUP L													
423.1	10.0	9.0	0.165	0.58	0	-0.00277	0.0175	0	0	0.0735	7.21	0.164	9-4-64
GROUP M													
423-2	9.0	8-9	0.140	-0.45	0	0.00277	-0.0279	0	0	-0.0943	6.78	0.280	9-4-64

TABLE II

IDENTIFICATION OF CONFIGURATIONS TESTED

SHORT PERIOD: ω_{sp} = 1.46 RAD/SEC

ζ_{sp} = 0.45

NOTE:

NUMBERS IN PARENTHESES ARE $M_{\delta_{ES}}$ AVERAGES FOR EACH GROUP. UNDERLINED VALUES NOT INCLUDED IN AVERAGES.

1	2	3	4		6	7	8	9	10	11	12	13	14
FLT. NO. CONFIG.	PILOT RATING	SAFETY PILOT RATING	ω_{n_p} RAD/SEC	ζ_p	$\delta_e/\Delta\hat{q}$ RAD/FT/SEC	$\delta_e/\dot{\hat{q}}$ RAD/FT/SEC	δ_p/u RAD/FT/SEC	δ_p/δ_{ES} RAD/INCH	δ_p/α RAD/RAD	$1/T_{h_1}$ 1/SEC	F_{ES}/δ_{ES} LB/INCH	$M_{\delta_{ES}}$ $\frac{RAD/SEC^2}{IN}$	DATE
GROUP N												(0.140)	
409-1	4.0	3.5-4	0.160	0.45	0	0	0.0308	0	0	0.119	7.50	0.079	8-24-64
407-2	4.0	4-3	0.146	0.22	0	0	0.0175	0	0	0.0860	7.07	0.170	8-21-64
412-2	4.5	3.5	0.154	0.13	0	0	0.0052	0	0	0.0372	7.34	0.170	8-26-64
408-1	6.0	5.0	0.112	0.11	0	0	-0.0052	0	0	-0.00411	6.95	0.093	8-24-64
407-1	7.0	4-5	0.124	-0.10	0	0	-0.0182	0	0	-0.0493	7.07	0.128	8-21-64
412-1	10.0	9.5	0.125	-0.15	0	0	-0.0223	0	0	-0.0617	7.16	0.164	8-26-64
408-2	9.5	8.0	0.164	-0.28	0	0	-0.0279	0	0	-0.0937	6.77	0.170	8-24-64
GROUP O												(0.164)	
436-1	4.0	3.0	0.135	0.10	0	0.00140	0.0175	0	0	0721	7.31	0.164	9-21-64
426-1	6.0	4.5-5	0.133	-0.25	0	0.00140	-0.0052	0	0	-0.00442	7.06	0.199	9-11-64
437-1	8.0	7-8	0.140	-0.40	0	0.00140	-0.0182	0	0	-0.0479	7.24	0.128	9-22-64
GROUP P												(0.151)	
427-2	4.0	4-5	0.219	0.50	0	-0.00140	0.0175	0	0	0.0857	6.82	0.140	9-14-64
426-2	3.5	4.0	0.166	0.29	0	-0.00140	-0.0052	0	0	-0.00432	6.90	0.170	9-11-64
434-1	5.5	5-4	0.139	0.15	0	-0.00140	-0.0182	0	0	-0.0478	7.01	0.128	9-18-64
428-1	9.0	9-8	0.150	-0.065	0	-0.00140	-0.0262	0	0	-0.0756	7.39	0.164	9-14-64
GROUP Q													
417-1	5.0	6.0	0.130	-0.18	0	0	0	-0.243	0	0.0188	7.52	0.199	8-28-64
417-2	7.0	7-8	0.146	-0.09	0	0	-0.0142	0.243	0	-0.0448	7.34	0.243	8-28-64
GROUP R												(0.197)	
440-2	4.5	7.0	0.336	0.025	-0.00168	0	0.0175	0	0	0.0853	6.72	0.207	9-24-64
415-1	3.5	4-3	0.285	-0.100	-0.00168	0	0	0	0	0.0136	7.03	0.164	8-27-64
436-2	3.5	3.0	0.300	-0.093	-0.00168	0	0	0	0	0.0165	7.10	0.170	9-21-64
444-2	5-5.5	5.0	0.312	-0.13	-0.00168	0	0	0	0	0.0163	7.41	0.207	9-29-64
442-1	6.5	3.5-4	0.316	-0.22	-0.00168	0	-0.0143	0	0	-0.0341	7.11	0.164	9-29-64
447-1	7.0	5.0	0.346	-0.27	-0.00168	0	-0.0182	0	0	-0.0466	24.7	0.199	10-1-64
448-2	10.0	10.0	0.320	-0.23	-0.00168	0	-0.0182	0	0	-0.0552	6.50	0.207	10-1-64
453-1	10.0	6.0	0.351	-0.28	-0.00168	0	-0.0182	0	0	-0.0462	6.88	0.199	10-7-64
456-1	7.0	4-5	0.339	-0.25	-0.00168	0	-0.0182	0	0	-0.0467	7.11	0.199	10-13-64
442-2	8.0	9-10	0.323	-0.28	-0.00168	0	-0.0143	0	0	-0.0871	6.62	0.243	9-29-64
446-2	10.0	10.0	0.277	-0.29	-0.00168	0	-0.0379	0	0	-0.134	6.61	0.207	9-30-64
GROUP S												(0.204)	
449-2	6.5	9.0	0.314	-0.071	-0.00168	0	0	0.227	0	-0.0270	6.73	0.207	10-2-64
449-1	5.5	6.0	0.344	-0.17	-0.00168	0	0	-0.297	0	0.0611	6.92	0.189	10-2-64
447-2	10.0	10.0	0.312	-0.20	-0.00168	0	-0.0182	0.227	0	-0.0989	9.42	0.207	10-1-64
448-1	9.0	7.0	0.320	-0.20	-0.00168	0	-0.0182	-0.297	0	0.000537	7.15	0.199	10-1-64
453-2	7-8	7-6	0.320	-0.22	-0.00168	0	-0.0182	-0.297	0	0.00102	7.00	0.207	10-7-64
456-2	5.5	4.0	0.357	-0.24	-0.00168	0	-0.0182	-0.297	0	0.00102	6.74	0.207	10-13-64
GROUP T													
444-1	9.5	7-8	0.397	-0.20	-0.00282	0	0	0	0	0.0132	6.55	0.164	9-29-64
GROUP U													
415-2	4.5	4-3	0.479	-0.12	-0.00348	0	0	0	0	0.0165	7.00	0.170	8-27-64
440-1	10.0	9.5	0.423	-0.16	-0.00348	0	0	0	0	0.0134	6.69	0.199	9-24-64
443-1	9.0	7.0	0.450	-0.22	-0.00348	0	0	0	0	0.0133	6.81	0.164	9-29-64
443-2	9.5	9-10	0.437	-0.27	-0.00348	0	-0.0182	0	0	-0.0563	6.02	0.243	9-29-64
GROUP V													
445-2	8.5	8.5	DIVERGENT $\lambda_1 \doteq .258$	CONVERGENT $\lambda_2 \doteq -.258$	-0.00120	0	0	0	0	0.0163	6.99	0 170	9-30-64

Key for Table I — [$\omega_{sp} \doteq 2.46$ rad/sec, $\zeta_{sp} \doteq 0.45$]

Group	ω_p	$M_{\dot u} \sim (\zeta_p)$	$X_u \sim (\zeta_p, 1/T_{h_1})$	$X_{\delta_{ES}} \sim (1/T_{h_1})$	$X_w \sim (\zeta_p, 1/T_{h_1})$
A	.15	0	Varied	0	T-33
B	.15	+	Varied	0	T-33
C	.15	-	Varied	0	T-33
D	.15	0	Varied	Varied	T-33
E	.32	0	Varied	0	T-33
F	.32	-	T-33	0	T-33
G	.32	0	Varied	Varied	T-33
H	.32	0	T-33	Filtered	Varied
I	.45	0	Varied	0	T-33
J	$\lambda \doteq \pm.194$	0	T-33	0	T-33
K	.10	0	T-33	0	T-33
L	.15	-	Stable	0	T-33 }
M	.15	+	Unstable	0	T-33 } $\delta_e/\dot\alpha$ Gain failure

Key for Table II — [$\omega_{sp} \doteq 1.46$ rad/sec, $\zeta_{sp} \doteq 0.45$]

Group	ω_p	$M_{\dot u} \sim (\zeta_p)$	$X_u \sim (\zeta_p, 1/T_{h_1})$	$X_{\delta_{ES}} \sim (1/T_{h_1})$	$X_w \sim (\zeta_p, 1/T_{h_1})$
N	.15	0	Varied	0	T-33
O	.15	+	Varied	0	T-33
P	.15	-	Varied	0	T-33
Q	.15	0	Varied	Varied	T-33
R	.32	0	Varied	0	T-33
S	.32	0	Varied	Varied	T-33
T	.40	0	T-33	0	T-33
U	.45	0	Varied	0	T-33
V	$\lambda \doteq \pm.258$	0	T-33	0	T-33

Key for Table I — [$\omega_{SP} \doteq 2.46$ rad/sec, $\zeta_{SP} \doteq 0.45$]

Group	ω_P	$M_{\dot{u}} \sim (\zeta_P)$	$X_u \sim (\zeta_P, \frac{1}{T_{h_1}})$	$X_{\delta_{ES}} \sim (\frac{1}{T_{h_1}})$	$X_w \sim (\zeta_P, \frac{1}{T_{h_1}})$
A	.15	0	Varied	0	T-33
B	.15	+	Varied	0	T-33
C	.15	-	Varied	0	T-33
D	.15	0	Varied	Varied	T-33
E	.32	0	Varied	0	T-33
F	.32	-	T-33	0	T-33
G	.32	0	Varied	Varied	T-33
H	.32	0	T-33	Filtered	Varied
I	.45	0	Varied	0	T-33
J	$\lambda \doteq \pm .194$	0	T-33	0	T-33
K	.10	0	T-33	0	T-33
L	.15	-	Stable	0	T-33 }
M	.15	+	Unstable	0	T-33 } $\frac{\delta_e}{\alpha}$ Gain failure

Key for Table II — [$\omega_{SP} \doteq 1.46$ rad/sec, $\zeta_{SP} \doteq 0.45$]

Group	ω_P	$M_{\dot{u}} \sim (\zeta_P)$	$X_u \sim (\zeta_P, \frac{1}{T_{h_1}})$	$X_{\delta_{ES}} \sim (\frac{1}{T_{h_1}})$	$X_w \sim (\zeta_P, \frac{1}{T_{h_1}})$
N	.15	0	Varied	0	T-33
O	.15	+	Varied	0	T-33
P	.15	-	Varied	0	T-33
Q	.15	0	Varied	Varied	T-33
R	.32	0	Varied	0	T-33
S	.32	0	Varied	Varied	T-33
T	.40	0	T-33	0	T-33
U	.45	0	Varied	0	T-33
V	$\lambda \doteq \pm .258$	0	T-33	0	T-33

3.2 DISCUSSION OF RESULTS

3.2.1 Pilot Rating Data

The pilot rating assigned each configuration was based on the amount of effort required relative to the precision of flight-path control achieved. The pilot evaluated the effort, skill, concentration, and the practicability of any special control techniques required to accomplish the task, as well as his performance in actually accomplishing it. His rating also reflects whether or not a configuration possessed any characteristic which he considered potentially dangerous. The pilot also considered the response of the configuration to turbulence, as well as to his control inputs.

The pilot rating data obtained for the configurations with the high-frequency short period are plotted in Figures 10a - 15a and the ratings obtained for the configurations with the low short-period frequency are plotted in Figures 10b - 14b. The pilot ratings for the various configurations tested ranged from 2 (Acceptable, Satisfactory, Good) to 10 (Unflyable). It should be pointed out that the configurations were presented to the pilot in a random order without identification as to the parameters that were being altered.

The most severe rating degradation occurred when: (1) $1/T_{h_1}$ was made negative (backside of drag-velocity curve); (2) the phugoid mode was made either statically or dynamically unstable; (3) the phugoid frequency was made high through use of M_u and turbulence was encountered; and (4) the short-period frequency was decreased.

The major objections to each of the above-mentioned factors are as follows:

Negative $1/T_{h_1}$ (backside of drag-velocity curve) — control of airspeed and altitude to follow a specific flight path requires continuous closed-loop control with both throttle and elevator. The concentration and effort required increases as $1/T_{h_1}$ is made more negative.

Unstable Phugoid — Pilot must constantly close an attitude-to-elevator loop to stabilize the system. If the phugoid is made very unstable, it may be necessary for the pilot to close an airspeed-to-throttle loop in addition to the attitude-to-elevator loop.

Phugoid Frequency — The phugoid frequency was varied through use of M_u. When the phugoid frequency was made high, the pilot commented that the airplane would pitch abruptly in response to wind shear and horizontal gusts. When trying to follow the glide slope at low altitude, the pilot would prefer to have the airplane maintain attitude and stay on the glide slope during turbulence-induced airspeed fluctuations rather than have it pitch abruptly to maintain airspeed constant.

Low Short-Period Frequency — The airplane does not maintain angle of attack or attitude as well as when the short-period frequency is higher. The pilot must provide attitude stabilization and must overdrive the airplane to obtain satisfactory attitude response.

The pilot ratings for the configurations in each group will be discussed in detail in the following paragraphs. A key has been printed on the fold out flap of pages 29 and 30 which will serve to keep the reader oriented during the following discussion.

Groups A, B, C and N, O, P

In these groups, the stability derivatives X_u and $M_{\dot{u}}$ were used to effect independent variations of $1/T_{h_1}$ and phugoid damping. In Figures 10a and 10b, the pilot ratings for these configurations are related to $1/T_{h_1}$ and ζ_p for the two short-period frequencies. The phugoid frequency was nominally $\omega_p \doteq 0.15$ rad/sec for the data in these two figures.

There are three sets of curves in each of Figures 10a and 10b. These relate pilot rating to $1/T_{h_1}$, ζ_p to $1/T_{h_1}$, and pilot rating to ζ_p. In these figures, the data points with a common value of $M_{\dot{u}}$ have been faired by light lines. In making the plot of pilot rating vs phugoid damping ratio, the ratings were plotted vs damping ratio values taken from the faired lines of the ζ_p vs. $1/T_{h_1}$ plot. This was done because the measurements of phugoid damping ratio contain variability caused by the turbulence environment which existed during each calibration record.

The heavy lines in Figures 10a and 10b indicate how the pilot rating varied as a function of $1/T_{h_1}$ for constant ζ_p in the upper plots, and as a function of ζ_p for constant $1/T_{h_1}$ in the lower plots.

Considering the data and curves of Figures 10a and 10b, the major observation is that pilot rating is essentially independent of $1/T_{h_1}$

when this parameter is positive, but the ratings degrade sharply when $1/T_{h_1}$ is made negative. Also, the ratings are essentially independent of phugoid damping ratio for values greater than $\zeta_p \doteq 0.15$. For damping ratio values less than $\zeta_p = 0.15$, the pilot ratings show a degradation. The pilot was able to cope with quite unstable values of ζ_p at this phugoid frequency.

The degradation in rating at high values of phugoid damping indicated in the lower plot of Figure 10a was caused by the increased pitch response to high-frequency horizontal gusts. This situation resulted from the use of the stability derivative $M_{\dot{u}}$ and is discussed further in Section 3.2.5.

A further observation is that there is a degradation of approximately two ratings between the low-frequency, short-period data of Figure 10b and the high-frequency, short-period data of Figure 10a. This increment in rating is consistent with that obtained in Reference 46 for these two short-period frequencies.

Groups D and Q

In Groups D and Q, the stability derivatives X_u and $X_{\delta_{ES}}$ were used to effect independent variations of $1/T_{h_1}$ and phugoid damping. The pilot ratings for these configurations are plotted in Figures 11a and 11b in the same format established in Figures 10a and 10b.

The solid symbols in Figures 11a and 11b represent two different specific values of X_u with $X_{\delta_{ES}}$ equal to zero. These points have been transferred from the faired lines of Figures 10a and 10b. Using these points as reference, $X_{\delta_{ES}}$ was used to change $1/T_{h_1}$ without changing ζ_p . The short lines through the data points indicate the trend of pilot rating with $1/T_{h_1}$ that was established in Figures 10a and 10b for constant phugoid damping ratio. It is seen that these trends tend to be supported by the data in Figures 11a and and 11b. However, the magnitude of the change in $1/T_{h_1}$ was not large enough to cause significant rating changes in most of these cases.

Groups E, F, and R

In Groups E, F, and R, the phugoid frequency was increased to $\omega_p \doteq .32$ rad/sec through M_u, and variations of $1/T_{h_1}$ and ζ_p were effected through X_u. It was originally intended that independent variations of phugoid damping ratio would again be made through $M_{\dot{u}}$, however, the pitch response at high frequencies to horizontal gusts was so severe when M_u was used that only one configuration was evaluated in Group F. Thus, the degradation in the pilot rating data plotted in Figures 12a and 12b cannot be partitioned between $1/T_{h_1}$ and ζ_p.

The following observations can be made from the plots in Figures 12a and 12b: The higher-frequency short-period configurations of Figure 12a are preferred over the lower-frequency short-period configurations of Figure 12b, although the rating increment at a given value of $1/T_{h_1}$ is a little smaller than it was between Figures 10a and 10b. That the increment in rating should be smaller is somewhat surprising, since the phugoid mode was less damped for the configurations of Figure 12b. The pilot comments, however, indicate that the reason for this result is that the pitch response to horizontal gusts is much more severe for the high-frequency short-period configurations of Group E than it was for the low-frequency short-period configurations of Group R. This aspect is discussed further in Paragraph 3.2.5.

The response of the configurations in Group E to wind shear and turbulence was a significant factor in the pilot's evaluation, and contributes to the apparent scatter in the rating data, since the turbulence environment was not the same for all of the evaluations.

The pilot ratings of Figure 12b also show considerable scatter in the region of $1/T_{h_1} = -.05$ and $-.09$. These configurations are discussed in the following subsection as part of Group S.

Groups G and S

In Groups G and S, the stability derivatives X_u and $X_{\delta_{ES}}$ were used to effect independent variations of $1/T_{h_1}$ and phugoid damping at $\omega_p \doteq .32$ rad/sec for the two short-period frequencies respectively. The pilot ratings for these configurations are plotted in Figures 13a and 13b in the same format established in Figures 11a and 11b.

The solid symbols in Figures 13a and 13b represent specific values of X_u with $X_{\delta_{ES}}$ equal to zero. These points have been transferred from Figures 12a and 12b. Using these points as reference, $X_{\delta_{ES}}$ was used to change $1/T_{h_1}$ without changing the phugoid damping. The data of Figure 13a again establishes the independent effect of $1/T_{h_1}$ on pilot rating. The pilot rating is essentially independent of $1/T_{h_1}$ for positive values, but degrades sharply when $1/T_{h_1}$ is made negative. The data of Figure 13a also indicate that the pilot rating was sharply degraded when the the phugoid damping ratio was made more negative than $\zeta_p \doteq -0.15$.

The approach time histories of the configurations represented by the circles in Figure 13a have been scaled and the pilot's elevator and throttle control inputs have been spectral-analyzed. These time histories and the spectral content of the control motions are discussed in Section 3.2.4.

Although the pilot did experience control difficulties during the evaluation of the point at $1/T_{h_1}$ = .165 and $P.R.$ = 5, which are discussed in Paragraphs 3.2.2 and 3.2.4, his rating may also have been unfavorably biased by the circumstances under which this evaluation was conducted. This point was evaluated on Flight 399-2 and on this flight there was considerable distraction in the form of aileron feel servo kicks, erratic operation of the ILS localizer receiver, and traffic interference from other airplanes, all of which may have influenced the evaluation rating.

The pilot ratings for the configurations in Group S are plotted in Figure 13b. These data illustrate the established trend of pilot rating with $1/T_{h_1}$, but they also indicate unusual scatter. The evaluations in Group S were run in pairs on specific flights. The flight numbers are noted on the line connecting the two points evaluated on each flight, and the number 1 or 2 beside each point in Figure 13b indicates whether the configuration was the first or second to be evaluated on that flight. Although the pilot was consistent within a given flight in his preference for the more positive value of $1/T_{h_1}$, there was a large difference from day to day in his rating of the configurations represented by the diamond symbol.

Comparison of the wire transcription and detailed pilot comments for configurations 447-1 and 456-1 with those of configurations 448-2 and 453-1 reveals that the ratings were influenced by the turbulence environment and the control technique used during the IFR portion of the approach. Configurations 447-1 and 456-1 were evaluated in smooth-to-light turbulence during the IFR portion of the descent, while configurations 448-2 and 453-1 were evaluated in light-to-moderate turbulence during this portion of the approach. The turbulence excitation and the very unstable phugoid damping ratio, $\zeta_p = -.25$, combined to make the task more difficult on Flights 448 and 453 and contributed to the poor rating.

Another factor which seems to be significant was the control technique that the pilot tried to use during the IFR portion of the approach. In general, he tended to think of the jet penetration as a constant-throttle, constant-speed task at a mean rate of descent. He usually tried to control airspeed through pitch attitude during this portion of the approach and made throttle adjustments to achieve the desired mean rate of descent. However, for these configurations with very unstable phugoid modes, he found he had to use very large attitude changes to control the airspeed when using this technique. A more effective technique for configurations of this type was to use the elevator to stabilize the pitch attitude at the value which should maintain the mean rate of descent, and to use the throttle to control the airspeed. Both of these control actions will stabilize or increase the damping of the phugoid mode.

The pilot used the latter technique during at least part of the IFR descent for configurations 447-1 and 456-1 and the increased success is apparently reflected in the rating. On the other hand, he attempted to use the attitude-control-of-airspeed technique for configurations 448-2 and 453-1, and the lack of success in these cases contributed to the poor rating.

Groups I and U

In Groups I and U, the phugoid frequency was increased to $\omega_p \doteq .45$ rad/sec through M_u, while variations of $1/T_{h_1}$ and ζ_p were effected through X_u.

The high-frequency short-period points of Group I are plotted in Figure 14a and the low-frequency short-period points of Group U are plotted in Figure 14b.

With the exception of one point in Group U, all the configurations that had the high-frequency phugoid were rated unacceptable.

The configurations in Group I plotted in Figure 14a had essentially zero phugoid damping; thus, the rating trend indicated is primarily due to the change in $1/T_{h_1}$. The configurations in Group I were rated unacceptable because of the extreme pitch response to airspeed variations from trim. Especially objectionable is the pitch response of these configurations to wind shear and horizontal gusts during the approach. This aspect of these configurations is discussed further in Paragraph 3.2.5.

The three configurations in Group U that were rated unacceptable had phugoid damping ratios more unstable than $\zeta_p \doteq -.18$. The pilot comments for these configurations indicate that, even with attitude stabilization, there was a plunging oscillation during the IFR descent. This is assumed to mean that the closed-loop phugoid mode was lightly damped for these configurations. The pilot comments for the configuration in Group U that was rated 4.5 do not contain this reference to a plunging oscillation, presumably because the open-loop phugoid damping was higher; $\zeta_p = -.09$. Assuming this is the major reason for the relatively good pilot rating for this configuration, it would appear that the unacceptable ratings obtained for the other three configurations in this group were primarily caused by the very unstable phugoid damping and not necessarily because of the high phugoid frequency.

The configuration rated 4.5 had a more stable damping ratio because this configuration was evaluated before the filter of Figure 5 was installed in the $\delta_e/\Delta\hat{\varphi}$ channel. The phase shift of this filter contributed to the low phugoid damping ratio of the repeat configurations.

Group H

In Group H, the phugoid frequency was increased to $\omega_p \doteq .32$ rad/sec through M_u, and variations in $1/T_{h_1}$ were effected through X_w and $X_{\delta_{ES}}$. The solid symbols identify the configurations for which $X_{\delta_{ES}}$ was zero, and the subscript "F" by the open symbols indicates whether or not the low-pass filter described in Figure 5 was acting on the elevator stick command to the drag petals.

These configurations were evaluated to explore the effects of a stick-to-throttle interconnect.

The phugoid damping ratio of all of the configurations represented by circles was $\zeta_p \doteq .15$. The remaining configuration represented by a solid square had a phugoid damping ratio of $\zeta_p \doteq .07$. The damping ratio of this configuration was lower because a smaller value of the δ_p/α gain was used.

It is seen that the reference configuration represented by the solid circle symbol had sufficient drag due to angle of attack to cause the pilot to rate it 5 (Acceptable, Unsatisfactory, Poor). Through the use of the filtered stick command to the drag petals, this rating was increased to a 2 in smooth air, but when the opposite sign of the stick command was used, the pilot rating was degraded to 10.

Two configurations in this group were down-rated because of the pitch response to wind shear and the horizontal component of turbulence.

It is interesting to note that when large values of the δ_p/δ_{ES} gain were used with the filter, the airplane appeared to the pilot to have either large or very small drag due to angle of attack. He did note some peculiarity when making rapid stick inputs, which was probably due to the inexact match of the dynamics of the filter in the δ_p/δ_{ES} channel and the short-period dynamics.

Groups J and V

On Flight 445, the stability derivative M_u was used to alter the phugoid mode from a complex pair of roots into a pair of real roots, one of which was unstable. This was done for the high-frequency, short-period on configuration 1 of Flight 445 and for the low-frequency, short-period on configuration 2 of Flight 445. $1/T_{h_1}$ was positive for both configurations.

Thus, the configurations of Flight 445 had fair to good short-period dynamics, but the airplane would gradually diverge if trimmed and released. The rate of divergence is indicated by the root values listed in Tables I and II. In terms of time to double amplitude; configuration 445-1 required 3.57 sec and configuration 445-2 required 2.68 sec.

The pilot rated both of these configurations unacceptable (P.R. = 8 and 8.5, respectively) because they required continuous attitude and airspeed control. He remarked that they weren't really too bad as long as he stayed tight closed loop, but if he looked away for very long, then he would find himself in deep trouble and in danger of running out of control. These configurations are discussed further in the following section on pilot comments, and the time history of 445-1 is discussed in Paragraph 3.2.4.

Group K

On Flight 396-1, the phugoid frequency was decreased to $\omega_p \doteq .10$ rad/sec through M_u. The phugoid damping ratio was measured as $\zeta_p = .27$. The pilot remarked that he had very little stick force feel to indicate airspeed errors. However, this was a fairly minor objection and he rated the configuration a 3.

Group T

On Flight 444-1, the phugoid frequency was increased to $\omega_p \doteq .40$ rad/sec through M_u which also caused the phugoid damping ratio to decrease to $\zeta_p \doteq -.20$. This frequency was intermediate to the values used for Groups R and U. This configuration was evaluated immediately after the two configurations on Flight 443 which were in Group U. The pilot observed that it was quite similar to the configurations of Flight 443, in that it had a tendency for a plunging type of oscillation during the IFR descent, but this was neither as rapid nor as potentially divergent. His rating was 9.5 for this configuration.

Groups L and M

Configurations 1 and 2 of Flight 423 were intended to be members of Groups C and B, respectively. However, a failure occurred in the $\delta_e/\dot{\alpha}$ channel, which caused the short-period damping ratio to be reduced to $\zeta_{sp} \doteq .11$. The reduced short-period damping combined with the increased attitude response to horizontal gusts, caused by use of $M_{\dot{u}}$, resulted in configurations with severe pitch response to turbulence. The approaches were made in moderate turbulence and the pilot compared flying these configurations to riding a bucking bronco. The pilot ratings for these configurations were 10 and 9 respectively.

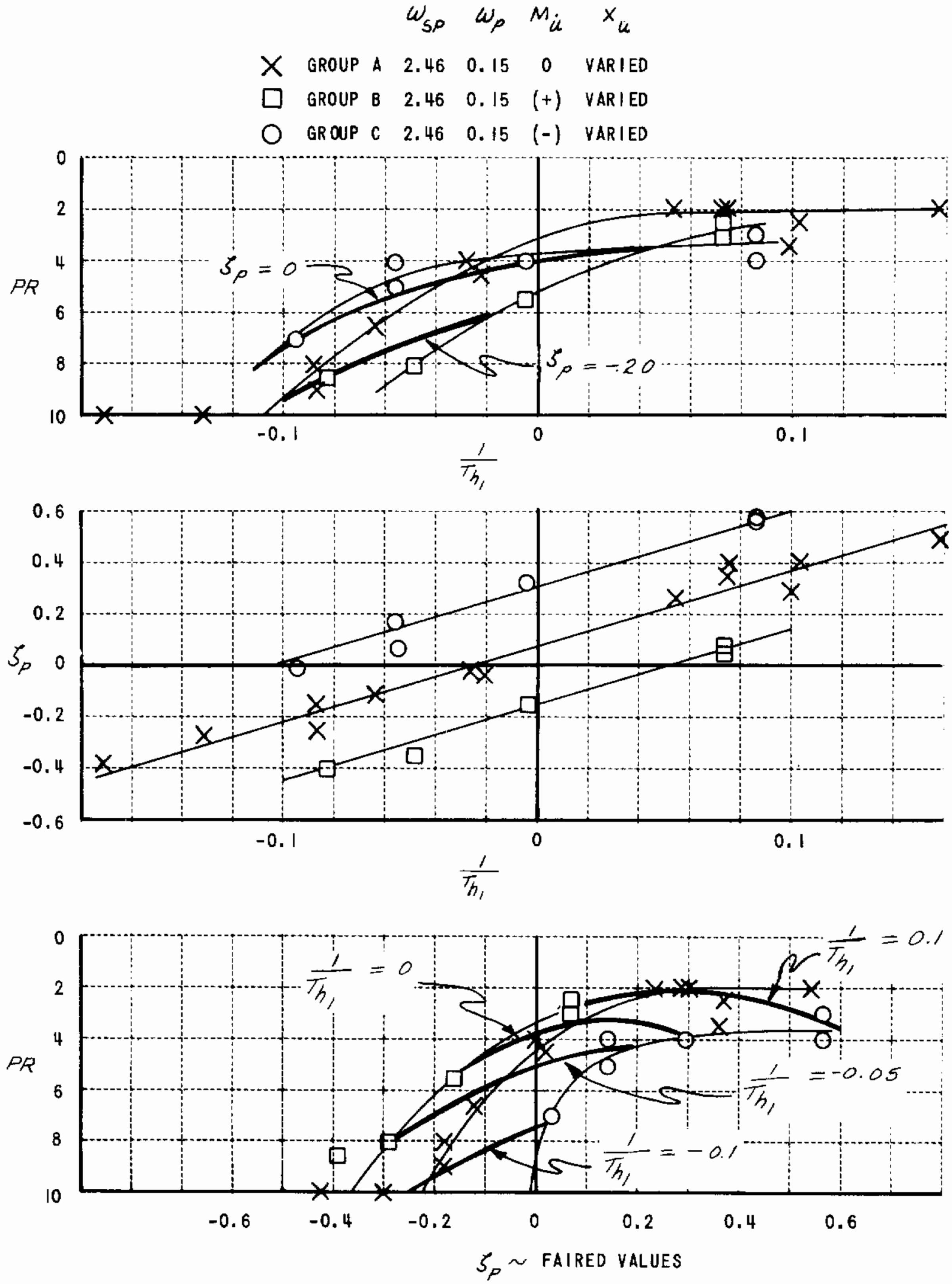


Figure 10a. PILOT RATING DATA OBTAINED FOR CONFIGURATIONS IN GROUPS A, B AND C

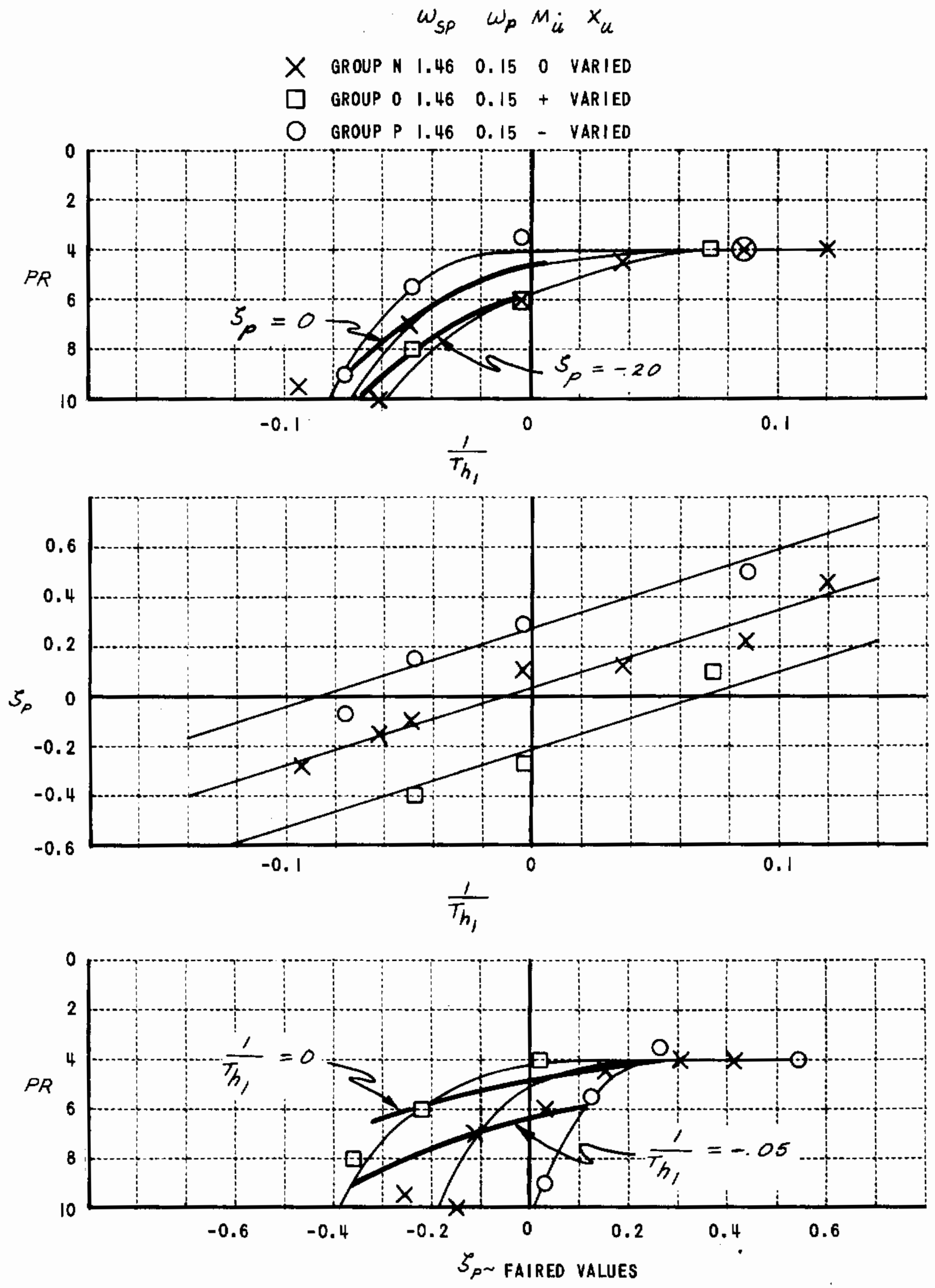


Figure 10b. PILOT RATINGS OBTAINED FOR CONFIGURATIONS IN GROUPS N, O AND P

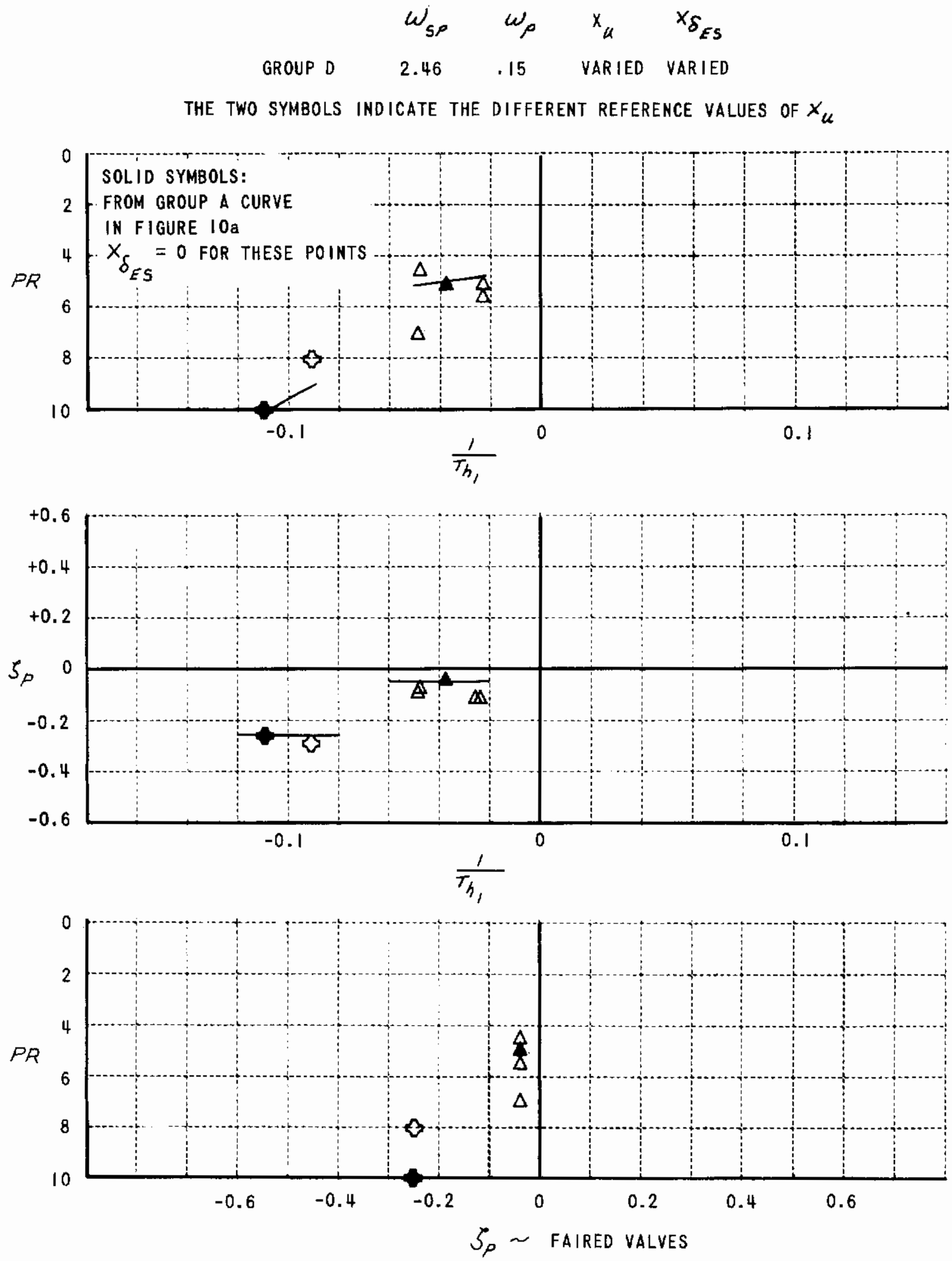


Figure 11a. PILOT RATING DATA OBTAINED FOR CONFIGURATIONS IN GROUP D

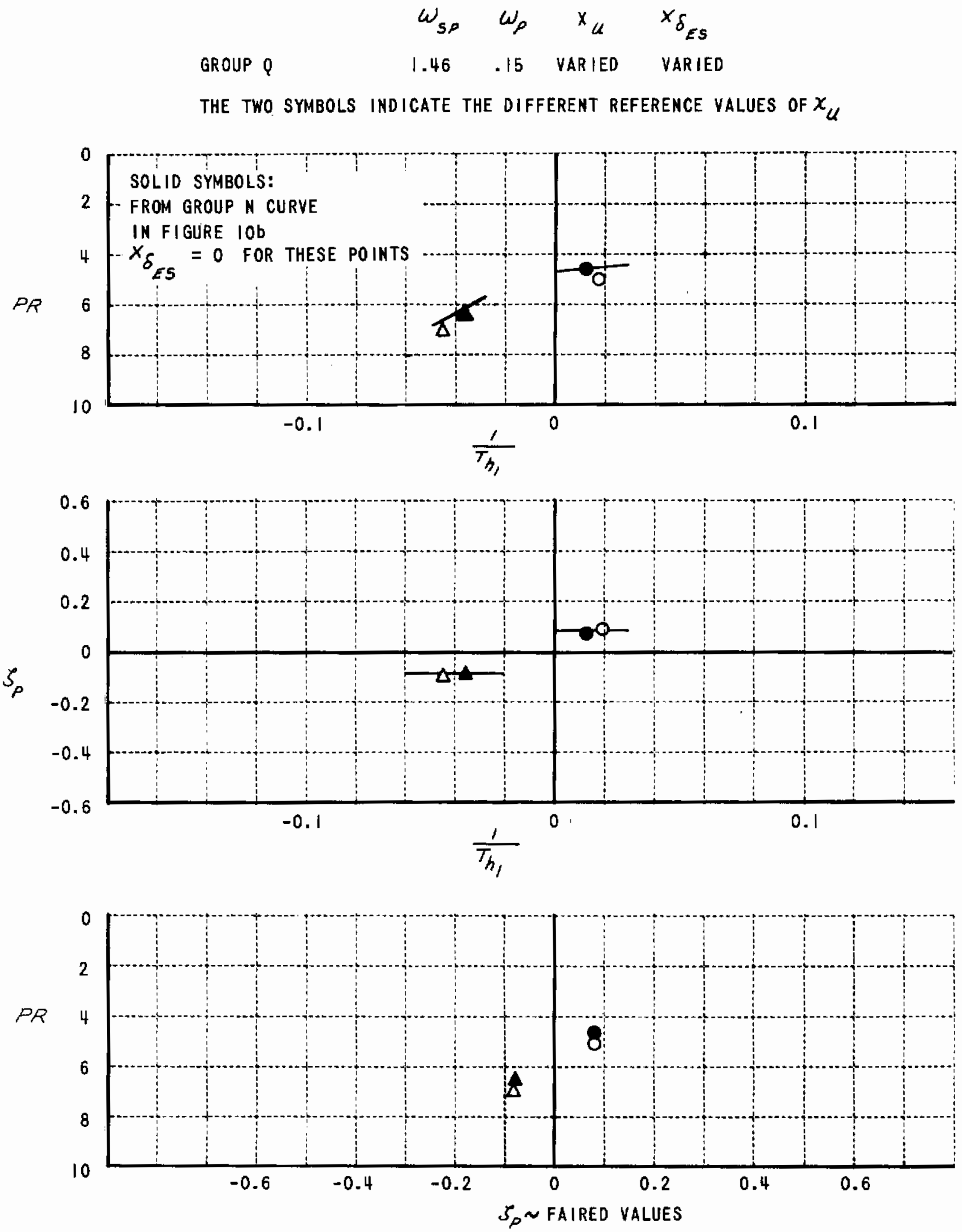


Figure 11b. PILOT RATING DATA OBTAINED FOR CONFIGURATIONS IN GROUP Q

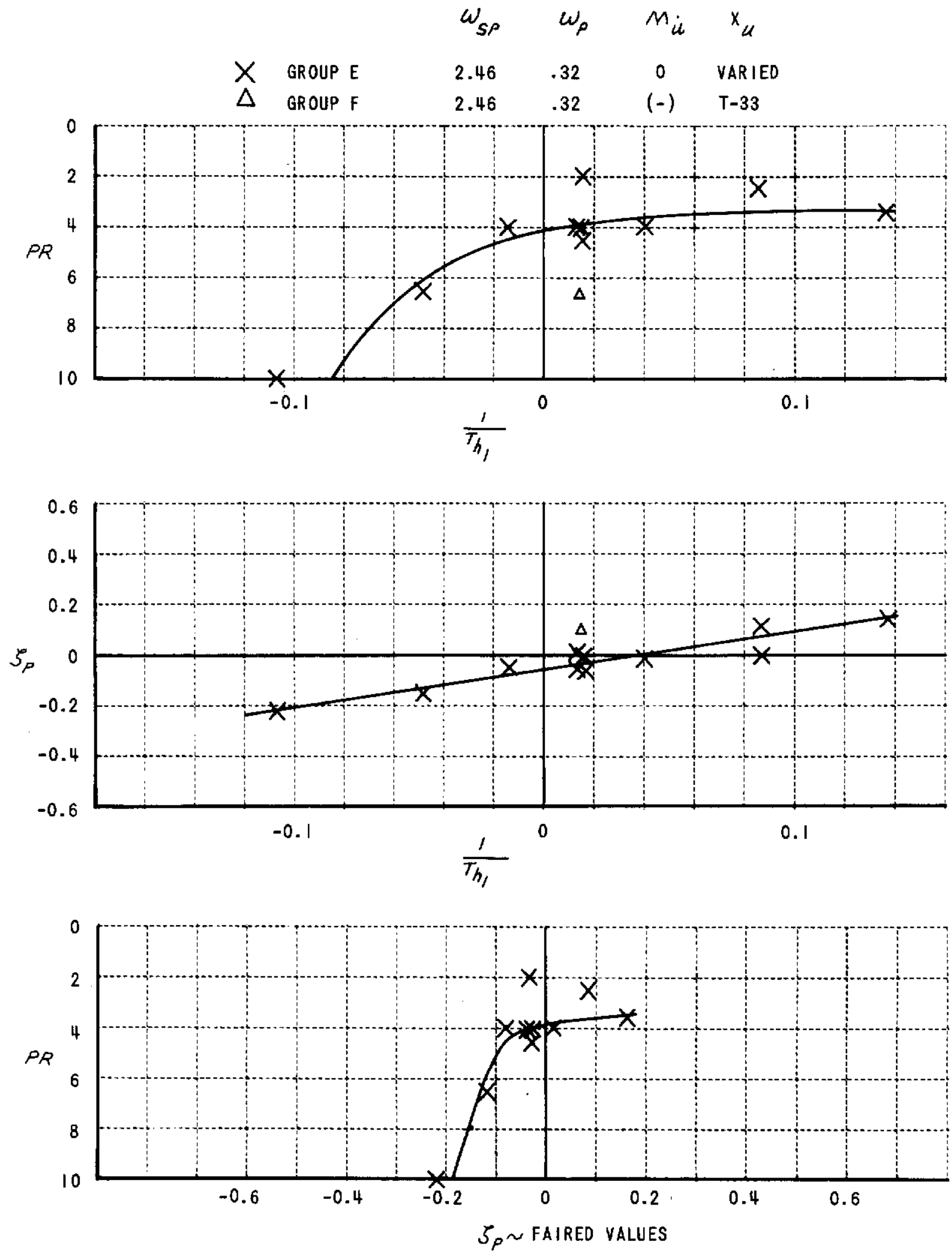


Figure 12a. PILOT RATING DATA OBTAINED FOR CONFIGURATIONS IN GROUPS E AND F

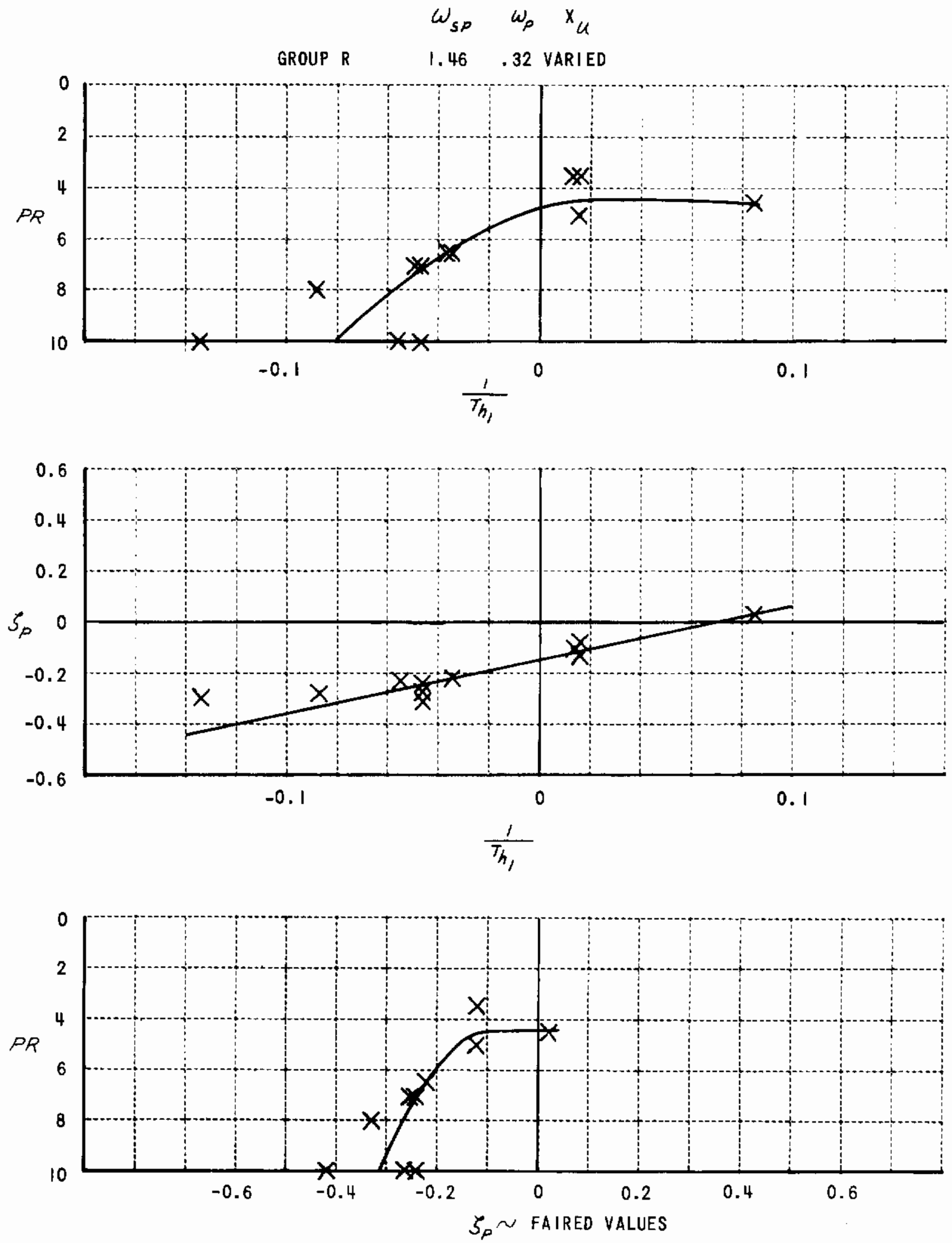


Figure 12b. PILOT RATING DATA OBTAINED FOR CONFIGURATIONS IN GROUP R

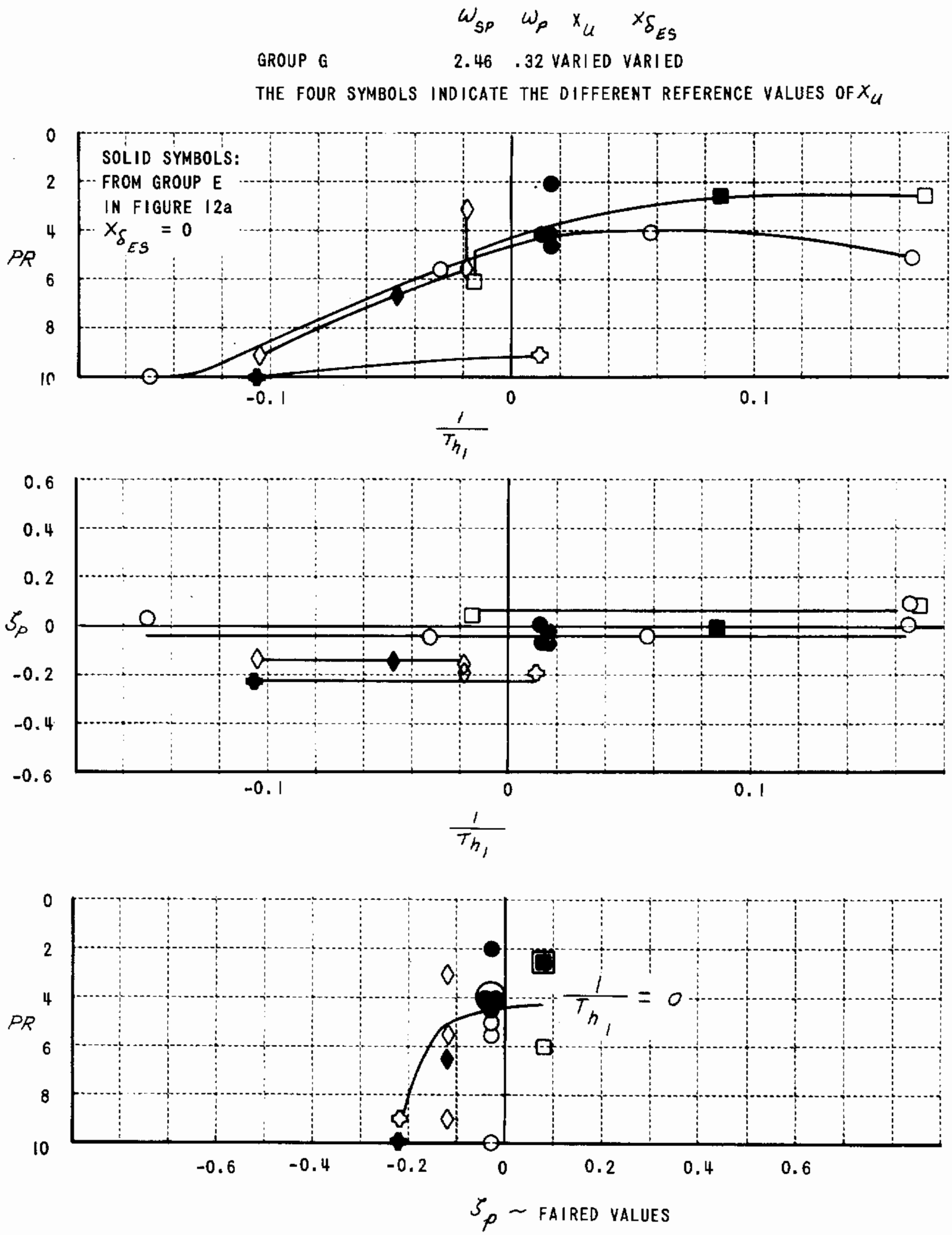


Figure 13a. PILOT RATING DATA OBTAINED FOR CONFIGURATIONS IN GROUP G

	ω_{sp}	ω_p	X_u	$X_{\delta_{ES}}$
GROUP S	1.46	.32	VARIED	VARIED

THE SYMBOLS INDICATE THE DIFFERENT REFERENCE VALUES OF X_u

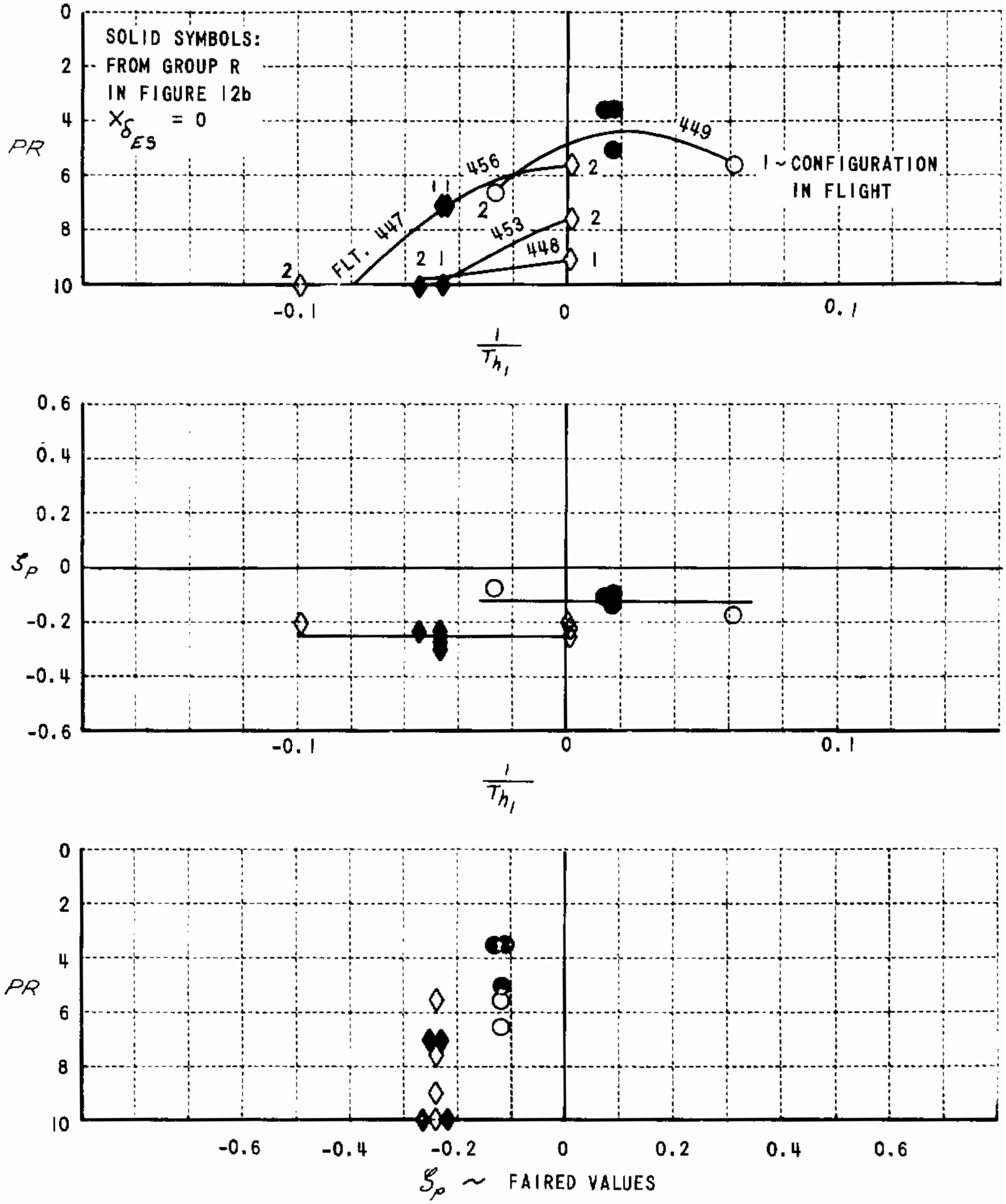


Figure 13b. PILOT RATING DATA OBTAINED FOR CONFIGURATIONS IN GROUP S

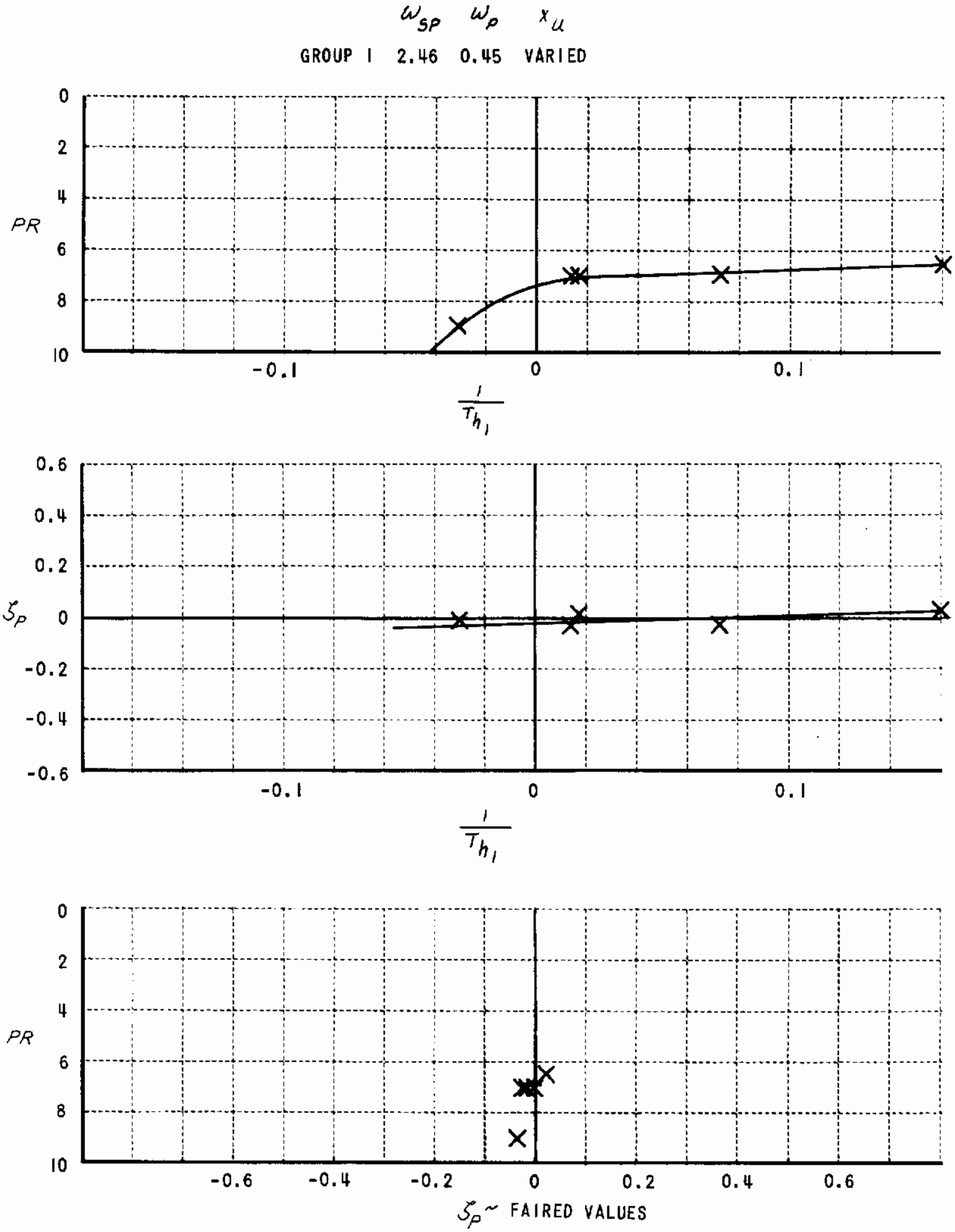


Figure 14a. PILOT RATING DATA OBTAINED FOR CONFIGURATIONS IN GROUP I

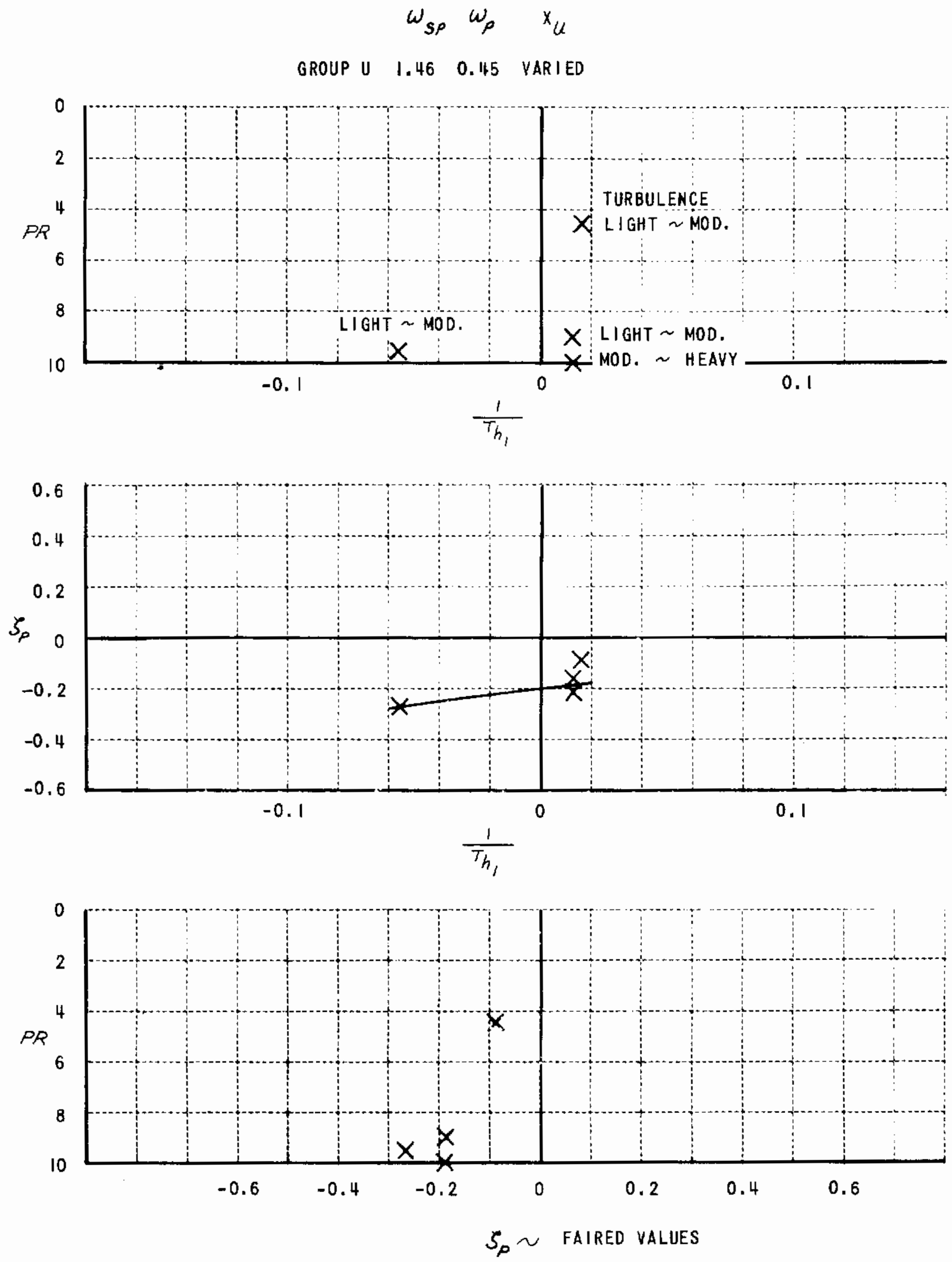


Figure 14b. PILOT RATING DATA OBTAINED FOR CONFIGURATIONS IN GROUP U

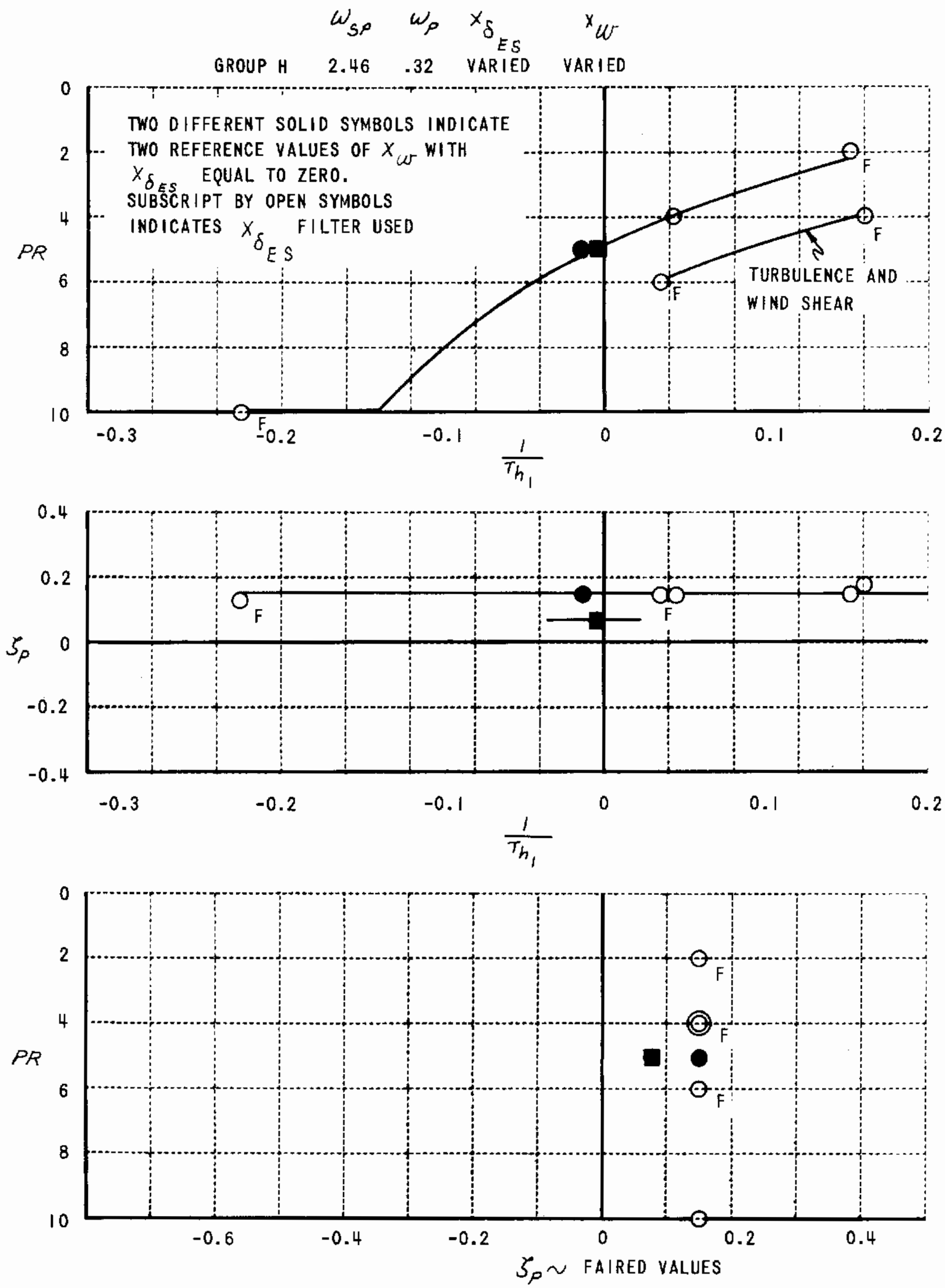


Figure 15a. PILOT RATING DATA OBTAINED FOR CONFIGURATIONS IN GROUP H

3.2.2 Pilot Comment Data

As indicated in Sections 1.2 and 2.2.4, when the pilot had completed each evaluation, he wire-recorded his observations, described the control difficulties experienced, and answered the specific questions listed in Paragraph 2.2.4. These questions were designed to determine how the pilot used the information and controls available to him in accomplishing the assigned task. The comment data generated were valuable in understanding the reasons for the pilot ratings and for identifying the airplane characteristics most significant to handling qualities.

These comments confirm the conclusion of Reference 46 that the pilot uses elevator and throttle in combination to control the speed and altitude of the airplane during the landing approach. In addition, the comments identify special control techniques adopted by the pilot to handle specific control problems.

The pilot's general comments and his answers to several of the specific questions are summarized in Tables III and IV. These tables are located at the end of this subsection. The comments for the various groups and the configurations in these groups are listed in Tables III and IV in the same sequence that they were listed in Tables I and II. The comments for the configurations of Groups A - M, ($\omega_{sp} \doteq 2.46$ rad/sec) are contained in Table III and the comments for the configurations of Groups N - V ($\omega_{sp} \doteq 1.46$ rad/sec) are contained in Table IV.

Tables III and IV have ten columns listing the following information:

Column 1 - Contains the Pilot Rating, Flight Number, Configuration Number, Group Letter, figure in which rating is plotted, and the symbol used in that plot to represent the configuration.

Column 2 - Contains information about atmospheric conditions, traffic, and equipment operation which might have influenced the pilot's experience with the configuration.

Column 3 - Contains a summary of the pilot's general observations and usually contains a remark about the major problem encountered.

Columns 4-11 - Contain a summary of the pilot's answers to questions 1, 2, 3, 4, 5, 6, 8 and 11, respectively, of Paragraph 2.2.4.

The answers to questions 7, 9 and 10 of the comment check list were not summarized separately for each configuration because the answers were nearly the same for all of the configurations.

Question 7 - What instruments are you using most? - was nearly always answered: Attitude and airspeed followed by rate of climb, altitude, angle of attack, heading and RPM. For configurations that required tight and continuous control of attitude and airspeed, the pilot was forced to pay less attention to the lower frequency outer loops, such as heading and altitude control, and as a result often had large errors in these variables.

The answers to questions 9 and 10 indicate that the elevator was used to control attitude, and the commanded pitch attitude, together with throttle inputs, was used to control flight path and velocity. Questions 9 and 10 were as follows:

Question 9 - Are throttle adjustments necessary?

Question 10 - Is elevator used to control:
Attitude? Rate of Climb? Other?
Altitude? Airspeed? Normal Acceleration?

This is discussed in Reference 46, Figures 15 and 16.

Questions 12, 13 and 14 call for descriptions of various parts of the visual portion of the evaluation task. Although this description was of general interest to the data analyst, it was not easily summarized in Tables III and IV.

The comment summaries of Tables III and IV should be studied with reference to the pilot rating plots of Figures 10a - 15a and Figures 10b - 14b. In the following paragraphs, the summarized pilot comment data are discussed.

Groups A, B, C and N, O, P

The summarized comments for the configurations in these groups are arranged in order of the value of $1/T_{h_1}$, and therefore control technique required can be seen by scanning the comments for these groups. (Also, see Figures 10a and 10b.) The major problem that developed as $1/T_{h_1}$ and ζ_p were made more negative was airspeed control. The control technique adopted by the pilot was tight attitude stabilization with the elevator, and high gain throttle inputs for airspeed errors. For Groups N, O and P, the pilot noted that the pitch attitude response to elevator control was slow and sluggish. In fact, this comment applies to all of the configurations in Table IV and is related to the low short-period frequency of these configurations.

Groups D and Q

In Groups D and Q (see Figures 11a and 11b,) $X_{\delta_{ES}}$ was used to change $1/T_{h_1}$ independent of ζ_p. The magnitude of change in $1/T_{h_1}$ was not large, however, particularly for the two configurations in Group Q. The pilot comments that $X_{\delta_{ES}}$ of the sense that back stick reduces the drag, is beneficial on the glide slope; however, during the constant-throttle IFR descent, he had considerable difficulty when trying to control airspeed with pitch attitude. For the configurations with $X_{\delta_{ES}}$ of the sense that back stick increased drag, the pilot found it easy to control airspeed during the constant-throttle IFR descent, but quite difficult to control airspeed on the glide slope. The reader is referred to the comment summaries for Groups D and Q in Tables III and IV.

It should be noted that Flight 429 in Group D was a repeat of Flight 416, and that on each of these flights, the first and second configurations differed by the value of $X_{\delta_{ES}}$. Thus, the above-noted effects of $X_{\delta_{ES}}$ can be observed from the comment summaries for these two flights.

Groups E, F and R

The summarized comments in these groups (Figures 12a and 12b) are again arranged in order of the value of $1/T_{h_1}$. The same general problems with airspeed control develop as occurred for Groups A, B, C and N, O, P when $1/T_{h_1}$ and ζ_p were made more negative. The pilot again adopted the technique of stabilizing attitude with elevator and correcting airspeed errors with throttle as the best control technique.

The comments for Groups E and F are dominated by the pilot's complaints about the pitch response to wind shear and horizontal gusts. In smooth air, the stiff phugoid gave a good sense of airspeed changes through stick force; however, in wind shear and turbulence, the pilot had to restrain the airplane in pitch to prevent it from pitching too far and causing an airspeed error of opposite sign. The latter observation results from the low or negative phugoid damping ratio.

The comments for Group R do not contain this strong objection about the pitch response to turbulence; even for configuration 440-2, which was evaluated in quite severe turbulence, the pilot termed the pitch response manageable. See Paragraph 3.2.5 concerning the effect of short-period frequency on pitch response to airspeed gusts.

The pilot's objections to the configurations in Group R are directed at the degree of closed-loop control required, the sluggish attitude response to elevator, and the difficulty experienced during the IFR descent when the pilot attempted to make the descent by using a constant power setting and correcting airspeed errors by making attitude changes.

The ratings and comments in Group R are strongly influenced by the unstable phugoid, the control technique used by the pilot during the IFR descent, and by the level of turbulence excitation to the unstable phugoid.

Groups G and S

In Groups G and S (Figures 13a and 13b), $X_{\delta_{ES}}$ was used to change $1/T_{h_1}$ independently of ζ_p. The magnitude of the change in $1/T_{h_1}$ that was made in these groups was quite large.

In Group G, four reference levels of $1/T_{h_1}$ and ζ_p were established through X_u with $X_{\delta_{ES}}$ equal to zero. Then, $X_{\delta_{ES}}$ was used to change the value of $1/T_{h_1}$ but not ζ_p. These configurations are identified in Table III by the same symbols used to represent them in Figure 13a. The two configurations represented by the open squares in Figure 13a were studied on Flight 458. The comments illustrate that $X_{\delta_{ES}}$ of the sense that back stick reduces the drag, makes flight path and airspeed control on the glide slope easier, and also relieves the requirement for coordinating power in turns. $X_{\delta_{ES}}$ of the opposite sense made airspeed control on the glide slope difficult and required lots of power in turns.

The four configurations represented by the open circles in Figure 13a cover a wide range of $1/T_{h_1}$ values for constant ζ_p. The comments for these configurations in Table III indicate the same major problem, i.e. airspeed control on the glide slope when $1/T_{h_1}$ is made negative, as was encountered in Group E when $1/T_{h_1}$ and ζ_p were made negative through X_u. There are, however, differences in the control problems such as the requirement to add lots of power during turns when $X_{\delta_{ES}}$ is large and negative. In this case the steady-state δ_{ES} that is required in level turns causes an increment in drag which must be balanced with added power if the airspeed is to remain constant. The same degree of backside operation produced by X_u does not require as large a change in steady-state power during turns; however, the power must still be coordinated to prevent airspeed errors from developing because once an airspeed error occurs it requires large throttle corrections to recover. There are also differences in the information cues and the control technique used by the pilot when $1/T_{h_1}$ is made negative through $X_{\delta_{ES}}$. In addition to closing the throttle-for-airspeed-errors loop he may make throttle inputs as a function of elevator stick inputs or as a function of steady state angle of attack.

Of the three configurations represented by the open diamond symbol in Figure 13a, two were studied on Flight 438 with opposite signs of $X_{\delta_{ES}}$. These again present the opportunity to make direct comparisons of the effect of $X_{\delta_{ES}}$ on the flight control task.

The configuration represented by the open cross in Figure 13a had a very unstable phugoid, and although $X_{\delta_{ES}}$ made $1/T_{h_1}$ positive, the pilot still had to use tight attitude stabilization and high gain throttle with airspeed errors to stabilize the phugoid.

In Group S, two reference values of $1/T_{h_1}$ and ζ_p were established through X_u with $X_{\delta_{ES}}$ equal to zero. The two configurations represented by the open circles in Figure 13b were both studied on Flight 449, and direct comparisons of the effect of $X_{\delta_{ES}}$ can again be made. This flight encountered moderate to heavy turbulence.

The four configurations represented by the open diamonds in Figure 13b were each studied in combination with one of the configurations of Group R, represented by the solid diamonds in Figure 13b. The three configurations for which $1/T_{h_1}$ was zero exhibit considerable scatter. It is thought that this scatter is caused by the very unstable phugoid mode which became a problem when turbulence was encountered, but was not particularly a problem in smooth air.

The experience with distractions and interruptions during the evaluation of configuration 453-2 is a good example of how not to conduct evaluation tests and exploratory investigations of handling quality characteristics. The pilot must be given the opportunity to try various control tasks and to observe the results without undue distraction if he is to make an intelligent report on the characteristics of the closed-loop pilot-airplane system.

Group H

The configurations in Group H, (Figure 15a) are of particular interest for several reasons. First, the phugoid damping ratio was high enough, for all but configuration 452-2, that this parameter was not a factor in causing rating degradation.

Second, the changes in $1/T_{h_1}$ were accomplished with X_w and filtered $X_{\delta_{ES}}$, which causes handling quality characteristics similar to X_w. This is of particular interest because the swept and delta wing designs, which have the problem of operating on the backside of the power required curve, get into this situation because of the contribution of the $X_w \frac{Z_u'}{Z_w}$ term in

Equation 9 rather than by having X'_u become positive. Thus, the pilot comments for the configurations of Group H are thought to be more representative of what would be encountered in an airplane with a delta wing than are the comments of Group E, for example. In Group E, $1/T_{h_1}$ was made negative through use of positive X_u .

Third, the feasibility of using a stick-to-throttle interconnect is explored. Large variations in $1/T_{h_1}$ were produced with filtered δ_p/δ_{ES} command to examine the possibilities of this technique for improving the landing-approach handling qualities of an airplane that is on the backside because of wing design.

Fourth, the turbulence and wind shear experienced on the various evaluations was such that some indication of the significance of this factor can be implied from the ratings and comments.

The pilot comments concerning Group H indicate that configurations which have high drag rise with angle of attack or steady state stick inputs, have the same general problem of airspeed control (whenever the flight path is constrained by elevator) as was encountered for the configurations of Groups A and E where $1/T_{h_1}$ was made negative with X_u . However, when the cause is drag rise with angle of attack or steady stick inputs, the configuration is more predictable and the pilot can coordinate the power with angle of attack, steady stick input, or bank angle, and does not have to watch the airspeed indicator quite as closely. The net result or gross effect, however, is the same. That is, the pilot must become a two-control man and is thus more loaded when $1/T_{h_1}$ is made negative.

The results of this part of the experiment are encouraging as regards the feasibility of a stick-to-throttle interconnect for improving the handling qualities of a configuration with negative $1/T_{h_1}$ in the landing approach.

The ratings in Figure 15a and the comments for Group H in Table III indicate a rating degradation of about two units because of the pitch response of these stiff-phugoid configurations to wind shear and turbulence.

Groups I, T and U

The configurations in these groups (see Figures 14a and 14b) had very high phugoid frequency and zero or very unstable phugoid damping. The pilot's comments are directed primarily at the extreme pitch response to airspeed changes and the tendency for the airplane to pitch too far and cause an airspeed error of the opposite sense. These characteristics were objectionable even in smooth air; but in turbulence and wind shear they were extremely troublesome to the pilot, especially when he was trying to stay on the glide slope near the ground.

The control technique adopted was, first of all, tight attitude stabilization with the elevator, which is a powerful way to increase the damping of the phugoid mode. In addition, when $1/T_{h_1}$ was made more negative, as in the case of configuration 425-1 of Group I, or when the phugoid damping ratio became very unstable, as was the case for all the configurations in Groups T and U except 415-2, the pilot found it necessary to use both tight attitude stabilization and a continuous throttle-to-airspeed loop.

The configurations in Groups I and U provide an opportunity to examine the control implications of not having the phugoid and short-period modes widely separated. In Group U the pilot often makes comments that the attitude response in the short-period mode is too slow and sluggish, and that the attitude response to airspeed or in the phugoid mode is large and difficult to control. In the case of configuration 440-1 the pilot comments about the relative magnitude of the angle of attack response in the short-period and phugoid modes, and remarks that he has to fly both modes.

In Group I the pilot considers the attitude response in the short period to be quite good; however, the attitude response to airspeed changes, or in the phugoid mode, is excessive and causes control difficulty.

These comments would seem to indicate that the absolute magnitudes of the phugoid and short-period natural frequencies and the residues of each mode are of importance, rather than the ratio of the two frequencies.

Groups J and V

On Flight 445 the stability derivative M_u was used to change the phugoid mode from a complex pair of roots into a pair of first-order real roots, one of which was unstable. This was done for the high-frequency short period on the first configuration and for the low-frequency short period on the second configuration of Flight 445. The divergence rate expressed in terms of time to double amplitude was 3.57 sec for configuration 445-1, and 2.68 sec for configuration 445-2.

The pilot found he could control these configurations as long as he stayed closed-loop on attitude and airspeed and did not let errors develop. There was always the danger that if he looked away, errors would develop and grow to such magnitude that he would run out of control.

It is interesting to note that the pilot did not have much difficulty finding the unstable trim condition, especially for configuration 445-1, which had the stiff short period.

Comments for Group J are in Table III and those for Group V are in Table IV.

Group K

On Flight 396-1 the phugoid frequency was decreased to $\omega_p = .10$ rad/sec with an attendant increase in ζ_p to 0.27. The pilot remarked that he had very little stick force feel to indicate airspeed errors. However, this was a fairly minor objection and he rated the configuration, P.R. = 3. See Table III for a summary of the pilot comments for this configuration.

Groups L and M

Configurations 1 and 2 of Flight 423 were intended to be members of Groups C and B, respectively, but a failure occurred in the $\delta_e/\dot{\alpha}$ channel which reduced the short-period damping ratio to $\zeta_{sp} \doteq .11$. The reduced short-period damping, combined with the increased attitude response to horizontal gusts caused by use of $M_{\dot{u}}$, resulted in severe pitch response to turbulence.

Configuration 423-2 had an unstable phugoid and negative $1/T_{h_1}$, while configuration 423-1 had a stable phugoid and a positive value of $1/T_{h_1}$. Although the pilot comments verify these conditions, the pilot for some reason rated configuration 423-2 slightly better than 423-1; possibly because the pitch response to turbulence was more severe for configuration 423-1. The comments for these configurations are summarized in Table III.

Table III SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
2 404-2 Group A Figure 10a X	MODERATE TURBULENCE CLOUDS AILERON FEEL KICKS CAN'T SEE AIRSPEED LIGHTS, SUN.	GOOD CONFIGURATION EVEN IN TURBULENCE	VERY EASY	O.K.	EXCELLENT	NO TROUBLE	O.K.	NO. WHEN YOU CHANGE FLIGHT PATH YOU HAVE TO CHANGE ATTITUDE TO KEEP SPEED	NONE	YES, VERY FINE THINK I MIGHT LIKE PITCH RESPONSE TO AIRSPEED ERRORS SO THE ERRORS WOULD BE CORRECTED FASTER
3.5 400-1 A	LIGHT WITH OCCASIONAL MODERATE GUSTS "MODERATELY TURBULENT" LOCALIZER, AILERON FEEL KICKS -- DOWNWIND APPROACHES AGAINST TRAFFIC		O.K. BUT DIDN'T SEEM TO HAVE ENOUGH SHORT PERIOD STIFFNESS	GEAR RATIO MAY HAVE BEEN SELECTED LITTLE LOW. TOO MUCH STICK MOTION	PITCH RESPONSE SEEMS SLUGGISH AND PILOT HAD TO POSITIVELY PRODUCE & MAINTAIN DESIRED ATTITUDE	NO.	NOT TOO BAD. DEPENDENT ON ABILITY TO HOLD ATTITUDE IN TURBULENCE	NO. SECRET SEEMED TO BE TO GET THE ATTITUDE RIGHT & HOLD IT.	YOU HAD TO OVER-DRIVE IT.	YES. (OBJECTIONS ARE VAGUE AND NOT VERY STRONG. DIRECTED MOSTLY AT ATTITUDE RESPONSE.)
2.5 405-1 A	TURBULENCE MODERATE - LIGHT, PATCHES AILERON FEEL KICKS, LOCALIZER ERRATIC	PRETTY GOOD CONFIGURATION. IF AIRSPEED ERROR EXISTS IT DOESN'T PITCH TO CORRECT THE ERROR AND THE ERROR IS SLOW TO TAKE CARE OF ITSELF.	EASY	O.K.	GOOD, BUT LITTLE SLOW	REAL GOOD	GOOD	NO, BUT DIDN'T GET MUCH CLUE ATTITUDE WRONG UNLESS LOOKED AT AIRSPEED AND SAW ERROR	NONE	YES. GOOD ONE
2 405-1 A	CLOUDS ON LETDOWN LIGHT - MODERATE TURBULENCE LOT OF AIRSPEED FLUCTUATIONS AILERON FEEL KICKS LOCALIZER ERRATIC	GOOD CONFIGURATION EVEN IN TURBULENCE	VERY, VERY EASY ESPECIALLY AIRSPEED	O.K.	YES, VERY GOOD	NO PROBLEM	WENT WELL	NO PROBLEM - GOOD AIRSPEED CONFIGURATION	NONE	YES, EXCELLENT
2 424-1 A	POOR VISIBILITY MODERATE, OCCASIONAL HEAVY GUST, 7 - 8 KNOTS	THIS IS A GOOD CONFIGURATION - EASY TO FLY AND NOT DISTURBED VERY MUCH BY TURBULENCE	EASY	O.K., PERHAPS A LITTLE HEAVY	O.K.	NO PROBLEM, COULD DO WITH REAL PRECISION	COULD DO WELL	NO PROBLEM	NONE. DON'T FIGHT THE HIGH FREQUENCY, TURBULENCE INDUCED, AIRSPEED CHANGES	YES. GOOD AIRPLANE
2 403-2 A	FAIRLY SMOOTH, OCCASIONAL GUSTS KICKS IN AILERON FEEL LOCALIZER ERRATIC	PRETTY DARN GOOD CONFIGURATION. NO PROBLEM WITH AIRSPEED	PRETTY EASY	O.K.	O.K., HAD FEELING PITCH WAS LITTLE SLOW	NO, EASY TO CORRECT	PRETTY REASONABLE FOR CHANGING RATE OF DESCENT	AIRSPEED DID NOT TEND TO DEVIATE FROM TRIM	NO	YES, EASY
4.5 402-1 A	CLOUDS, CALM, LIGHT TURBULENCE, VISIBILITY GOOD	SOME TROUBLE WITH AIRSPEED CONTROL	SOME TROUBLE GETTING AIRSPEED & ALTITUDE RIGHT AT THE SAME TIME	O.K.	YES, VERY DEFINITELY I LIKED THE SHORT PERIOD	NO	NO PROBLEM	YES, IT TENDS TO SLIP AWAY	AIRSPEED TO THROTTLE AND ELEVATOR	DEFINITELY COULD BUT YOU HAVE TO WATCH AIRSPEED
4 394-1 A	SMOOTH, GOOD VISIBILITY	FIRST CONFIGURATION OF THE PROGRAM. NO LANDING LIGHTS. ELEVATOR SPRING RATE 13.8 lb/in. PILOT CONSIDERED STICK FORCE GRADIENT TO BE LIGHT	NOT TOO MUCH	O.K.	GOOD	NO PROBLEM	PRETTY GOOD	YES, MAIN PROBLEM	NO	YES

Table III (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
6.5 403-1 Group A	OCCASIONAL GUSTS AILERON FEEL KICKS. LOCALIZER ERRATIC	PRINCIPAL DIFFICULTY WAS CONTROL OF AIRSPEED	YES, HARD TO PEG AIRSPEED	O.K.	GOOD	SOMEWHAT A PROBLEM HOLDING ALTITUDE	SPECIFIC RATE OF DESCENT WAS SOMEWHAT A PROBLEM BECAUSE OF AIRSPEED	PRINCIPAL PROBLEM	YES, THROTTLE TO COUNTERACT AIRSPEED ERRORS	YES
9 400-2 A Figure 10a X	MODERATE, DOWNWIND	HAVE TO ADD POWER AS FUNCTION OF AIRSPEED ERRORS AND USE LARGE THROTTLE CHANGES PER UNIT AIRSPEED ERROR. YOU HAD TO CATCH AIRSPEED ERRORS EARLY WHILE THEY WERE SMALL THUS AIRSPEED REQUIRED LOTS OF ATTENTION.	DIFFICULT TO TRIM. DIFFICULT TO GET THE AIRSPEED RIGHT.	O.K.	O.K.	YES	VERY DIFFICULT IF YOU TRY TO DO IT FIXED THROTTLE	MAIN PROBLEM, MUST CLOSE TIGHT THROTTLE CONTROL IN AIRSPEED	TIGHT, THROTTLE WITH AIRSPEED	NO, MISERABLE
8 405-2 A	LIGHT - MODERATE LOCALIZER ERRATIC. AILERON FEEL KICKS RAIN SHOWER, C-113 IN AREA	PRETTY MISERABLE - DANGEROUS. USED TIGHT CONTINUOUS THROTTLE TO AIRSPEED ERROR USED AIRSPEED LIGHTS	VERY DIFFICULT AIRSPEED	O.K.	O.K., PERHAPS A LITTLE SLOW	YES	COULD CONTROL ONLY IF CONTROL OF AIRSPEED WITH THROTTLE WAS MAINTAINED	AN EXTREME PROBLEM	TIGHT AIRSPEED TO THROTTLE LOOP	EMERGENCY
10 402-2 A	LIGHT-MODERATE	MISERABLE - AIRSPEED CONTROL WAS TERRIBLE. HAD TO USE REAL TIGHT THROTTLE TO AIRSPEED ERROR LOOP	IMPOSSIBLE TO TRIM	YES	YES, VERY GOOD	HAVE TO SPEND LOTS OF TIME ON AIRSPEED CONTROL	COULD'T MAINTAIN RATE OF DESCENT	AIRSPEED CONTROL IS CRITICAL	VERY, VERY TIGHT AIRSPEED TO THROTTLE	NO
10 406-1 A	CALM, VERY SMOOTH AT ALTITUDE. LIGHT TO MODERATE ON DESCENT	SYSTEM DUMPS. DID NOT DO APPROACHES. EXTREMELY UNSTABLE AIRSPEED MODE. AIRSPEED EXCURSIONS LARGE ENOUGH TO CAUSE PETALS TO REACH STOPS. ± 8 KNOTS. FOR FIXED THROTTLE DESCENT, HAD TO USE EXTREME PITCH ATTITUDE CHANGES TO TRY TO HOLD AIRSPEED TRIED USING TIGHT AIRSPEED-THROTTLE CLOSURE BUT ENGINE RESPONSE IS MARGINAL								

Table III (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
2.5 420-1 Group B Figure 10a ☐	LIGHT	GOOD CONFIGURATION. IT WAS EASY TO FLY AND I WAS ABLE TO FLY IT WITH FAIR AMOUNT OF PRECISION. HOWEVER, IT DID TEND TO PITCH IN TURBULENCE. WE ONLY ENCOUNTERED LIGHT TURBULENCE. IN THE LEVEL OF TURBULENCE I EXPERIENCED, IT'S A GOOD AIRPLANE BUT I HAVE SOME RESERVATIONS ABOUT MORE SEVERE TURBULENCE.	GOOD IN SMOOTH AIR	O.K., SLIGHTLY HEAVY BUT I DID HAVE REASONABLE SENSE OF AIRSPEED	YES	NO PROBLEM	IN SMOOTH AIR I WAS ABLE TO MAKE A SPECIFIC CHANGE IN RATE OF DESCENT WITH PRECISION	NO PROBLEM, EASY	NONE	YES
3 422-1 B	LIGHT - SMOOTH	A FAIR CONFIGURATION. VERY LITTLE TENDENCY TO NOTICE INITIAL AIRSPEED ERRORS AND YOU HAD TO PUSH THE ATTITUDE AROUND TO GET IT TO RESPOND. IN THE VERY LIGHT TURBULENCE THERE WAS A FAIR AMOUNT OF PITCHING IN RESPONSE TO TURBULENCE.	TRIMMED PRETTY WELL	ON HEAVY SIDE, BUT SATISFACTORY	ON SLOW SIDE, BUT SATISFACTORY	NO	WENT PRETTY WELL. HAD TO FLY ATTITUDE CLOSELY TO KEEP AIRSPEED.	DEPENDED ON ABILITY TO MAINTAIN ATTITUDE ATTITUDE IS DISTURBED BY TURBULENCE & YOU HAD TO PAY ATTENTION TO IT.	NONE	CERTAINLY COULD
5.5 419-2 B	MODERATE, GOOD CLEAR DAY. TRAFFIC. APPROACHES AGAINST TRAFFIC.	CONFIGURATION HAD A GENERAL LACK OF PRECISION. ALSO IT HAD PITCH DISTURBANCES IN TURBULENCE. HAD AIRSPEED PROBLEMS ON GLIDE SLOPE UNSATISFACTORY, PRIMARILY BECAUSE OF THE AIRSPEED CONTROL PROBLEMS AND RATHER POOR PERFORMANCE ON THE GLIDE SLOPE.	HAD TO TIGHTLY STABILIZE ATTITUDE TO TRIM IT.	O.K.	O.K., ON SLOW SIDE	A PROBLEM IN TURNS. HAD TO CHANGE NOSE POSITION TO HOLD AIRSPEED DURING TURNS.	DIDN'T OBSERVE	A PROBLEM PARTICULARLY ON GLIDE SLOPE TENDED TO GO FROM FAST TO SLOW, ETC.	NONE	YES
6 418-1 B	LIGHT TO MODERATE. CROSS WIND FROM RIGHT	ALWAYS CHASING AIRSPEED. FLEW ATTITUDE WITH ELEVATOR AND USED THROTTLE TO CONTROL AIRSPEED WORKED BEST. HAD TO BE CONTINUOUS CLOSED LOOP. USED AIRSPEED LIGHTS BUT ALSO NEEDED AIRSPEED RATE SO HAD TO USE AIRSPEED INDICATOR. RATHER MISERABLE AND UNACCEPTABLE CONFIGURATION	YES, ESPECIALLY IF YOU TRY TO TRIM OUT AT A SPECIFIC ALTITUDE	SELECTED A LITTLE SENSITIVE TO PERMIT CONTROL WHEN OUT OF TRIM AIRSPEEDWISE	HAD TENDENCY TO BOBBLE IN PITCH. IT STARTS FAST, ALMOST STOPS, THEN GOES ON IN RESPONSE TO ELEVATOR.	INDEED A PROBLEM IF YOU TRY TO HOLD AIRSPEED ALSO, IN TURNS, CONTROLLED ATTITUDE WITH ELEVATOR AND AIRSPEED WITH THROTTLE.	COULDN'T DO IT IN TIME I HAD	YES, WAS PROBLEM. IF YOU CLOSED AN AIRSPEED LOOP WITH THROTTLE, IT WAS WITHIN YOUR CAPABILITY TO KEEP IT FAIRLY CONSTANT AND YOUR SUCCESS WAS ALMOST COMPLETELY DEPENDENT ON THE ATTENTION, ACTIVITY AND DILIGENCE WITH WHICH YOU PURSUED THE CLOSURE OF AIRSPEED TO THROTTLE	ACTIVE AIRSPEED TO THROTTLE	NOT CONSISTENTLY
6.5 421-1 B	CLOUDS -- MODERATE	THE BIGGEST PROBLEM IS AIRSPEED CONTROL AND ALSO PITCHING DISTURBANCES IN TURBULENCE. BEST CONTROL TECHNIQUE IS ATTITUDE STABILIZATION AND A HIGH GAIN THROTTLE CLOSURE ON AIRSPEED ERRORS. IT TAKES VERY LARGE THROTTLE CLOSURES, THOUGH. THIS IS NO AIRPLANE TO GIVE ANYBODY TO FLY IN LANDING APPROACHES	YES	O.K.	NO COMMENT	NOT REALLY TOO MUCH IF YOU START FROM TRIM AND CONTROL ATTITUDE WITH ELEVATOR AND AIRSPEED WITH THROTTLE. IF YOU START FROM OUT OF TRIM IT'S DIFFICULT. IF THE AIRSPEED ERRORS GET VERY LARGE IT'S A REAL SON OF A GUN TO STAY ALIVE IN.	CAN DO IT BUT REQUIRES VERY TIGHT CLOSED-LOOP CONTROL	VERY CONSIDERABLE PROBLEM. ABILITY TO FLY ALMOST COMPLETELY DEPENDS ON KEEPING AIRSPEED ERRORS SMALL	ATTITUDE STABILIZE WITH ELEVATOR AND REAL TIGHT AIRSPEED TO THROTTLE	IT'S POSSIBLE BUT I WOULDN'T WANT TO. SOONER OR LATER IT WILL GET AWAY FROM YOU.

Table III (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
4 420-2 Group C Figure 10a ○	LIGHT TO MODERATE	THIS WAS A REAL GOOD AIRPLANE FOR THE IFR CONSTANT SPEED PORTION, BUT ON THE GLIDE SLOPE I JUST DIDN'T SEEM TO HAVE GOOD POSITIVE CONTROL OF THE FLIGHT PATH. IN TURBULENCE IT TENDS TO PITCH AND ON THE GLIDE SLOPE WHERE I'M PURPOSELY TRYING TO MAINTAIN MY PITCH ATTITUDE WITH THE ELEVATOR IT GIVES ME CONSIDERABLE TASKS. I'M RATING IT A 4 BECAUSE OF THE EFFECT OF TURBULENCE ON KEEPING THE GLIDE SLOPE. HOWEVER, I FEEL I'M BEING A LITTLE SEVERE.	QUITE EAST. I HELD ATTITUDE AND VARIED POWER. AIRSPEED RESPONSE WAS QUITE FAST AND DIDN'T OVERSHOOT	O.K.	LITTLE OBJECTIONABLE. HAD FEELING OF BEING BEHIND PITCH DISTURBANCES	NO PROBLEM. AIRSPEED REALLY STAYED GLUED IN TURNS	RATE OF DESCENT WAS VERY WELL CONTROLLED	NO PROBLEM	NONE	YES, CERTAINLY
3 424-2 C	MODERATE WITH OCCASIONAL HEAVY GUSTS.	IN SMOOTH AIR IT LOOKED QUITE GOOD BUT IN TURBULENCE THE ATTITUDE RESPONSE WAS SOMEWHAT OBJECTIONABLE. WAS THINKING OF 2 OR BETTER IN SMOOTH AIR, BUT IN TURBULENCE THERE ARE ENOUGH OBJECTIONS TO TALK ABOUT THAT I'LL CALL IT A 3.	EASY	O.K.	SATISFACTORY EXCEPT IT WAS NOTICEABLY RESPONSIVE TO PITCH IN TURBULENCE	NO PROBLEM.	DON'T THINK IT WAS AS GOOD AS 424-1. IT WAS BOTHERED MORE BY TURBULENCE.	NO PROBLEM. TURBULENCE CAUSED DISTURBANCES BUT GENERALLY AIRSPEED STAYED PRETTY WELL. THERE WERE ATTITUDE DISTURBANCES THOUGH.	NONE	YES
4 419-1 C	BEAUTIFUL DAY. CROSSWIND FROM RIGHT DOWNWIND APPROACHES - MODERATE. TRAFFIC.	BASICALLY IT WAS PRETTY GOOD UNTIL WE GOT INTO TURBULENCE. THEN I NOTICED THE AIRPLANE PITCHED CONSIDERABLY. GOOD AIRPLANE IN SMOOTH AIR, BUT THE PITCH RESPONSE IN TURBULENCE MAKES IT UNSATISFACTORY.	QUITE EASY TO TRIM IN SMOOTH AIR	LITTLE SENSITIVE. GEAR RATIO THAT GAVE GOOD INITIAL RESPONSE WAS LITTLE HEAVY & I WAS AFRAID MAYBE I COULD'NT OVERPOWER TRIM FORCES AS I GOT OFF AIRSPEED	INITIAL RESPONSE IS LITTLE SENSITIVE WITH THIS GEAR RATIO.	NO PROBLEM EXCEPT IN TURBULENCE. THIS CAUSED LOT OF PITCHING THAT MADE IT A LITTLE DIFFICULT.	DIDN'T GET GOOD CHECK	NO PROBLEM IN SMOOTH AIR. IN TURBULENCE IT WAS MORE DIFFICULT.	NONE	YES, GOOD
5 418-2 C	LIGHT, OCCASIONAL MODERATE	IT WAS AN AGGRAVATING CONFIGURATION BECAUSE I WASN'T ABLE TO DO AS WELL AS I THOUGHT I SHOULD. IT SEEMED LIKE THE AIRSPEED WAS KIND OF SLIPPING OR ELUSIVE AND I DIDN'T HAVE A GOOD SENSE OF WHEN AN ERROR WAS DEVELOPING. I WAS ALWAYS MAKING CORRECTIONS ON THE GLIDE SLOPE AND THE RESPONSE TO CORRECTIONS WAS SLOW. BIGGEST PROBLEM ON GLIDE SLOPE IS AIRSPEED ERRORS.	INTERMEDIATE DIFFICULTY. DON'T HAVE GOOD POSITIVE CONTROL OF AIRSPEED	O.K., MAYBE LITTLE HIGH	SOMEWHAT UNSATISFACTORY. INITIAL RESPONSE LITTLE LOOSE	LITTLE PROBLEM	IMPRECISE	IMPRECISE. TENDED TO DRIFT AROUND TRIM	WORK ON AIRSPEED WITH THROTTLE	YES
4 422-2 C	VERY LIGHT. TRAFFIC, MADE TWO VISUAL CLOSED PATTERNS	IN SMOOTH AIR EVERYTHING WAS GOING REAL WELL. THEN I GOT DISTRACTED BY A C-119 IN PATTERN AHEAD OF ME AND WITHOUT REALIZING IT, I LOST 10 KT AND FOUND IT TOOK SEVERAL POWER CORRECTIONS BEFORE GOT AIRSPEED CHECKED AND BACK TO TRIM. ALSO, IN CLOSE ON GLIDE SLOPE, I HAD TO WORK TO STAY ON FLIGHT PATH AND AIRSPEED. IF IT DIDN'T HAVE AIRSPEED CONTROL PROBLEM, I THINK IT WOULD BE SATISFACTORY	LITTLE DIFFICULT TO GET AT TRIM AIRSPEED.	O.K.	O.K., LITTLE SLOW	NO PROBLEM	WENT FAIRLY WELL BUT HAD TO WATCH AIRSPEED	CAN BE A PROBLEM. IT REQUIRES THROTTLE CLOSURE, NOT A REAL STRONG ONE, BUT ONE YOU CAN'T NEGLECT	OVERDRIVE IN PITCH & MONITOR AIRSPEED WITH THROTTLE	YES
7 421-2 C	MODERATE	A PRETTY LOUSY CONFIGURATION. AIRSPEED CONTROL WAS PRETTY DIFFICULT. COULD SENSE AIRSPEED ERRORS IN THE STICK. REQUIRED VERY LARGE POWER CHANGES TO CORRECT AIRSPEED. USED AIRSPEED LIGHTS AND ALSO THE INDICATOR BECAUSE I NEEDED AIRSPEED RATE INFORMATION TO FLY IT MORE PRECISELY. IT REQUIRES A MAJOR PORTION OF PILOT'S ATTENTION.	INTERMEDIATE DIFFICULTY. REQUIRES CONTINUOUS CLOSED-LOOP ATTITUDE STABILIZATION AND THROTTLE AS FUNCTION OF AIRSPEED.	O.K. INITIAL RESPONSE WITHOUT GETTING TOO LIGHT STEADY STATE.	O.K.	DIFFICULT TO MAINTAIN ALTITUDE AND AIRSPEED.	NOT VERY GOOD.	YES, REQUIRES A THROTTLE CLOSURE ON AIRSPEED AND AIRSPEED RATE.	TIGHT ATTITUDE STABILIZATION AND THROTTLE WITH AIRSPEED	YES, BUT LARGE AIRSPEED ERRORS ARE PROBABLE.

Table III (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
5 416-1 Group D Figure 11a △	SMOKE AND HAZE LIGHT TO MODERATE LOCALIZER WORKED WELL.	HAD TROUBLE ACHIEVING TRIM BECAUSE OF DRAG VARIATION WITH ELEVATOR STICK COUPLED WITH TRIM CHANGES CAUSED BY POWER. DON'T LIKE IT BECAUSE OF TRIMMING DIFFICULTY BUT ON THE GLIDE SLOPE IT'S A REASONABLE CONFIGURATION. IT'S MARGINALLY SATISFACTORY P.R. = 3.5 ON GLIDE SLOPE, BUT OVERALL IT'S POOR CONFIGURATION, P.R. – 5. (PILOT DID NOT DIAGNOSE THIS CONFIGURATION FULLY UNTIL AFTER HE HAD EVALUATED THE SECOND CONFIGURATION WHICH HAD OPPOSITE $X_{\delta_{ES}}$.) CONSTANT THROTTLE DESCENT PORTION: IF I'M DESCENDING AND I GET A LITTLE SLOW, I NOSE OVER. THAT REQUIRES FORWARD STICK WHICH PRODUCES DRAG WHICH TENDS TO KEEP THE AIRSPEED FROM INCREASING AS MUCH AS IT WOULD IF THAT WASN'T THERE. BUT THEN AS THE PITCH ATTITUDE GETS STEEPER AND STEEPER, TWO THINGS HAPPEN. THE LONGITUDINAL FORCE DUE TO PITCH ANGLE (I.E., THE WEIGHT COMPONENT) GETS BIGGER AND ALSO YOU TEND TO START SLACKING OFF ON THE ELEVATOR SINCE YOU ARE REACHING THE DESIRED ATTITUDE CHANGE AND HENCE THERE WAS A DRAG REDUCTION WHICH FURTHER TENDED TO INCREASE THE LONGITUDINAL FORCE AND HENCE THE AIRSPEED WHICH HAD BEEN SLUGGISH AND SLOW TO RESPOND INITIALLY NOW TAKES OFF AND THEN YOU'D HAVE TO SUDDENLY MAKE A CHANGE IN THE OPPOSITE DIRECTION. SO I ENDED UP PITCHING UP AND DOWN AND HAVING AIRSPEED CONTROL PROBLEMS.	QUITE DIFFICULT	O.K. (PILOT FOUND HE COULD REDUCE $X_{\delta_{ES}}$ EFFECT BY INCREASING $M_{\delta_{ES}}$, SO HE PICKED LARGER THAN NORMAL $M_{\delta_{ES}}$)	MARGINALLY SATISFACTORY BUT ADEQUATE FOR TASK.	IF YOU ARE IN CAREFUL TRIM IT IS FAIRLY EASY, BUT IF YOU ARE NOT TRIMMED UP IT IS QUITE DIFFICULT. DIFFICULT TO ACHIEVE ALTITUDE & AIRSPEED TOGETHER	ONCE YOU GET SET UP YOU CAN MAINTAIN FAIRLY WELL.	MAINTAINING AIRSPEED IS PROBLEM WHENEVER YOU CHANGE FLIGHT PATH	WORK PRETTY HARD	YES
7 416-2 D △	VISIBILITY QUITE POOR LIGHT TO MODERATE	THIS ONE TRIMS PRETTY WELL AND IS GOOD, EASY TO MAINTAIN AIRSPEED ON CONSTANT THROTTLE DESCENT. IT IS REAL EASY TO LOSE ALTITUDE AND DIFFICULT TO CLIMB. ON GLIDE SLOPE IT IS VERY DIFFICULT TO MAINTAIN AIRSPEED AND ALTITUDE. FAIRLY GOOD DURING CONSTANT SPEED IFR DESCENT BUT ON GLIDE SLOPE IT WAS POOR.	EASY TO GET AIRSPEED WITH ATTITUDE BUT WOULD BE DIFFICULT TO GET BOTH AIRSPEED AND ALTITUDE.	O.K. (PILOT SELECTED HIGH $M_{\delta_{ES}}$ TO REDUCE EFFECTS OF $X_{\delta_{ES}}$)	O.K.	PARTICULAR PROBLEM IN TURNS, REQUIRED LARGE THROTTLE INPUTS.	O.K. BUT HAD TO MONITOR AIRSPEED CLOSE.	AIRSPEED WAS PROBLEM PARTICULARLY ON GLIDE SLOPE AND REQUIRED ACTIVE THROTTLE.	ACTIVE USE OF THROTTLE	YES, BUT NOT SURE YOU COULD LAND ON CARRIER. COULD BE DANGEROUS IF PILOT IS DISTRACTED
5.5 429-1 D △	MODERATE, OCCASIONAL HEAVY GUST. CROSSWIND FROM LEFT.	IN SOME AREAS IT SEEMED PRETTY GOOD, AND OTHERS, VERY TROUBLESOME. IT HAS DRAG CHANGES WITH ELEVATOR CONTROL AND THE PHASING OF THE DRAG SEEMS TO BE DIFFICULT FOR ME TO HANDLE ON THE FIXED THROTTLE DESCENT PORTION. HAD AIRSPEED CONTROL DIFFICULTIES. IF I WAS SLOW, I'D PUSH THE NOSE OVER, THE AIRSPEED WOULDN'T CHANGE MUCH AND I'D HOLD THE NOSE DOWN ELEVATOR UNTIL THERE WAS A SUBSTANTIAL ATTITUDE CHANGE. THEN WHEN THE AIRSPEED STARTED TO COME IN, I WOULD HOLD ATTITUDE AND THE AIRSPEED WOULD START TO RESPOND QUITE RAPIDLY. AS I APPROACHED ZERO ERROR, THEN I WOULD PULL UP THE NOSE, AND THE AIRSPEED WOULD START TO INCREASE EVEN MORE RAPIDLY AND GO RIGHT THROUGH THE DESIRED SPEED. I WAS ABLE TO DAMP IT BUT THERE WAS ALWAYS A TENDENCY TO OVERSHOOT AIRSPEED WHEN TRYING TO CORRECT WITH ATTITUDE. ON GLIDE SLOPE IT WAS QUITE GOOD. IN TURNS AT ALTITUDE, I HAD PROBLEMS HOLDING AIRSPEED. IT'S BEST ON THE GLIDE SLOPE. (THIS WAS THIRD FLIGHT OF DAY AND PILOT COMMENTED AT THE END THAT HE WAS MENTALLY WEARY AND SLUGGISH AND WAS HAVING TROUBLE MANAGING THE SITUATION AT THE BEGINNING OF THE FLIGHT BUT PART WAY THROUGH HE BEGAN TO FEEL BETTER)	SOMEWHAT DIFFICULT.	O.K., BUT I HAD TROUBLE PICKING IT. RESPONSE TO ELEVATOR PECULIAR. IF I PULL BACK NOSE COMES UP AND YOU ACCELERATE. IF I PUSH ON THE STICK, NOSE GOES DOWN SLOWLY AND AIRPLANE DECELERATES.	LITTLE SLOW	IN TURNS, AIRSPEED TENDS TO GET OFF.	HARD TO HOLD AIRSPEED WITH ATTITUDE	PROBLEM IN LEVEL TURNS AND WHEN CHANGING FLIGHT PATH. TEND TO GET FAST ON PULL UPS.	TIGHT AIRSPEED TO THROTTLE.	YES
4.5 429-2 D △	CROSSWIND, SUN IN EYES FROM LEFT MODERATE	ANOTHER ONE WITH DRAG DUE TO ELEVATOR BUT OF OPPOSITE SENSE OF WHAT I HAD ON 429-1. WITH THIS ONE I CAN KEEP AIRSPEED CONSTANT WITH ALTITUDE DURING THE DESCENT. THE TURNS AT ALTITUDE WENT BETTER ALSO. TENDED TO LOSE AIRSPEED WHEN I REDUCED RATE OF DESCENT. FLYING THIS AIRPLANE WAS RELATIVELY COMPLICATED AND REQUIRED A LOT OF ATTENTION AND WORK TO FLY IT.	INTERMEDIATE DIFFICULTY, BUT EASIER THAN 429-1	O.K.	PRETTY GOOD	PROBLEM STRAIGHT AND LEVEL, BUT NOT IN TURNS	WENT WELL.	IF I TRIED TO HOLD ALTITUDE, I GOT OFF ON AIRSPEED. COULD NOT TELL TOO WELL ON APPROACH BECAUSE I TRIED TO USE THE AIRSPEED LIGHTS, & GUSTY AIR CONFUSED THE INFORMATION THEY GAVE.	HAVE TO COORDINATE POWER WITH ELEVATOR WHEN MANEUVERING	YES.

Table III (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?	MAINTAINING AIRSPEED A PROBLEM?
8 460-2 Group D Figure 11a ○	LIGHT. TRAFFIC RUDDER FEEL SERVO	IF YOU KEPT THE AIRSPEED NEAR TRIM WITH EITHER ATTITUDE OR POWER IT WASN'T TOO BAD. IT HAD A DIVERGENT AIRSPEED MODE THAT OCCURRED WITH VERY LITTLE PITCH CHANGE. ALSO HAD UNCERTAINTY BETWEEN ATTITUDE AND AIRSPEED THAT I HAD WITH THE FIRST ONE. IT WAS DIFFICULT TO MAKE AN AIRSPEED CORRECTION. IT REQUIRED VERY LARGE ATTITUDE OR POWER CHANGES IF AN ERROR DEVELOPED. THIS ONE SNEAKS AWAY. IT STARTS SLOW, BUT THEN IT STARTS TO GO WITH AN INCREASING RATE SO THEN I'D HAVE TO MAKE A VERY LARGE ATTITUDE OR THROTTLE CORRECTION. IT WORKS BEST TO USE ATTITUDE TO CORRECT SMALL AIRSPEED ERRORS AND TO USE THROTTLE FOR BIGGER ERRORS. BOTH GLIDE SLOPE APPROACHES WERE DISTRACTED BY TRAFFIC AND FUEL CONSIDERATIONS BUT I FELT IT COULD BE FLOWN ON THE GLIDE SLOPE.	DON'T KNOW	O.K.	MARGINALLY SATISFACTORY.	NOT IF YOU CLOSE A THROTTLE TO AIRSPEED LOOP	ONLY IF YOU USE A PRETTY HIGH GAIN THROTTLE TO AIRSPEED ERROR LOOP. VERY DIFFICULT TO DO FIXED THROTTLE.	AIRSPEED CONTROL IS CONSIDERABLE PROBLEM	HIGH GAIN THROTTLE TO AIRSPEED ERRORS LOOP. ATTITUDE STABILIZE IT ALSO.	IN FAVORABLE SITUATION IT COULD BE DONE. IT REQUIRES TOO MUCH CLOSED LOOP ATTENTION.

Table III (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
3.5 431-1 Group E Figure 12a X	GOOD VISIBILITY. CROSSWIND FROM RIGHT. LIGHT TO MODERATE WITH OCCASIONAL MODERATE TO HEAVY.	WIRE RECORDER MALFUNCTIONED. PILOT COMMENTED DURING DEBRIEFING THAT HE LIKED THIS CONFIGURATION EXCEPT FOR PITCH RESPONSE TO WIND SHEAR AND GUSTS.								
5 - 5 428-2 E	GOOD STIFF CROSSWIND FROM LEFT. MODERATE WITH OCCASIONAL HEAVY.	ATTITUDE AND TURBULENCE WERE MY PROBLEMS. RESTRAINING THE ATTITUDE AND COUNTERING EFFECTS OF GUSTS. GUSTS WERE FELT IN STRONG ATTITUDE RESPONSE. AIRSPEED ERRORS PRODUCE LARGE PITCH ATTITUDE CHANGES, AS MUCH AS 10°. I DIDN'T SEEM TO BE ABLE TO STABILIZE AIRSPEED AND KEEP IT ON, ALTHOUGH IT DIDN'T WANT TO GO VERY FAR OFF. BIGGEST PROBLEM SEEMED TO BE PITCH RESPONSE IN TURBULENCE. MIGHT BE DUE TO THE FACT THAT IT'S DIFFERENT FROM WHAT I'M USED TO BUT IT WAS PECULIAR, ALMOST ARTIFICIAL. I CAN'T RATE THIS CONFIGURATION; I'M CONFUSED. I HAD CONFLICTING CAPABILITIES WITH IT. MAYBE I'M JUST TIRED, BUT I CAN'T PLACE IT ANY CLOSER THAN 5-8. YOU WILL JUST HAVE TO GIVE IT TO ME AGAIN SOMETIME.	REASONABLY EASY IN SMOOTH AIR; DIFFICULT IN ROUGH AIR. (cont.)	O.K. (cont.)	LITTLE LOOSE INITIALLY. TENDENCY TO BOBBLE. SLIGHTLY UNSATISFACTORY. (cont.)	NOT PARTICULARLY (cont.)	FELT UNEASY. BIG PROBLEM WAS FIGHTING ATTITUDE IN TURBULENCE. (cont.)	MAINTAINING AIRSPEED IS PROBLEM BECAUSE MAINTAINING ATTITUDE IS ONE. IF I KEPT ATTITUDE CONSTANT, AIRSPEED SEEMED TO TAKE CARE OF ITSELF. (cont.)	TIGHT ATTITUDE CONTROL.	NOT SURE.
2.5 430-2 E	GOOD VISIBILITY. TAIL WIND. LIGHT TO MODERATE.	A GOOD AIRPLANE BUT IT WASN'T REAL EASY TO GET ON THE GLIDE SLOPE. IF THE AIRSPEED GOT LOW THE NOSE WOULD DROP AND I HAD TO RESTRAIN IT. IT WANTED TO GO IN THE RIGHT DIRECTION IN CORRECTING THE AIRSPEED ERROR BUT IT WANTED TO GO TOO FAR AND I HAD TO RESTRAIN IT. THERE WERE SOME ATTITUDE CHANGES THAT WERE LARGER THAN I WANTED, AND I HAD TO WORK TO KEEP THEM FROM BEING THAT LARGE. REASONABLY GOOD AIRPLANE BUT NOT OPTIMUM.	QUITE EASY IN SMOOTH AIR. (cont.)	O.K. (cont.)	GOOD (cont.)	(DIDN'T ANSWER SPECIFIC QUESTIONS.)				
4 446-1 E	MODERATE.	LACKS GOOD POSITIVE CONTROL. THE BIGGEST PROBLEM WOULD BE PITCH RESPONSE IN TURBULENCE.	EASY IN SMOOTH AIR.	LITTLE ON HEAVY SIDE	MARGINALLY SATISFACTORY	NO PROBLEM IN SMOOTH AIR, BUT IN TURBULENCE YOU HAVE TO RESTRAIN IT IN ATTITUDE	WENT FAIRLY WELL	NO PROBLEM IF YOU RESTRAIN IT IN ATTITUDE.	GOOD TIGHT ATTITUDE STABILIZATION	YES.
2 396-2 E	QUITE SMOOTH ABOVE 3900 FT. LIGHT - MODERATE. VERY POOR VISIBILITY. TRAFFIC CONCERN.	HAD A SENSE OF AIRSPEED IN STICK FORCE. IT SEEMED VERY DESIRABLE; HOWEVER, AT LOW ALTITUDE THERE WAS SOME TENDENCY TO PITCH IN TURBULENCE. REQUIRED LESS TIME ON ATTITUDE AND AIRSPEED THAN ON FIRST ONE. $\omega_p \doteq .1$. THINKS STICK MOTION RATE LARGE.	NO.	O.K., EXCEPT STICK MOTION IS LARGE.	O.K.	NO PROBLEM	COULD DO IT O.K. FELT BETTER THAN 396-2. AIRSPEED & ATTITUDE TOOK CARE OF THEMSELVES IN IFR DESCENT.	NOT A PROBLEM	NONE	YES.
4 414-1 E	BEAUTIFUL DAY. MODERATE	HAS A LOT OF STIFFNESS IN AIRSPEED. LOT OF PITCHING MOMENT WITH AIRSPEED. IN SMOOTH AIR, THIS GIVES GOOD SENSE OF AIRSPEED CHANGES THROUGH STICK FORCE. HOWEVER, IN WIND SHEAR OR TURBULENCE, IT PITCHES TOO MUCH. IF YOU DIDN'T RESTRAIN IT, THE SPEED WOULD OVERSHOOT DUE TO THE PITCH CHANGE. PITCH RESPONSE IN TURBULENCE MAIN OBJECTION.	AIRSPEED TENDS TO OSCILLATE. MUST STABILIZE THROUGH TIGHT ATTITUDE ELEVATOR LOOP	O.K. SENSITIVE INITIAL RESPONSE - HEAVY FORCE WITH AIRSPEED.	INITIAL RESPONSE A LITTLE ABRUPT.	NO.	----	TENDS TO OSCILLATE, CONTROL THROUGH STRONG TIGHT ATTITUDE - ELEVATOR.	TIGHT ATTITUDE STABILIZATION	YES.
4.5 425-2 E	LIGHT.	IT JUST SEEMED TO BE DIFFICULT TO ESTABLISH IN A REAL STEADY STATE FLIGHT PATH. DOWNRATE IT SOMEWHAT BECAUSE OF IMPRECISION ON GLIDE SLOPE. NOTE: COMMENTS MADE ON GROUND IN AIRPLANE, BUT THERE WAS ACTIVITY AROUND THE AIRPLANE WHICH TENDED TO DISTRACT PILOT AND INTERRUPT HIS TRAIN OF THOUGHT.	SOMEWHAT DIFFICULT	O.K.	SHORT PERIOD O.K. BUT THE ATTITUDE CHANGES WITH AIR SPEED CAUSED DIFFICULTIES.	NO PARTICULAR PROBLEM	SOME DIFFICULTY	NOT A PARTICULAR PROBLEM.	NONE	YES.

Table III (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
4 452-1 Group E Figure 12a X	SMOOTH - LIGHT	VERY NICE COMFORTABLE SHORT TERM RESPONSE. THE BASIC PROBLEM WITH IT IS ITS PILOT RESPONSE TO TURBULENCE AND WIND SHEAR THAT WE HAD. IT WANTED TO OVERRESPOND IN PITCH TO AIRSPEED DISTURBANCES AND THE PILOT HAD TO RESTRAIN IT. IN THE DESCENT IT WAS COMFORTABLE AND HAD GOOD ATTITUDE CONTROL. ALSO, ATTITUDE CONTROL GAVE IN THE ELEVATOR STICK FORCES. ON GLIDE SLOPE, IS WORST ASPECT.	REAL WELL IN SMOOTH AIR.	O.K., PICKED A LITTLE OR LIGHT SIDE	PRETTY GOOD EXCEPT FOR RESPONSIVENESS TO TURBULENCE.	GOOD IN SMOOTH AIR. IN TURBULENCE, IT HAD TO BE RESTRAINED IN PITCH.	WENT FAIRLY WELL. THE RESPONSIVENESS IN TURBULENCE IS THE ONE BAD FACTOR THAT TENDS TO DISTURB RATE OF DESCENT.	NO PROBLEM, BUT YOU HAVE TO RESTRAIN IT IN PITCH WHEN YOUR ARE IN TURBULENCE.	NONE, EXCEPT CONSTRAIN PITCH ATTITUDE IN TURBULENCE.	CERTAINLY COULD.
			GOOD CONTROL OF AIRSPEED AT CONSTANT THROTTLE. I WAS ABLE TO SPEND A FAIR AMOUNT OF TIME ON THE LOCALIZER. IT HAS A GOOD SENSE OF AIRSPEED USED THROTTLE TO CONTROL AIRSPEED AND ALTITUDE. HAD A LITTLE TENDENCY TO GO UP AND DOWN ON THE GLIDE SLOPE. PITCH RESPONSE TO TURBULENCE							
4 441-1 E	EXCELLENT VISIBILITY. LIGHT - SMOOTH	HAVE TO CONTROL ATTITUDE TIGHTLY OR YOU GET AN EXCHANGE OF AIRSPEED AND ATTITUDE. HAS FORCE FEEL IF AIRSPEED GETS OFF TRIM. AIRSPEED DID NOT HOLD REAL WELL WHERE I WANTED IT.	FAIRLY EASY	SATISFACTORY. PICKED LIGHT BECAUSE OF EXCESS FORCE WITH SPEED CHANGE.	SATISFACTORY BUT SPEED CHANGE HAS STRONG EFFECT ON ATTITUDE.	O.K. IF YOU STAY TIGHT ON ATTITUDE.	WENT WELL.	AGGRAVATING AND TIED UP WITH ATTITUDE CONTROL	TIGHT ATTITUDE	YES.
6.5 430-1 E	VISIBILITY GOOD. TAIL WIND. LIGHT - MODERATE	PRETTY GOOD IN SMOOTH AIR. SMALL AIRSPEED AND PITCH ATTITUDE OSCILLATION UNLESS IT IS RESTRAINED AND THEN YOU HAVE FORCE OSCILLATION. IN TURBULENCE AND WIND SHEAR IT HAS LARGE PITCH ATTITUDE DISTURBANCES WHICH MUST BE RESTRAINED BY THE ELEVATOR.	FAIRLY EASY IN SMOOTH AIR, EXCEPT DOESN'T TEND TO HOLD AIRSPEED PRECISELY. IN ROUGH AIR, WOULD BE MIGHTY DIFFICULT.	O.K. WOULDN'T WANT INITIAL RESPONSE ANY LIGHTER. STEADY FORCES WITH ANGLE OF ATTACK ARE O.K. BUT WOULD LIKE THE STEADY FORCES WITH AIRSPEED A LITTLE LIGHTER.	O.K.	TENDS TO EXCHANGE AIRSPEED AND ALTITUDE. YOU'RE ALWAYS HUNTING A BIT.	WOULD BE DIFFICULT IN TURBULENCE.	SOMEWHAT A PROBLEM. VERY POOR ON GLIDE SLOPE. ON DESCENT WE HAD A PLUNGING GALLOPING LONG PERIOD OSCILLATION.	TIGHT ATTITUDE STABILIZATION AND AIRSPEED TO THROTTLE	WOULD BE DIFFICULT IN TURBULENCE.
10 431-2 E	LIGHT TO MODERATE. GOOD VISIBILITY	WIRE RECORDER MALFUNCTIONED.	PILOT HAD GREAT DIFFICULTY CONTROLLING AIRSPEED. WHEN AIRSPEED GOT OFF THE TRIM VALUE, THE STICK FORCE TO MAINTAIN ATTITUDE WAS VERY LARGE. HE STATED HE WAS AT LIMITS OF CAPABILITY BOTH IN ABILITY TO COMPREHEND THE SITUATION AND TO DECIDE ON CONTROL ACTION BUT ALSO AS TO CONTROL AUTHORITY AVAILABLE, I.E., ENGINE THRUST AND PITCH EFFECTIVENESS OF ELEVATOR.							
6.5 437-2 Group F Figure 12a △	WIND SHEAR LIGHT, OCCASIONAL MODERATE	REASONABLE IN SMOOTH AIR BUT MISERABLE IN TURBULENCE. IN TURBULENCE ON THE GLIDE SLOPE, IT WOULD PITCH SO A LOT OF MY ATTENTION WAS DEVOTED TO MINIMIZING ATTITUDE ERRORS SO I'D FLY SOMEWHERE NEAR THE GLIDE SLOPE. THIS IS A TOUGH ONE. IT'S QUITE GOOD IN SOME AREAS, BUT TOO RESPONSIVE TO TURBULENCE.	EASY. COULD TRIM IT FOR ATTITUDE AND ANGLE OF ATTACK AND ADJUST THROTTLE TO GET AIRSPEED.	O.K., BUT WHEN I GOT IT HIGH ENOUGH SO STEADY FORCES WITH AIRSPEED WERE LIGHT, THEN IT WAS TOO LOOSE INITIALLY IN PITCH. THE HIGH GAIN HELPED IN TURBULENCE.	IT'S NICE AND STIFF BUT INITIAL RESPONSE IS LITTLE TOO LOOSE, I.E., INITIAL PITCH RESPONSE IS LARGE COMPARED TO FINAL.	IN SMOOTH AIR, IT WAS NO PROBLEM. IN TURBULENCE AND WIND SHEAR IT IS DIFFICULT.	DIDN'T GO WELL IN TURBULENCE.	A PROBLEM ON THE GLIDE SLOPE IN TURBULENCE.	TRY TO SMOOTH OR RESTRAIN ATTITUDE IN TURBULENCE.	YES, BUT IF YOU HIT A STRONG GUST CLOSE TO THE GROUND, IT COULD BE DANGEROUS.

Table III (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
5 456-2 Group G Figure 13a □	SMOOTH LATE IN DAY, LOOKING INTO SUN.	WITH THE PILOT HANGING ON THE ELEVATOR STICK, IT WAS DIVERGENT IN AIRSPEED. IT HAS LARGE DRAG DUE TO ELEVATOR, BACK STICK INCREASES DRAG, SO TO MAKE TURNS YOU HAVE TO ADD LOTS AND LOTS OF POWER. DURING TURNS THE AIRSPEED KEPT WANTING TO GET AWAY, ESPECIALLY IF YOU TRIED TO HOLD ALTITUDE. SO WITH ME IN THE LOOP IT LOOKED LIKE THERE IS A DIVERGENCE IN AIRSPEED. THE THING TO DO IS TO FLY AROUND TRIM AS MUCH AS POSSIBLE. ON THE GLIDE SLOPE I HAD LOTS OF ERRORS IN ALTITUDE AND AIRSPEED. IN SMOOTH AIR WE HAD, I WAS ABLE TO STAY OUT OF THE ELEVATOR LOOP AND SO DIDN'T HAVE TOO BAD A TIME, BUT IN TURBULENCE I'M NOT SO SURE I COULD DO AS WELL.	SOMEWHAT DIFFICULT. PROBABLY EASIER IF YOU DON'T USE THE STICK.	O.K.	ATTITUDE WAS O.K., BUT EVERY TIME I GRABBED HOLD OF THE STICK I HAD AIRSPEED PROBLEMS.	HAD TROUBLE IN TURNS.	HAD DIFFICULTY IN ESTABLISHING IT.	A CONSIDERABLE PROBLEM WHEN I WAS RESTRAINING THE FLIGHT PATH.	THROTTLE FOR AIRSPEED ERRORS AND ALSO WHEN I PULLED BACK ON THE STICK.	YES
2.5 458-1 G □	LIGHT – SMOOTH LATE IN DAY – LOOKING INTO SUN.	COULD PRETTY WELL DO WHAT I WANT WITH THIS CONFIGURATION – COUPLE OF MINOR OBJECTIONS. IT IS A LITTLE LOOSE IN PITCH, I.E., A LITTLE OVERSHOOT IN THE PITCH RESPONSE. ALSO, IT IS A LITTLE UNCERTAIN ABOUT CHANGING FLIGHT PATH, I.E., DURING ATTITUDE CHANGES TO ESTABLISH A RATE OF DESCENT AND AIRSPEED. NOTED ACCELERATIONS AND DECELERATIONS WHEN I MOVED CONTROLS. VERY GOOD ON THE GLIDE SLOPE. I DIDN'T HAVE TO ADD ANY POWER DURING TURNS.	LITTLE DIFFICULT TO GET FINE TRIM IF I WAS USING THE ELEVATOR.	O.K.	LITTLE LOOSE.	NO PROBLEM.	WENT VERY WELL IN SMOOTH AIR.	NO PROBLEM AT ALL.	NONE	YES
10 399-1 G ○	TURBULENCE. AILERON KICKS. LOCALIZER ERRATIC	IT HAS A LOT OF DRAG DUE TO ELEVATOR, BACK STICK INCREASES DRAG. MIGHT LEARN TO COORDINATE THROTTLE WITH STICK IN SMOOTH AIR. BUT THE STICK MOTIONS WERE PRETTY HIGH FREQUENCY & YOU MIGHT ABUSE THE ENGINE. IF A GUST UPSETS YOU IN PITCH AND YOU WERE ALL STABILIZED IN SPEED, YOU APPLY ELEVATOR TO CORRECT THE PITCH AND YOU HAVE TO APPLY A THROTTLE CORRECTION ALSO. IF YOU HIT A HORIZONTAL GUST OR WIND SHEAR, THE STIFF PHUGOID CALLS FOR STRONG NOSE-UP TENDENCY. TO STAY ON THE GLIDE SLOPE YOU HAVE TO PUSH FORWARD ON THE STICK, AND IF YOU PUSH FORWARD ON THE STICK YOU HAVE AIRSPEED PROBLEMS.	YES, IT'S DIFFICULT.	NOT REALLY. I SHOULD HAVE PICKED IT HIGHER TO COMBAT THE TRIM CHANGE WITH AIRSPEED.	IT STARTS O.K., BUT LARGE X_{δ_e} CAUSES SPEED TO CHANGE & AND THEN THE NOSE JUST STOPS AND SORT OF HANGS THERE. STICK SORT OF ORDERS ATTITUDE.	DEFINITELY A PROBLEM. ANY TIME YOUR ARE FLYING IT WITH THE ELEVATOR. IF YOU PULL BACK ON THE STICK AT CONSTANT THROTTLE, AIRSPEED WILL DECREASE AND YOU SINK. IN TURNS IF YOU DON'T GET THE THROTTLE ON AT JUST THE RIGHT AMOUNT, THE AIRSPEED WILL BLEED, NOSE WILL DROP, & IF YOU PULL MORE ON THE STICK TO HOLD ALTITUDE IT WILL SINK LIKE MAD. MISERABLE!	NO!	YES	USE THROTTLE CORRECTIONS ACCORDING TO AIRSPEED ERRORS & ELEVATOR PITCH INPUTS. PHASING THROTTLE WITH ELEVATOR, ETC. IS VERY DIFFICULT.	NO. MISERABLE!
5.5 439-2 G ○	QUITE LIGHT. LOTS OF TRAFFIC AND RADIO CHATTER.	NOT A VERY GOOD CONFIGURATION. RUN OUT OF POWER IN A 30° BANKED TURN. TRIED NOT TO LET THIS INFLUENCE ME TOO MUCH. SOME AIRSPEED PROBLEMS ON THE GLIDE SLOPE. IF I'M HANGING ON THE STICK TO MAKE THE AIRPLANE DO SOMETHING, THE AIRSPEED MODE SEEMS TO BE UNSTABLE.	DIDN'T GET A GOOD LOOK, BUT I THINK I HAD SOME AIRSPEED PROBLEMS.	O.K.	YES. DURING STICK STEPS, WHEN YOU PULL THE STICK BACK THE SPEED DROPS OFF BUT WHEN YOU REVERSE IT AND PUSH FORWARD, THE AIRSPEED KIND OF SLOWS ITS RATE OF DECREASE WHILE YOU'RE BRINGING THE NOSE BACK DOWN AGAIN. THIS HAS ADVANTAGES.	YES, ESPECIALLY IN TURNS. YOU HAVE TO COORDINATE THE THROTTLE WITH ELEVATOR TO MAINTAIN SPEED.	O.K.	YES, IT IS PROBLEM IF YOU'RE HOLDING FLIGHT PATH. IT REQUIRES TIGHT AND LARGE AMPLITUDE THROTTLE CLOSURE WITH LOW FREQUENCY OR STEADY ELEVATOR INPUTS.	THROTTLE WITH ANGLE OF ATTACK CHANGES OR STEADY ELEVATOR INPUTS AND ALSO LARGE AMPLITUDE THROTTLE CORRECTIONS WITH AIRSPEED ERRORS.	YES

Table III (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
4 439-1 Group G Figure 13a ○	POOR VISIBILITY. VERY LIGHT.	STARTED OUT THINKING OF A RATING OF 3, BUT DECIDED IT HAD SOME OBJECTIONABLE CHARACTERISTICS. WENT 20-30 FEET LOW IN LEVELING OUT AT 600 FT ABOVE GROUND AND IT FELT A LITTLE "SLIPPERY" ON THE GLIDE SLOPE. STAYED ON THE GLIDE SLOPE O.K. BUT COULDN'T PIN DOWN AIRSPEED. LITTLE UNDECIDED ON RATING, CONSIDERED 3 TO 4.5. DECIDED ON 4.	SOME DIFFICULTY.	O.K.	O.K.	LITTLE BIT OF PROBLEM STRAIGHT AND LEVEL.	WENT PRETTY WELL.	NOT A PROBLEM FOR FIXED THROTTLE. BUT TENDED TO GET A LITTLE SLIPPERY ON GLIDE SLOPE.	NO.	YES
5 339-2 G ○	FAIRLY TURBULENT. SYSTEM DUMPS, TRAFFIC INTERFERENCE. LOCALIZER ERRATIC AILERON FEEL KICKS.	DIDN'T KNOW WHAT TO DO WITH CONTROLS TO MAKE FLIGHT PATH DO WHAT I WANTED IT TO DO IN THE PRESENCE OF TURBULENCE, ESPECIALLY CLOSE TO THE GROUND, WHERE I NEED TO HAVE IT RESPOND RAPIDLY AND CORRECTLY. I WOULD LIKE TO SEE THIS ONE AGAIN WHEN I HAD MORE TIME AND FEWER DISTRACTIONS.	NOT TOO DIFFICULT.	O.K.	SEEMED SLUGGISH.	GOOD IN TURNS. DOWN LOW IF I HIT A GUST, THE NOSE WOULD TEND TO RISE AND I'D PUSH FORWARD ON THE STICK AND I'D TEND TO GET FAST, BUT MAINTAIN MY FLIGHT PATH.	NO COMMENT.	NO PROBLEM IN TURNS BUT A LITTLE TENDENCY TO HAVE TROUBLE IN TURBULENCE.	NONE.	YES
9 438-1 G ◊	LIGHT, OCCASIONAL MODERATE. TRAFFIC.	IT WAS UNSTABLE AIRSPEEDWISE IF YOU CONSTRAINED THE FLIGHT PATH WITH THE ELEVATOR. COULDN'T HOLD ALTITUDE IN TURNS BECASE OF DRAG RISE, RAN OUT OF POWER. ON GLIDE SLOPE I FLEW ATTITUDE WITH ELEVATOR AND AIRSPEED WITH THROTTLE. FOUND I NEEDED AIRSPEED RATE INFORMATION. TRIED LEAVING ELEVATOR ALONE AND USING THROTTLE BUT THE RESPONSE TIME WAS TOO LONG.	YES.	O.K.	NOT REALLY. IF YOU PULLED BACK ON THE STICK THE RESPONSE WAS PECULIAR. IT WOULD RESPOND INITIALLY, THEN KIND OF STOP AS AIRSPEED WOULD DROP OFF. I COULDN'T REALLY SEE SHORT PERIOD.	ANY TIME I'M IN THE LOOP WITH THE ELEVATOR, IT'S AN EXTREME PROBLEM.	DIFFICULT WHEN TRYING TO MAINTAIN WITH THE ELEVATOR.	PROBLEM WHENEVER I'M FLYING THE AIRPLANE WITH THE ELEVATOR.	NO COMMENT.	NO
3 438-2 G ◊	HAZY. LIGHT. TRAFFIC.	I SEEMED TO HAVE GOOD POSITIVE CONTROL OF THE CONFIGURATION AND KNEW WHAT I WAS DOING AT ALL TIMES. MADE GOOD GLIDE SLOPE APPROACHES USING ELEVATOR TO CONTROL ATTITUDE AND THROTTLE TO CONTROL AIRSPEED IN A VERY NATURAL WAY. I TRIED NOT TO OBJECT TO THINGS JUST BECAUSE THEY WERE DIFFERENT THAN I'M USED TO. MY MOST SERIOUS OBJECTION WAS TO THE EFFECT OF ELEVATOR CONTROL ON AIRSPEED IN SYMMETRICAL PUSHOVERS AND PULLUPS. ON THE GLIDE SLOPE IN SMOOTH AIR, THOUGH, IT WAS GOOD	CAN BE A LITTLE DIFFICULT IF YOU USE THE ELEVATOR BECAUSE IT AFFECTS AIRSPEED. EASIER IF YOU TRIM AIRSPEED WITH THROTTLE. IF I PULL UP FROM NOSE LOW POSITION, AIRSPEED INCREASES RAPIDLY THEN HOLDS PRETTY CONSTANT UNTIL ATTITUDE GETS QUITE HIGH. WHEN I REVERSE ELEVATOR STICK, AIRSPEED DROPS QUITE A BIT. YOU ARE NOSE HIGH WITH AIRSPEED JUST STARTING TO SLOW DOWN. WHEN YOU TAKE CORRECTIVE ACTION ON THE ELEVATOR, IT CAUSES THE AIRSPEED TO BLEED OFF RAPIDLY. THIS IS ONE THING I DON'T LIKE ABOUT THIS CONFIGURATION.	O.K.	ATTITUDE SEEMED TO WANDER JUST A LITTLE BIT.	NOT A PROBLEM, ALTHOUGH IT FEELS A LITTLE ODD DURING TURN ENTRIES.	SATISFACTORY.	NO PROBLEM EXCEPT SMALL ERRORS IN TRIMMING.	NONE.	YES

Table III (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
5.5 441-2 Group G Figure 13a ◊	CLOUDS. LIGHT TO MODERATE.	DURING IFR, CONTROL OF AIRSPEED WITH ATTITUDE WAS NOT A PRECISE THING TO DO. ALSO, WHEN I TRIED TO CHANGE FLIGHT PATH AT CONSTANT SPEED, I GOT AN AIRSPEED DISTURBANCE. IT WAS PRETTY GOOD ON THE GLIDE SLOPE. ON CIRCLING FIELD, IT WAS DIFFICULT TRYING TO FIND AN ATTITUDE THAT WOULD HOLD AIRSPEED AT CONSTANT THROTTLE. ITS POOREST PART IS IFR.	YES	O.K.	O.K.	SOMEWHAT. TENDED TO GET FAST IN TURNS.	ONE OF POOREST THINGS ABOUT CONFIGURATION. QUITE DIFFICULT TO MAINTAIN CONSTANT RATE OF DESCENT AT CONSTANT SPEED.	A PROBLEM IFR, BUT NOT ON GLIDE SLOPE.	HAVE TO LEAD THROTTLE TO CONTROL AIRSPEED. STABILIZE ATTITUDE. ATTITUDE IS POOR CONTROL FOR AIRSPEED.	YES.
9 460-1 G ○	LIGHT TO MODERATE TRAFFIC. RUDDER FEEL SERVO.	VERY PECULIAR CONFIGURATION TO FLY. IT HAS A GOOD SHORT PERIOD, A VERY UNSTABLE PHUGOID, AND LOTS OF DRAG DUE TO ELEVATOR IN THE SENSE THAT BACK STICK REDUCES DRAG. ON THE FIXED THROTTLE DESCENT, IF IT GOT A LITTLE SLOW AND PUSHED OVER THE NOSE TO GET BACK THE AIRSPEED. AS I WAS PUSHING THE NOSE OVER, NOTHING HAPPENED SO I TENDED TO GO TO RELATIVELY LARGE ATTITUDE CHANGES. WHEN THE AIRSPEED FINALLY STARTED BACK. BY THIS TIME IT WAS MAYBE DOWN TO 152 KT AND I'D HAVE QUITE AN ATTITUDE AND SINK RATE. I'D START BACK ON THE STICK TO START BRINGING THE ATTITUDE BACK TO THE REFERENCE VALUE AND THE AIRSPEED WOULD JUST TAKE OFF IN THE OTHER DIRECTION AND WOULD GO HIGH. I FOUND I COULD PLAY TRICKS WITH IT. FOR EXAMPLE, IF THE AIRSPEED WAS LOW AND THE RATE OF CHANGE WAS ZERO AND THE ATTITUDE WAS ALSO LOW, THEN INSTEAD OF PUSHING ON THE STICK I'D PULL BACK ON IT. AIRSPEED WOULD COME UP TO 160 ABOUT THE TIME I GOT LEVEL PITCH ATTITUDE AND EVERYTHING WOULD BE ALL RIGHT. BUT THAT'S KIND OF CONTRARY TO WHAT I'D DO IN OTHER SITUATIONS, SO IT'S CONFUSING. ANOTHER THING ABOUT IT WAS THAT BY ITSELF, THE AIRPLANE HAS PRETTY NEGATIVELY DAMPED PHUGOID. IT'S STIFF IN THE PHUGOID AND WHEN THERE IS AN AIRSPEED ERROR. IT RESPONDED IN ATTITUDE AND WAY TOO FAR. SO ALL IN ALL, IT WAS EXTREMELY DIFFICULT TO CONTROL AIRSPEED WITH ATTITUDE AT FIXED THROTTLE. I FELT MUCH RELIEVED TO BE VISUAL. IT WAS CERTAINLY BETTER ON THE GLIDE SLOPE THAN IT WAS IFR BUT IT CERTAINLY WASN'T GOOD. IT WAS TOO VARIABLE IN ITS RESPONSE IN DIFFERENT PARTS OF THE APPROACH, SO I WAS NEVER COMFORTABLE WITH IT. THE SHORT PERIOD WAS ONE OF THE BLESSINGS OF THIS CONFIGURATION. IT WAS DIFFICULT TO FIND PROPER ATTITUDE TO MAKE THE AIRPLANE DO WHAT YOU WANT IT TO DO. ONE OF THE PROBLEMS IS THAT YOU GET CONFLICTING CUES. I'M NOT SURE WHAT THEY ARE - MAYBE THEY'RE FORCE FEEL WITH AIRSPEED OR MAYBE THEY ARE LONGITUDINAL ACCELERATIONS, BUT YOU CERTAINLY GET CUES THAT TEND TO MAKE YOU DISBELIEVE YOUR ATTITUDE.	MODERATE DIFFICULTY.	TRIED IT LOW, AND THE FORCES WERE TOO HIGH WITH AIRSPEED CHANGES. I TRIED IT HIGH AND LONGITUDINAL ACCELERATIONS WERE NOTICEABLE. FOR THE VALUE THAT I PICKED, THEY TEND TO BLEND WITH THE AIRPLANE RESPONSE.	SHORT PERIOD IS O.K. BUT OVERALL ATTITUDE IS ALMOST UNACCEPTABLE	IT'S ONE OF THE DIFFICULTIES, BUT I'M NOT SURE WHY.	COULDN'T DO IT.	CONSIDERABLE PROBLEM.	TIGHT ATTITUDE CLOSURE AND HIGH GAIN THROTTLE WITH AIRSPEED ERROR.	NOT CONSISTENTLY.

Table III (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING / FLIGHT NO. / GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
5 452-2 Group H Figure 15a ●	LIGHT. TRAFFIC.	THIS ONE HAS A LOT OF DRAG DUE TO ANGLE OF ATTACK. AT ALTITUDE, THIS WAS A PREDICTABLE CONFIGURATION, I.E., EVERY TIME YOU CHANGED ANGLE OF ATTACK TO ALTER FLIGHT PATH OR MAKE TURNS YOU ADD OR REDUCE POWER. WHENEVER I HAD A STEADY ANGLE OF ATTACK CHANGE I'D MAKE THROTTLE CHANGES. HOWEVER, WHENEVER I TRIED TO RESTRAIN THE FLIGHT PATH SUCH AS ON THE GLIDE SLOPE I HAD AIRSPEED PROBLEMS. THIS IS NOT A GOOD GLIDE SLOPE AIRPLANE. ONE THING I NOTICED WAS WHEN I HIT TURBULENCE IT WAS COMPLETELY DIFFERENT THAN THE PREVIOUS CONFIGURATION. I DIDN'T HAVE TO RESTRAIN IT SO MUCH. WHEN A GUST HIT THE NOSE MOVED UP GRADUALLY AND ABOUT THE RIGHT AMOUNT. IT WAS A COMFORTABLE SORT OF TURBULENCE AIRPLANE. THE PRINCIPAL OBJECTION IS DIFFICULTY IN AIRSPEED CONTROL WHEN THE PILOT IS RESTRAINING FLIGHT PATH.	PRETTY EASY IF YOU DON'T TRY TO TIE IT TO AN ALTITUDE.	GOOD.	SATISFACTORY.	WHEN I TRIED TO MAINTAIN ALTITUDE I HAD TROUBLE WITH AIRSPEED.	WENT FAIRLY WELL.	NOT A PROBLEM JUST FLYING AROUND BUT ON THE GLIDE SLOPE AIRSPEED GOT TO BE A PROBLEM.	THROTTLE WITH ANGLE OF ATTACK AND AIRSPEED ERRORS.	YES.
5 454-1 H ●	MODERATE.	LOTS OF DRAG DUE TO ANGLE OF ATTACK. STRAIGHT AND LEVEL, IT WAS A PRETTY GOOD AIRPLANE. DURING JET PENETRATION I WAS ABLE TO DO A GOOD JOB AT FIXED THROTTLE. ATTITUDE WAS A GOOD CONTROL OF AIRSPEED. IF AIRSPEED GOT OFF, THE NOSE WOULD DROP BUT WOULDN'T GO TOO FAR LIKE SOME OF THE LIGHT OR NEGATIVELY DAMPED PHUGOID CONFIGURATIONS. I DIDN'T HAVE TO RESTRAIN IT AS MUCH. IN TURBULENCE, THOUGH, IT SEEMED AWFULLY RESPONSIVE IN PITCH. THIS TENDS TO ACT AS A DISTURBANCE. IT'S NOT TOO BAD, BUT IT'S THERE. ANOTHER PROBLEM IS THE VERY HIGH DRAG RISE IN TURNS OR WHEN YOU'RE PULLING g. IN TURNS, IT'S STRICTLY A THROTTLE AIRPLANE, YOU HAVE TO LEARN THE RIGHT AMOUNT OF THROTTLE TO USE AS A FUNCTION OF BANK ANGLE. IF YOU DON'T, THE SINK RATE BUILDS UP VERY, VERY RAPIDLY, AND IF YOU RESTRAIN RATE OF SINK THE AIRSPEED DIVERGES. IT HAD THE APPEARANCE OF BEING UNSTABLE. YOU HAVE TO BE A TWO-CONTROL PILOT IN ALL MANEUVERING FLIGHT. ON GLIDE SLOPE A HIGH AND FAST IS HARD TO CORRECT. THIS AIRPLANE TENDS TO LOAD THE PILOT. IT HAS HIGH DRAG RISE WITH ANGLE OF ATTACK AND THE OVERSENSITIVE PITCH RESPONSE TO TURBULENCE.	NOT REAL GOOD.	LITTLE DIFFICULT TO PICK. WHEN I GOT FORCES IN TURN RIGHT, INITIAL PITCH RESPONSE WAS TOO SENSITIVE. (FORCES IN TURN MAY HAVE BEEN HIGH IF PILOT DIDN'T MAINTAIN AIRSPEED - CAUSED BY PHUGOID OR M_u EFFECT.)	FAIRLY GOOD, BUT A LITTLE TOO SENSITIVE.	CONSIDERABLE PROBLEM IN TURNS.	WENT QUITE WELL FOR WINGS LEVEL	A PROBLEM IN TURNS OR ACCELERATED FLT. WHEN YOU'RE RESTRAINING THE FLIGHT PATH.	LOTS OF THROTTLE WITH ANGLE OF ATTACK - VERY HIGH GAIN.	YES, BUT YOU HAVE TO ACCEPT THE FACT THAT YOU'RE MORE LOADED BY BEING A TWO-CONTROL MAN EVERY TIME YOU BANK.
6 455-1 H ○	LIGHT - MODERATE STRONG CROSSWIND FROM LEFT. δ_{e_s} FILTER	I BASICALLY DIDN'T LIKE IT. I COULDN'T ALWAYS MAKE IT DO WHAT I WANTED IT TO. EVERY ONCE IN A WHILE, FOR EXAMPLE, THE NOSE WILL PITCH UP WHAT LOOKS LIKE 4-5° I LET IT GO ONCE AND IT OSCILLATED IN THE PHUGOID AND DAMPED. BUT IT WAS A LARGE DISTURBANCE. IT IS VERY RESPONSIVE IN PITCH TO DISTURBANCES AND IT'S NOT PREDICTABLE. I HAVE HAD SOME THAT HAD NEGATIVELY DAMPED PHUGOIDS AND AN AIRSPEED DISTURBANCE WOULD CAUSE IT TO PITCH QUITE FAR, ABOUT TWICE AS FAR AS IT SHOULD TO CORRECT THE ERROR. I KNOW WHAT THAT IS, BUT I DON'T KNOW WHAT THIS IS A FUNCTION OF. IT WAS PRETTY GOOD DURING THE IFR PORTION WHEN THE TURBULENCE WAS LIGHT. WHEN WE WENT TO THE GLIDE SLOPE I HAD TROUBLE GETTING IT TO PITCH OVER. I REALLY HAD TO PUSH SO IT SEEMED TO BE AN AIRPLANE THAT WAS SLUGGISH TO BEND THE FLIGHT PATH. HAD CONSIDERABLE TURBULENCE AND WIND SHEAR ON THE APPROACH SO IT WAS DIFFICULT TO TELL WHAT THE AIRSPEED ERRORS WERE. I DON'T THINK IT WAS TOO BAD ON THE GLIDE SLOPE. I DIDN'T HAVE PRECISE ATTITUDE CONTROL BECAUSE OF THE TURBULENCE SO I TENDED TO MAKE ALTITUDE CORRECTIONS WITH POWER AND TO LEAVE THE ATTITUDE CONSTANT. IN SO DOING I TENDED TO GET BEHIND AND OSCILLATE ABOUT THE GLIDE PATH. ALL THE WAY THROUGH I FELT LIKE I WAS FLYING AN ELEPHANT. IT DID WHAT IT WANTED TO AND I KIND OF KEPT NUDGING IT AROUND INFLUENCING WHAT IT WAS GOING TO DO. I DON'T HAVE POSITIVE CONTROL OF ATTITUDE.	HARD TO TELL IN THE TURBULENCE. SAY MODERATE.	O.K. FELT LIGHT INITIALLY IN PULLUPS. PICK IT A LITTLE HEAVY.	NOT SATISFACTORY.	HAD TO ADD POWER IN TURNS. NEVER KNEW HOW MUCH. TURBULENCE WAS A FACTOR.	NO COMMENT.	MODERATE PROBLEM IN TURNING FLIGHT.	ADD POWER WITH ANGLE OF ATTACK.	YES, BUT NOT VERY WELL IN TURBULENCE.
10 461-2 H ○	LIGHT δ_{e_s} FILTER	BY ITSELF THE AIRPLANE APPEARED TO HAVE A PRETTY GOOD SHORT PERIOD, A STIFF AND PRETTY WELL DAMPED PHUGOID AND AS LONG AS I DIDN'T TOUCH THE STICK, IT WAS A REASONABLE AIRPLANE. BUT UNFORTUNATELY, THE PILOT HAS TO TAKE HOLD OF THE DRIVER'S STICK AND WIGGLE IT TO TRY TO MAKE IT GO WHERE HE WANTS IT TO, AND WHEN HE DOES THAT WITH THIS ONE, IT JUST FALLS APART AT THE SEAMS. AS NEAR AS I CAN TELL IT HAS A WHOLE LOT OF DRAG DUE TO ANGLE OF ATTACK. I CAN'T DETECT ANY DECELERATIONS THAT ARE OUT OF PHASE WITH THE RESPONSE. ANYWAY, ANY TIME I TRIED TO MANEUVER WITH THE STICK I HAD GREAT DIFFICULTIES. ALSO HAD DIFFICULTIES WHENEVER I GET INTO TURBULENCE. I RAN OUT OF POWER IN TURNS FAR LESS THAN 30° BANK. ON THE FIXED THROTTLE DESCENT, IT WAS FAIRLY GOOD BUT I WAS JUST MAKING TINY INPUTS AND MOSTLY JUST LETTING IT FLY. WHEN I GOT INTO TURBULENCE AT LOWER ALTITUDE, I HAD TO USE THE STICK MORE AND ALTITUDE AND AIRSPEED ERRORS BECAME A PROBLEM. GOT HEADING ERROR OF 30°. ON THE GLIDE SLOPE I WAS MAKING VERY LARGE POWER CHANGES. I FOUND I NEEDED AIRSPEED RATE WHICH I COULDN'T GET FROM THE LIGHTS AND I COULDN'T AFFORD TO LOOK AT THE AIRSPEED INDICATOR BUT I FOUND I COULD PUT THROTTLE INPUTS IN BY THE LONGITUDINAL ACCELERATIONS. WELL, THE OTHER DAY I SAID SOMETHING ABOUT WHY DIDN'T THEY GIVE ME ONE I COULDN'T FLY AND I THINK THEY TOOK ME UP ON IT. THIS ONE I COULD FLY, BUT SOME PEOPLE MIGHT LOOK AT IT AND WONDER IF IT'S REALLY FLYING.	FAIRLY EASY AT CONSTANT ANGLE OF ATTACK. IMPOSSIBLE IF YOU GET INTO ELEVATOR LOOP.	O.K. I DIDN'T SELECT IT - IT WAS GIVEN TO ME.	AT CONSTANT SPEED IT WAS O.K.	O.K. STRAIGHT AND LEVEL IF I COULD STAY OFF THE STICK. DID NOT HAVE ENOUGH POWER IN TURNS.	VERY DIFFICULT OR IMPOSSIBLE IF YOU GET INTO TURBULENCE	VERY DIFFICULT IF PILOT'S IN THE LOOP	STAY OUT OF THE ELEVATOR LOOP	NO.

Table III (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
4 454-2 Group H Figure 15a ○	LIGHT TO MODERATE	WE GOT SHORT OF FUEL SO IT WASN'T A VERY THOROUGH EVALUATION. THE PHUGOID AND SHORT PERIOD DYNAMICS OF THIS ONE AND THE FIRST ONE WERE ESSENTIALLY THE SAME. IT SEEMS THAT YOU HAVE GOTTEN RID OF THE DRAG DUE TO ANGLE OF ATTACK THROUGH DRAG DUE TO ELEVATOR BY USING BACK STICK REDUCES DRAG. I CAN DETECT THIS BY THE PHASING BETWEEN THE TWO THAT CAUSES THE AIRPLANE TO DO THINGS I DON'T INTEND IT TO DO. THE RESPONSE OF THIS ONE AND THE FIRST ONE BOTH TO ELEVATOR STICK STEPS WAS PECULIAR. THE NOSE STARTS UP AND THEN STOPS AND STARTS THE OTHER WAY AND YOU'RE STILL PULLING BACK. MAYBE IT'S A STIFF PHUGOID. THE IFR STRAIGHT AND LEVEL AND CONSTANT THROTTLE DESCENT PORTIONS WENT VERY WELL. HAD LOTS OF TIME FOR THE LOCALIZER. GOOD AIRSPEED CONTROL. MADE GLIDE SLOPE RUN LOOKING ENTIRELY AT THE GLIDE SLOPE AND AIRSPEED LIGHTS. AIRSPEED CONTROL DIDN'T SEEM TO BE A PROBLEM. HAD LITTLE ALTITUDE CONTROL PROBLEM THOUGH. THIS ONE DIDN'T HAVE THE HIGH DRAG RISE IN TURNS THAT THE FIRST ONE HAD. THE CONFIGURATION DIDN'T SEEM TO BE TOO RESPONSIVE TO TURBULENCE. I'M COMPARING THIS ONE WITH THE FIRST ONE ON THIS FLIGHT, AND I THINK THIS ONE IS SUBSTANTIALLY BETTER THAN THE FIRST ONE. MAKES ME WONDER IF MAYBE I RATED THE FIRST ONE TOO GOOD. THIS CONFIGURATION DOES TEND TO REMOVE THE OBJECTIONS I HAD WITH THE FIRST ONE. IT IMPROVED MOST OF MY MANEUVERING PROBLEMS THAT I HAD WITH THE FIRST ONE, I.E., NOT HAVING TO ADD POWER IN THE STEADY TURNS AND IT UNLOADS THE PILOT. HOWEVER, THE PHASING BETWEEN DRAG DUE TO ELEVATOR AND DRAG DUE TO ANGLE OF ATTACK MAY BE CAUSING THIS PECULIAR FEEL OR BOBBLE TENDENCY. IT CERTAINLY IS IMPROVED OVER THE OTHER CONFIGURATION AND THE IMPROVEMENT SEEMS TO BE WORTH MORE THAN ONE RATING AND THAT BOTHERS ME BUT IT'S BOUNDED ON THE GOOD SIDE BECAUSE I STILL CONSIDER IT TO BE UNSATISFACTORY.	APPEARED TO BE EASY.	SATISFACTORY.	THAT 'S MY MAJOR OBJECTION. FOR SMOOTH STEADY INPUTS IT WAS O.K. BUT FOR QUICKER INPUTS I DEFINITELY HAD A TENDENCY TO BOBBLE IT.	DIDN'T OBSERVE VERY MUCH BUT IT DIDN'T SEEM TO BE A PROBLEM.	WENT WELL.	NOT A PROBLEM.	MAYBE SMOOTH YOUR ELEVATOR INPUTS.	YES.
4 461-1 H O_F	LIGHT, WIND SHEAR. δ_{ES} FILTER	IN SMOOTH AIR THIS WAS QUITE AN AIRPLANE, KIND OF HARD TO DO ANYTHING WRONG WITH IT. VERY EXCELLENT AIRSPEED-KEEPING QUALITIES, EASY TO TRIM. MY TROUBLE WITH THIS CONFIGURATION WAS THAT WHEN YOU CHANGE SPEED, THE ELEVATOR FORCES WERE FAIRLY HEAVY AND IT WAS DIFFICULT TO RESTRAIN THE AIRPLANE IN ATTITUDE. SOME OF THIS CHARACTERISTIC IS A GOOD THING BUT TOO MUCH OF IT IS A PROBLEM. THIS CONFIGURATION CERTAINLY HAD TOO MUCH AND I'M AFRAID MAKES IT AN UNSATISFACTORY AIRPLANE. IN SMOOTH AIR I WAS THINKING OF 1.5 TO 2 RATING. BUT IN TURBULENCE, THERE WAS PITCH RESPONSE TO GUSTS AND A TENDENCY FOR A PLUNGING TYPE OSCILLATION. IT WAS ALL KIND OF SMALL, THOUGH ON THE GLIDE SLOPE WE ENCOUNTERED A WIND SHEAR AND THE AIRPLANE RESPONDED IN ATTITUDE AND FLIGHT PATH AND I FOUND IT DIFFICULT TO RESTRAIN IT IN ATTITUDE IN ORDER TO RESTRAIN THE FLIGHT PATH. I HAD A PONDEROUS HEAVING OSCILLATION ON THAT WHOLE FIRST APPROACH. I TRIED TO USE POWER AS I FELT THE HEAVE COMING AND TOOK OFF POWER, BUT YOU'RE SUFFICIENTLY BEHIND THE AIRPLANE DOING IT THAT WAY THAT YOU DON'T HAVE GOOD PRECISE FLIGHT PATH CONTROL. YOU HAVE TO USE ATTITUDE TO FLY THE GLIDE SLOPE FLIGHT PATH. IT IS HARD TO KEEP THIS CONFIGURATION ON THE GLIDE SLOPE; IT WANTS TO STAY AT CONSTANT AIRSPEED. IF YOU RUN INTO DIFFERENT KINDS OF AIR, THEN IT DOESN'T STAY ON THE FLIGHT PATH I WANT IT TO. TURNS IN SMOOTH AIR WERE ABSOLUTELY BEAUTIFUL. IN SMOOTH AIR, IT'S NEAR A 2 AIRPLANE, BUT IN TURBULENCE AND WIND SHEAR NEAR THE GROUND ON THE GLIDE SLOPE IT'S NOT GOOD BECAUSE IT WANTS TO HOLD AIRSPEED AND I WANT TO HOLD THE GLIDE SLOPE.	IN SMOOTH AIR, IT WAS BEAUTIFUL.	A LITTLE ON HEAVY SIDE. I DIDN'T SELECT THE GAIN ON THIS, IT WAS SPECIFIED FOR ME. I WOULD HAVE LIKED TO TRY A LIGHTER ONE.	AT CONSTANT SPEED, IT'S FINE. THE ATTITUDE CONTROL IN PRESENCE OF SPEED CHANGE IS NOT NEARLY SO GOOD.	NO PROBLEM IN SMOOTH AIR. IN TURBULENCE ON THE GLIDE SLOPE IT TENDS TO BE A PROBLEM.	NO PROBLEM.	NO.	NO.	YES.
2 462-1 H O_F	POOR VISIBILITY SMOOTH δ_{ES} FILTER	THIS WAS A PRETTY DOGGONE GOOD CONFIGURATION. THE AIR WAS QUITE SMOOTH HOWEVER, I THOUGHT I HAD A LOT OF DRAG DUE TO ANGLE OF ATTACK BUT FOUND IN 45° BANKED TURN THAT I DIDN'T HAVE TO ADD ANY POWER. YET WHEN I'M CHANGING ANGLE OF ATTACK THERE IS SOMETHING THAT IS A LITTLE PECULIAR BUT I CAN'T POINT IT OUT. THIS AIRPLANE TENDS TO RESIST CHANGE OF FLIGHT PATH, IT TENDS TO WANT TO BE CONSTANT AIRSPEED TYPE OF CONFIGURATION BY ITSELF. IF YOU ADD POWER, THEN IT'S WILLING TO HAVE ITS FLIGHT PATH CHANGED. HAD POOR VISIBILITY SO HAD LINE UP ERRORS AND HAD LARGE CORRECTIONS TO GET ON THE GLIDE SLOPE BUT I WAS ABLE TO DO THESE QUITE WELL. DIDN'T HAVE TO WORRY ABOUT AIRSPEED. IT'S A GOOD AIRPLANE IN THIS SMOOTH AIR. I WISH I COULD HAVE SEEN IT IN SOME TURBULENCE.	QUITE EASY.	O.K.	SATISFACTORY. YOU GOT A FEELING THAT THERE'S SOMETHING FUNNY WHEN YOU CHANGE ANGLE OF ATTACK. WHEN YOU'RE CHANGING IT, YOU FEEL A LITTLE SHUDDER OR A LITTLE LONGITUDINAL DECELERATION. I DON'T KNOW WHAT GOES ON EXACTLY. IT FEELS A LITTLE FUNNY AND THEN YOU RE-ESTABLISH A NEW FLIGHT PATH AND IT SEEMS ALL RIGHT AGAIN.	NO PROBLEM	WENT FAIRLY WELL.	NO PROBLEM AT ALL.	NONE	YES.

Table III (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
6.5 434-2 Group I Figure 14a X	VERY POOR VISIBILITY LIGHT.	IN SMOOTH AIR YOU CAN MAKE BEAUTIFUL CONSTANT SPEED APPROACHES, BUT IF ANYTHING CAUSES AIRSPEED DISTURBANCES, THE AIRPLANE RESPONDS TREMENDOUSLY IN PITCH. WHEN I'M CLOSE TO THE GROUND I DON'T LIKE THINGS THAT INTERFERE WITH ME FLYING REASONABLE CONSTANT ATTITUDE. IN PARTICULAR, I DON'T LIKE TO HAVE THE NOSE COME WAY UP FOR AN AIRSPEED ERROR OF A COUPLE OF KNOTS. I WAS ALWAYS FIGHTING THE AIRPLANE TO KEEP THE PITCH ATTITUDE WHERE I WANTED IT.	QUITE EASY IN SMOOTH AIR.	PICK IT A LITTLE LIGHT BECAUSE OF STRONG PITCH WITH AIRSPEED.	SHORT PERIOD QUITE GOOD, BUT IT HAS A MIND OF ITS OWN IN RESPONSE TO AIRSPEED CHANGES.	NOT IN SMOOTH AIR. IN ROUGH AIR, IT IS QUITE A PROBLEM.	DIDN'T GO WELL IN TURBULENCE.	IT TRIES TO MAINTAIN AIRSPEED AT ALL COSTS.	FIGHT ATTITUDE.	IN TURBULENCE, IT WOULD BE A REAL BEAR TO CONTROL ATTITUDE AT TOUCHDOWN.
7 437-1 I	LIGHT, OCCASIONAL MODERATE GUST	IN SMOOTH AIR IT HAS A STRONG TENDENCY TO PITCH IN A DIRECTION TO CORRECT AIRSPEED ERRORS. HOWEVER, THE DAMPING IS LOW SO IT TENDS TO PITCH TOO MUCH AND CAUSE AN EQUAL AIRSPEED ERROR IN OPPOSITE SENSE. THE PILOT MUST RESTRAIN THE PITCHING TENDENCY AND HOLD THE ATTITUDE THAT WILL CORRECT THE AIRSPEED WITHOUT OVERSHOOT. REQUIRES LARGE FORCES AND MUST BE UNDER CONSTANT CONTROL. AT LOW ALTITUDE THE ATTITUDE RESPONSE TO TURBULENCE OR WIND SHEAR CAUSES LARGE DISTURBANCE TO THE FLIGHT PATH WHICH GIVES YOU CONSIDERABLE TROUBLE. HAVE TO FIGHT IT ATTITUDEWISE TO MAINTAIN AIRSPEED AND ALTITUDE.	WON'T HOLD ATTITUDE AND AIRSPEED	O.K. PICKED IT LIGHTER THAN I LIKED FOR SHORT PERIOD ATTITUDE CONTROL BUT I NEEDED IT LIGHT TO RESTRAIN THE ATTITUDE RESPONSE TO AIRSPEED AND TURBULENCE.	O.K. FOR SHORT TERM, BUT NOT IN THE LONG PERIOD OR PHUGOID.	IN SMOOTH AIR IT WAS O.K., BUT NOT IN TURBULENCE.	O.K. FOR SMOOTH AIR, BUT TURBULENCE CAUSED ATTITUDE DISTURBANCES.	IN A SENSE IT WAS, BUT REAL PROBLEM WAS ATTITUDE AND ALTITUDE.	TIGHT ATTITUDE STABILIZATION.	YES IN SMOOTH AIR, BUT IN TURBULENCE, IT WOULD BE REAL BATTLE.
7 414-2 I	MODERATE -- OCCASIONAL HEAVY GUSTS	RESPONDS QUITE STRONGLY IN PITCH TO AIRSPEED CHANGES. NOT TOO OBJECTIONABLE IN SMOOTH AIR, BUT ALARMING IN ROUGH AIR CLOSE TO GROUND. SCARES ME IN ROUGH AIR NEAR GROUND.	LITTLE DIFFICULT. AIRSPEED TENDS TO DEPART QUICKLY, MUST STABILIZE ATTITUDE.	MIGHT LIKE A HIGHER GAIN TO COUNTER THE PITCH RESPONSE TO AIRSPEED CHANGES.	MIGHT LIKE A LITTLE MORE DAMPING, I'M NOT SURE.	SMOOTH AIR, NO: IN ROUGH AIR, YES. NOT BAD AT ALTITUDE BUT ON GLIDE SLOPE WHERE SMALL DEVIATIONS ARE IMPORTANT IT WAS LOUSY.	SMOOTH AIR IT'S VERY EASY BUT IN ROUGH AIR IT'S A PROBLEM.	YES IF YOU TRY TO STABILIZE THE ATTITUDE & ALTITUDE.	TIGHT ATTITUDE STABILIZATION.	YES IN SMOOTH AIR, BUT NOT IN TURBULENCE.
7 425-1 I	LIGHT - MODERATE	HAD TO LEARN TO USE THIS ONE. IT HAS A VERY HIGH FREQUENCY PHUGOID. THIS CAUSES REAL LARGE AND RAPID CHANGES IN MY FORCE FEEL FOR ALMOST INSIGNIFICANT AIRSPEED CHANGES. AT FIRST IT DIDN'T UNDERSTAND THIS, AND I WAS VERY ALARMED. ONCE I HAD IT FIGURED OUT I LEARNED TO USE THIS INFORMATION TO KEEP AIRSPEED UNDER BETTER CONTROL. PHUGOID DAMPING WAS LOW OPEN LOOP, AND EFFECT ON CLOSED LOOP WAS THAT AN OSCILLATION OCCURRED WHICH REFLECTED ITSELF IN MY STICK FEEL AND ALSO STRONGLY ON THE ATTITUDE. IF YOU DIDN'T DIMINISH ITS EFFECT ON THE AIRPLANE IT WOULD REALLY OVERPOWER YOU IN WHAT YOU ARE TRYING TO DO. IN SMOOTH AIR THE SECRET WAS TO ATTITUDE STABILIZE IT AND MAKE USE OF THE STICK FORCE INFORMATION TO CONTROL AIRSPEED WITH POWER. HOWEVER, WHEN YOU RAN INTO SOME TURBULENCE OR WIND SHEAR, THE AIRPLANE WOULD BE DISTURBED AND YOU HAD TO FIGHT IT IN ATTITUDE AND THIS WAS BAD. EVEN IN SMOOTH AIR, THOUGH, YOU ALWAYS HAD TO BE WITH IT. AIRPLANE FELT VERY LOOSE IN ITS ATTITUDE RESPONSE. ANY DISTURBANCE TENDED TO MAKE IT PITCH. IN TURBULENCE IT REQUIRES MAJOR PORTION OF PILOT'S ATTENTION.	REQUIRES TIGHT ATTITUDE CONTROL AND USE OF THROTTLE TO CORRECT AIRSPEED.	O.K.	TOO LOOSE AND TOO EASILY DISTURBED.	NOT BAD IN STRAIGHT & LEVEL, SMOOTH AIR, BUT IN TURNS IT WAS A PROBLEM BECAUSE SPEED WOULD TEND TO VARY AND THEN I HAD LARGE ELEVATORS FORCES. HAVE TO KEEP REAL TIGHT ATTITUDE STABILIZATION TO HOLD ALTITUDE.	COULD DO IT IN SMOOTH AIR BUT IN ROUGH AIR, PITCH DISTURBANCES MADE IT DIFFICULT.	NOT A PARTICULAR PROBLEM. BIG PROBLEM WAS ATTITUDE & FLIGHT PATH CHANGES WHICH OCCURRED WHEN AIRSPEED GOT OFF.	TIGHT ATTITUDE STABILIZATION AND USE OF THROTTLE TO CORRECT AIRSPEED.	SMOOTH AIR, CAN BE, BUT I THINK IN ROUGH AIR, WOULD BE VERY DIFFICULT. COULD DO IT IN LIGHT TURBULENCE TODAY.

Table III (Concluded) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 2.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
9 394-2 Group I Figure 14a X	PRETTY SMOOTH LOCALIZER ERRATIC, AILERON FEEL KICKS ELEVATOR SPRING 17.6 lb/in.	PRETTY MISERABLE - SOMEBODY ELSE IS FLYING THIS AIRPLANE IN PITCH TO MAINTAIN CONSTANT AIRSPEED AND SOMETIMES THEY DO THINGS WITH PITCHING MOMENTS SUCH THAT I DON'T CARE WHAT THE AIRSPEED IS, I DON'T WANT THEM TO DO. SUCH AS PITCHING DOWN OR UP VIOLENTLY WHEN YOU ARE ON FINAL APPROACH. IN SMOOTH AIR, IT IS KIND OF NICE, HAS LARGE CHANGE IN STICK FORCE WITH SPEED WHICH GIVES GOOD SENSE OF AIRSPEED ERRORS STARTING TO DEVELOP. PHUGOID IS STIFF, BUT DAMPING IS LOW, SO I GET AIRSPEED OSCILLATION. TURBULENCE OR NONUNIFORM AIR, IT PITCHES SEVERELY TO START CORRECTION OF AIRSPEED VARIATIONS. ON FINAL APPROACH THE PILOT WOULD PREFER TO HAVE ATTITUDE REMAIN CONSTANT AND ACCEPT THE AIRSPEED VARIATIONS. HIGH FREQUENCY, LOW DAMPED PHUGOID MAKES IT NECESSARY FOR PILOT TO STABILIZE ATTITUDE AND CORRECT AIRSPEED ERRORS WITH THROTTLE AND SMALL MEAN ATTITUDE CHANGES.	PHUGOID DAMPING IS LOW AND I FOUND IT DIFFICULT TO SUPPRESS THE AIRSPEED OSCILLATIONS.	PICKED HIGH SO I COULD SUPPRESS PITCH DISTURBANCES THAT OCCUR WITH AIRSPEED.	O.K.	NO PROBLEM.	IF YOU GET INTO AIRSPEED PERTURBATIONS THE AIRPLANE PITCHED AND ATTITUDE AND RATE OF CLIMB GOT OFF.	DIFFICULT TO GET AIRSPEED AND ATTITUDE RIGHT AT THE SAME TIME.	NONE REALLY EXCEPT MAINTAIN ATTITUDE.	YES IN SMOOTH AIR. IN TURBULENCE IT WOULD BE DANGEROUS.
8 445-1 Group J	LAYERS OF CLOUDS LIGHT TO MODERATE CROSS WIND FROM RIGHT	THIS CONFIGURATION HAS A GOOD SHORT PERIOD, I.E., ANGLE OF ATTACK CONTROL BY THE PILOT IS GOOD AS LONG AS YOU'RE NEAR TRIM AIRSPEED. BUT IT HAS AN UNSTABLE ROOT BECAUSE IF YOU GET FAST, THE NOSE DROPS AND IT DIVERGES SO YOU HAVE TO HOLD BACK STICK. IF IT GETS SLOW YOU HAVE TO PUSH SO THIS IS BACKWARDS FROM THE WAY YOU USUALLY FLY AIRPLANES. HOWEVER, WITH THE GOOD SHORT PERIOD, THE PILOT CAN FLY THIS BY BEING ATTENTIVE. ON THE GLIDE SLOPE IT'S POOR BECAUSE THE AIRSPEED TENDS TO GET OFF WHEN YOU RESTRAIN THE FLIGHT PATH. THE WHOLE SECRET IS TO KEEP ERRORS SMALL. IT SCARES YOU OR YOU WORRY CONSTANTLY ABOUT THE ERRORS GETTING BIG BECAUSE YOU WOULD RUN OUT OF CONTROL. IT FELT LIKE AIRPLANE'S IN THE "TUCK REGION". (COMPARE WITH GROUP V)	NOT TOO DIFFICULT. THE STIFF SHORT PERIOD HELPS A LOT. YOU HAVE TO CONTROL ATTITUDE AND GET AIRSPEED WITH POWER.	PICKED VALUE THAT GAVE GOOD COMFORTABLE LEVEL OF FORCE WITH ANGLE OF ATTACK. YOU ALSO WANT A HIGH VALUE TO CONTROL DIVERGENCE IF IT GETS STARTED BUT TOO HIGH A GAIN INCREASES CHANCES OF INADVERTENT DISTURBANCES.	ATTITUDE IN SHORT PERIOD WAS EXCELLENT BUT UNSTABLE AIRSPEED MODE MAKES IT UNACCEPTABLE.	CAN BE IF I DON'T CONTROL ATTITUDE CLOSELY AND LET AIRSPEED ERRORS DEVELOP.	NOT TOO BAD.	IT'S A PROBLEM. TENDS TO DIVERGE.	FLY ATTITUDE AND AIRSPEED. DON'T LET ERRORS DEVELOP AND STAY CLOSED LOOP.	IN EMERGENCY, BUT NOT ROUTINELY.
3 398-1 Group K	POOR VISIBILITY - LESS THAN 2 MILES LIGHT TURBULENCE	VERY LITTLE TENDENCY FOR AIRPLANE TO TRY TO HOLD AIRSPEED. VERY LITTLE CUE OF AIRSPEED CHANGE IN STICK FORCE. MAIN PROBLEM IS LACK OF FEEL FOR AIRSPEED CHANGES DURING IFR PORTION. POOR VISIBILITY RESULTED IN LINE-UP ERRORS AND COULD NOT USE LIGHTS VERY WELL.	NO.	O.K., SEEMED LITTLE HEAVY IN TURN.	O.K.	NO PROBLEM	COULD DO O.K.	NO PROBLEM, BUT THERE WAS VERY LITTLE FORCE CUE IN STICK FOR AIRSPEED ERROR.	STRONG ATTITUDE AND CROSSCHECK AIRSPEED	YES.
10 423-1 Group L	MODERATE. VISIBILITY BAD. TRAFFIC. CROSSWIND FROM LEFT. FAILURE IN $\delta_e/\dot{\alpha}$ CHANNEL	TEND TO BOBBLE THE AIRPLANE IN PITCH IN SMOOTH AIR. IN TURBULENCE AT LOW ALTITUDE, IT BUCKED LIKE A BUCKING BRONCO. WOULDN'T GO NEAR THE GROUND ON ANYTHING BUT A CALM DAY.	QUITE EASY. SMOOTH AIR; IMPOSSIBLE IN ROUGH AIR.	QUITE SATISFACTORY.	NO. IT'S POOR	NOT A PROBLEM	O.K. IN SMOOTH AIR, NOT IN TURBULENCE.	NO PROBLEM IN SMOOTH AIR.	NONE THAT WORKED	APPROACH, BUT NOT TO LAND IN GUSTY AIR.
9 423-2 Group M	TRAFFIC. MODERATE. POOR VISIBILITY. CROSSWIND. FAILURE IN $\delta_e/\dot{\alpha}$ CHANNEL	A MISERABLE CONFIGURATION. AIRSPEED WAS VERY DIFFICULT TO HOLD. I SPENT VERY LITTLE TIME AT 160 KT AND IT WAS A REAL STRUGGLE TO GET THERE. HAD AIRSPEED VARIATIONS FROM 150 TO 170 KT. THERE WAS CONSIDERABLE TURBULENCE.	YES. IT IS HARD TO STOP IT AT THE TRIM AIRSPEED. REQUIRES LARGE THROTTLE CORRECTIONS.	O.K.	SATISFACTORY, BUT IT HAS TENDENCY TO BOBBLE.	YES. IT'S A PROBLEM BECAUSE YOU CAN'T HOLD AIRSPEED.	COULDN'T DO IT BECAUSE OF AIRSPEED PROBLEMS.	EXTREME PROBLEM. REQUIRES VERY HIGH THROTTLE GAIN ON AIRSPEED. TURBULENCE INTRODUCES INACCURACIES IN YOUR ABILITY TO CLOSE THE LOOP AND THINGS GO TO POT.	VERY TIGHT THROTTLE TO AIRSPEED ERROR.	UNDER IDEAL CONDITIONS MAYBE, BUT SOONER OR LATER IT WILL KILL YOU.

Table IV SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 1.46$ rad/sec

PILOT RATING / FLIGHT NO. / GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
4 409-1 Group N Figure 10b X	GENERALLY LIGHT. MODERATE GUSTS OCCASIONALLY	OSCILLOGRAPH HUNG UP. PRETTY FAIR CONFIGURATION. PITCH RESPONSE IS TOO SLOW WHICH CAUSES SOME AIRSPEED AND FLIGHT PATH CONTROL PROBLEMS. LIKE AN ELEPHANT.	NOT DIFFICULT, BUT IT ISN'T EASIEST EITHER.	O.K., PICKED LIGHT TO OVERDRIVE BUT STILL HAVE SOME STEADY FORCES.	LITTLE SLUGGISH.	PRETTY GOOD. LITTLE DIFFICULT TO KEEP NOSE RIGHT IN TURNS.	O.K., BUT NOT MUCH SENSE OF AIRSPEED ERRORS IN FEEL.	AIRSPEED TENDS TO TAKE CARE OF ITSELF. SLOW TO SEEK TRIM. ATTITUDE ERRORS CAUSED SPEED ERRORS. NOT MUCH FEEL IN STICK FOR THESE ERRORS.	OVERDRIVE ATTITUDE A LITTLE.	YES.
4 407-2 N	LIGHT TO MODERATE RAIN SHOWER DOWNWIND 5 - 8 KNOTS	NONLINEAR PHUGOID. DIFFICULT TO FLY ATTITUDE. AIRSPEED WAS SLUGGISH. DIDN'T HAVE GOOD CUE OF AIRSPEED ERRORS UNLESS HE LOOKED AT AIRSPEED. FEELS LIKE AN ELEPHANT.	NOT THE EASIEST. SLUGGISH AIRSPEED.	YES.	SLUGGISH. HAD TO PUSH IT AROUND.	SOMEWHAT A PROBLEM.	DIFFICULT TO GET THE PROPER ATTITUDE.	SLUGGISH AIRSPEED.	OVERDRIVE ATTITUDE.	YES.
4.5 412-2 N	MODERATE.	FAIR CONFIGURATION WITH SOME OBJECTIONS. DIFFICULT TO MAKE FAST ACCURATE CORRECTIONS.	FAIR. BETTER CLOSED LOOP THAN OPEN LOOP	O.K.	SLOW, SLUGGISH. HAD TO PUSH IT AROUND.	NOT A PROBLEM. COULD DO IT FAIRLY WELL.	WENT FAIRLY WELL.	NOT A REAL PROBLEM BUT YOU HAD TO WORK AT IT.	OVERDRIVE IT IN PITCH.	CERTAINLY COULD.
6 408-1 N	CLOUDS. LIGHT.	DARN POOR CONFIGURATION. DIFFICULT TO FLY PRECISELY IN IFR FLIGHT. TEND TO CUSS IT. AIRPLANE SLOW TO RESPOND. GOT GALLOPING. LOW FREQUENCY FLIGHT PATH OSCILLATION.	NOT EASY.	YES, PICKED IT SENSITIVE TO PERMIT OVERDRIVING IT.	NO. SLOW.	ALTITUDE IS DEFINITE PROBLEM.	YES, BECAUSE IT IS HARD TO FIND THE ATTITUDE REQUIRED TO HOLD SPEED AND RATE OF DESCENT.	YES BECAUSE ATTITUDE CONTROL WAS PROBLEM, & ALSO DIDN'T GET CUE OF AIRSPEED IN STICK FORCE.	FLY TIGHT ATTITUDE & OVERDRIVE IT IN PITCH.	YES, BUT PRETTY POOR.
7 407-1 N	LIGHT TO SMOOTH	NONLINEAR PHUGOID. POOR ON THE INSTRUMENT APPROACH. VERY POOR AIRSPEED KEEPING QUALITIES AND THE SHORT PERIOD IS SLOW RESPONDING.	DIFFICULT TO TRIM. CAN FIND UNSTABLE TRIM.	O.K. HIGH VALUE TO GET INITIAL RESPONSE BUT STEADY FORCES ARE NOT TOO LIGHT.	UNDESIRABLE - SLOW.	DIFFICULT. SO MUCH TIME ON ATTITUDE THAT AIRSPEED AND ALTITUDE WOULD GET OFF. REQUIRED BOTH THROTTLE & ELEVATOR CONTINUOUSLY.	DIFFICULT BECAUSE OF AIRSPEED PROBLEM.	EXTREME PROBLEM.	THROTTLE DUE TO AIRSPEED ERRORS.	EMERGENCY
10 412-1 N	MODERATE - OCCASIONAL HEAVY	PRETTY MISERABLE CONFIGURATION. AIRSPEED MADE IT QUITE UNSTABLE.	EXTREMELY DIFFICULT. LARGE ATTITUDE AND THROTTLE CHANGES REQUIRED TO GET AIRSPEED UNDER CONTROL.	YES.	SLUGGISH BUT ADEQUATE.	NEARLY IMPOSSIBLE. IF I TRY TO HOLD ALTITUDE, AIRSPEED GOES TO POT. TURBULENCE CAUSES GREAT DIFFICULTY.	NOT VERY SUCCESSFUL.	NEARLY IMPOSSIBLE, UNLESS YOU COMPLETELY FORGOT ABOUT FLIGHT PATH. MUST USE CONTINUOUS CLOSURE AND EXTREME GAINS ON POWER.	TIGHT ATTITUDE CONTROL AND CONTINUOUS CLOSURE OF THROTTLE WITH AIRSPEED.	NO.
9.5 408-2 N	CLOUDS. LIGHT - MODERATE	AIRSPEED MADE IT QUITE UNSTABLE. IT'S DOWNRIGHT DANGEROUS.	EXTREMELY DIFFICULT	YES.	TOO BUSY WITH AIRSPEED TROUBLES TO OBSERVE VERY WELL.	VERY VERY DIFFICULT	COULDN'T ESTABLISH A SPECIFIC VALUE.	EXTREME PROBLEM.	HOLD APPROXIMATE ATTITUDE FOR TRIM AND USE THROTTLE TO CONTROL AIRSPEED.	NOT CONSISTENTLY.

Table IV (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 1.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
4 436-1 Group O Figure 10b □	POOR VISIBILITY. LIGHT. TRAFFIC.	ESSENTIALLY IFR. IT'S A SLOW SLUGGISH AIRPLANE IN PITCH. YOU CAN'T FLY IT PRECISELY ENOUGH UNLESS YOU OVERDRIVE IT. THIS LEADS TO STICK STIRRING OR STICK PUMPING BY THE PILOT, ESPECIALLY ON THE GLIDE SLOPE.	ESSENTIALLY IFR CONDITIONS. COULD TELL VERY WELL ABOUT FLIGHT PATH TRIM. AIRSPEED TRIM WAS FAIRLY EASY.	O.K. LITTLE HEAVY TO GET FORCES IN TURNS AND STEADY STATE.	TOO SLOW. IT'S UNSATISFACTORY AND MAKES FLIGHT PATH CONTROL POOR.	IN TURNS, THERE WAS A PROBLEM.	FAIR.	NOT A BASIC PROBLEM. ERRORS OCCURRED DUE TO POOR ATTITUDE PRECISION.	OVERDRIVE IN PITCH AND FLY VERY TIGHT ATTITUDE CONTROL.	YES.
6 426-1 O	GOOD VISIBILITY. SMOOTH TO LIGHT.	SLOW RESPONDING. SLUGGISH ATTITUDE RESPONSE MAKES IT DIFFICULT TO PREDICT WHERE IT'S GOING. AIRPLANE HAS NO SPEED SENSE AT ALL. THE ONLY WAY YOU KNOW AIRSPEED IS TO LOOK AT THE INSTRUMENT. I HAVE TO STABILIZE THE ATTITUDE AND READ AIRSPEED AND ADJUST THROTTLE. COULD NOT BE SURE WHAT WAS HAPPENING WITHOUT READING THE INSTRUMENTS. I DON'T LIKE IT. IT GAVE ME AIRSPEED TROUBLES. YOU WOULD HAVE TO TEACH PILOTS TO WATCH SPEED.	MODERATELY DIFFICULT	O.K.	NO. RESPONSE TIME IS TOO LONG. AIRPLANE DOES THINGS AFTER YOU STOP DOING THINGS WITH THE CONTROLS.	SOME DIFFICULTY.	CAN BE DONE IN SMOOTH AIR.	A BIG PROBLEM. THERE WERE NO CUES SO IT REQUIRES TIGHT MONITORING OF THE INSTRUMENTS.	HAVE TO PUSH AIRPLANE AROUND AND HAVE TO GET ATTITUDE INFORMATION FROM INSTRUMENTS.	YES, BUT IF ATTENTION IS DIVERTED, COULD GET INTO AIRSPEED TROUBLE.
8 437-1 O	LIGHT. VISIBILITY GOOD.	BASIC PROBLEM IS AIRSPEED CONTROL AND THIS LED TO POOR FLIGHT PATH CONTROL. ALSO ATTITUDE CONTROL IS SLUGGISH. IT DIDN'T HAVE VERY GOOD STICK FEEL FOR AIRSPEED ERRORS. REQUIRES TOO MUCH ATTENTION FOR AIRSPEED CONTROL.	MODERATELY DIFFICULT BECAUSE IT DOESN'T HOLD ATTITUDE WELL & IT'S NECESSARY TO USE THROTTLE TO CORRECT AIRSPEED.	O.K.	A LITTLE SLOW BUT SATISFACTORY FOR THIS AIRSPEED MODE.	HAD TROUBLE. EITHER AIRSPEED WOULD BLEED OFF, OR IF I KEPT AIRSPEED RIGHT, ATTITUDE ERRORS WOULD DEVELOP.	FAIRLY WELL IF TIGHT ATTITUDE LOOP IS USED.	CONSIDERABLE PROBLEM. HAD TO BE CLOSED LOOP ALL THE TIME.	GOOD TIGHT ATTITUDE CONTROL, OVERDRIVE AIRPLANE IN PITCH AS NECESSARY AND A REASONABLY TIGHT AIRSPEED TO THROTTLE LOOP.	YES, BUT IT WOULD PROBABLY LEAD TO ACCIDENTS.
4 427-2 Group P Figure 10b ○	VERY LIGHT.	RATHER SLUGGISH HEAVY FEELING AIRPLANE. AIRSPEED WAS NO PROBLEM, IT GRADUALLY TOOK CARE OF ITSELF EITHER BACK TO TRIM OR TO A NEW TRIM. IT IS PONDEROUS FEELING. CAN GET A GALLOPING TYPE FLIGHT PATH CORRECTION.	PRETTY EASY.	O.K. EXCEPT IN FINAL PART OF GLIDE SLOPE. MOTION SEEMED EXCESSIVE.	LITTLE TOO SLOW.	IN TURBULENCE, IT TENDS TO PITCH AND REQUIRES ATTITUDE STABILIZATION TO MAINTAIN ALTITUDE.	NOT SERIOUS.	NOT A PROBLEM.	OVERDRIVE ATTITUDE	YES.
3.5 426-2 P	LIGHT AND MODERATE IN PATCHES.	IT'S PONDEROUS AND DIFFICULT TO GET IT ON THE FLIGHT PATH ONCE IT'S DISTURBED. IT HAS SOME SENSE OF AIRSPEED IN THE STICK FORCE WHICH MAKES AIRSPEED A LOT EASIER TO CONTROL. UNDECIDED BETWEEN 3.5 OR 4 BUT CALLED IT 3.5. IF THE ATTITUDE WAS OFF AND THE AIRSPEED STARTED OFF, IT WOULD GRADUALLY TEND TO PITCH IN THE DIRECTION TO CORRECT THE AIRSPEED.	NO.	O.K. MADE IT LIGHT SO I COULD GET IT MOVING, BUT NOT TOO LIGHT.	PONDEROUS	NO PROBLEM.	O.K. IN SMOOTH AIR.	NOT A PROBLEM.	NONE.	YES.
5.5 434-1 P	VERY POOR VISIBILITY. VERY LIGHT TURBULENCE.	CONDUCTED IN ESSENTIALLY IFR CONDITIONS. IT DOESN'T HAVE ANY SPEED STABILITY. TO CONTROL AIRSPEED I CONTROL ATTITUDE AND WATCH AIRSPEED INDICATOR. IT HAS VERY LITTLE FEEL IN THE CONTROLS DUE TO AIRSPEED ERRORS. IT HAS VERY LITTLE TENDENCY TO CORRECT AIRSPEED AND YOU HAVE TO PUSH IT EVERYWHERE YOU WANT IT TO GO. IT HAS LOTS OF DRAG WITH AIRSPEED SO IF SPEED GETS OFF IT REQUIRES LARGE THROTTLE CORRECTION AND THE ACCELERATION BACK TO TRIM IS LOW. I DON'T KNOW WHAT IT'S DOING HALF OF THE TIME. ATTITUDE DRIFTS OFF THE VALUE I WANT EVERY TIME I DIVERT MY ATTENTION. I HAVE TO OVERDRIVE IT TO MAKE CORRECTIONS. HAD TO ADD NOSE-DOWN TRIM WHEN POWER WAS INCREASED.	INTERMEDIATE DIFFICULTY.	O.K.	TOO SLOW AND SLUGGISH BUT ACCEPTABLE	DIDN'T HAVE POSITIVE CONTROL.	FAIRLY WELL.	DEFINITE PROBLEM. TENDS TO SLIP AWAY.	OVERDRIVE IT IN PITCH. STABILIZE PITCH ATTITUDE & CONTROL AIRSPEED WITH THROTTLE.	CAN BE DONE BUT IT TENDS TO SNEAK UP ON YOU AND AIRSPEED GETS OUT OF HAND.

Table IV (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{SP} \doteq 1.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
9 428-1 Group P Figure 10b ○	MODERATE.	AIRSPEED CONTROL IS LOUSY. ONE OF THE REASONS IS THAT THE PITCH ATTITUDE CHARACTERISTICS ARE POOR. SHOULD STABILIZE ATTITUDE AND USE THROTTLE TO CORRECT AIRSPEED, BUT WHEN I DIVERT MY ATTENTION FROM ATTITUDE TO MAKE AN AIRSPEED CORRECTION, I FIND THAT THE ATTITUDE HAS CHANGED, SO THE CONTROL WAS POOR. HAD ATTITUDE CHANGES OF ±5 DEG DURING DESCENT IN TRYING TO HOLD AIRSPEED.	YES, IT IS DIFFICULT; MUST HOLD ATTITUDE AND CONTROL AIRSPEED WITH THROTTLE.	O.K., LITTLE LIGHT IN TURNS.	DEFINITELY NOT SATISFACTORY.	IN TURNS, VERY POOR. IT REQUIRES CONTINUOUS CLOSED-LOOP CONTROL ON BOTH ATTITUDE & AIRSPEED	NO, IT WAS LOUSY.	EXTREME PROBLEM.	OVERDRIVE IT IN PITCH AND CONTROL ATTITUDE AS PRECISELY AS YOU CAN, THEN GO AFTER AIRSPEED WITH THE THROTTLE.	NO. AS AN ALL-WEATHER AIRPLANE, THIS IS RIDICULOUS.
5 417-1 Group Q Figure 11b ○	CLOUDS. POOR VISIBILITY. LIGHT TO MODERATE	HAD TROUBLE HOLDING AIRSPEED. LARGE ATTITUDE CHANGES REQUIRED TO STOP AN AIRSPEED ERROR AND START IT BACK. THEN THE RATE OF CHANGE BACK BECOMES LARGE AND IT GOES RIGHT THROUGH ZERO AND OVERSHOOTS TO OTHER SIGN. ON THE GLIDE SLOPE, IT WAS FAIRLY GOOD. IN TURNS, IT INITIALLY GAINS SPEED AND THEN LOSES IT UNLESS POWER IS ADDED. ON GLIDE SLOPE, IT WAS PRETTY GOOD - PR 3.5	IF YOU FLY CONSTANT THROTTLE AND USE ATTITUDE TO TRIM, IT'S DIFFICULT. IF YOU GET APPROXIMATE ATTITUDE AND CONTROL AIRSPEED WITH THROTTLE, IT IS EASIER.	FOUND THAT WITH THE MORE SENSITIVE GEAR RATIO, THE EFFECTS OF DRAG CHANGE WITH ELEVATOR WERE LESSENED, SO TENDED TO PICK MORE SENSITIVE	SLOW AND SLUGGISH BUT HIGH GEAR RATIO HELPED.	YES, IT'S A PROBLEM DURING STRAIGHT AND LEVEL AND IN TURNS. I THINK YOU NEED A THROTTLE CLOSURE, BUT I'M NOT SURE HOW.	SPECIFIC RATE OF DESCENT WAS DIFFICULT.	DIFFICULT IF YOU TRY TO MAINTAIN AIRSPEED THROUGH ATTITUDE AT CONSTANT THROTTLE.	IT'S SPECIAL CONFIGURATION.	YES.
7 417-2 Q △	LIGHT TO MODERATE. VISIBILITY POOR INTO SUN ON APPROACH. CROSSWIND FROM LEFT	UNACCEPTABLE CONFIGURATION ALWAYS FELT LIKE I WAS JUST MARGINALLY IN CONTROL OF THE SITUATION.	FAIRLY DIFFICULT. CAN'T GET AIRSPEED AND ALTITUDE TOGETHER.	PICKED AS COMPROMISE OF INITIAL RESPONSE, STEADY FORCES AND DRAG VARIATION - TENDED TO PICK HIGH.	DISTINCT LAG IN PITCH RESPONSE. NOTICEABLE IN TRYING TO CORRECT AIRSPEED WITH ATTITUDE THAT THERE WAS A DRAG CHANGE THAT OCCURRED MUCH SOONER.	MAINTAINING ALTITUDE AN EXTREME PROBLEM. HAVE TO CARRY HIGH POWER SETTING AND COULD NOT PINPOINT THE POWER SETTING THAT WOULD HOLD ALTITUDE	NOT TOO BAD BUT DIDN'T FIND THE POWER SETTING THAT WOULD GIVE THE RIGHT RATE OF DESCENT WHILE HOLDING AIRSPEED CONSTANT.	YES, EVEN IN THE JET PENETRATION WHEN I WASN'T TRYING TO HOLD FLIGHT PATH.	COULDN'T FIND ONE THAT WORKED.	YES, BUT HIGH PROBABILITY OF GETTING INTO TROUBLE.

Table IV (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{SP} \doteq 1.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
4.5 490-2 Group R Figure 12b X	VERY STRONG HEAD WIND HEAVY	THERE WAS SOME PITCH RESPONSE TO TURBULENCE BUT IT WAS MANAGEABLE. I DIDN'T HAVE THE POSITIVE CONTROL OF PITCH THAT I WOULD LIKE. ON THE GLIDE SLOPE IN TURBULENCE THIS APPARENTLY CAUSED ME PROBLEMS. THE TURBULENCE MADE IT VERY DIFFICULT TO KNOW WHAT TO DO WITH THE THROTTLE. THE AIRSPEED LIGHTS FLASHED SO MUCH THEY WERE OF LITTLE HELP. THE AIRSPEED READINGS HAD TO BE TREATED STATISTICALLY. SLOW PITCH RESPONSE AND LACK OF ABILITY TO MAKE PRECISE ATTITUDE CORRECTIONS RAPIDLY TO COUNTER THE EFFECTS OF TURBULENCE AND TO CONTROL THE FLIGHT PATH VERY PRECISELY.	DIDN'T SEE ANY DIFFICULTIES IN SMOOTH AIR.	PICKED LIGHT TO BE ABLE TO OVERDRIVE IN PITCH AND HANDLE TRIM CHANGE WITH AIRSPEED.	SLOW AND SLUGGISH. HAD SOME SPEED FEEL. DIDN'T RESPOND TO TURBULENCE IN PITCH AS MUCH AS IT WOULD IF IT WAS FASTER.	NOT PROBLEM IN SMOOTH AIR. HELD SPEED IN TURNS.	NOT BAD UNTIL I GET IN HEAVY TURBULENCE AT 600 FT. THEN INSTRUMENT PANEL WAS SHAKING SO HARD I COULD HARDLY READ IT.	NOT A PROBLEM. IN TURBULENCE. IT WAS DIFFICULT TO DECIDE WHAT THE MEAN WAS.	OVERDRIVE IT IN PITCH	YES.
3.5 415-1 R	LIGHT	SURPRISINGLY GOOD ONE. SLOW, SLUGGISH SHORT PERIOD, BUT THE STIFF PHUGOID GIVES GOOD STICK FEEL OF AIRSPEED ERRORS. SHORT PERIOD MADE IT DIFFICULT TO CORRECT ERRORS ON GLIDE SLOPE QUICKLY. KIND OF MARGINAL ON GLIDE SLOPE. I WOULD LIKE TO SEE IT IN MORE TURBULENCE.	REASONABLY EASY.	SATISFACTORY COMPROMISE. PICKED LIGHT TO GET INITIAL RESPONSE.	LITTLE TOO SLOW. ESPECIALLY ON GLIDE SLOPE.	NO PROBLEM.	YES, FAIRLY WELL. AIRPLANE NOSED COMFORTABLY INTO SMALL GUSTS.	LITTLE BIT OF A PROBLEM.	OVERDRIVE THE RESPONSE IN PITCH.	YES.
3.5 436-2 R	POOR VISIBILITY. LIGHT.	ATTITUDE CHARACTERISTICS WERE NOT AS GOOD AS I WOULD LIKE. KIND OF SLOW. IT DIDN'T HAVE ANY PARTICULAR AIRSPEED CONTROL PROBLEMS. HAD A GOOD BIT OF STICK FORCE CHANGE WITH AIRSPEED.	O.K.	O.K.	LITTLE ON SLOW SIDE, LEADING TO SOME IMPRECISION IN PRODUCING THE DESIRED ATTITUDE CHANGES.	NO PROBLEM. BUT HAD TO WORK AT ATTITUDE CONTROL IN TURNS.	O.K.	LITTLE PROBLEM. HAD TO USE THROTTLE.	OVERDRIVE IT IN PITCH. A LITTLE THROTTLE WITH AIRSPEED ERRORS.	YES.
5 - 5.5 444-2 R	VERY LIGHT. CROSSWIND FROM RIGHT.	BASIC OBJECTIONS ARE THE DIFFICULTY IN MANEUVERING ON INSTRUMENTS AND IN PRODUCING THE RIGHT ANGLE OF ATTACK OR ATTITUDE. AIRSPEED CONTROL ON THE GLIDE SLOPE WAS EASY AND GOOD. TOWARD END OF APPROACH I FOUND I WAS STIRRING OR DITHERING THE STICK IN ORDER TO CATCH THE SLIGHTEST DEPARTURE AND CORRECT INPUT TO STOP IT ATTITUDEWISE.	LITTLE DIFFICULT. HAD TO HOLD ATTITUDE AND CORRECT AIRSPEED WITH THROTTLE.	PICKED IT LIGHT. HELPED IN STICK STIRRING ON APPROACH	LACKS GOOD POSITIVE CONTROL.	LITTLE PROBLEM BECAUSE OF LACK OF POSITIVE ATTITUDE CONTROL.	FAIRLY WELL BY HAVING GOOD TIGHT ATTITUDE CONTROL.	RESTRAIN ATTITUDE & USE SMALL THROTTLE ADJUSTMENTS.	TIGHT ATTITUDE CONTROL.	YES.
6.5 442-1 R	LIGHT.	STABILIZE ATTITUDE AND CROSSCHECK AIRSPEED. IT REQUIRES CLOSED-LOOP CONTROL. RATE OF CHANGE OF AIRSPEED WAS SUCH THAT I SEEMED TO BE ABLE TO CORRECT IT WITH THROTTLE.	STABILIZE ATTITUDE AND TRIM AIRSPEED WITH THROTTLE.	SATISFACTORY. I WANTED TO BE ABLE TO OVERDRIVE IT AND TO BE ABLE TO HANDLE TRIM CHANGE WITH AIRSPEED, BUT NOT TOO LIGHT TO BE ABLE TO HOLD STEADY ATTITUDE	TOO SLOW AND SLUGGISH. YOU HAVE TO TRIM IT AND THEN IF THE AIRSPEED GETS OFF YOU HAVE TO HOLD THE OUT OF TRIM FORCE AND CORRECT AIRSPEED ERROR & HOPE THE OUT OF TRIM FORCE WILL GO AWAY. IF YOU START FIGHTING THE TRIM, I THINK IT WOULD BE DIFFICULT TO FLY.	NOT REAL GOOD BECAUSE OF UNCERTAINTY IN HOLDING ATTITUDE.	WENT TOLERABLY WELL BUT I HAD TO SACRIFICE LOCALIZER CONTROL ATTENTION.	A PROBLEM. I FLY ATTITUDE TIGHTLY AND USE RATHER LARGE THROTTLE CORRECTIONS FOR AIRSPEED.	OVERDRIVE IN PITCH. STABILIZE PITCH & USE THROTTLE TO AIRSPEED LOOP.	YES, UNDER GOOD CIRCUMSTANCES. REQUIRES A LOT OF CLOSED-LOOP ATTENTION.

Table IV (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 1.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
7 447-1 Group R Figure 12b X	POOR VISIBILITY. HAZE. VERY LIGHT. TRAFFIC.	HAVE IMPRECISE ATTITUDE CONTROL AND AIRSPEED CONTROL PROBLEMS. AIRSPEED LIGHTS DIDN'T SEEM TO GIVE ENOUGH INFORMATION - THOUGHT I NEEDED AIRSPEED RATE INFORMATION. I WOULD LIKE SOME INDICATION OF THROTTLE TRIM, EITHER IN THE FORM OF AN INSTRUMENT UP IN MY FIELD OF VIEW OR MAYBE SOME THROTTLE FEEL. AFTER I MAKE A CORRECTION IT'S DIFFICULT TO KNOW WHERE TO PUT THE THROTTLE TO HOLD TRIM.	INTERMEDIATE.	GOOD. PICK HIGH TO PERMIT OVERDRIVING ATTITUDE.	TOO SLOW. LITTLE UNCERTAINTY IN CONTROL DUE TO LAG IN SHORT PERIOD RESPONSE.	SOMEWHAT A PROBLEM BECAUSE OF IMPRECISE ATTITUDE CONTROL.	NOT VERY WELL.	AIRSPEED TENDED TO GET AWAY.	THROTTLE CLOSURE WITH AIRSPEED AND OVERDRIVE THE PITCH ATTITUDE.	NOT REGULARLY.
10 448-2 R	LIGHT TO MODERATE.	I HAD REAL TROUBLE WITH THIS CONFIGURATION. YOU WOULD THINK YOU HAD IT ALL RIGHT AND YOU'D KIND OF TURN YOUR HEAD A LITTLE AND GRADUALLY THINGS WOULD CHANGE ON YOU. I WASN'T AWARE OF IT HAPPENING AND SUDDENLY I WOULD DISCOVER I WAS RUNNING OUT OF AIRSPEED OR SINKING MADLY OR SOMETHING THAT I DIDN'T HAVE THE FAINTEST IDEA WAS GOING ON. HAD ATTITUDE VARIATIONS OF ±7° IN TRYING TO HOLD AIRSPEED DURING THE DESCENT. DIDN'T HAVE TIME TO MONITOR HEADING AND LOCALIZER. WENT 200 FT LOW IN LEVELING OUT AT 600 FT, WORST I'VE DONE ON ANY OF THE EVALUATIONS. IT WAS A RELIEF TO GO VFR. ON THE GLIDE SLOPE I HAD DIFFICULTY HOLDING AIRSPEED INITIALLY AND IN CLOSE I HAD DIFFICULTY STAYING ON THE GLIDE PATH AS I OFTEN DO WHEN THE SHORT PERIOD IS SLUGGISH. IT WAS VERY DEMANDING ON MY PART. IT IS AN AIRPLANE THAT YOU THINK YOU HAVE UNDER CONTROL AND START TO TEND TO SOMETHING ELSE AND YOU FIND YOU'RE IN TROUBLE BEFORE YOU'RE EVEN AWARE OF IT. ANOTHER THING THAT SCARED ME WAS DURING A TURN I GOT UP TO ABOUT 45° BANK AND A PRETTY HIGH ANGLE OF ATTACK AND MAY HAVE GOTTEN A LITTLE FAST OR WAS OUT OF TRIM AT START, BUT I ENDED UP HOLDING ZERO STICK FORCE AND I WAS RIGHT ON THE EDGE OF STALL BUFFET.	DIDN'T GET A GOOD LOOK.	O.K. I PICKED IT HIGH.	TOO SLOW. I COULD NOT MAKE THE OTHER VARIABLES DO WHAT I WANTED THEM TO, THOUGH.	COULDN'T DO VERY WELL AT CONSTANT THROTTLE.	CHANGING FLIGHT PATH ON INSTRUMENTS IS VERY, VERY DIFFICULT.	BIGGEST PROBLEM. AIRSPEED COULD GET AWAY WITHOUT YOUR KNOWING IT.	TIGHT ATTITUDE CONTROL WITH ELEVATOR & CONTINUOUS WATCH OF AIRSPEED WITH THROTTLE.	ABSOLUTELY NOT.
10 453-1 R	DOWNWIND APPROACHES. VARIABLE - HIGHER AT ALTITUDE. LIGHT TO MODERATE.	A MISERABLE CONFIGURATION. THINGS CHANGED ON ME AND I WASN'T AWARE THAT THEY WERE CHANGING UNTIL THEY HAD CHANGED TOO FAR, LIKE AIRSPEED. WHEN THE AIRSPEED HAD CHANGED FAIRLY FAR AND I FIRST BECAME AWARE OF IT, IT WAS VERY DIFFICULT TO CORRECT IT BACK AGAIN. I'D ADD BITS OF POWER AND IT WAS VERY SLOW TO BRING AIRSPEED BACK. BUT WHEN IT STARTED BACK YOU HAD TO BE CAREFUL TO PULL IT OFF TO TRIM REAL QUICK BECAUSE IT WOULD GO RIGHT THROUGH THE TRIM AIRSPEED AND YOU'D HAVE AN ERROR IN THE OPPOSITE SENSE IF YOU DIDN'T CATCH IT. IFR WAS EXTREMELY DIFFICULT. ATTITUDE WAS NOT A GOOD CONTROLLER OF AIRSPEED. IT REQUIRED TOO LARGE ATTITUDE CHANGES AND THEY WERE DIFFICULT TO MAKE PRECISELY BECAUSE OF THE POOR PITCH ATTITUDE CONTROL. ALTHOUGH OPEN LOOP, THE PHUGOID WAS OSCILLATORY DIVERGENT, FROM THE COCKPIT THIS THING LOOKS LIKE IT HAS A PURE DIVERGENCE. THIS CREATES REAL PROBLEMS IN CONTROLLING THE CONFIGURATION BECAUSE YOU DON'T HAVE TIME TO LOOK AWAY AND ATTEND TO OTHER THINGS. IF YOU LOOK AT LOCALIZER AND HEADING THE AIRSPEED GOES TO POT. IT WAS A GREAT RELIEF TO GO VISUAL. ON THE GLIDE SLOPE I STILL HAD CONSIDERABLE AIRSPEED DIFFICULTIES. PITCH CONTROL IS QUITE POOR WITH THIS CONFIGURATION.	VERY DIFFICULT. ATTITUDE & AIRSPEED WANT TO DIVERGE.	O.K.	UNACCEPTABLE.	VERY DIFFICULT.	THINK I COULD IN SMOOTH AIR BY REAL TIGHT ATTITUDE AND AIRSPEED CONTROL.	VERY DIFFICULT TO MAINTAIN AIRSPEED.	TIGHT ATTITUDE CONTROL & THROTTLE CLOSURE ON AIRSPEED. VERY TIGHT THROTTLE LOOP.	ABSOLUTELY NOT. WELL, MAYBE IN SMOOTH AIR, BUT THERE IS ABSOLUTELY NO ROOM FOR ERROR WITH THIS ONE.
7 456-1 R	OVERCAST. LIGHT. CROSSWIND FROM LEFT.	IF YOU KEEP THE ERRORS SMALL IT FLIES FAIRLY WELL. CERTAINLY FAR FROM GOOD. BUT IF YOU LET THE AIRSPEED GET OFF, THINGS GO TO POT IN A HURRY. IT HAS A VERY SLUGGISH SHORT PERIOD AND A STIFF PHUGOID. IF THE AIRSPEED GETS FAST, IT WILL PITCH UP AND PULL G IN THE PHUGOID AND YOU CAN END UP PUSHING FORWARD WHEN THE NOSE IS COMING UP AND YOU'RE PULLING G. IF YOU TRY TO CONTROL AIRSPEED WITH ATTITUDE, YOU END UP DOING AN AWFUL LOT OF HUNTING AND END UP OVERSHOOTING. THE JET PENETRATION WAS DIFFICULT, I.E., FIXED THROTTLE OPERATION. A THROTTLE CLOSURE WITH THIS CONFIGURATION IS VERY HELPFUL. THROTTLE CLOSURE WITH AIRSPEED ERRORS. I USED A THROTTLE CLOSURE FOR THE REDUCED RATE OF SINK PORTION CLOSE TO THE GROUND AND IT WAS MANAGEABLE. ON GLIDE SLOPE I USED THE AIRSPEED AND ALTITUDE LIGHTS AND ALTHOUGH I HAD TO MAKE NUMEROUS CORRECTIONS, IT WENT WELL. IT IS EASIER TO FLY THIS ONE VISUALLY THAN IT IS IFR. AIRSPEED IS UNSTABLE AND I HAVE TO CLOSE THROTTLE LOOP TO STABILIZE IT. IT TENDS TO GET AWAY IF YOU ATTEND TO OTHER TASKS. REQUIRES A MAJOR PORTION OF PILOT'S ATTENTION.	MODERATELY.	O.K.	TOO SLOW AND SLUGGISH IN THE SHORT TERM.	NOT A GREAT PROBLEM	ONLY POSSIBLE IF YOU USE THROTTLE CLOSURE, THEN IT'S NOT VERY PRECISE.	AIRSPEED IS THE FUNDAMENTAL PROBLEM. REQUIRES A THROTTLE CLOSURE. IF YOU RESTRAIN FLIGHT PATH, YOU GET AIRSPEED DIVERGENCE THAT HAS TO BE STOPPED BY THROTTLE. AIRSPEED CONTROL WITH ATTITUDE IS LIGHT DAMPED CLOSED-LOOP SYSTEM.	THROTTLE WITH AIRSPEED AND ATTITUDE WITH ELEVATOR.	NOT ROUTINELY.

Table IV (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 1.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
8 442-2 Group R Figure 12b X	LIGHT.	THIS ONE HAS AIRSPEED PROBLEMS. IFR, IF I TRY TO HOLD ATTITUDE AT CONSTANT POWER, THE AIRSPEED DIVERGES. SO I HAVE TO USE LARGE ATTITUDE CHANGES TO HOLD AIRSPEED. ON THE GLIDE SLOPE, I HELD ATTITUDE AND CLOSED A THROTTLE ON AIRSPEED LOOP.	YES, CAN'T GET AIRSPEED.	O.K.	SLOW	YES, CAN'T ESTABLISH A SPECIFIC ALTITUDE EASILY.	NO, COULDN'T GET STABILIZED.	INDEED A PROBLEM.	HAVE TO BE CONTINUOUS CLOSED LOOP. TIGHT ATTITUDE CONTROL AND RELATIVELY HIGH GAIN AIRSPEED TO THROTTLE.	NO, NOT CONSISTENTLY.
10 446-2 R	MODERATE. TRAFFIC.	ANY TIME I WAS OPERATING CONSTANT THROTTLE, THE ATTITUDE CHANGES REQUIRED TO CONTROL AIRSPEED WERE JUST HORRENDOUS. IF THE AIRSPEED WAS BLEEDING, I WOULD PUSH PRETTY HARD TO GET THE ATTITUDE TO STAY UP WITH IT AND KEEP IT FROM DECREASING FURTHER, AND THEN THE ACTUAL ATTITUDE NECESSARY TO START THE AIRSPEED INCREASING WAS TREMENDOUS. THE TROUBLE WAS AS SOON AS THE AIRSPEED STARTED TO INCREASE, THEN YOU'D HAVE TO START TO COME BACK AND ROTATE AS FAST AS YOU COULD IN ORDER TO MINIMIZE THE OVERSHOOT IN AIRSPEED. DOING THE BEST I COULD, THE PETALS WOULD STILL REACH THE STOPS. SO I CHANGED TO CONTROLLING ATTITUDE AND RATE OF CLIMB WITH ELEVATOR AND USED THE THROTTLE TO CONTROL AIRSPEED. THIS WORKED REASONABLY WELL AS LONG AS I REMAINED CLOSED LOOP ON PITCH ATTITUDE AND AIRSPEED. IT WAS EASIER AFTER I WENT VISUAL BECAUSE I DIDN'T HAVE TO SPEND AS MUCH TIME SAMPLING DIFFERENT INSTRUMENTS TO GET MY SITUATION, I.E., I COULD GET PITCH, BANK AND HEADING ALL FROM LOOKING OUT THE WINDOW. I HAD TO USE SUCH LARGE AND RAPID THROTTLE INPUTS THAT THE THROTTLE FRICTION AND ENGINE LAG BECAME A SIGNIFICANT PROBLEM. DURING GO-AROUND I WATCHED THE DRAG PETALS AND MADE LARGE RAPID THROTTLE INPUTS TO TRY TO KEEP THE PETALS FIXED AT ABOUT 30°. THIS GAVE ME SOME LEAD ON THE AIRSPEED CHANGES AND I WAS ABLE TO FLY IT THAT WAY. PILOT RATING 10. (WIRE BROKE - END OF COMMENTS.)								

Table IV (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 1.46$ rad/sec

PILOT RATING / FLIGHT NO. / GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
6.5 449-2 Group S Figure 13b ○	MODERATE TO HEAVY. STRONG CROSSWIND FROM LEFT.	THIS CONFIGURATION IS SIMILAR OPEN-LOOP TO THE FIRST ONE EXCEPT THE SIGN OF THE DRAG DUE TO ELEVATOR IS OPPOSITE. I PICKED A GEAR RATIO THAT WAS A LITTLE LOW SO THAT IT TENDED TO MINIMIZE THIS TENDENCY TO OVERDRIVE THE AIRPLANE AND THEREFORE MINIMIZE THESE FORE AND AFT ACCELERATIONS DUE TO ELEVATOR CONTROL. (NOTE: ACTUALLY THE GAINS SELECTED WERE NEARLY IDENTICAL.) THUS I WAS BEHIND THE AIRPLANE CLOSE IN ON THE GLIDE SLOPE, BUT I WASN'T DOING VERY WELL ANYWAY, SO I'M NOT SURE I WOULD HAVE DONE SIGNIFICANTLY BETTER WITH A LIGHTER ONE. DURING THE DESCENT, I WAS CONTROLLING ONLY LOW FREQUENCIES. I HAD TO MAKE FAIRLY LARGE AMPLITUDE CHANGES TO CONTROL AIRSPEED. HELD HIGH RATE OF DESCENT IN CLOSE AND WENT 100 FEET LOW IN LEVEL-OFF. AIRSPEED CONTROL ON GLIDE SLOPE WAS SOMEWHAT DIFFICULT. DIDN'T SEEM TO HAVE THE DEGREE OF PRECISION WITH THIS ONE THAT I HAD WITH THE FIRST ONE. IT WAS FAIRLY PREDICTABLE IN THAT IF AIRSPEED WAS LOW YOU KNEW IT WAS GOING TO STAY LOW UNLESS YOU DID SOMETHING. IT WAS KIND OF SLOW IN RESPONDING TO CORRECTIONS. AIRSPEED LIGHTS WEREN'T TOO GOOD BECAUSE OF TURBULENCE, SO I USED THE AIRSPEED INDICATOR ON THE SECOND APPROACH. I ALSO FOUND THAT ON THIS ONE, I COULD DO BETTER IF I DIDN'T CHANGE PITCH ATTITUDE AND CONSCIOUSLY PUT IN POWER CORRECTIONS WITH ALTITUDE. WHEN I DID THIS I HAD LESS AIRSPEED PROBLEM. I TRIED TO SUPERIMPOSE AN AIRSPEED CONTROL WITH THE THROTTLE ALSO. WHAT I SEEMED TO BE DOING WAS MAKING ONLY SLOW PITCH ATTITUDE CORRECTIONS NOT AS A FUNCTION OF JUST ONE VARIABLE BUT AS A FUNCTION OF BOTH AIRSPEED AND ALTITUDE AND I FOUND TIGHT THROTTLE ON ALTITUDE ERROR HELPED THIS CONFIGURATION. IN RETROSPECT, I GUESS WHAT I FOUND WAS THAT LESS ACTIVITY WITH THE ELEVATOR IMPROVED MY SITUATION QUITE A BIT. (I.E., LESS DRAG VARIATIONS OF THE GENERALLY DETRIMENTAL SENSE.) GUESS I WAS FORTUNATE THAT POWER CHANGES OF THE MAGNITUDE THAT I WAS USING DIDN'T CAUSE ATTITUDE DISTURBANCES. IT WAS PRETTY GUSTY ON BOTH EVALUATIONS, BUT THIS AIRPLANE DIDN'T RESPOND IN TURBULENCE THE WAY THE PREVIOUS ONE DID. IT WAS MORE SOLID FEELING AS REGARDS TURBULENCE, BUT IT WAS MORE DIFFICULT AS REGARDS AIRSPEED CONTROL. CONTRASTING FIRST AND SECOND CONFIGURATIONS: SECOND ONE HAD MORE AIRSPEED CONTROL PROBLEMS. WHENEVER IT WAS FLYING CONSTANT ALTITUDE OR FLIGHT PATH WITH THE SECOND ONE, I HAD TO CLOSE THE THROTTLE LOOP AND I DIDN'T SEEM TO HAVE TO DO THAT WITH THE FIRST ONE. WITH THE FIRST ONE, I COULD USE ELEVATOR TO CONTROL THE FLIGHT PATH AND IT WAS EASIER SINCE IT WASN'T AS DEMANDING. THE SECOND ONE WAS NOT AS RESPONSIVE IN PITCH TO TURBULENCE, THOUGH, AND I DON'T KNOW WHY THIS IS SO.	DON'T REALLY KNOW. DIDN'T HAVE TIME TO LOOK AT IT.	O.K., ALTHOUGH I PICKED IT HEAVY.	TOO SLOW.	YES, IT SEEMED TO BE WHENEVER I REALLY TRIED TO MAINTAIN ALTITUDE.	DIDN'T DO IFR. HAD TROUBLE OBTAINING & FOLLOWING GLIDE SLOPE.	CONSIDERABLE PROBLEM. YOU HAVE TO BE ATTENTIVE.	TIGHT THROTTLE TO ALTITUDE AND AIRSPEED ERRORS AND MINIMUM USE OF ELEVATOR.	MARGINAL.
5.5 449-1 S ○	CLOUDS, TRAFFIC. MODERATE OR WORSE. STRONG CROSSWIND FROM LEFT.	INTERESTING AND SURPRISINGLY GOOD CONFIGURATION FOR WHAT IT APPEARED TO BE OPEN LOOP. BASICALLY, IT HAD A STRONG NEGATIVELY DAMPED PHUGOID, LONG RESPONSE TIME SHORT PERIOD, AND SUBSTANTIAL AMOUNT OF LONGITUDINAL FORCE DUE TO ELEVATOR DEFLECTION IN SENSE THAT BACK STICK REDUCED DRAG. THE LONGITUDINAL ACCELERATIONS WITH ELEVATOR STICK WERE DISTRACTING AND I FOUND THAT IF I REDUCED THE GEAR RATIO, THERE WAS LESS TENDENCY TO OVERDRIVE THE CONFIGURATION AND THIS KIND OF FILTERED MY INPUTS, SO THE LONGITUDINAL ACCELERATIONS DUE TO CONTROL KIND OF BLENDED IN LIKE THEY WERE DRAG VARIATIONS DUE TO ANGLE OF ATTACK. I THOUGH ABOUT RUNNING THE EVALUATION WITH HEAVY FORCES BUT THEN I REMINDED MYSELF THAT I WOULD NEED THE CONTROL AUTHORITY WHEN I GOT CLOSE IN ON THE GLIDE SLOPE WITH THIS SLOW SHORT PERIOD AND THERE WAS ALSO QUITE A BIT OF PITCH RESPONSE TO AIRSPEED. SO I DECIDED TO USE A HIGHER GEAR RATIO AND LIGHTER FORCES. WHEN WE ENCOUNTERED TURBULENCE AND WIND SHEAR, THE AIRPLANE WAS QUITE RESPONSIVE IN PITCH. IT IS KIND OF A HEAVING MOTION THAT YOU GET TO A GUST DISTURBANCE, IT DOESN'T HAPPEN INSTANTLY. YOU HIT THE GUST, YOU FEEL IT, AND THE AIRPLANE KIND OF PITCHES UPWARD AND YOU END UP WITH SUBSTANTIAL ELEVATOR STICK DEFLECTIONS. I WAS USING RATHER LARGE CONTROL INPUTS TO CONTROL ATTITUDE AND THIS CAUSED ACCELERATIONS AND DECELERATIONS WHICH WERE DISTRACTING AND NOT REALLY DISORIENTING, BUT THEY TEND TO BE DISORIENTING. SO I TRY TO KEEP TRIMMED AND TAILOR MY INPUTS TO AVOID THESE PULSATIONS THAT RAPID CONTROL INPUTS CAUSE. THE GLIDE SLOPE PART WENT PRETTY WELL. IT'S THE KIND OF CONFIGURATION THAT YOU COULD SET THE THROTTLE AND JUST CONTROL ATTITUDE TO CONTROL ALTITUDE. THIS WAS RATHER COMFORTING. I DON'T LIKE IT IN TURBULENCE.	FAIRLY EASY.	O.K.	TOO SLOW. YOU HAVE TO REALLY WATCH IT & ALWAYS BE PREDICTING WHAT IT'S GOING TO DO 4-5 SECONDS LATER.	NOT IN SMOOTH AIR, BUT IN TURBULENCE IT IS A PROBLEM. TURBULENCE IS A STRONG FACTOR IN THIS EVALUATION.	ONLY TOLERABLE, BECAUSE OF TURBULENCE.	NOT PARTICULAR PROBLEM. IT WASN'T REAL EASY BUT IT NEVER GOT OUT OF HAND.	OVERDRIVE IN PITCH & ATTEMPT TO KEEP IT IN TRIM, I.E., THE ELEVATOR STICK IN TRIM FOR THE AIRSPEED.	YES.
10 447-2 S ◊	HAZE. LIGHT.	I SURE DIDN'T HAVE THE SECRET OF FLYING THAT CONFIGURATION - ABOUT ALL I DID WAS CUSS IT. IT'S OBVIOUS THAT IT HAS LOTS OF DRAG WITH ELEVATOR IN THE SENSE THAT BACK STICK INCREASED DRAG. SO YOU MIGHT THINK I SHOULD COORDINATE THROTTLE WITH ELEVATOR. I'VE TRIED THIS, BUT THERE ARE TIMES WHEN I DO THINGS WITH THE ELEVATOR THAT ARE CONTRARY TO THE THROTTLE CHANGE THAT WOULD BE REQUIRED JUST TO COMPENSATE FOR ELEVATOR DRAG. SUPPOSE THE NOSE IS UP AND I'M SLOW, I WOULD PUSH FORWARD ON THE STICK AND WITH THIS CONFIGURATION, THAT WOULD REDUCE THE DRAG. SO IF I WAS GOING TO CLOSE A THROTTLE LOOP WITH ELEVATOR STICK I WOULD TAKE OFF POWER, BUT I'M NOT GOING TO TAKE OFF THROTTLE WHEN THE AIRSPEED IS LOW. SO, IN THAT INSTANCE, I HAVE A REQUIREMENT PERHAPS OF ADDING THROTTLE AND TAKING IT OFF TOO. SO WHAT I'M SAYING IS THAT WHAT I THINK I SHOULD DO WITH THE THROTTLE IS A FUNCTION OF ELEVATOR, AIRSPEED AND ATTITUDE. I TRIED TO CONTROL ATTITUDE WITH ELEVATOR AND USE THROTTLE WITH SPEED, BUT I NEVER DID GET IT HACKED VERY WELL. ON GLIDE SLOPE, I HAD TO SPEND MORE TIME WATCHING THE AIRSPEED LIGHTS THAN I DID THE GLIDE SLOPE LIGHTS. ON FIRST APPROACH IT GOT FAST AND LEVELED OUT AND I JUST COULDN'T GET IT TO GO DOWN.	VERY DIFFICULT. ELEVATOR INPUTS TO CORRECT ATTITUDE AFFECT AIRSPEED.	O.K.	TOO SLOW & SLUGGISH. HAD TO OVERDRIVE IT & TRY TO LEAD IT. IT'S ACCEPTABLE BUT POOR IN THE SHORT PERIOD BUT WHEN YOU CONSIDER THE AIRSPEED MODE THAT THIS CONFIGURATION HAS, BECAUSE WHEN YOU PUT ELEVATOR INPUT IN, THE WAY THE ATTITUDE STARTED TO RESPOND & THE WAY IT RESPONDED 2 SEC. LATER WERE 2 DIFFERENT THINGS, IT IS UNACCEPTABLE.	YES. IT'S A PROBLEM	COULDN'T ESTABLISH IT OR MAINTAIN IT.	VERY SERIOUS PROBLEM. COULDN'T FIGURE OUT HOW TO MAINTAIN AIRSPEED WITH ANYTHING NEAR THE PRECISION REQUIRED FOR LANDING.	I TRIED ATTITUDE WITH ELEVATOR AND THROTTLE WITH AIRSPEED BUT THE PERFORMANCE I ACHIEVED WAS PRECIOUS POOR.	NO!

Table IV (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 1.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
9 448-1 Group 5 Figure 13b ◊	HAZE. LIGHT TO MODERATE TRAFFIC.	WHEN I PULL BACK ON STICK, WE ACCELERATE AND IF I PUSH FORWARD ON THE STICK, IT DECELERATES. SHORT PERIOD IS A LITTLE TOO SLOW AND SLUGGISH AND THE AIRSPEED MODE IS VERY UNSTABLE. IT'S NOT ALWAYS EASY TO KNOW WHAT TO DO WITH THE THROTTLE TO PRODUCE THE DESIRED RESULT, PARTICULARLY REGARDING AIRSPEED. THIS ONE IS A LOT MORE PREDICTABLE THAN 448-7 THAT I HAD THIS MORNING, PARTICULARLY IN TURNS. IN FACT, THIS ONE IS QUITE A BIT BETTER ALMOST EVERYWHERE, ESPECIALLY WHEN I'M CONTROLLING FLIGHT PATH. I DID MUCH BETTER AND FELT MUCH MORE IN COMMAND OF THE SITUATION THAN I DID WITH THE ONE THIS MORNING, BUT IT'S STILL A PRETTY UNREASONABLE CONFIGURATION.	YES. EVERYTHING I DID WITH THE ELEVATOR CHANGED THE AIRSPEED OR INSTIGATED A CHANGE IN AIRSPEED & THAT'S ALL IT TOOK FOR THE AIRSPEED TO TAKE OFF.	O.K.	UNSATISFACTORY. SLOW AND SLUGGISH & I TENDED TO DITHER IT ON FINAL.	PRETTY GOOD IN TURNS.	CAN BE DONE, BUT IS A CLOSED-LOOP SITUATION.	YES, IT'S A PROBLEM. TENDED TO GET FAST A LOT.	ELEVATOR TO HOLD ATTITUDE. THROTTLE TO CONTROL AIRSPEED. HIGH AND FAST IS HARD TO CORRECT. REQUIRED TAKING OFF A LOT OF THROTTLE.	NOT ROUTINELY. IT REQUIRES TOO MUCH CLOSED-LOOP CONTROL. IF YOU LEAVE IT ALONE OR LOOK AWAY YOU'RE IN DEEP TROUBLE.
7 - 8 453-2 5 ◊	DOWNWIND APPROACHES. LIGHT TO MODERATE TRAFFIC.	I THINK I'M GOING TO REFUSE TO RATE THIS ONE. WE HAD TOO MANY DISTRACTIONS. MADE APPROACHES DOWNWIND AND AGAINST TRAFFIC, HAD TO MAKE 360° HOLDING TURNS AND TALK TO PEOPLE, ETC. I JUST DIDN'T GET A CHANCE TO KEEP TRACK OF WHAT I WAS TRYING TO DO AND HOW IT WAS TURNING OUT AND MY ABILITIES TO DO WHAT I WANTED TO DO. I'LL TALK ABOUT IT, BUT I DON'T THINK I CAN RATE IT. WE HAD TURBULENCE AT ALTITUDE AND IT TOOK LOTS OF TIME TO GET ENGAGED AND TO TRY TO GET THE DATA RECORDS SO WE WERE SHORT ON FUEL. THIS ONE HAD A LOT OF DRAG DUE TO ELEVATOR, BACK STICK REDUCED DRAG. I PICKED FAIRLY HEAVY FORCES, BUT THE CHOICE WAS REASONABLE. IT WAS DIFFICULT TO FLY THIS ONE STRAIGHT AND LEVEL IN THE TURBULENCE WE HAD AND WITH ALL THE DISTRACTIONS. THE BEST THING I DID WITH THE CONFIGURATION WAS ON THE GLIDE SLOPE. ON THE GLIDE SLOPE IT WASN'T HALF BAD. I WAS SURPRISED AND IMPRESSED. ON FIXED THROTTLE DESCENT, IT REQUIRED FAIR ATTITUDE CHANGES TO KEEP AIRSPEED UNDER CONTROL. THIS WAS PROBABLY INFLUENCED BY THE TURBULENCE. BUT IT KEPT ME BUSY IFR. I HAD TO DO TWO 360° HOLDING TURNS AFTER I WENT VISUAL. FOUND THAT I HAD TO TAKE OFF THROTTLE IN THE TURNS, AND ADD THROTTLE WHEN I ROLLED OUT. THIS IS APPARENTLY BECAUSE DRAG REDUCTION DUE TO ELEVATOR IS MORE THAN THE DRAG INCREASE DUE TO ANGLE OF ATTACK. DURING THE SECOND TURN I WRAPPED IT UP TO 45° BANK AT 800 - 900 FEET ABOVE THE GROUND AND WAS FAIRLY COMFORTABLE. ON THE GLIDE SLOPE I DID A HALF WAY DECENT JOB. I USE THE AIRSPEED LIGHTS AND WORK ON AIRSPEED ERRORS WITH POWER. I CONTROLLED THE ALTITUDE WITH THE ELEVATOR AND WAS ABLE TO KEEP THE AIRSPEED ERRORS BOUNDED IN THE TURBULENCE. I THOUGHT THAT WAS PRETTY GOOD. I GOT SLOW IN THE CLIMB BECAUSE I WAS TOO STEEP. HAD TRAFFIC INTERFERENCE AGAIN AND HAD TO DO ANOTHER 360° TURN. I APPARENTLY DIDN'T GET STABILIZED AS WELL ON THE SECOND APPROACH BECAUSE THE ERRORS WERE LARGER. I WAS STILL MAKING PITCH CORRECTIONS RIGHT DOWN TO THE LAST. MY DIFFICULTIES IN FLYING THE CONFIGURATION WERE VARIABLE AND MY PERFORMANCE WAS VARIABLE. IT WASN'T TOO BAD ON THE GLIDE SLOPE, BUT OTHER TIMES I THOUGHT IT WAS PRETTY MISERABLE. I JUST DON'T KNOW HOW TO SUM UP ALL THESE VARYING OPINIONS. I THINK I PREFER TO SAY THAT WHEN I FEEL THIS UNCERTAIN, I SHOULDN'T SAY ANYTHING. MAYBE MY GUESS WOULD BE REAL GOOD. YOU'D FEEL GOOD ABOUT IT OR MAYBE IT WOULD BE REAL BAD AND YOU WOULD DISCOUNT IT AS A GUESS. I JUST DON'T FEEL HAPPY WHEN I DON'T GET TO FLY A CONFIGURATION TO THE POINT WHERE I WANT TO GIVE A RATING. NOW THIS ONE, I ACTUALLY SPENT PROBABLY AS LONG A TIME FLYING IT, BUT I DIDN'T FLY IT IN MANEUVERS THAT ALTOGETHER DEFINED MY ABILITY TO FLY THE CONFIGURATION'S MISSION. PLUS THERE WERE DISTRACTIONS DURING MY ASSESSMENT WHICH INTERFERED WITH MY OBSERVATIONS OF MY PERFORMANCE AND REALLY ALTERED MY AIMS, WHAT I WAS TRYING TO DO WITH THE CONFIGURATION. I DIDN'T TRY TO TAKE IT AND MAKE IT DO SPECIFIC THINGS LIKE I LIKE TO DO AND THEN SEE HOW WELL I PERFORM AND HOW WELL I'M ABLE TO DO THESE THINGS. MUCH OF THE TIME I WAS JUST CIRCLING AROUND JUST TRYING TO STAY OUT OF THE ROAD OF OTHER AIRPLANES. I DID OBSERVE MY PERFORMANCE IN DOING THAT AND I CAN COMMENT ON IT, BUT THEY DON'T TELL ME ALL THE THINGS I NEED TO KNOW TO RATE THE THING FOR THE LANDING APPROACH MISSION. I THINK ON THE BASIS OF WHAT I SAW, I HAD TO RATE IT AS JUST NOT ACCEPTABLE. I WOULDN'T WANT TO ADVISE ANYBODY TO BUY THIS AIRPLANE. BUT ONCE AGAIN, I HATE, ON THE BASIS OF WHAT I SAW, TO ADVISE THEM NOT TO BUY IT. I SAY IT IS NOT ACCEPTABLE IN THIS LIMITED EVALUATION, MOSTLY ON THE BASIS OF OVERALL DIFFICULTIES I HAD IN GENERALLY MAKING IT DO WHAT I WANTED IT TO DO. THERE WERE CERTAIN EXCEPTIONS. PORTIONS OF THE TURNS WERE BETTER, AND PART OF THE GLIDE SLOPE WAS BETTER THAN THAT SORT OF RATING BUT OVERALL, I JUST HAD A GREAT DEAL OF TROUBLE FLYING THIS CONFIGURATION. BY THE SAME TOKEN, I DON'T THINK IT IS A 10, AND I CAN'T REALLY THINK IT IS A 9. I FIND IT DIFFICULT TO TIE IT DOWN MUCH BETTER THAN THAT. IF I TRY TO RATE IT, I'M KIND OF KIDDING MYSELF AND ALL I'M DOING IS AVERAGING THESE BOUNDARIES. I THINK I'M JUST GOING TO HAVE TO SAY I CAN'T RATE IT - SORRY. (AFTER FLIGHT, THE PILOT NARROWED THE RATING DOWN TO 7 - 8.)								

Table IV (Cont.) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 1.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
5.5 456-2 Group S Figure 13b ◇	OVERCAST, VISIBILITY POOR. LIGHT TURBULENCE	IN SMOOTH AIR, IN MANY RESPECTS, IT WAS FAIRLY GOOD. IF I WAS IN THE LOOP I COULD DO FAIRLY WELL WITH IT AND YET IT SEEMED I HAD UNCERTAINTIES AS TO WHERE TO PUT THE ATTITUDE TO MAKE IT FLY PROPERLY WHEN I WAS MAKING A FLIGHT PATH CHANGE. ONCE I WAS ESTABLISHED, IT WAS O.K., BUT WHEN I CHANGE FLIGHT PATH ON INSTRUMENTS I WAS NEVER SURE WHAT WAS GOING ON. AT FIXED THROTTLE THE AIRSPEED CONTROL WAS FAIRLY GOOD. DURING THE DESCENT, HAD TIME TO LOOK AT THE LOCALIZER. MADE A PRETTY GOOD GLIDE SLOPE APPROACH USING THE AIRSPEED AND GLIDE SLOPE LIGHTS ALL THE WAY IN. ERRORS WERE SMALL, BUT THE AIR WAS PRETTY SMOOTH. CLOSE IN I TENDED TO DITHER THE ELEVATOR TO GET ATTITUDE CONTROL PRECISION. WENT QUITE LOW ON THE PASS. EVALUATION UNDER NEAR IDEAL CONDITIONS. IT'S PRETTY GOOD WITH ME IN THE LOOP. OPEN LOOP THE PHUGOID WAS PRETTY UNSTABLE, BUT I DIDN'T SEE THAT CLOSED LOOP. HAD SOME UNCERTAINTY WHEN TRANSITIONING FROM ONE FLIGHT PATH TO ANOTHER. PRETTY GOOD ON THE GLIDE SLOPE.	DIDN'T GET TO DO. APPARENTLY NOT BAD.	O.K.	NOT SATISFACTORY. NEVER KNOW WHAT TO DO WITH ATTITUDE WHEN CHANGING THE FLIGHT PATH.	NOT A PROBLEM. I WASN'T ABLE TO CONTROL ATTITUDE QUITE AS PRECISELY AS I WOULD LIKE.	WENT FAIRLY WELL. VERY UNCERTAIN WHEN TRYING TO ESTABLISH BUT O.K. ONCE SETTLED DOWN.	RELATIVELY SMALL PROBLEM. IT NEVER SEEMED TO BE DIVERGENT OR UNSTABLE BUT AIRSPEED ERRORS DID OCCUR AND I HAD TO CORRECT THEM. HOW THEY WERE CORRECTED HAD TO BE CONSISTENT WITH THE ALTITUDE ERRORS THAT EXISTED.	I SEEMED TO HAVE TO TAKE OFF A LITTLE POWER IN 30° BANK TURN.	YES, BUT NOT A GOOD ONE.
9.5 444-1 Group T	CROSSWIND FROM RIGHT. LIGHT TURBULENCE	UNCOMFORTABLE AIRPLANE. I DON'T HAVE POSITIVE CONTROL OF IT. ABOUT THE ONLY SUCCESS I HAD WAS TO FLY TIGHT ATTITUDE AND THEN CONTROL AIRSPEED WITH THE THROTTLE. YOU DON'T TRY TO CHANGE RATE OF DESCENT OR FLIGHT PATH QUICKLY BECAUSE IF YOU DO, YOU EXCITE THIS AIRSPEED MODE AND GET YOURSELF IN TROUBLE, SO YOU JUST FLY ATTITUDE AND BRING THE NOSE UP AND GRADUALLY ADD POWER. ALSO, IT'S NOT A GLIDE SLOPE AIRPLANE. ALL I COULD DO WITH IT WAS MINIMIZE THE ERRORS. I DIDN'T HAVE POSITIVE CONTROL OF THE FLIGHT PATH. REQUIRES COMPLETE ATTENTION FOR CLOSED-LOOP CONTROL.	FAIRLY EASY IN SMOOTH AIR WITH AN ATTITUDE REFERENCE.	I'D LIKE TO TRY THIS ONE AGAIN WITH A HIGHER GEAR RATIO. I COULDN'T OVERDRIVE THE RESPONSE AS RAPIDLY AS I WANTED.	UNACCEPTABLE. I'M TOO FAR BEHIND IN CORRECTING DISTURBANCES AND ERRORS.	IT'S A PROBLEM UNLESS YOU MAINTAIN ATTITUDE REAL TIGHT AND CORRECT AIRSPEED WITH THE THROTTLE.	TEND TO GET LONG PERIOD PLUNGING OSCILLATION WITH CONSTANT THROTTLE.	HAD GOOD CONTROL WITH THE THROTTLE.	OVERDRIVE AND CONTROL ATTITUDE WITH ELEVATOR AND AIRSPEED WITH THROTTLE.	NOT ON A REGULAR BASIS.
4.5 415-2 Group U Figure 14b ✕	LIGHT TO MODERATE	BASICALLY A PONDEROUS TYPE AIRPLANE WITH AN AWFUL LOT OF PHUGOID STIFFNESS, I.E., LARGE PITCH RESPONSE WITH AIRSPEED. THE AIRPLANE HAD A NOTICEABLE TENDENCY TO PITCH IN RESPONSE TO TURBULENCE.	MUST STABILIZE THE ATTITUDE TO GET THE AIRSPEED TO SETTLE DOWN.	TENDED TO PICK HIGH TO OVERDRIVE THE AIRPLANE AND CONTROL PITCH WHEN AIRSPEED CHANGED. BUT THEN TEND TO LOSE FEEL FOR MANEUVERING FORCES IN SHORT PERIOD.	SLOW & SLUGGISH. IN FINAL STAGES ON THE GLIDE SLOPE, IT WAS PONDEROUS.	SOME PROBLEM IN TURNS. TURNS PRETTY GOOD IF STARTED FROM TRIM BUT IF YOU DO NOT START FROM TRIM, IT GETS CONFUSING & YOU MAY HAVE TO PUSH ON STICK TO KEEP LEVEL TURN.	WENT WELL. AIRPLANE TENDS TO PITCH SLOW ENOUGH THAT ALL YOU HAVE TO DO IS RESTRAIN IT IN PITCH TO KEEP AIRSPEED FROM BEING OVERCORRECTED. FORCES ARE QUITE LARGE THOUGH.	NOT A PARTICULAR PROBLEM IF YOU RESTRAIN ATTITUDE.	GOOD ATTITUDE STABILIZATION AND OVERDRIVE THE PITCH RESPONSE.	YES.

Table IV (Concluded) SUMMARY OF PILOT COMMENTS FOR CONFIGURATIONS WITH $\omega_{sp} \doteq 1.46$ rad/sec

PILOT RATING FLIGHT NO. GROUP	ATMOSPHERIC CONDITIONS AND CIRCUMSTANCES	GENERAL REMARKS	DIFFICULT TO TRIM?	ELEVATOR CONTROL GAIN SATISFACTORY?	ATTITUDE CONTROL SATISFACTORY?	MAINTAINING ALTITUDE A PROBLEM? a) STRAIGHT b) TURNS	CAN YOU ESTABLISH SPECIFIC RATE OF DESCENT?	MAINTAINING AIRSPEED A PROBLEM?	SPECIAL CONTROL TECHNIQUE REQUIRED?	COULD YOU MAKE A LANDING APPROACH AT THIS SPEED?
10 440-1 Group U Figure 14b X	VERY WINDY. MODERATE TO HEAVY. WIND SHEAR.	VERY GUSTY, TURBULENT DAY AND WILL UNDOUBTEDLY INFLUENCE MY RATING BUT IT'S CERTAINLY A GOOD THING TO SEE CONFIGURATIONS LIKE THIS IN JUST THAT KIND OF A DAY. I SEE A VERY SHORT AIRSPEED MODE, SO SHORT AND SO VIOLENT THAT IT CAUSES LARGE ACCELERATIONS IF DISTURBED. THE AIRPLANE IS VERY RESPONSIVE IN PITCH ATTITUDE TO TURBULENCE, AND NOT JUST THE INITIAL GUSTS, BUT ALSO DUE TO THE AIRSPEED CHANGE. IF YOU DON'T RESTRAIN IT ON THE INITIAL RESPONSE, THE NEXT CYCLE WILL KILL YOU. WENT 100 FEET LOW DURING LEVEL PORTION AT 800 FEET AND I COULDN'T PREVENT IT, CAN'T HOLD ALTITUDE ANY CLOSER THAN ±100 FEET. THE RESPONSE OF ANGLE OF ATTACK AND ATTITUDE TO ELEVATOR IS SLOW. IF YOU TRY TO CORRECT ALTITUDE WITH POWER, IT'S HARD TO ROTATE THE AIRPLANE PRECISELY AND IF YOU GET FAST, THE AIRPLANE PITCHES UP, SO YOU WIND UP PUSHING FORWARD TO RESTRAIN IT SO YOU MAY NOT LET THE ATTITUDE GO UP AS HIGH AS IT SHOULD IN ORDER TO HOLD THE AIRSPEED CONSTANT. IF YOU BRING THE NOSE UP TOO FAST, IT GETS SLOW AND JUST SINKS OUT FROM UNDER YOU. SO IT'S HARD TO MAKE AN ALTITUDE CORRECTION. IT'S EASIER TO FLY VISUAL THAN IFR. TRIED TO FLY TIGHT ATTITUDE STABILIZATION AND AIRSPEED TO THROTTLE BUT I COULDN'T KEEP UP WITH THOSE GUSTS WITH THE THROTTLE. THE AIRSPEED CHANGED TOO FAST.	NOT TOO BAD IN SMOOTH AIR.	O.K. I PICKED HIGH SO I COULD CONTROL TRIM CHANGES WITH AIRSPEED.	TOO SLOW AND SLUGGISH. YOU TEND TO FLY IT WITH PULSES.	NOT TOO MUCH IN SMOOTH AIR. IT IS EXTREME PROBLEM IN TURBULENCE. BUT EVEN IN SMOOTH AIR IT'S PECULIAR. I THINK THE ANGLE OF ATTACK RESPONSE OF THE PHUGOID IS AS BIG OR BIGGER THAN IT IS IN THE SHORT PERIOD. IN OTHER WORDS, I CAN PUT AN ELEVATOR INPUT IN, AND I GET AN ANGLE OF ATTACK RESPONSE FINALLY (SLOW SHORT PERIOD) AND AN AIRSPEED RESPONSE WHICH CREATES AN ANGLE OF ATTACK THAT IS AS BIG OR BIGGER. IT MAKES IT DIFFICULT TO FLY BECAUSE I HAVE TO FLY BOTH MODES.	NO COMMENT.	CONSIDERABLE PROBLEM, LARGELY DUE TO ATTITUDE CHANGES AND GUST INPUTS.	RESTRAIN IT IN ATTITUDE. OTHERWISE IT WILL STALL FROM PITCH RESPONSE TO TURBULENCE.	NO.
9 443-1 U	LIGHT TO MODERATE	CERTAINLY UNACCEPTABLE. YOU GET A PLUNGING OSCILLATION ANY TIME YOU'RE NOT RESTRAINING ATTITUDE. EVEN WHEN I RESTRAIN ATTITUDE WITH CONSTANT THROTTLE. THE CLOSED-LOOP DAMPING WAS PRETTY LOW. ON THE GLIDE SLOPE I RESTRAINED ATTITUDE AND CONTROLLED AIRSPEED WITH THE THROTTLE. BUT DIDN'T DO TOO WELL.	WAS ABLE TO HOLD AN AIRSPEED.	PICKED SO I COULD RESTRAIN THE ATTITUDE WHEN AIRSPEED CHANGED.	POOR ANGLE OF ATTACK CONTROL. STIFF PHUGOID TENDS TO MAKE SHORT PERIOD LOOK FASTER. ATTITUDE CONTROL IS UNACCEPTABLE.	CAN'T DO IT FIXED THROTTLE, BUT WITH THROTTLE TO CONTROL AIRSPEED. IT'S NOT TOO BAD.	HAVE TO CLOSE THROTTLE TO AIRSPEED LOOP.	YES, IT IS A PROBLEM. ALSO, THE FORCES REQUIRED TO RESTRAIN ATTITUDE WHEN THE AIRSPEED CHANGES ARE HORRENDOUS.	TIGHT ATTITUDE LOOP WITH ELEVATOR AND TIGHT THROTTLE LOOP WITH AIRSPEED.	NO, YOU WOULD HAVE TO BE LUCKY.
9.5 443-2 U	LIGHT TO MODERATE.	DIFFICULT TO HANDLE AIRSPEED MODE. HAS VERY LARGE PITCH ATTITUDE CHANGE WITH AIRSPEED. ALSO VERY LARGE PITCH RESPONSE TO GUSTS. COULD CLOSE LOOPS AND CONTROL IT, BUT REQUIRED CONTINUOUS ATTENTION. THE CLOSER I GOT TO THE GROUND, THE MORE CONCERNED I GOT ABOUT THIS PLUNGING OSCILLATION. HAVE TO RESTRAIN IT IN ATTITUDE AND USE POWER TO GET AIRSPEED.	NOT TOO DIFFICULT. RESTRAIN IT IN ATTITUDE AND USE POWER TO GET AIRSPEED.	O.K. PICKED LIGHT TO OVERDRIVE AND TO HANDLE TRIM CHANGE WITH AIRSPEED.	OVERALL QUITE DIFFICULT DUE TO RESPONSE TO AIRSPEED.	NOT IN SMOOTH AIR, BUT IF YOU GET DISTURBANCES, IT IS IMPOSSIBLE.	MUST CONTROL ATTITUDE TIGHTLY AND USE THROTTLE.	YES, IT'S A PROBLEM. YOU HAVE TO RESTRAIN ATTITUDE.	TIGHT AS YOU CAN ON ATTITUDE WITH ELEVATOR AND THROTTLE TO AIRSPEED.	NO, THIS ONE WILL KILL YOU.
8.5 445-2 Group V	CLOUD LAYERS. CROSSWIND FROM RIGHT MODERATE.	WOULD LIKE TO TALK ABOUT THIS ONE IN COMPARISON TO THE FIRST ONE ON THIS FLIGHT. I THINK THE DIVERGENT ROOTS ARE ABOUT THE SAME, BUT THIS SHORT PERIOD IS A LOT LOWER. THIS ONE IS A LITTLE MORE DIFFICULT TO FLY; IT SEEMS LESS PREDICTABLE. FIRST ONE HAD A GOOD PREDICTABLE SHORT PERIOD RESPONSE TO STICK INPUTS, SO ALL I HAD TO WORRY ABOUT WAS KEEPING AIRSPEED BOUNDED. BUT THIS ONE HAS A DELAY BETWEEN MY INITIATING A CORRECTION AND MY PRODUCING IT. THIS WAS LESS PREDICTABLE AND NOT AS PRECISE. THIS UNCERTAINTY ABOUT WHAT I WAS GOING TO GET JUST MADE INSTRUMENT FLYING A MORE DEMANDING TASK. I'D MUCH RATHER HAVE THE FIRST ONE. ON GLIDE SLOPE I TENDED TO GET BEHIND IN CORRECTIONS AND TENDED TO DITHER THE STICK AS I GOT CLOSE IN. ALSO, IT TENDED TO HEAVE OFF THE GLIDE SLOPE IN TURBULENCE. AIRSPEED DIDN'T SEEM TO GIVE ME AS MUCH TROUBLE, THOUGH, AS THE FIRST ONE DID. YOU COULD NEVER LOOK AWAY VERY LONG WITHOUT GETTING OFF IN EITHER ATTITUDE OR AIRSPEED. (COMPARE WITH GROUP J)	LITTLE MORE DIFFICULT. YOU DON'T SENSE POSITIVELY IF YOU'VE GOT ZERO PITCH RATE OR NOT WHEN YOU LET GO OF STICK. YOU HAVE TO SIT THERE & WAIT TO SEE WHAT IS GOING TO HAPPEN. IF AIRSPEED CHANGES WHILE YOU'RE WAITING, THAT LOUSES UP YOUR TRIM, SO IT IS MORE DIFFICULT.	O.K.	UNACCEPTABLE. TOO SLOW TO RESPOND AND DOESN'T HOLD ANGLE OF ATTACK WELL.	HAD TO WORK AT HOLDING ATTITUDE AND AIRSPEED.	HAD TO WORK AT IT.	IT WAS A PROBLEM.	CLOSE ATTITUDE AND AIRSPEED LOOPS CONTINUOUSLY. YOU HAVE TO USE BOTH ATTITUDE AND THROTTLE TO CONTROL AIRSPEED WITH THIS ONE. ATTITUDE IS QUITE EFFECTIVE.	IN AN EMERGENCY, BUT NOT ROUTINELY. REQUIRES TOO MUCH CLOSED-LOOP ATTENTION.

3.2.3 Longitudinal Control Gain Selected by Pilot

In this program and in the program of Reference 46, the pilot was required to select a stick-to-elevator gear ratio prior to evaluating each configuration. He was asked to select an elevator gear ratio prior to commencing the approach maneuver by performing symmetrical maneuvers and turns. He was then asked to comment on this selection after the approach evaluation was complete.

In Reference 46, the control gain data obtained in this way were used to calculate values of $M_{\delta_{ES}}$ as a function of short-period frequency and damping ratio. All the data obtained in that program were used in the computation of $M_{\delta_{ES}}$ without regard for the value of X_W or $1/T_{h_1}$. This assumption was justified by the pilot comments about the factors which entered into his selection of the control gain. His comments indicated that the longitudinal control gain selected was a compromise between his desire for comfortable and adequate steady forces in turns and his requirement that he be able to make rapid and precise pitch attitude changes.

In the current program, the pilot comments indicate that these same factors were of primary concern to his selection of the control gain but, in addition, when the phugoid frequency was increased through use of M_u , the pitch response to airspeed changes was also a significant factor in the selection of the control gain.

The values of $M_{\delta_{ES}}$ that the pilot selected for each configuration are listed in Tables I and II. Since the configurations in each group are listed in the order of the value of $1/T_{h_1}$ and phugoid damping ratio, it can be seen that the value of $M_{\delta_{ES}}$ selected by the pilot is independent of these parameters simply by scanning the $M_{\delta_{ES}}$ values in each group. In view of this observation, the $M_{\delta_{ES}}$ values in each group have been averaged and the group averages are noted in parentheses in Tables I and II.

Certain configurations in Groups D, G and Q are underlined to indicate that they were not included in the group average, because the procedure for selecting the control gain was different on these flights.

These groups are the ones in which $X_{\delta_{ES}}$ was a variable. On the first few flights for which $X_{\delta_{ES}}$ was to be simulated, the δ_p/δ_{ES} gain was set and the pilot was asked to select the δ_e/δ_{ES} gain. While sampling various values of δ_e/δ_{ES} gain, he noted that he could diminish the longitudinal accelerations which accompanied rapid stick motions by selecting a high value of the δ_e/δ_{ES} gain. This introduced a factor into the gain selection compromise which was dependent on the way the T-33 system was mechanized. This factor was eliminated on later flights by varying both the δ_p/δ_{ES} and the δ_e/δ_{ES} gains so that their ratio remained constant as the pilot sampled various control gain levels. The value of $1/T_{h_1}$ is also dependent on the ratio of the δ_p/δ_{ES} and the δ_e/δ_{ES} gains, as can be seen from Equation 9.

The underlined configurations in Group H were not included in the average for that group because the pilot did not select the gear ratio for these configurations. Instead, the gear ratio was specified by the test conductor and the pilot was asked to comment on the adequacy of the control gain. This was done because the maximum available δ_p/δ_{ES} gain was being used.

The average values of $M_{\delta_{ES}}$ for each group have been plotted as a function of the nominal phugoid frequency in Figure 16. The faired lines for each short-period frequency have been drawn through the overall average $M_{\delta_{ES}}$ values at each nominal phugoid frequency.

From Figure 16, it is observed that the pilot increased the elevator control gain approximately 25 percent when the phugoid frequency was doubled, but did not increase it further when the phugoid frequency was increased beyond $\omega_p = .35$ rad/sec.

It should be noted that, although the $M_{\delta_{ES}}$ values selected by the pilot varied by as much as ±45 percent of the mean within a given group, the majority of the points are within ±15 percent of the mean. The variation in the $M_{\delta_{ES}}$ values selected is due in part to the fact that the pilot was instructed only to select the gain with enough precision such that no significant improvement in the overall rating could be obtained by further optimization.

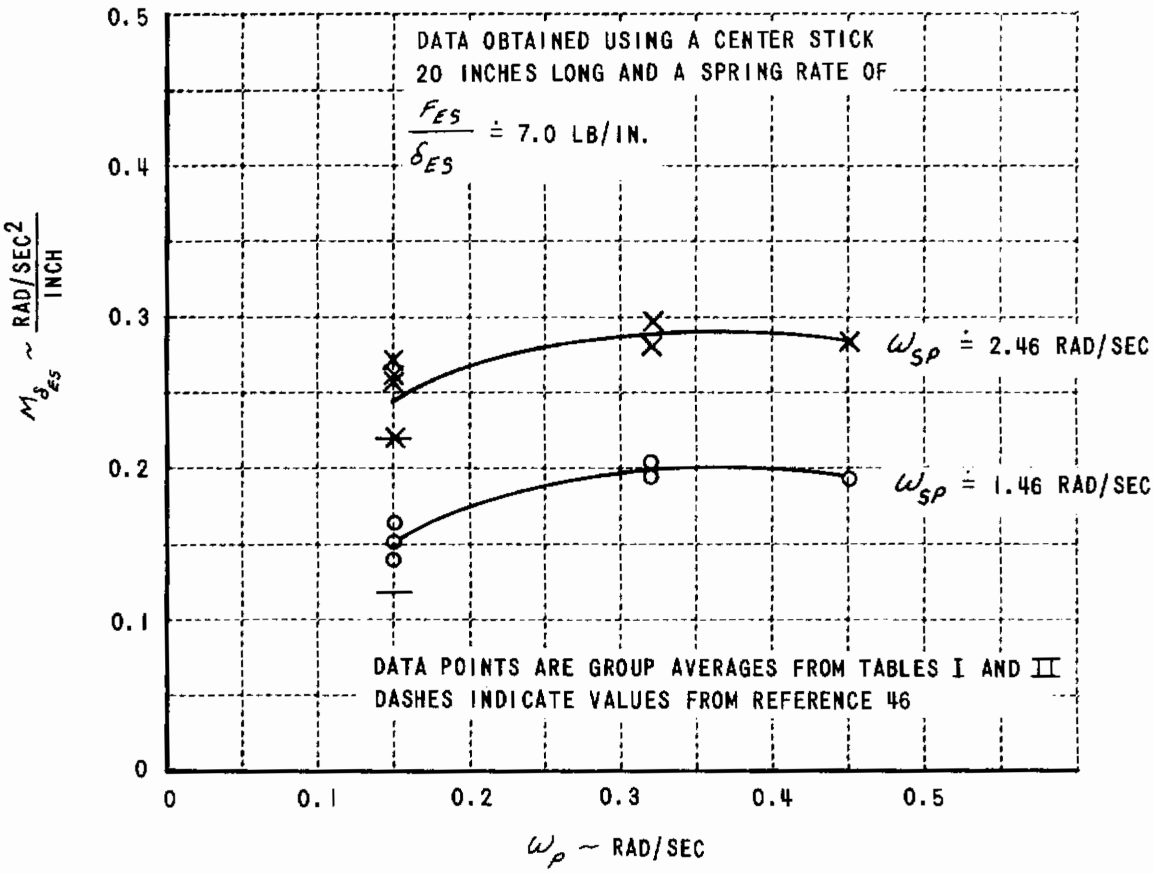


Figure 16. LONGITUDINAL CONTROL SENSITIVITY SELECTED BY THE PILOT FOR THE LANDING APPROACH TASK

It is of interest to compare the average $M_{\delta_{ES}}$ values selected at the low nominal phugoid frequency, $\omega_p = .15$ rad/sec, with the values of $M_{\delta_{ES}}$ indicated in Figure 14 of Reference 46 for the two nominal short-period configurations.

Figure 14 of Reference 46 indicates the pilot would select $M_{\delta_{ES}} = .22 \frac{\text{rad/sec}^2}{\text{inch}}$ for the $\omega_{SP} \doteq 2.46$ rad/sec, $\zeta_{SP} \doteq .45$ short-period configurations, and a value of $M_{\delta_{ES}} = .12 \frac{\text{rad/sec}^2}{\text{inch}}$ for the $\omega_{SP} \doteq 1.46$, $\zeta_{SP} \doteq .45$ short-period configurations. These values are indicated in Figure 16 by the short-dash lines at $\omega_p \doteq .15$ rad/sec. It is seen that these values are 10-25 percent lower than the values selected by the pilot in the current program.

This agreement between the two experiments is considered to be quite reasonable, in view of the rather wide tolerance for this factor that is indicated by the variability of the $M_{\delta_{ES}}$ values selected in a given group.

3.2.4 Approach Time Histories

Oscillograph records were taken of the visual portion of the first landing approach made with each configuration evaluated. The records were approximately one minute long and included a short portion of level flight after the pilot had gone to visual reference, followed by the pushover and power reduction, tracking on the glide slope, and the waveoff. The early portions of these records usually included lateral maneuvers to correct for runway line-up errors and crosswinds. The oscillograph paper speed was such that these records were approximately 5 feet long; thus, it was awkward to study or manipulate these data without some compression in size. It was impractical to scale and replot each of the available records, so a selection was made which was intended to illustrate the effects of the main parameters in the experiment.

For each of these records, the traces listed below were read every 0.20 seconds, punched on IBM cards, and then scaled and plotted by a machine plotter. The data on the punched cards were also available for digital computer processing. The traces read were: elevator stick deflection, angle of attack, pitch attitude, bank angle, aileron stick deflection, rudder pedal deflection, throttle displacement or in some cases engine RPM, altitude, and airspeed.

The scaled time histories are plotted in Figures 17 through 32. These figures are grouped at the end of this discussion, Paragraph 3.2.4. The detailed pilot comments concerning the visual approach have been extracted from the comment data for each of these configurations. There were usually three sections of the wire recording where comments pertinent to the first visual approach were made. The first is the conversation between the evaluation pilot and the safety pilot during the actual approach. The wire recorder was turned on at this time to identify oscillograph records and to note the safety pilot's subjective description of turbulence, wind, visibility, traffic, etc. Often, this was the only information recorded during this time; however, if the configuration happened to be a particularly exciting one, then the conversation and comments by the pilots is enlightening. In his evaluation comments, the pilot usually reviewed the flight in detail and answered the questions listed in Paragraph 2.2.4. Thus, description of the first visual approach can also be found in the section of his comments where he was reviewing the flight or in his answer to question 12 of Paragraph 2.2.4.

The following configurations were selected to be scaled. The items of major interest for each configuration are noted in the column at the right.

		Group	Pilot Rating	Configuration	Comments
$\omega_{sp} \doteq 2.46$ rad/sec	$\omega_p \doteq .15$	A	2	404-1	Good configuration, large longitudinal wind shear encountered.
		A	10	400-2	Severe speed instability, unstable phugoid.
	$\omega_p \doteq .32$ rad/sec	G	5	399-2	Large positive $X_{\delta_{ES}}$, turbulence.
		G	4	439-1	Good configuration.
		E	4	452-1	Good configuration.
		G	5.5	439-2	Speed instability.
		G	10	399-1	Severe speed instability, large gust encountered.
		H	2	462-1	Filtered $X_{\delta_{ES}}$, smooth air, poor visibility.
		H	4	461-1	Filtered $X_{\delta_{ES}}$, turbulence.
		H	10	461-2	Filtered $X_{\delta_{ES}}$, severe speed instability, pilot elevator and throttle gain.
	$\omega_p \doteq .45$	I	7	425-1	High frequency phugoid, pilot elevator gain.
$\lambda_1 \doteq \pm .194 \frac{1}{sec}$		J	8	445-1	Statically unstable phugoid, pilot elevator gain.
$\omega_{sp} \doteq 1.46$ rad/sec	$\omega_p \doteq .32$ rad/sec	S	7	456-1	Speed instability, negative damped phugoid, smooth air.
		S	10	453-1	Speed instability, negative damped phugoid, turbulence, pilot elevator gain.
		S	10	448-2	Speed instability, negative damped phugoid, turbulence, pilot elevator gain.
		T	9	448-1	Negative damped phugoid, pilot elevator gain, large wind shear encountered, low frequency throttle inputs.

In Reference 46, it was shown that the mean square stick motion is related to the power spectral density of stick motion by the following equation:

$$\overline{\delta_{ES}^2} = \int_{-\infty}^{\infty} f \, \Phi_{\delta_{ES}} \, d(\ln f)$$

By plotting $f \Phi_{\delta_{ES}}$ vs f, with f measured on a log scale, the resulting curve indicates the distribution of elevator stick motion with frequency and the area under the curve between two frequencies is equal to the mean square stick motion in that frequency band. Note that the steady state or zero frequency value of δ_{ES} is eliminated from such a plot. The value of $\Phi_{\delta_{ES}}$ and Φ_{δ_T} was computed for each of the configurations selected for scaling. For flights before Flight 402, engine RPM was recorded instead of throttle position and, in these cases, Φ_{RPM} was computed.

In the following paragraphs, the visual approach records will be discussed and contrasted. Reference will be made to the scaled time histories of Figures 17 through 32, to the power spectral density plots of elevator and throttle inputs in Figures 33 through 35, and to the pilot's verbal description and comments.

Group A Configuration 404-1

This configuration was selected to demonstrate a good configuration. It had a stiff short period, a positive value of $1/T_{h_1}$, a well-damped phugoid mode, and little coupling between airspeed disturbances and pitch at high frequency. The latter aspect is illustrated by the $\left|\frac{\theta}{u_g}\right|$ Bode plot in Figure 36 and by the small pitch disturbance that resulted when the large wind shear was encountered at $t \doteq 11$ sec in Figure 17. The elevator inputs by the pilot were small and the throttle inputs were in the form of trim adjustments. See the power spectra plots of Figure 33.

The pilot comments for this visual approach were as follows:

Infanti: Okay, now. Okay. Oscillograph on, visual. Oscillograph on at 482 gals fuel remaining.

Harper: I think it's lined up. --- What happened? I felt a deceleration. Did the petals come open?

Infanti: Nope.

Harper: They sure did, Nello. Something happened then.

Infanti: Did what come open?

Harper: The petals came open.

Infanti: Which petals?

Harper: I don't know what happened.

Infanti: Is your dive brake switch up?

Harper: Yep.

Infanti: I felt that but I don't know what it was.

Harper: It might have been a longitudinal gust.

Infanti: Okay. Oscillograph off at 474 gals and going around. I felt that too, Bob, and I looked out at the ---

Harper: It might have been a longitudinal gust because I looked -- my airspeed had been right on and it's easy to hold airspeed with this configuration.

Infanti: Yeh, wait a minute --

Harper: I looked down --

Infanti: Keep going out -- did he say check on base leg?

Harper: I don't know.

Infanti: Okay, go ahead -- Okay, Bob, what were you saying?

Harper: Well, anyway, when I felt that I looked at the airspeed indicator and it said 170, so it probably was a longitudinal gust.

Infanti: Well, when I did look out at the petals they looked pretty normal.

Harper: Yeh, I just felt the deceleration and it was kind of a step change and I didn't know whether they were malfunctioning or not.

Infanti: Of course they can move pretty fast, so I could have missed it completely. Okay, we're on downwind at 458 gals. Right now --- incidentally, I would call this turbulence out here moderate. OFF

Transition To Visual Flight

I made a line-up correction. I was a little low in the glide slope and I continued on in, got in on glide slope, adjusted the power. About that time, after I got in a little bit, I hit that longitudinal gust and Nello and I talked about that a couple of times and by that time I was fairly close in on the glide slope and I made a couple other corrections which seemed to go all right and took the waveoff.

Second Visual Approach

On the visual glide slope, again I was getting low when I picked up the lights. I drove it on in, got on the glide slope and went on down with minor corrections again and I experienced the longitudinal gusts at the same place as I had before. It was apparently definitely a wind shear.

Group A Configuration 400-2

This configuration had a negative $1/T_{h_1}$ and the phugoid damping ratio was quite unstable. Thus, the pilot had to continuously close an attitude-to-elevator loop and an airspeed-to-throttle loop in order to stabilize this configuration. The pilot's gain in the attitude-elevator loop is initially low when he is flying level to intercept the glide slope. Then, as he intercepts the glide slope and gets closer and closer to the ground, the task becomes more precise and the pilot's elevator inputs become higher in frequency. This is particularly true for configurations that are unstable or when there are external disturbances. This aspect of elevator control is illustrated by large peaks in the elevator stick power spectral density plots of Figure 33.

For Configuration 400-2, the pilot found it very difficult to maintain airspeed and found it necessary to use large and rapid throttle inputs to control airspeed errors.

The time history for this approach is scaled in Figure 18. The pilot comments for this visual approach were as follows:

Infanti: Oscillograph is on, Robert, and you may become visual now. 209 gals fuel remaining.

Harper: With pleasure.

Infanti: 209 gals when this oscillograph came on.

Harper: Did you call the outer marker?

Infanti: Yes, I did. And he said; all clear. Okay. Oscillograph has gone off at 202 gals fuel remaining and we're going around in closed pattern. Go ahead and comment. Wait until I tell them first.

Harper: That was interesting. I looked up to see where that airplane was and I lost 10 knots of airspeed.

Infanti: That was for sure.

Harper: Well, what I was about to say was that thank goodness for the lights here. I don't think I would have been able to do that if I hadn't had the lights. They were very helpful. Cause man, I'll tell you, this thing has got an airspeed problem.

Infanti: I got them up.

Harper: Yeh. This thing has got an airspeed mode that -- it won't let me do much about it. Except work the throttle like mad. I feel like I'm abusing the poor old airplane. But, boy, when that airspeed starts to drop, you only get one choice. Ram it home. Now the airspeed's way off. Now, come on fellas. Gee whiz. Airspeed errors of 10 or 15 knots are common with this configuration.

Infanti: Yeh, much too common. You may start your crosswind here, Robert.

Harper: I think it was this configuration that I said I used the lights so much but I'm not sure now. Yes, I think I did. That's right. I said I wouldn't have been able to fly the approach if I didn't have the lights. And that's true. The lights allowed me to close an airspeed loop while I was making this approach and looking directly at the lights to get my altitude error information. Now, that's the whole secret. I don't know why -- I'm not even going to sit up here and talk a long time about this. It's just what you've got to do and if anything keeps you from doing that, this is a mighty dangerous airplane and almost anything you do to fly an airplane will eventually keep you from looking at the airspeed sometime.

Question 12: -- When on transition it was a little low on both times. I drove it on in, reduced the power and pushed over and first approach flew airspeed tightly which helped. Second approach I flew airspeed but more by gage rather than by lights and that went almost as well but not really as well. I mean I was looking back and forth so I was interrupting my information each time I looked at one or the other. When you get in close, you get to feeling bound up doing that. In other words, if you get in close small error in altitude, really small error in flight path angle, creates a large angular error on the glide slope. When you're in close and if you look away these errors build up pretty fast so you hate to look away so you look faster and faster and feel like the thing is galloping on ahead of you.

With this configuration I checked airspeed all the way until I rotated I think for the waveoff. End.

Group G Configurations 399-1 and 399-2

Configurations 399-1 and 399-2 had the same characteristic equation but they had large values of $X_{\delta_{ES}}$ of opposite signs. These configurations were evaluated early in the program and the pilot had not yet settled on a "standard" for selecting the elevator control gain. He tended to select a low gain to get heavier stick forces on this flight and as a result when he got into turbulence he had to use rather large elevator inputs to control the pitch response to airspeed variations. See the time histories in Figures 19 and 20, the power spectral density plots of Figure 33, and the $\left| \frac{\theta}{u_g} \right|$ Bode plot of Figure 36. On both approaches on Flight 399, a large horizontal gust was encountered ($t \doteq 23$ sec on 399-1 and at $t \doteq 15$ sec on 399-2). The airplane responded abruptly in pitch in both cases and when the pilot pushed the stick forward to try to stay on the glide slope, he recovered quite well in the case of configuration 399-2, but not in the case of 399-1. For configuration 399-1, forward stick caused a large reduction in drag which tended to cause the airspeed to increase; also, the airplane pitched down both in response to the pilot's input and because the gust had decayed. The net result of the reduced drag and the nose down attitude was for the airspeed to increase and as the airspeed increased, the airplane tended to pitch up and to balloon or heave above the glide slope. When the pilot tried to regain the glide slope by pushing the nose down, the drag was further reduced and the airspeed continued to increase. The only chance for recovery was to reduce power but the throttle was already back to approximately 70 percent rpm and the pilot did not want to reduce it further because the engine response time would then be such that he would not be able to recover if the airspeed started to drop or a sink rate developed. The pilot elected to abandon the approach.

The pilot comments for the visual approach of configuration 399-1 were as follows:

Infanti: Okay. The oscillograph is off now. 440 gallons. Just so we have enough paper here for the visual portion, if we ever get there.

Harper: I don't think we will. I can't fly this.

Infanti: Come on -- Don't give up so easy! How come you give up so easy?

Harper: Look at that airspeed go. God bless it. I've got to do something with this throttle, I don't know what, but --- Hey, I'm going to close an airspeed loop on the throttle real tight and see if that will help.

Infanti: Okay. Oscillograph is on, at visual, Bob. At 435 gallons fuel remaining. Lights are on out there. These glide slope lights. On the go-around Robert, you've got to be a little "ginger."

Harper: I will be. I'm not sure I'm going to go down there. I think that this is going to be my minimum altitude. Look at this son-of-a-pup! See that? Look at the airspeed. Holy Mackerel. Look at the stick full forward. I've got it on the forward stop. Look, I've got the stick on the stop. Look at this. Holy mackerel, Andy!

Infanti: Ha---Okay. Oscillograph off at 430 gallons as we go around.

Harper: Ten, -- ten, ten.

Infanti: Do you want to complete this thing or do you want to just climb back up, Bob? I don't see much chance in continuing.

Harper: I've got the stick on the forward stop.

Infanti: I don't see much sense in continuing this.

Harper: I don't either. I've got the stick on the forward stop.

Infanti: Okay. I'll help you. I'll push.

Harper: So if you hit a horizontal gust, which we did on final approach, when we finally got in on that one, the stiff phugoid calls for strong nose-up tendency and in order to stay on the glide slope you've got to push forward on the stick and if you push forward on the stick then you have certain problems in airspeed, namely the ones I'm telling you about. The airspeed control gets pretty stinko. So, I push forward on the stick and then the airspeed wants to increase even more, then it does, and you end up with the stick against the forward stop and that is what I was complaining about. I don't like it. It's a rating of 10.

Question 12: -- When I transition visually I couldn't make the airplane go where I wanted it to. I got fast. I seemed to have a horizontal gust somewhere coming up near the railroad track, but about 1/2 or 3/4 of a mile east of it, and that just heaved me and I pushed forward on the stick and I got faster and faster. I had the stick against the stop and I was going up over the glide path, I was pulling the throttle off and none of it did any real good. I didn't even come down very low on the approach. I was scared of the darn thing anyway and we didn't make the circling approach because we had already used up quite a bit of fuel as I am doing, doing all this talking. So, I'll skip the rest since we didn't do it. The instrument flight: I've described the instrument, the turning technique and it's a problem, but in smooth air you can figure out ways to handle it. But anyway it's a rating of 10. Unflyable for the mission. Wire recorder off.

Toward the end of the approach for configuration 399-2, an oscillation occurred which the safety pilot described as being like a roller coaster. A second-by-second analysis of the Δu, θ, $\Delta \alpha$, δ_T and δ_{ES} traces in Figure 20 indicates a sequence of gust disturbances and control inputs which result, at $t = 42.5$ seconds, in the pilot holding a large nose-down δ_{ES} input to correct a nose-up attitude. Just as the airplane started to pitch down, in response to this elevator stick command, another gust was encountered which decreased the airspeed and the airplane pitched violently down to $\theta \doteq -2°$. At $t \doteq 44$ sec, the pilot applied a large back stick input which was held until $t \doteq 47.5$ sec. During this time interval, the nose was down, the stick was back (which reduced the drag), and the pilot was applying throttle; all of which should have increased the airspeed. The record, however, shows little tendency for the airspeed to respond.

It is difficult to decide whether or not the control difficulty encountered on this approach was characteristic of configurations with a stiff phugoid and large positive $X_{\delta_{ES}}$ or whether it results from a chance occurrence of pilot inputs and gust encounters. The pilot comments for this visual approach were as follows:

Infanti: Oscillograph is on. On visual, Bob. 146 gallons fuel remaining. We're just about center line right now. I'm sure my localizer needle right now is reading about 2 dots off to the right. We're right on center line right now.

Harper: No, we're a little to the left.

Infanti: Well, as I say --

Harper: We're on center line, reading 1 circle off

Infanti: Mine is reading $1\frac{1}{2}$ to 2 dots off to the right --- Inner marker. Little roller-coaster Robert, come on now! Okay, Buddy, better go around. Okay. Oscillograph is off. Going around at 138 gallons. --- Okay the wire is still on. We're at 129 gallons fuel remaining. I think we can maybe just make it. We're in a little bit of turbulence here.

Harper: I'm going to start a normal short approach here.

Infanti: Okay. Mannnn! You know that was like going down the rollercoaster there, on that last half mile.

Harper: Yeah! I didn't think I was going to have that much trouble with it. I really didn't.

Harper: I came visual at the 2 mile point and attempted to come down the glide slope and I thought I was doing fairly well until I got down to about the 3/4 mile point and from then on in, I guess I normally tighten my gain as I get close in and I must put in sharper and quicker elevator inputs and it seemed that in this region it was where I started to have difficulty staying on the glide slope. I believe it went high, but I couldn't be sure. Anyway I couldn't get back on it the way I wanted to. Turbulence seemed to bother me an awful lot with this configuration and with the previous one, configuration (399-1), it was intolerable.

Question 12: -- When I transitioned to visual I was off to the right due to my localizer problems. The visual approach, I think was made in a normal fashion with perhaps less throttle than normal, and in encountering some difficulties with -- I guess more the airspeed response to turbulence. In other words when I encounter turbulence disturbances, what I had to do with the stick to control those disturbances caused errors in either my airspeed or flight path, and I really think that what happened was that it caused airspeed errors and those airspeed errors then caused flight path errors. I believe this is probably what happened. I was checking airspeed fairly far down, but I wasn't overly concerned about it. Except that this thing got fast, and got away from me right at the last. The waveoff was not uncomfortable.

Group G Configurations 439-1 and 439-2

Configurations 439-1 and 439-2 had the same characteristic equation as the configurations of Flight 399. They also had intermediate values of $X_{\delta_{ES}}$ which was positive for configuration one and negative for configuration two. The air was fairly smooth during this flight and the time histories of Figures 21 and 22 are relatively smooth. The throttle inputs used were small in both cases. The elevator gain selected for these configurations was about a factor of two higher than was used on Flight 399. The higher control gain and the smaller disturbances are reflected in the low amplitude elevator stick displacements and power spectra curves of Figure 34. The elevator stick motions become more frequent as the approach progresses and the pilot tightens his attitude-to-elevator loop. This is illustrated in the power spectra plot of Figure 34 by the increased amplitude at ω = 3 to 8 rad/sec.

The pilot comments for these two visual approaches were as follows:

Infanti: ON. We're now at 600 ft above terrain at the outer marker. Some very slight, light turbulence. OFF.

Infanti: ON. Visibility is still poor. Quite hazy. It's a little better down underneath us. Okay. Oscillograph on at 510 gallons. You can come visual.

Harper: Okay.

Infanti: Still slight light turbulence.

Harper: Going around.

Infanti: Okay. Oscillograph off. 501 gallons. Still have to rate the turbulence level as smooth down to the final approach and then I'd say we'd call it light, very light. OFF.

Harper: When I transitioned to glide slope, it felt very slippery on the glide slope in that I couldn't pin down the airspeed. I didn't have too much trouble with it but it was - just kind of tended to get away from me a little. I used the throttle a fair amount and it seemed that I had some uncertainty in the throttle required because I had to keep changing it all the way down. But the first approach was pretty good. Stayed pretty much on the glide slope most of the way and I'd say my principal problem was airspeed control. We waved off at low altitude, climbed up. The climb was comfortable.

Question 12: -- No comment.

The comments for the visual approach for configuration 439-2 were as follows:

Infanti: Okay, we're down now. There's an awful lot of chatter going on, traffic and so forth. We're at 600 ft above terrain now and in light turbulence inside the outer marker. And 167 gallons. Okay. Oscillograph is on the 165 gallons and visual.

Harper: Okay, visual.

Infanti: It's about 2½ miles from touchdown. We'd better look for that light airplane traffic. Now you go ahead and fly. I don't see him yet but -- that light airplane had already gone around but that's allright, I have him. Okay, oscillograph off at 157 gallons. Going around.

Author: The following comments were made on the ground after a series of calibration records had been run on the ramp before engine shut down.

Harper: I came in and intercepted the glide slope and I don't remember the details of the run now, they've faded from my memory except that I wasn't real happy with the first approach. It wasn't too bad or too good but I don't really remember the details that well.

Question 12: -- I checked the airspeed lights all the way in. My basic objection to the configuration is that when I'm hanging on to that stick making the airplane do something, the airspeed mode seems to be unstable.

Group E Configuration 452-1

This configuration had the same characteristic equation as the configurations of Flights 399 and 439. The value of $X_{\delta_{ES}}$ was zero, however, although the turbulence was called quite smooth by the safety pilot, the time histories for this flight, Figure 23, show more evidence of turbulence than was indicated in the time histories of Flight 439. The safety pilot was different on these two flights. Because of gusts and flight path errors which occurred during this approach, the pilot used tight attitude stabilization with the elevator and used attitude commands to correct the flight path and airspeed errors that occurred. These elevator stick inputs are indicated by the peaks in the power spectra plot of Figure 34.

The pilot comments for this visual approach were as follows:

Meeker: ON. We are now at 1300 feet MSL and will be going visual in a minute. You can come on visual now, Bob.

Harper: Okay.

Meeker: Oscillograph on. 500 gallons of fuel remaining. We are now in the visual portion of our approach. I say the air is still quite smooth at this level.

Meeker: Oscillograph off at this point. We are starting our go around at 492 gallons of fuel remaining. OFF.

Harper: Went visual fairly well lined up by the way. On the descent portion I was able to spend a fair amount of time on the localizer heading and was able to, in the nice smooth air, track the localizer well. Went visual to the glide slope and started down comfortably. Had one tendency to go a little low but responded quite well to a little bit of throttle and came right back on. Couldn't use the lights very well. The sun was behind us this morning. It is a very bright morning and even though the nose is a little bit to the left for a little southerly component for a crosswind it still didn't help me very much. I could read the lights when I looked at them but I didn't get much out of my peripheral vision, so I tended to use a combination of the airspeed indicator and the lights. However, it was perfectly adequate. You had a good sense of the airspeed in your elevator stick forces, not particularly concerned about airspeed and used the throttle to control it and to control altitude errors. I'd say the common throttle motions were as much due to control altitude errors as they were to control airspeed. I don't know how the two were linked up, but I did have some tendency to go up and down on the glide slope. Had a little bit of trouble trying to find that groove that went straight down.

Group H Configuration 461-1, 461-2 and 462-1

Configurations 462-1 and 461-1 were the same configuration evaluated one day apart in different atmospheric conditions. The time histories are in Figures 24 and 25 respectively.

The elevator gain was set fairly low for these configurations to make the ratio of $X_{\delta_{ES}}$ to $M_{\delta_{ES}}$ large and therefore achieve the maximum change in $1/T_{h_1}$. As a result the pilot had to use fairly large elevator stick motions to control the flight path and airspeed and to counter pitch disturbances caused by horizontal gusts and wind shear. These elevator inputs are indicated in the power spectra plots of Figure 34. The phugoid was stable and $1/T_{h_1}$ was positive so throttle inputs were neither large nor frequent, although the poor initial conditions on Flight 462-1 did make throttle corrections necessary during that approach and the wind shear encountered in Flight 461-1 also required small corrections.

There is little evidence that the pilot had to use a tight attitude-to-elevator loop. His elevator inputs are mostly low frequency in nature.

The pilot comments for these two configurations follow with those of 462-1 first.

Meeker: ON. We're now at 1400 feet on the final, and I'd say the turbulence level at low altitude would be considered light. OFF.

Meeker: ON. Oscillograph on at 524. We're just on visual . . .

Harper: Okay, I'm going to start my approach on the glide . . . okay, there I've got the . . .

Meeker: Okay, I might add the visibility is quite poor on this. We're now on the go-round at 518 gallons of fuel remaining. Oscillograph coming off. OFF.

Meeker: ON. We're now at 1600 feet on the downwind and I'd say the turbulence level is still light.

Harper: If we called what we had this morning light, I think I'd say this is very light, almost smooth.

Harper: Transition to glideslope, I couldn't see; you couldn't see the run-way, and I had to fish. By fishing I mean I had to kind of search around and find buildings that I recognized and got fairly well lined up. But I didn't get lined and so I was coming in and I wasn't lined up; I was angling and I was - I got low. I'm not sure why I did; I must have taken off too much power. But I did the same thing on the second approach. So I really was not squared away, after I had passed the railroad track, I still wasn't on centerline either vertically or horizontally. On the first approach, I was close in enough so that I was about to transfer my attention from the lights, glideslope lights to the center of the runway, and I still was a little off. I transferred, and anyway I got the airplane on centerline, vertically, horizontally, before I got in. I thought that was pretty good; I didn't really expect to. And so I got aboard; no sweat with that first pass. That was pretty low visibility situation as far as getting lined up.

Question 12: -- I didn't use the lights very much. But I did occasionally.

The pilot comments for configuration 461-1 were as follows:

Meeker: Oscillograph on, ON, 524 gallons of fuel remaining. We're now on the visual portion of our first low approach. There is a little bit more turbulence down here at low level. I would say light though.

Meeker: Oscillograph coming off. We're on the go-round 516 gallons fuel remaining. OFF.

Harper: About the time I was ready to level off, Jim told me to go visual, so I never actually leveled off, but I'm sure that would have gone alright too. Then I started down the glide slope, and I had adequate visibility, and I couldn't see my airspeed lights too well, but I didn't really need to, too much with this configuration, so they were adequate. And, my big trouble was on the glide slope. Because as I ran through areas of wind shear, the airplane responded in attitude and flight path, and I found it difficult to restrain it in attitude in order to restrain the flight path. In other words, as I came across the railroad tracks, we apparently ran into windshear which gave me a little bit of headwind, and the airplane heaved up off the glide-slope and I was pushing forward, and taking off power, and it just seemed I was behind it. In other words, I was dealing a little bit with an elephant. And then as I - the airplane responded, let's say then I had to be sure I got the power back on at the right time, and anyway, it was kind of a ponderous heaving oscillation on that whole first approach. I heaved up, I came back down, put the power on, I heaved up, and I was trying to restrain it in attitude but the elevators were not real effective in restraining it in attitude in the presence of these velocity changes. And when I tried to accommodate the velocity changes with power, in other words, as I felt the heave coming and took the power off, you're sufficiently far behind the airplane doing it that way, that that's not - you don't have good precise flight path control. You really got to use the attitude to fly this flight path by that glideslope. I had difficulty doing it. Okay, then the next . . . Okay we waved off. I wouldn't have gotten aboard that first time, by the way.

Question 12: -- No comment.

Configuration 461-2 had the same characteristic equation as configurations 461-1 and 462-1. However, $X_{\delta_{ES}}$ was large and negative and $1/T_{h_1}$ was very large and negative. This, of course, caused extreme flight path and airspeed control problems. See Figure 26 for time history of this approach. The elevator and throttle inputs used by the pilot were large and frequent. The elevator power spectra plot in Figure 34 shows a large peak at ω = 3.6 rad/sec which is associated with the tight attitude stabilization loop that the pilot found necessary for this configuration. In addition, there were large low frequency inputs required because of the airspeed errors which occurred. The power spectra plots of throttle inputs also shows large peaks at ω = .35, 1.15 and 1.75 rad/sec.

The pilot comments for this visual approach were as follows:

Meeker: Okay, all right. ON. We're starting our descent from 5000 feet, 254 gallons of fuel remaining. OFF.

Harper: Oh, boy this is interesting.

Meeker: Yes.

Harper: Beautiful airplane, as long as you don't change the angle of attack. Holy mackerel!

Meeker: ON. We're now at 1600 feet on our low approach, and there is a little bit of turbulence, here, I call it light turbulence.

Harper: O Solo mio. I don't know what you gave me here, but, holy mackerel Andy.

Meeker: I'm kind of sorry I did it, but Chick wanted to.

Harper: I mean a . . . we're surviving so far.

Meeker: Uh huh.

Harper: We aren't going to do anything abrupt here, but I'm afraid we'd . . . I'd spin us in.

Meeker: Okay, you can come visual. ON. Oscillograph on, 226 gallons fuel remaining. We're now visual on the first low approach.

Harper: Ha, Ha, Ha, Ha, (Laughs)

Meeker: We're making the go-around at 216 gallons of fuel remaining. Oscillograph off. OFF.

Harper: I certainly became a lot more anxious the closer I got to the ground. When I went visual, I still wasn't quite down on my altitude, but then I went down, felt better once I got visual. Staggered up to the glide slope and my . . . I staggered, I mean I felt I was staggering and started down. I'm not sure I can make a very good analysis of what went on on the glideslope, but it seemed that I was late pulling the power all the way off because I was real fast, then as the airspeed started to bleed off, jamming the throttle on to catch it. Here's an interesting observation. You know, I was controlling the throttle by longitudinal acceleration, I found out. Cause I was first of all, so busy, I was busy looking outside to catch any kind of cue I could as to what was going to happen next and get some lead on it. I'd look at my airspeed indicator I was in the cockpit, I couldn't leave what was going on outside that much. The lights, they didn't do me a whole lot of good. I seemed to need more information than they gave me. In other words, If I waited for the . . . say the yellow light was on and I pulled the power back. If I waited for the green light to come on, before I could even get the power on, because I pulled it off so far, the red light would be on. So the lights were not adequate. So I looked outside the airplane, got my cues from what was going on outside, and one of those very strong cues was longitudinal acceleration, because I got to wondering what I was using to control the airplane with, and I'd sneak peeks at the airspeed indicator to validate my senses of longitudinal acceleration and also my visual cues from what was going on outside, but I didn't . . . I still found I was actuating throttle as a function of longitudinal acceleration. In other words, especially if I had the throttle off, and the airspeed was high I could feel the drag come on. And when I felt that drag start on, I'd jam that throttle on and try to catch it. One of our problems was that I didn't know where the trim throttle position was, I sure didn't have time to look down at the rpm gauge to figure it out. So what I did was just used longitudinal acceleration and snuk peeks at the airspeed indicator, and I looked outside. I didn't - I don't think I got aboard the first time. I think I could have landed on a field though. I wouldn't have gotten aboard a carrier.

Group I Configuration 425-1

This configuration had a very stiff phugoid mode, ω_p = .45 rad/sec, which was slightly unstable, $\zeta_p \doteq -0.034$. The time history for configuration 425-1 is contained in Figure 27. From the first half of this time history and from the $\left|\frac{\theta}{u_g}\right|$ Bode plot of Figure 36 it can be seen that this configuration had extreme pitch response to airspeed variations. The pilot found that he had to close a very tight attitude-to-elevator loop in order to stay on the glide slope. The power spectra plot for elevator stick inputs in Figure 35 has a very high peak at $\omega \doteq 6.5$ rad/sec which is associated with these attitude stabilization inputs. The broad peak at low frequency in this plot is associated with the elevator inputs required to constrain the pitch attitude when airspeed variations occurred because of turbulence or improper power settings.

It should be noted that the pilot changed his attitude-to-elevator gain from a low value during the first half of the approach to a very high value for the last half of the approach. When a spectral analysis is made of the elevator stick trace for a configuration where the pilot's gain was time varying, several peaks may occur in the resulting power spectral density plot or the energy may be distributed over a wide frequency band rather than in a sharp peak.

The throttle inputs for this configuration were small but fairly continuous and rapid in nature.

The pilot comments for this visual approach were as follows:

Infanti: ON, we are now down to 500-600 feet above terrain. Turbulence I would say is still about light to moderate. Maybe closer to moderate, but it is not very bad. Oscillograph is ON at 511 gallons. ON visual.

Harper: OK, visual. That's real centerline approach, wasn't it?

Infanti: Yep, pretty good. Just as you said that, the sun shone on you. A ray of sunshine and this is about it, too.

Harper: I started oscillating and haven't quit since. Tight attitude -- come on let's go. Tight, tight, come on. There's a little power. That's it. Now we're going. Now you're going down there. Now, we're going a little low, little low. That's it, that's it, the green light is on. The yellow light is on.

Infanti: Oscillograph OFF at 502 gallons and going around.

Infanti: OK, I guess we'll have to rate that turbulence as light to moderate. It's even closer to light, I guess.

Harper: It was lighter on the glide slope than it was coming in. I agree with light to moderate up to when I got on the glide slope. Then it was light.

Harper: Question 12 - Transition to visual flight -- the nose was pitching quite a bit due to the turbulence. I finally got the nose down to the trim attitude and the throttle back to what would hold the right air speed. I came steaming down and found I had to use real tight elevator to attitude. Real tight and it worked good. I almost had a continuous dither going because I had my gain cranked up pretty good and the pitch is fairly loose. I kept the attitude -- working about the desired attitude. Then I would use the throttle to control air speed errors on the glide slope or altitude errors if I was off. If I got off on the air speed and it was on altitude, then I would have to make a small attitude correction too. It worked in the smooth air. I think it would be very difficult in the rough air.

Group J Configuration 445-1

This configuration had a statically unstable phugoid mode; i.e., the phugoid mode consisted of two real roots, one of which was unstable. The time history for this configuration is contained in Figure 28. Because the phugoid was unstable the pilot again found it necessary to close a tight attitude-to-elevator loop. Except for the large low frequency inputs, the elevator stick time history and power spectral density plots, see Figure 35, for this configuration are quite similar to those of configuration 425-1.

The airspeed variations occurring for configuration 445-1 were quite large; however, the pitch response to these airspeed variations was not as extreme as in the case of configuration 425-1. It should also be noted that the sign of the pitch response to airspeed variations was reversed for configuration 445-1; when the airspeed increased this configuration would pitch down, and when the airspeed decreased it would pitch up.

The pilot made a large and rapid throttle input to correct a low airspeed condition in the middle of this approach and several small corrections during the last half.

The pilot comments for this visual approach were as follows:

Infanti: ON, We're now 600 ft above terrain now and, oscillograph's on at 440 visual.

Harper: Visual. I am.

Infanti: Turbulence level is light here. Okay, now we're about 250 feet above terrain. The turbulence there was moderate. Okay, oscillograph off at 431 gallons. I guess the visual portion of that pattern we'll call light to moderate turbulence. OFF.

Harper: On the glide slope the airspeed was very slippery and I had trouble controlling airspeed. We had a cross wind from the right today, and with the nose to the right, the airspeed lights were well out of my view. On the first approach I used the airspeed indicator itself. I didn't really use the lights very much. I thought it was because I wanted rate information. I went down, and I think we got aboard all right. It wasn't the best, in the carrier landing, but it was okay. Real tight closed loop though.

Question 12 -- No comment.

Group S Configurations 456-1, 453-1 and 448-2

These three configurations were selected because they were repeats done on different days and in different atmospheric conditions. The short-period frequency was ω_{SP} = 1.46 rad/sec and the phugoid frequency was $\omega_p \doteq$ 0.32 rad/sec. The phugoid damping ratio was ζ_p = -0.25 and $1/T_{h_1}$ = -0.05.

The low-frequency short period, the high-frequency unstable phugoid, and the negative $1/T_{h_1}$ are all conditions which require the pilot to use tight attitude-to-elevator and airspeed-to-throttle loops to control the flight path and airspeed. As would be expected there is considerable elevator stick and throttle activity in the time histories and the power spectral density plots for these configurations exhibit peaks at high frequency, especially when there was turbulence or wind shear.

The time histories for configurations 456-1, 453-1 and 448-2 are contained in Figures 29, 30 and 31. The power spectral density data for the elevator and throttle inputs are plotted in Figure 35.

The pilot comments for the visual approach of configuration 456-1 were as follows:

Meeker: ON. You can come visual now, Bob. Oscillograph coming on at 498 gallons of fuel remaining for the low approach. The turbulence has picked up a little as we come down low. It's still around ±2 knots variation on the airspeed indicator.

Harper: And the lights are really standing out today, I'll tell you. It's a good day for seeing the glideslope lights; one of the best I've ever seen.

Meeker: 488 gallons fuel remaining, oscillograph off. We're on the go-round now. OFF.

Harper: Then, when I went visual, the lighting was excellent today. I could see the glideslope lights and interpret then at the point where I went visual. My airspeed lights were lined up nicely due to the left crosswind. Cross wind from the left. Actually I felt very comfortable on the glideslope, and I didn't look at my throttle or airspeed indicator at all. I just used the light information; the glideslope lights and the airspeed lights, and my visual view of my attitude of the airplane. Flew the approach, and I wasn't on centerline when I intercepted, and I got up on it, and I went down it with numerous corrections and I was correcting for airspeed and everything, but it was well within my capabilities. The - I flew the first approach. It was - I had the feeling I was a little bit behind the airplane towards the last, when I got close in, but I'm pretty sure that I had adequate control and it would have been a satisfactory approach. The waveoff was comfortable.

Question 12: -- transition to visual flight - it definitely improved things. It's an easier airplane to fly when you have your visual reference, and it kind of unloads you, you don't have to close an attitude loop quite as tightly. You can pay more attention to airspeed errors. I've discussed the approach as well as I know it.

During the visual approach of configuration 453-1 the safety pilot (Meeker, on his second flight as safety pilot) called the turbulence light and the evaluation pilot voiced some disagreement with this description. In any event, the turbulence level throughout the evaluation was a very significant influence on the pilot's rating and the time history of the visual approach, Figure 30, indicates at least two fairly large gusts; one which decreased the airspeed at t = 10-13 sec and one which increased the airspeed at

t = 45-47 sec. The pitch response to these gusts was quite small when compared to the pitch response which resulted from similar gusts on configuration 399-1 and 399-2 of Figures 19 and 20. The phugoid frequency was the same for these configurations as it was for configuration 453-1, but the short-period frequency was lower for configuration 453-1. The effect of the lower short-period frequency on the high-frequency pitch response to airspeed variations can be seen by comparing the $\left| \frac{\theta}{u_g} \right|$ Bode plots in Figures 36 and 37.

The pilot comments for this visual approach were as follows. The comments about visual reference easing the task of closing all of the required control loops is particularly interesting.

Meeker: ON. Oscillograph on at 474 gallons of fuel remaining. We just became visual on this part of the approach. Let's still call the turbulence level light at this level. Oscillograph off. OFF. 464 gallons of fuel remaining. We are on the go around. ON. We are now mid downwind 1600 feet. The turbulence is still light. Probably a little bit lighter down here at low level than when we were up at altitude. OFF.

Harper: ON again. Just so they can have my observation. I'd have called, at least on the scale we were talking about before (my feelings are influenced by the configuration and the way it flies). I'd say it was approaching moderate at altitude and down here it varies from very light to light to moderate. Right now at 1600 feet, it is very light.

Harper: When he told me to go visual, I was very relieved. It was the kind of configuration that going visual helps a great deal. Apparently because I can continuously close the attitude loops and perhaps devote more attention to airspeed and I'm taking care of my heading and track continuously also. Once I got on the glideslope, I felt much better and much more in command of the situation. I still continued to have considerable airspeed difficulties in trying to hold constant airspeed on the glideslope. I didn't ever really achieve it, but it seemed that I could keep it bounded and within reasonable limits. I think the first approach I would have gotten aboard. I got two slow signals and two fast signals, but I used my airspeed lights. I found them very useful for the configuration. In fact, I suspect if I had had to use the cockpit airspeed indicator I would have considerable difficulty with the configuration. Primarily because when you look away from it attitude wise, it just seems to want to take off. It is never, when you come back to it, where it was. Visual reference seemed to help because I could keep more or less continuous track of attitude while I was looking at other things.

Question 12: -- No comment.

Configuration 448-2 was evaluated under circumstances similar to that of configuration 453-1 and with quite similar results. The pilot again remarks on the reduction in concentration and effort that he experienced when he went to visual reference.

At $t = 19.5$ sec in Figure 31 a sharp wind shear was encountered and the pitch response was again quite small as compared to configuration 399-1 and 399-2.

The power reduction to start the descent and the power application at waveoff are clearly recorded on this approach and as a result the power spectral density plot of throttle motion in Figure 35 has large amplitude at very low frequency.

The pilot comments for this visual approach were as follows:

Infanti: ON. Okay, we're now down to 1500 MSL and we're in some ---

Harper: God.

Infanti: Apparently light turbulence. I suppose we could make light to moderate throughout so far. OFF.

Infanti: ON. Oscillograph on at 159 gallons, come on visual.

Harper: Thank God!!! What the hell have I got here?!

Infanti: You just fly the airplane and ...

Harper: Geez. That's as much trouble as I've had, I think. There, I forgot to look where I was going.

Infanti: Oscillograph off, 152 gallons, and going on around.

Harper: And about that time he told me to go visual, and I did, and it was with a wonderful sigh of relief. I can't tell you how good it felt. Came in and got established on the glideslope the details of the approach I don't remember too well, but I know that flying in attitude with the elevator to stay on the glideslope and throttle to control airspeed, the airspeed variations were large and difficult corrections to make. Very very hard to get the airspeed back and to stay there. Towards the - let's see, I don't remember the first - the whole thing is beginning to fade a little bit, but . . . the details of the approach I don't really remember. I remember fighting airspeed and having large errors - relatively difficult time with the holding, or trying to achieve the approach airspeed, and then towards the last, I had trouble holding the flight path, as I often do, with a sluggish short period like I had here. So the airplane was bobbling a bit and attitude and the throttle was getting moved quite a bit. Nello, I mean, when I started to initiate the waveoff, the throttle was already starting forward in my hand, so he wasn't very trusting, although I didn't feel badly about the approach. It wasn't that bad, but all the indications I'm sure to him up to that point, was that I didn't have very good control of the configuration. I don't know whether I would have gotten aboard that first time or not. I think there's some possibility I might have. The way things are going right there at the last, I'm not sure. The airspeed was getting away from me.

Question 12: -- No comment.

Group T Configuration 448-1

Configuration 448-1 had the same characteristic equation as the configurations of Group U, however, $1/T_{h_1}$ was made approximately zero through positive $X_{\delta_{ES}}$. The high-frequency unstable phugoid mode together with the turbulence level and the low-frequency short period again made it necessary for the pilot to close the attitude-to-elevator loop. The increase in gain in this loop during the last half of the approach is evident in the elevator stick time history of Figure 32 and in the power spectral density plot in Figure 35.

The effect of the rather large positive $X_{\delta_{ES}}$ in diminishing the requirement to coordinate throttle with flight path changes is illustrated by this configuration. As it happened on this approach, the descent from 5000 ft was made fairly close in to the airport so that the level portion before intercept of the glide slope was shorter than usual. Because of the $X_{\delta_{ES}}$, the pilot found that he could bend the flight path level for a short time and then down to the glide slope without making a power adjustment. Again, at the end of the approach he was able to start the waveoff and climb without close coordination of throttle. This effect of $X_{\delta_{ES}}$ on the throttle inputs is illustrated in the power spectral density plot of Figure 35 by the very low amplitude at low frequency.

The reduced pitch response to wind shear of this configuration compared to configuration 399-1 and 399-2 is illustrated by the large wind shear that was encountered at $t \doteq 20$ sec in Figure 32.

The pilot comments for this configuration were as follows:

Infanti: ON. Oscillograph on 487 gallons. Come on visual.

Harper: Busy. Oh.

Infanti: Airplane landing on runway 28 (?). Oscillograph is coming off at 480. We're having a little problem with some airplane out here, that doesn't understand instructions. Okay. You better keep an eye on him, I don't know where the hell . . .

Harper: I never did find out where he was.

Infanti: Ha, there he is.

Harper: Where?

Infanti: Just taxiing off. OFF.

Infanti: ON. We're now going around 1600 ft MSL, actually turbulence level is you might say, light to moderate is a good average turbulence level for that pass. OFF.

Harper: Then, we were fairly close in so the reduced rate of sink portion almost didn't exist, but I got a good look at changing the flight path in trying to make it level, and I didn't do it very precisely but I didn't feel I was about to lose the airplane. In other words, when I rotated the flight path upward, by golley, there was nothing - well, actually, the airspeed almost tended to increase, and it certainly didn't tend to bleed away or sink out from under me. Went to visual and started down the glideslope; the errors weren't too bad in the beginning. I used elevator to control my attitude, and the throttle to control airspeed, as long as I was on the glideslope, I used the throttle just to control airspeed. I think I got a little high once, and I used throttle. Pulled a little extra throttle off in order to sink down. With this configuration, it seemed pretty difficult to correct the high and fast. They correct it, but it took quite a bit of throttle. I had to take off quite a bit of throttle. When we came down, it seemed when we got close in, my - I had to crank up my gain, or I did crank up my gain anyway. Lots of pitching oscillation going on as I was sampling and trying to stay tight on this airplane. It just seemed to be natural that I did that. The first approach was a little hairy. I think we would have gotten aboard. The wave off was comfortable, when I came back on the stick, the airspeed almost seemed to increase.

Question 12: - - No comment.

This concludes the section on time histories of visual approaches.

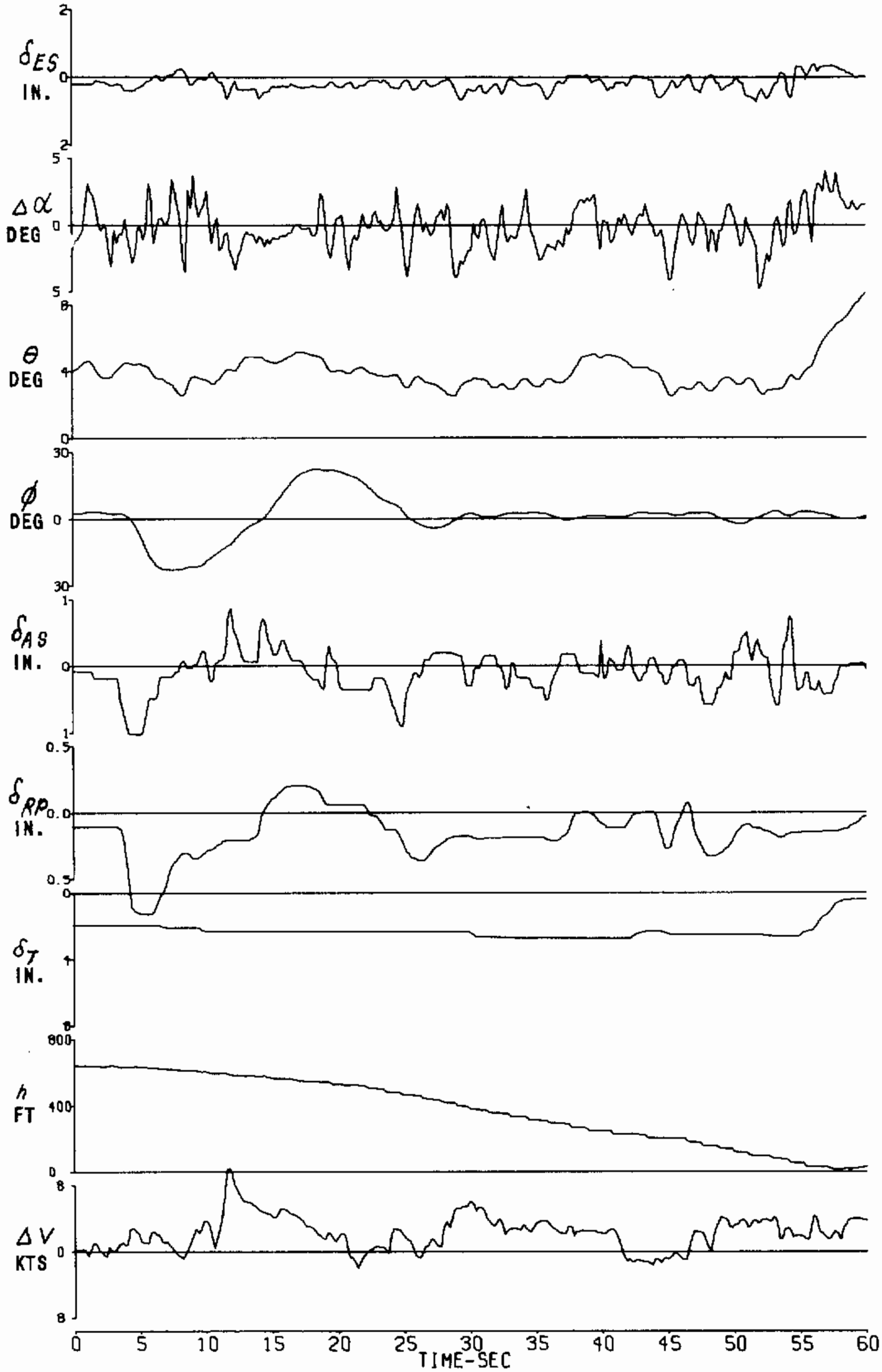


Figure 17. TIME HISTORY OF LANDING APPROACH GROUP A - CONFIGURATION 404-I

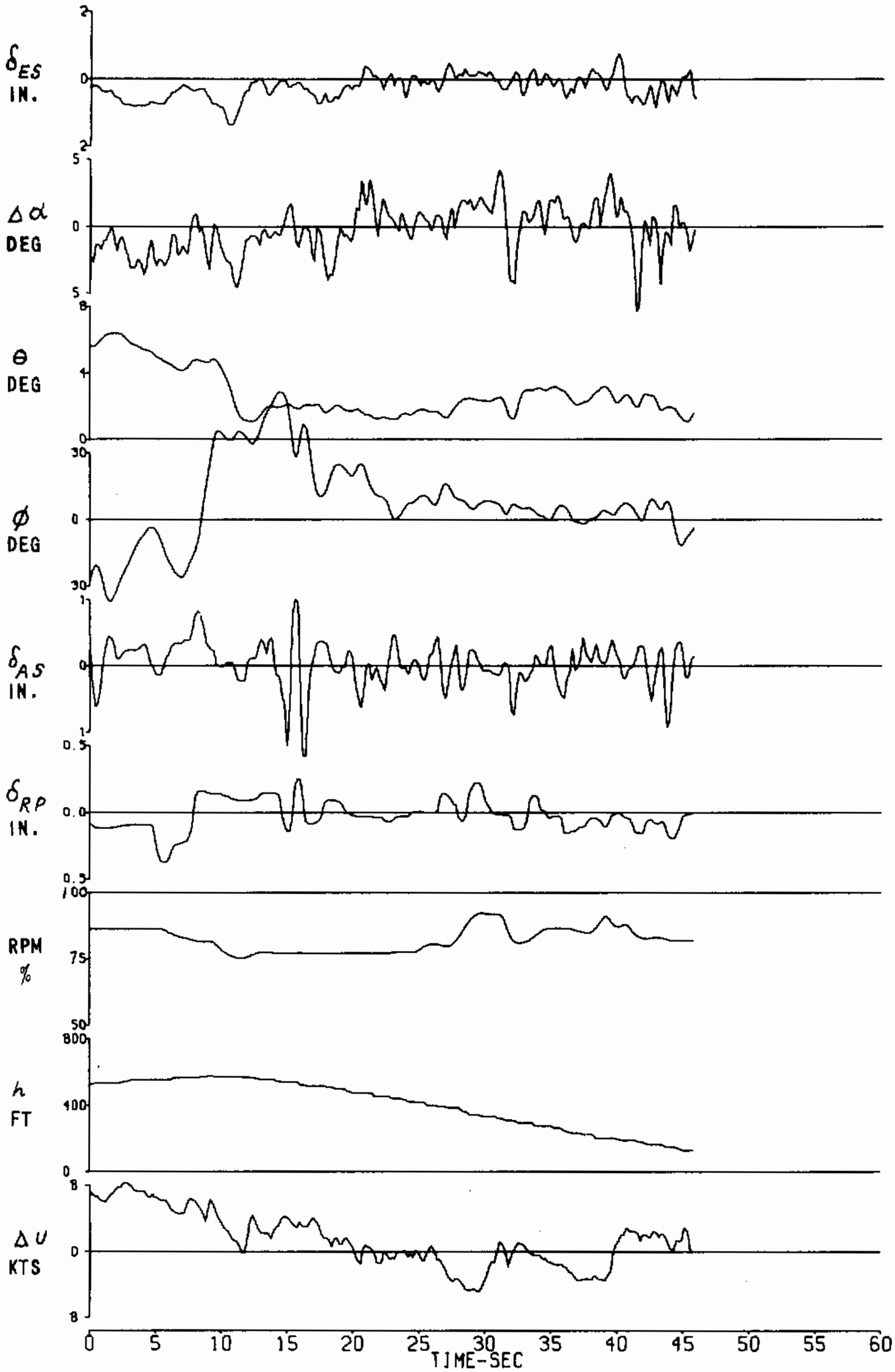


Figure 18. TIME HISTORY OF LANDING APPROACH
GROUP A - CONFIGURATION 400-2

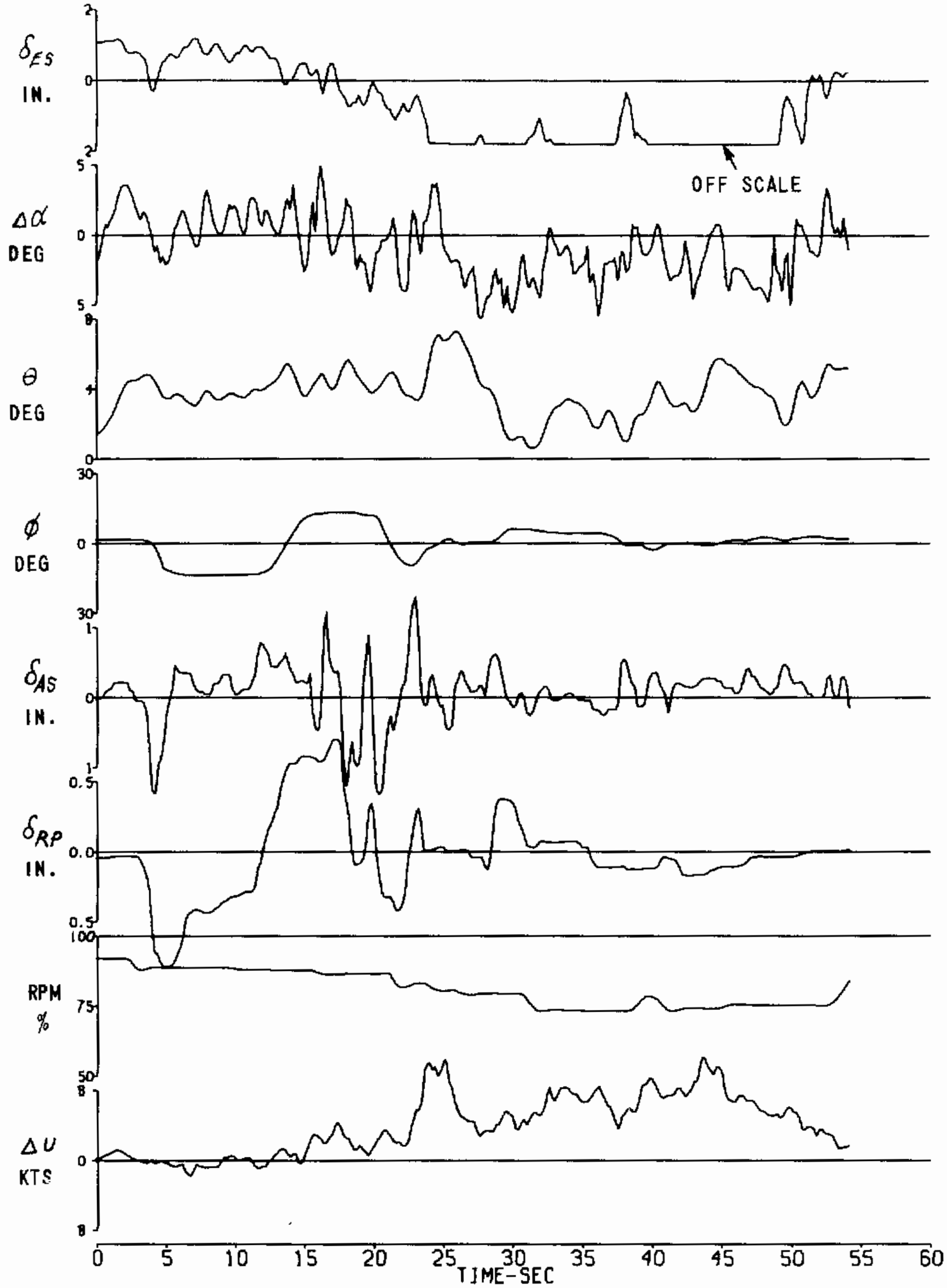


Figure 19. TIME HISTORY OF LANDING APPROACH
GROUP G - CONFIGURATION 399-1

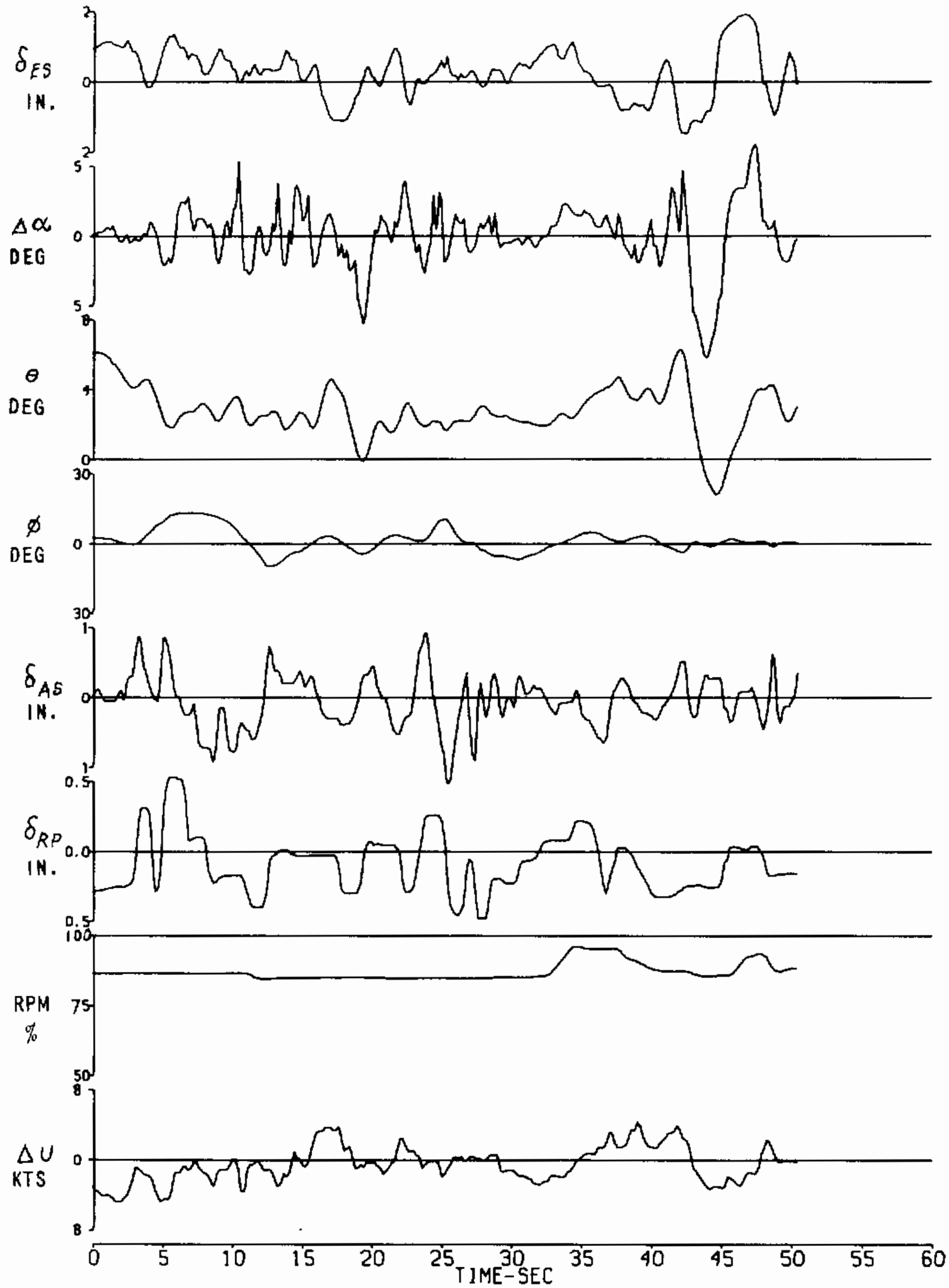


Figure 20. TIME HISTORY OF LANDING APPROACH
GROUP G - CONFIGURATION 399-2

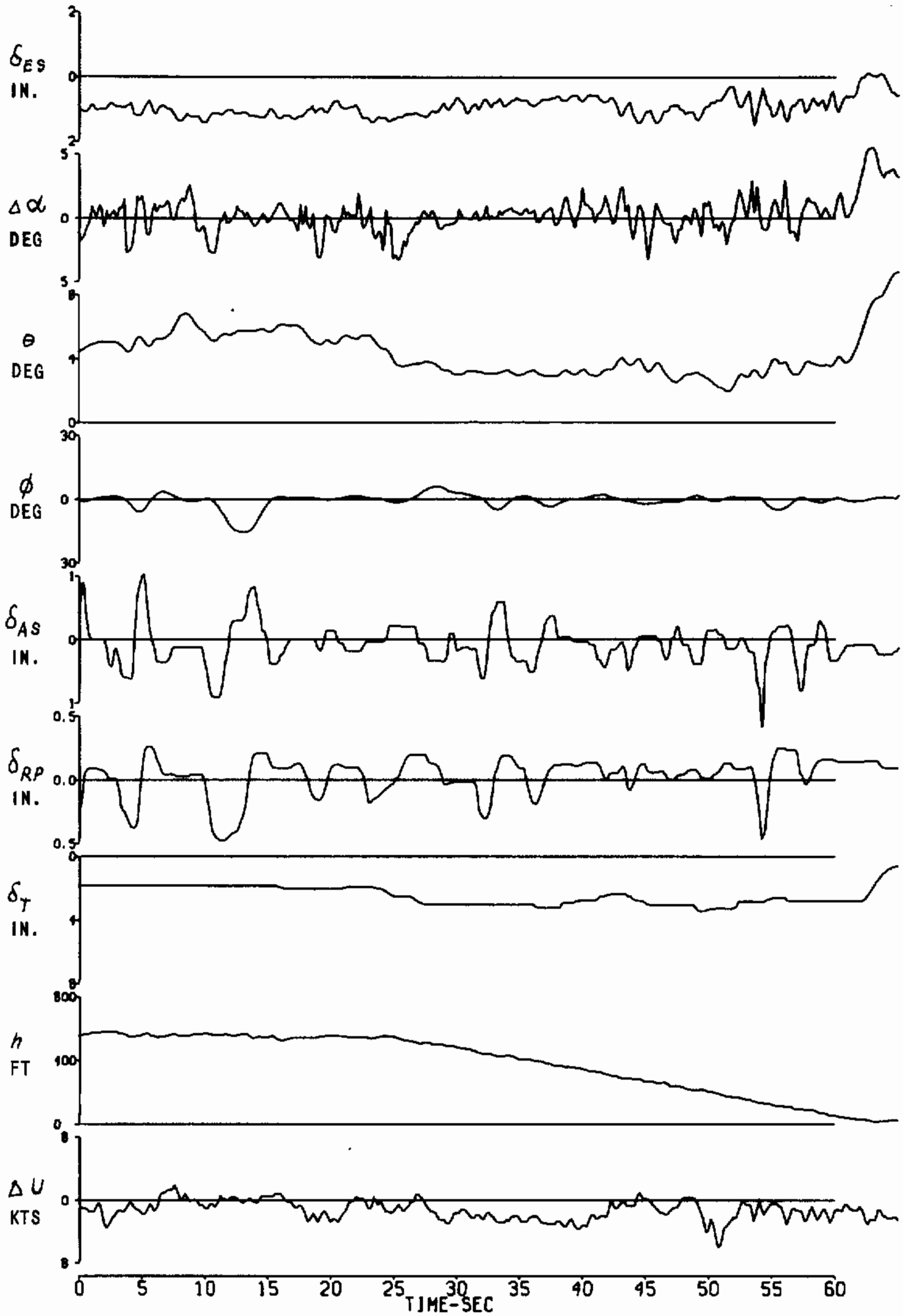


Figure 21. TIME HISTORY OF LANDING APPROACH
GROUP G - CONFIGURATION 439-1

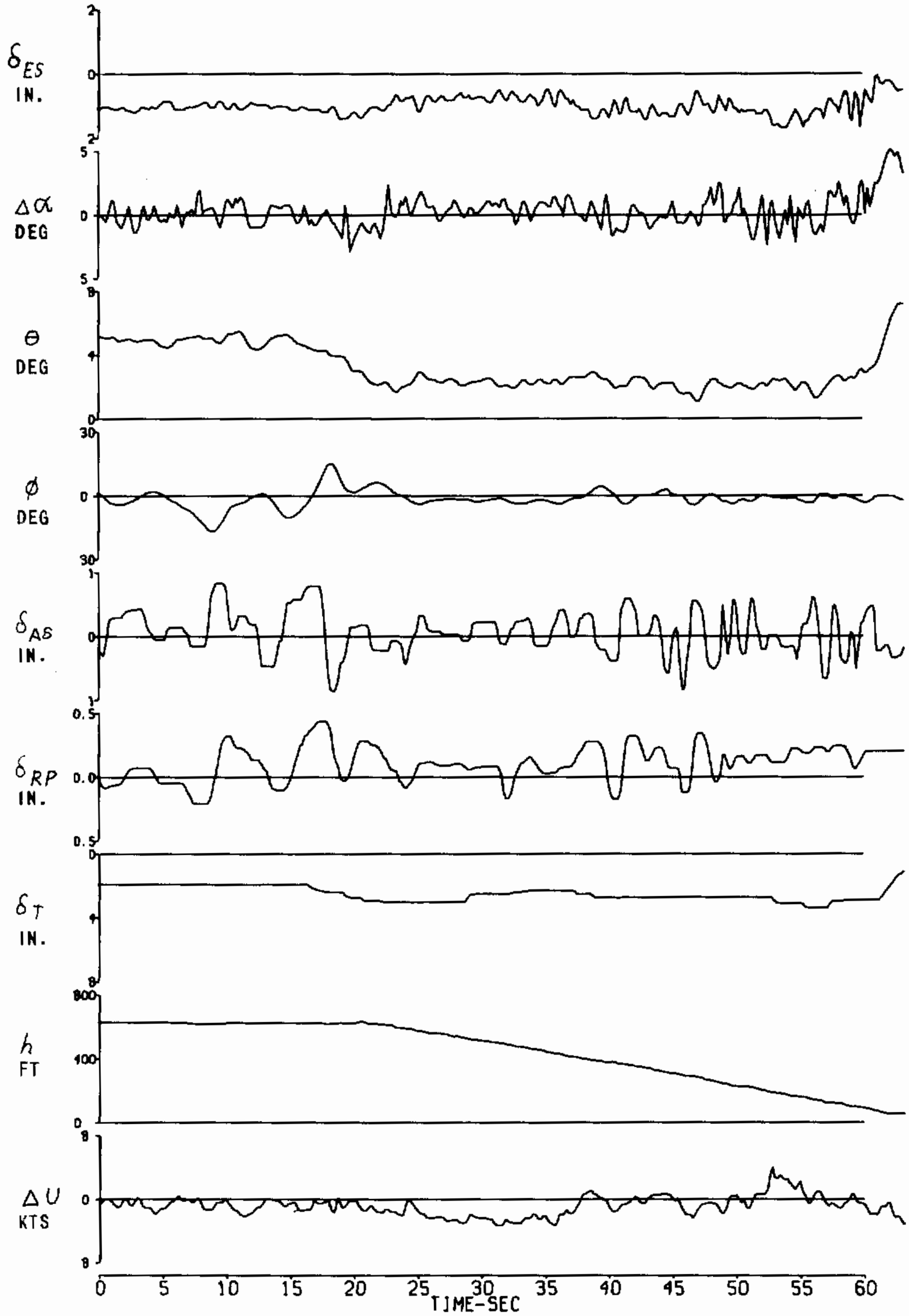


Figure 22. TIME HISTORY OF LANDING APPROACH
GROUP G - CONFIGURATION 439-2

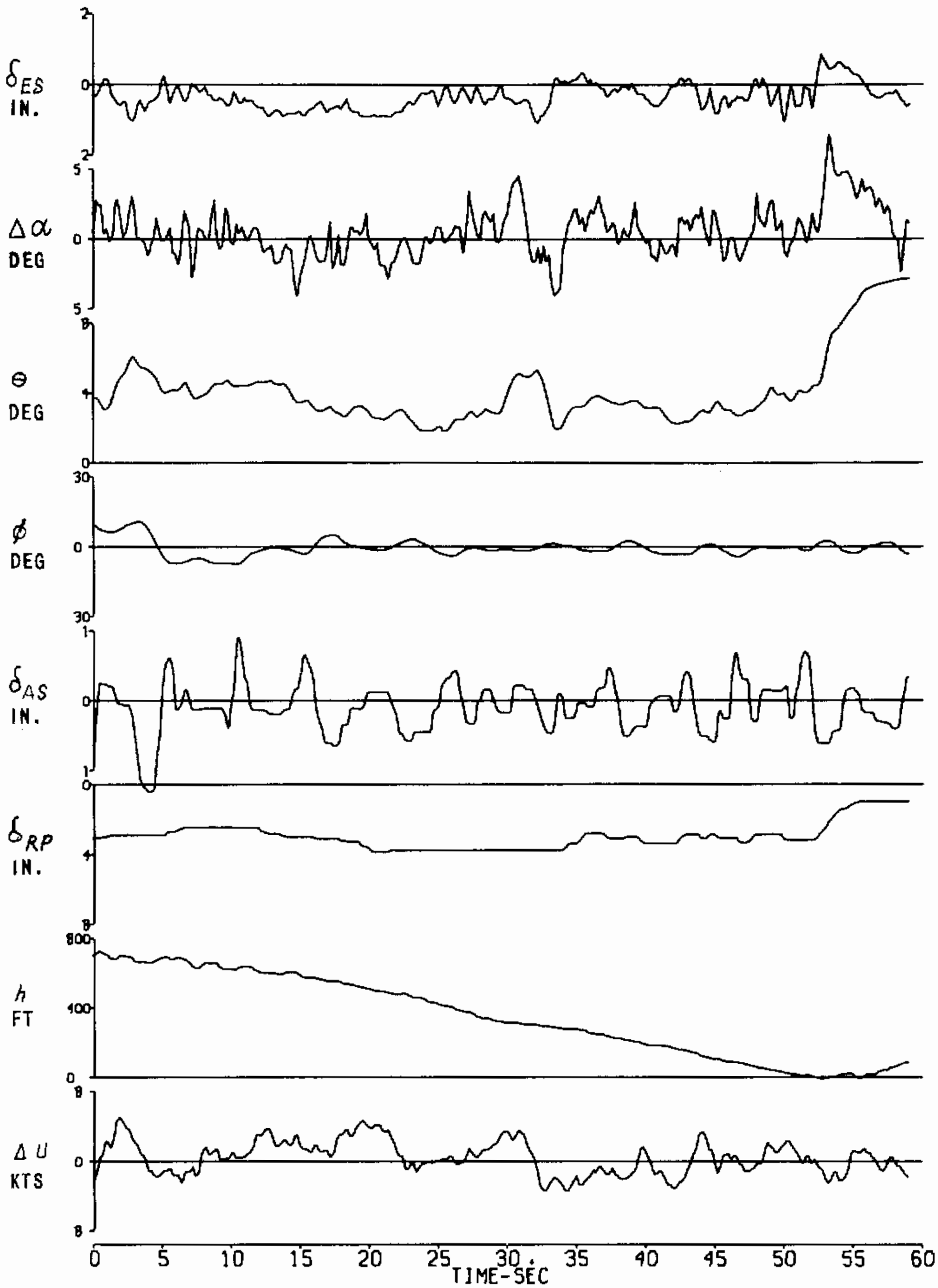


Figure 23. TIME HISTORY OF LANDING APPROACH GROUP E - CONFIGURATION 452-I

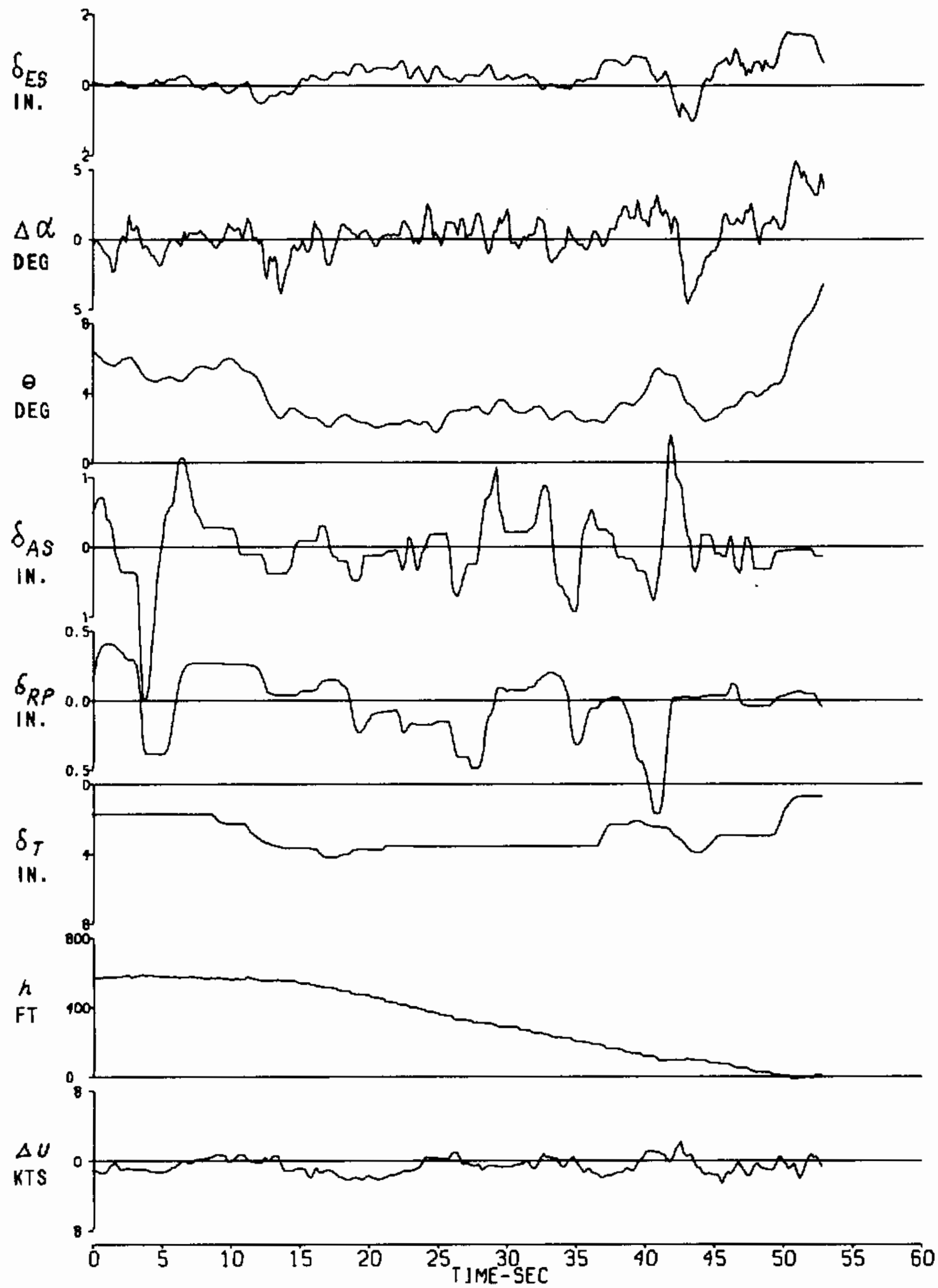


Figure 24. TIME HISTORY OF LANDING APPROACH GROUP H - CONFIGURATION 462-I

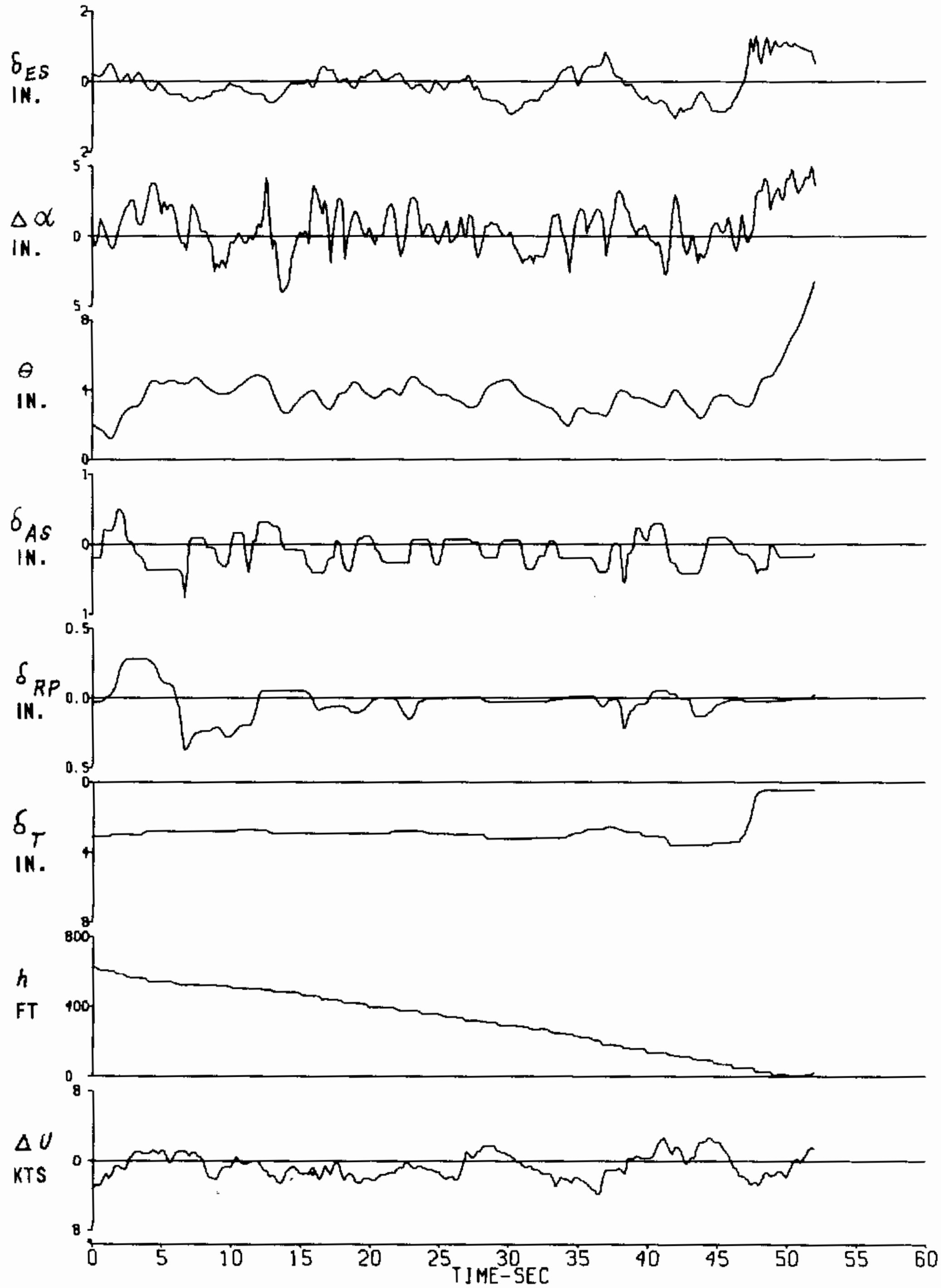


Figure 25. TIME HISTORIES OF LANDING APPROACHES
GROUP H - CONFIGURATION 461-1

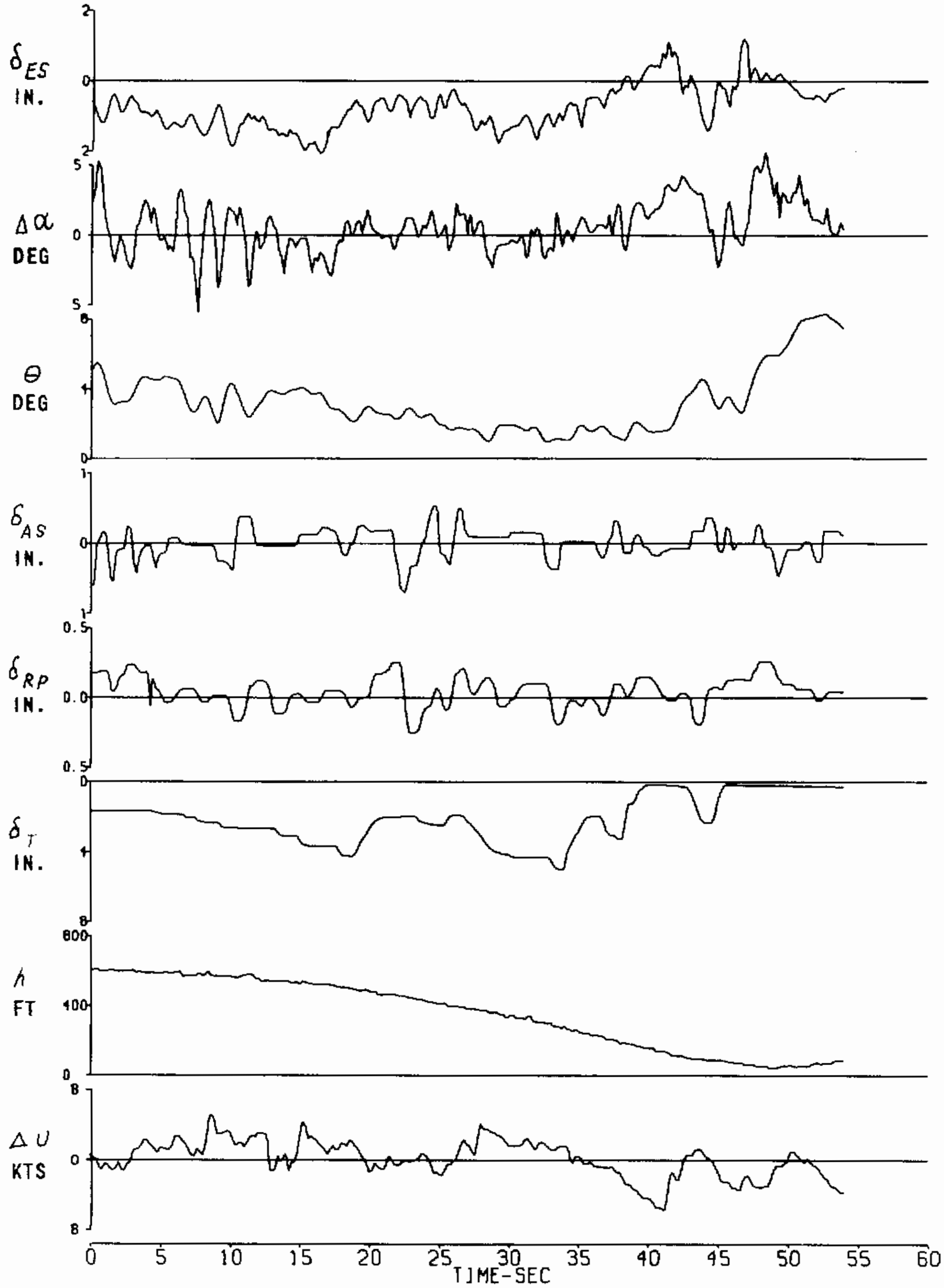


Figure 26. TIME HISTORIES OF LANDING APPROACHES
GROUP H - CONFIGURATION 461-2

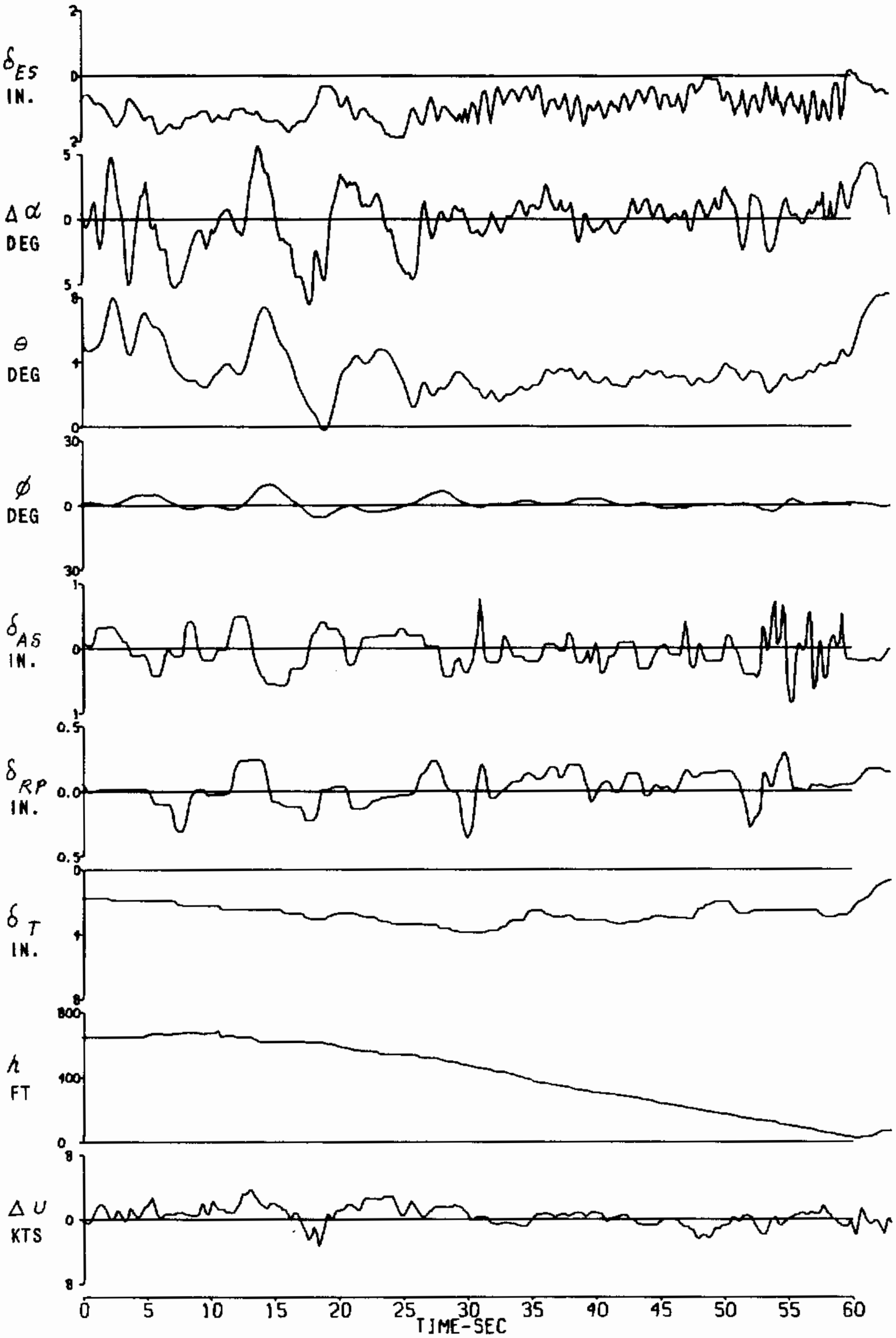


Figure 27. TIME HISTORIES OF LANDING APPROACHES GROUP I - CONFIGURATION 425-I

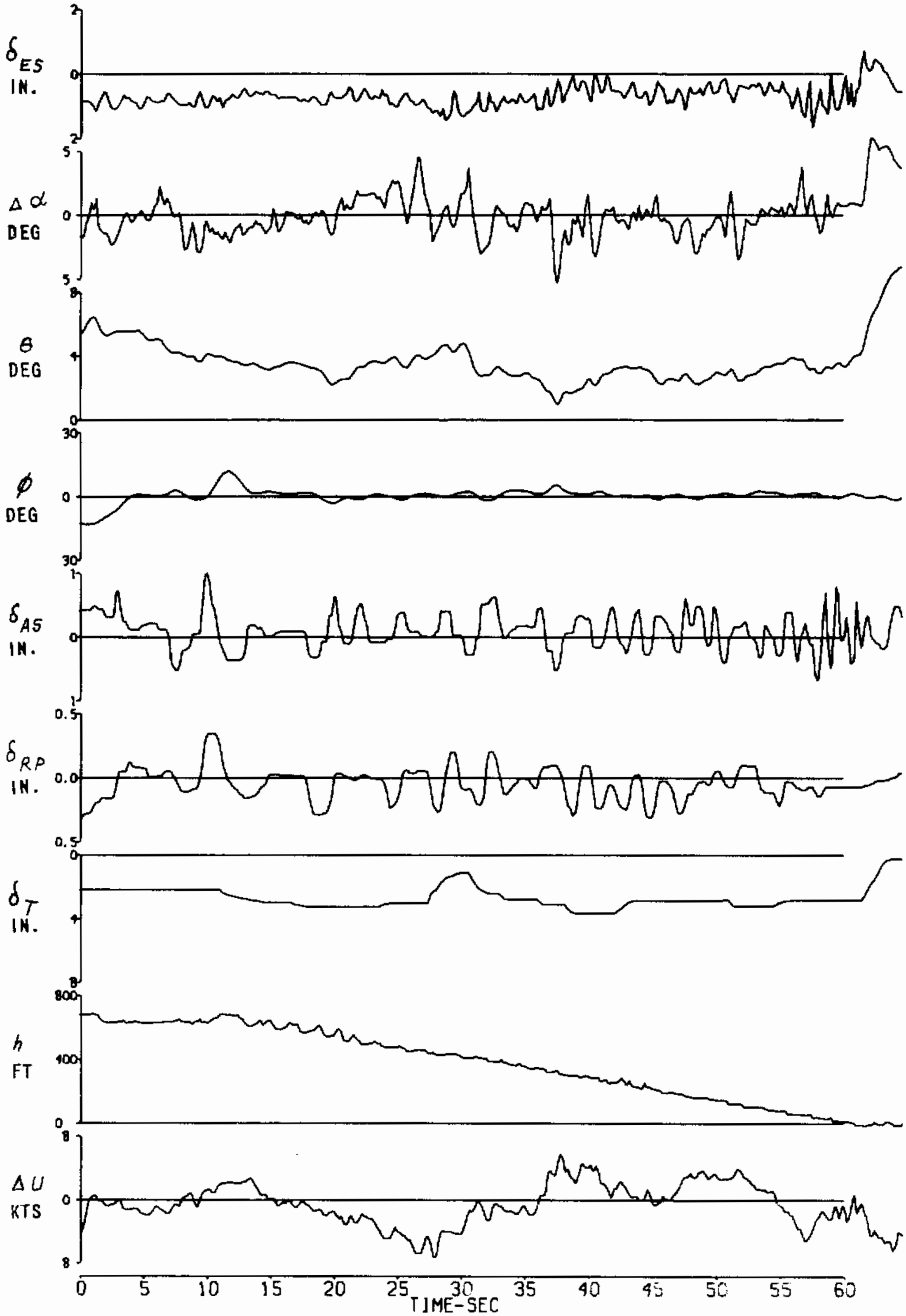


Figure 28. TIME HISTORIES OF LANDING APPROACHES
GROUP J - CONFIGURATION 445-I

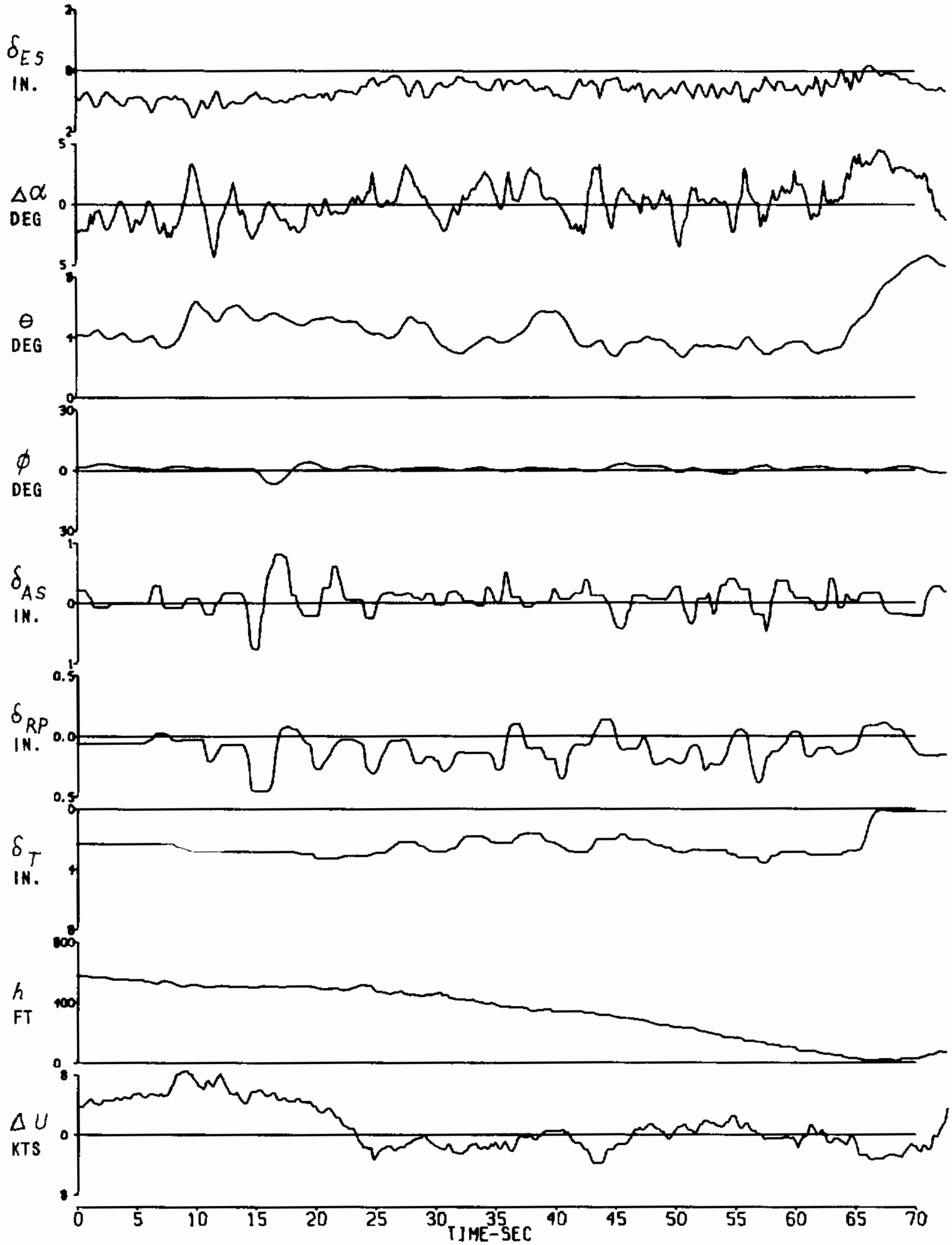


Figure 29. TIME HISTORIES OF LANDING APPROACHES
GROUP S - CONFIGURATION 456-I

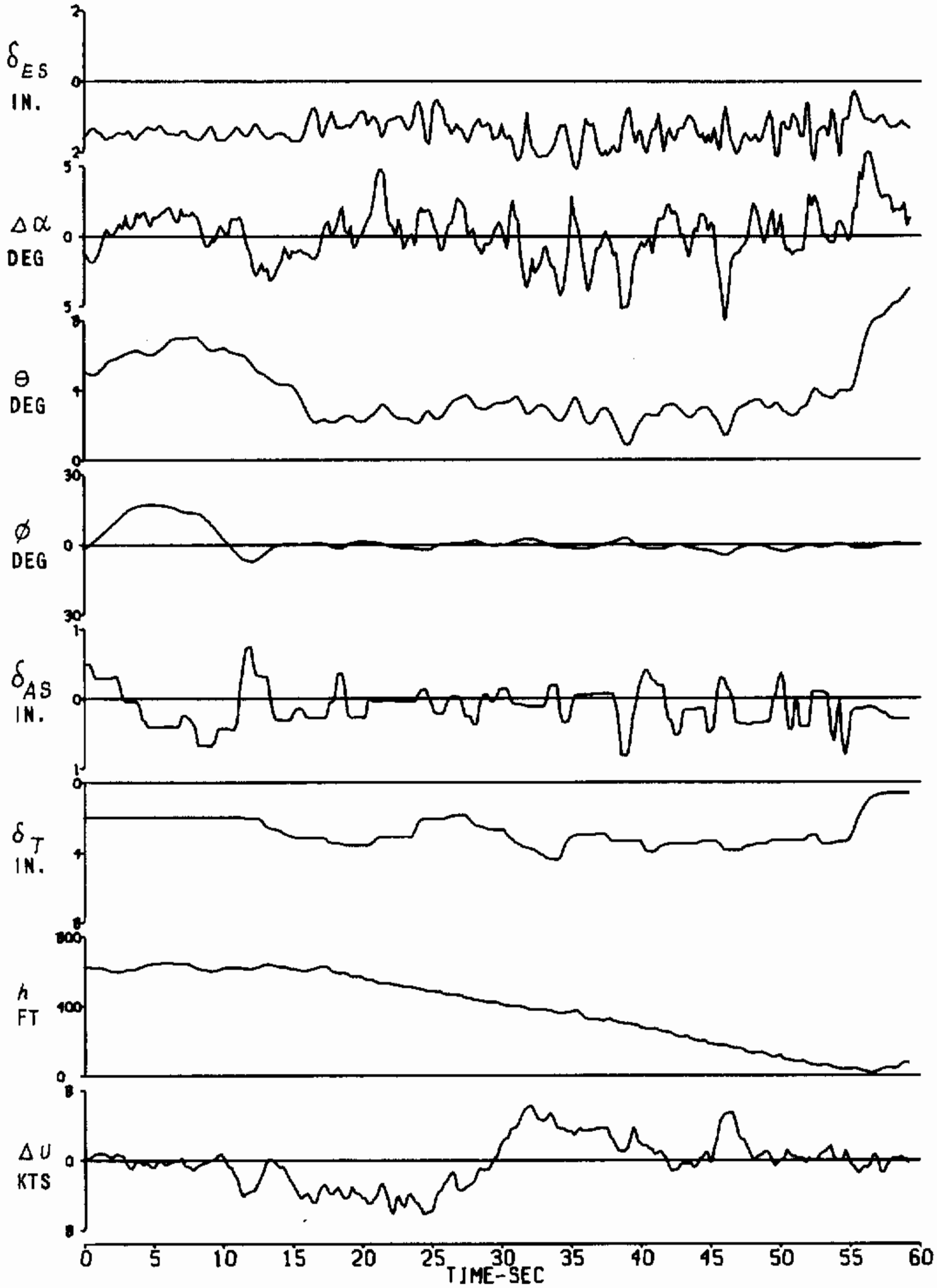


Figure 30. TIME HISTORIES OF LANDING APPROACHES
GROUP S - CONFIGURATION 453-1

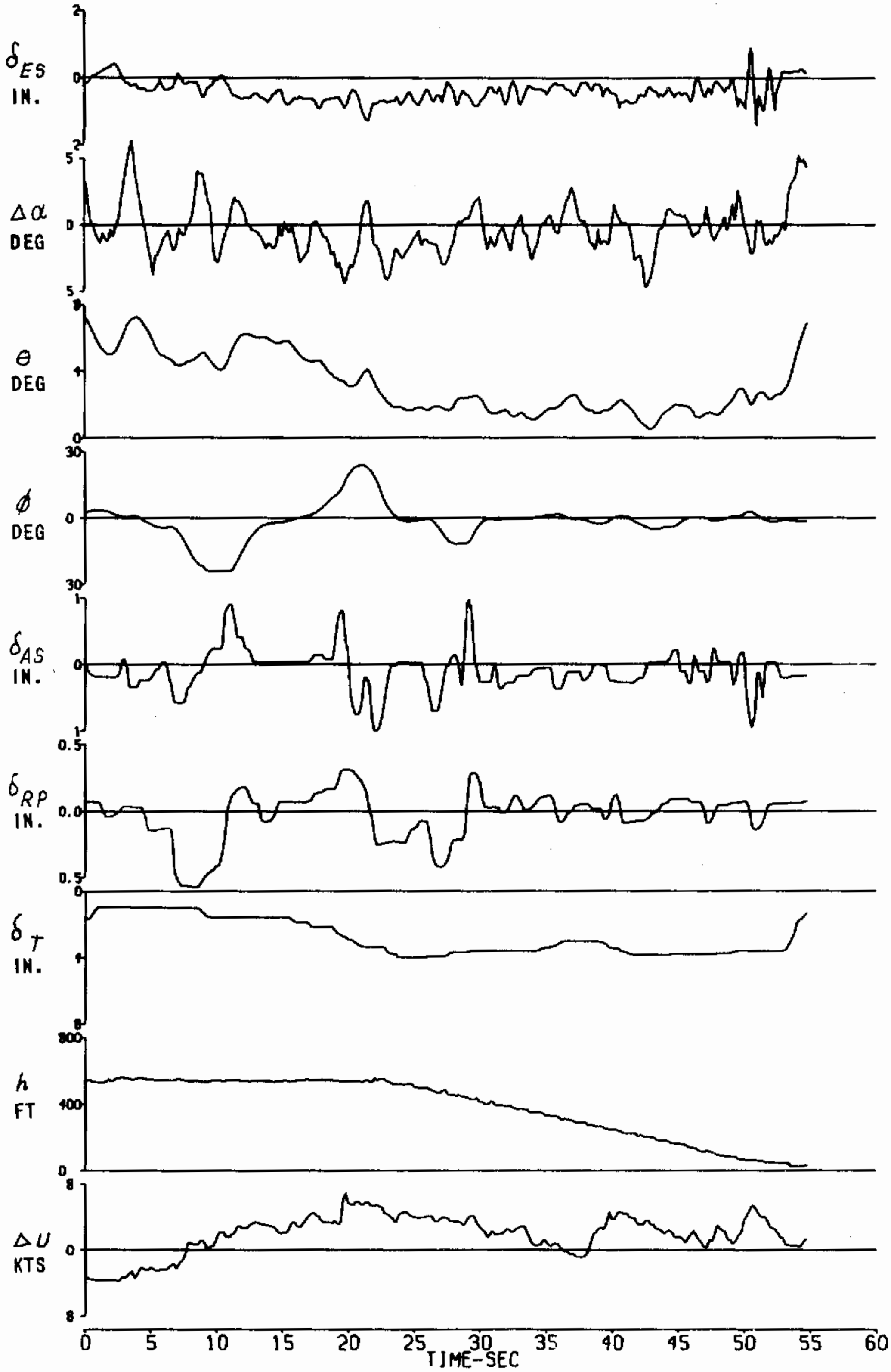


Figure 31. TIME HISTORIES OF LANDING APPROACHES
GROUP S - CONFIGURATION 448-2

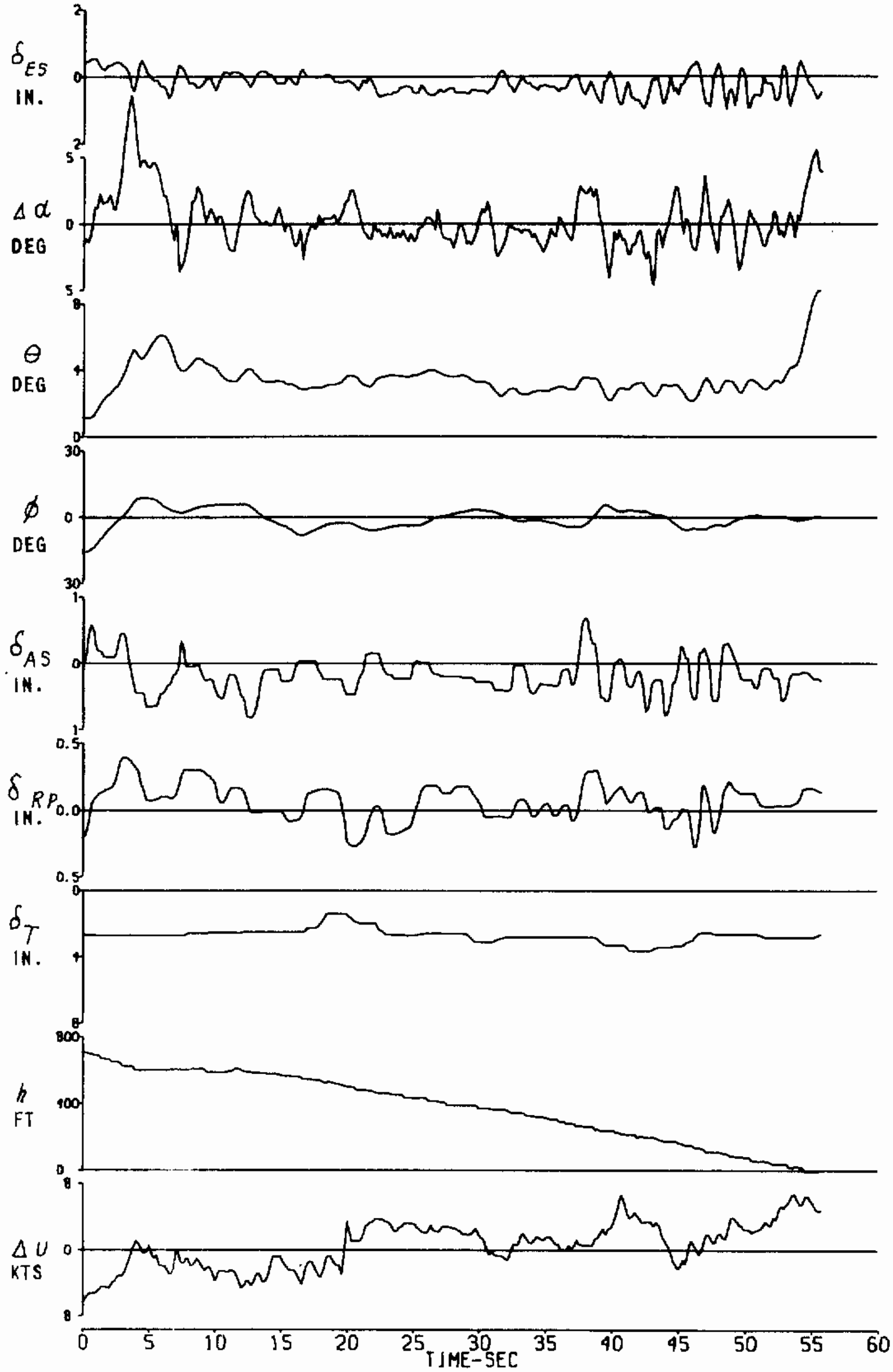


Figure 32. TIME HISTORIES OF LANDING APPROACHES GROUP T - CONFIGURATION 448-1

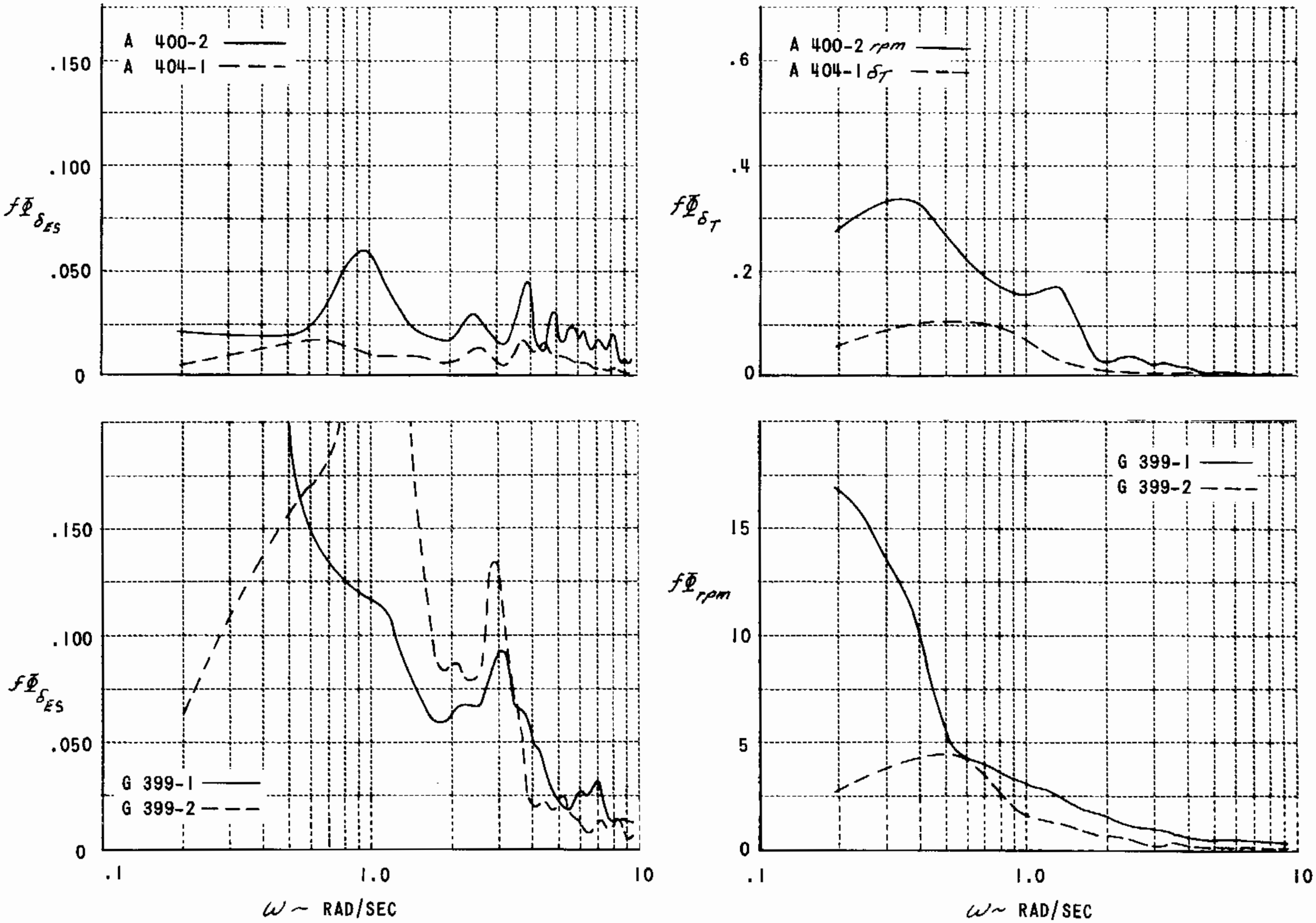


Figure 33. POWER SPECTRA OF ELEVATOR STICK AND THROTTLE MOTIONS CONFIGURATIONS 404-1, 400-2, 399-1 AND 399-2

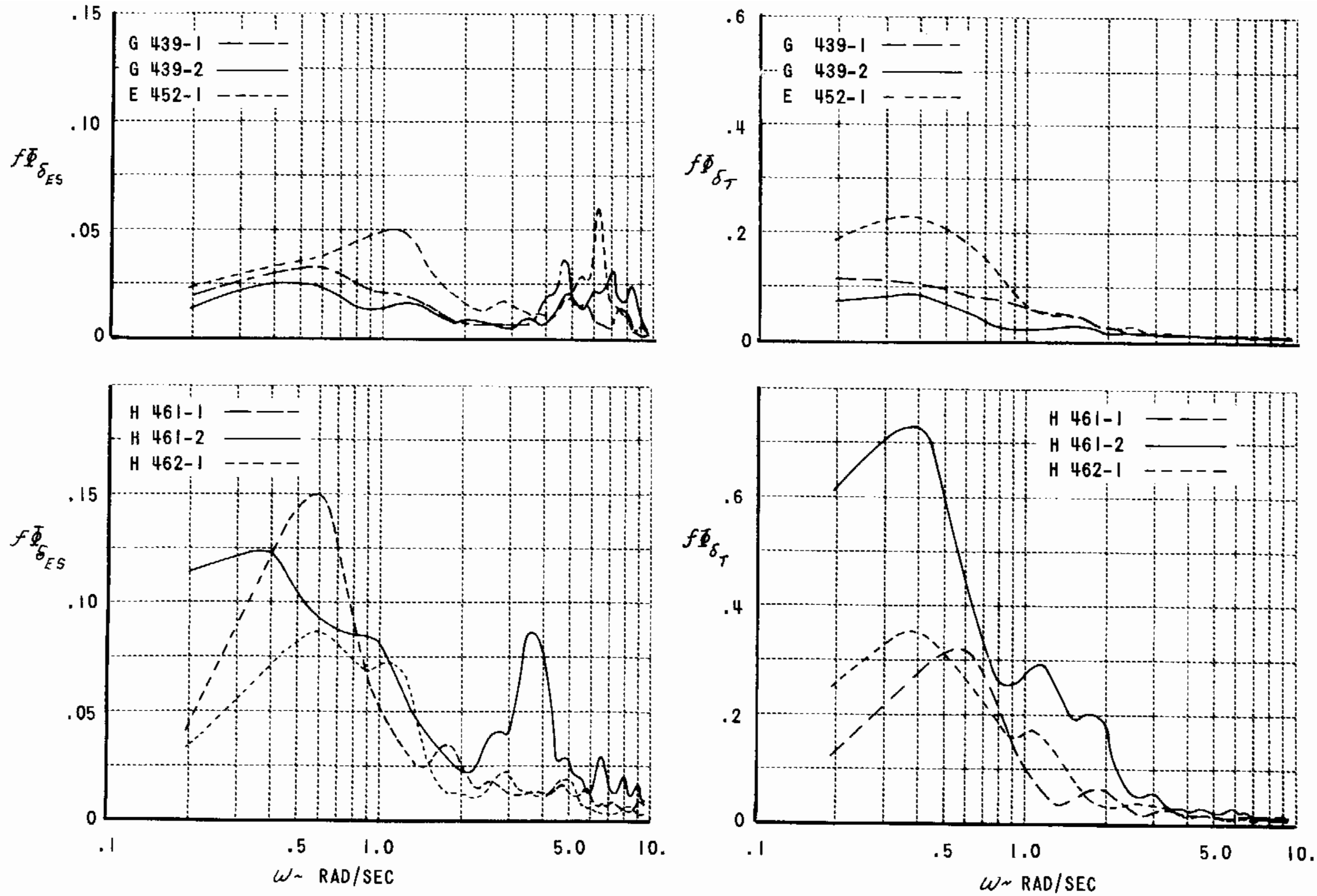


Figure 34. POWER SPECTRA OF ELEVATOR STICK AND THROTTLE MOTIONS CONFIGURATIONS 452-1, 439-1, 439-2, 461-1, 461-2 AND 462-1

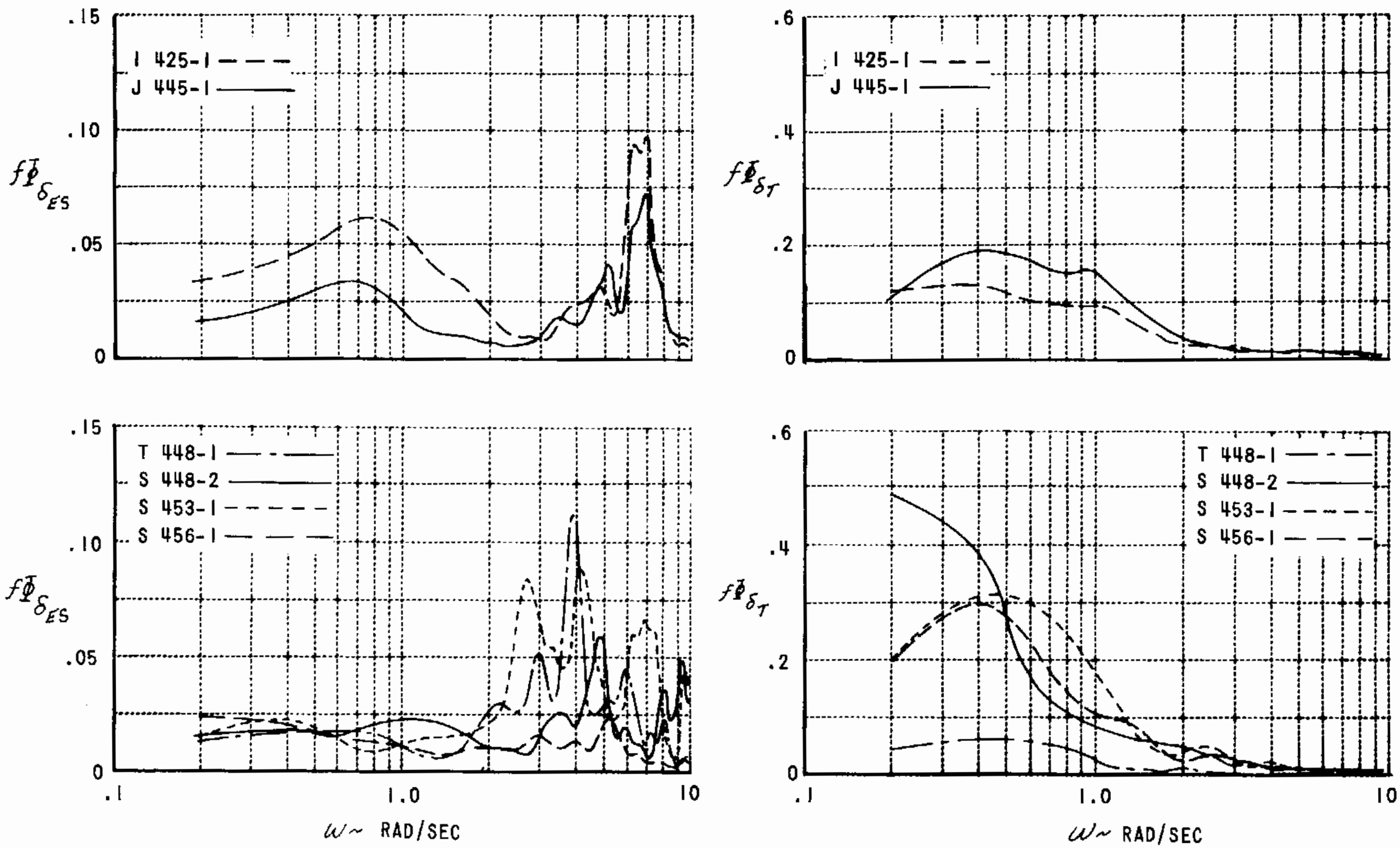


Figure 35. POWER SPECTRA OF ELEVATOR STICK AND THROTTLE MOTIONS
CONFIGURATIONS 425-1, 445-1, 456-1, 453-1, 448-1 AND 448-2

3.2.5 Turbulence Effects

The pilot's handling quality rating of an airplane must consider both the response to his control inputs and the response of the airplane to external disturbances such as wind gradients and atmospheric turbulence.

The evaluation flights in this landing-approach program were conducted in a variety of wind and turbulence conditions and, since the pilot was instructed to rate the configuration on the basis of what he observed under the existing conditions, it is necessary to consider the turbulence environment in which the evaluation was made and the airplane's response to this environment when interpreting the pilot rating data.

The pilot comments indicate that, for the configurations evaluated, the most objectionable characteristic was the pitch response to airspeed variations caused by wind shear and turbulence.

An approximate transfer function relating pitch attitude to horizontal gusts will now be derived.

If the gust disturbance is assumed to be made up of only horizontal and vertical components which are directed along the X and Z axes, then the aerodynamic forces and moments due to the gusts can be expressed as follows: (The stability derivatives $Z_{\dot{u}}$ and $Z_{\dot{w}}$ are assumed to be negligible, u_g is defined to be positive forward, and w_g is defined to be positive down.)

$$\begin{bmatrix} X_{FORCE} \\ Z_{FORCE} \\ M_{MOMENT} \end{bmatrix} = \begin{bmatrix} -X_u & -X_w \\ -Z_u & -Z_w \\ -sM_{\dot{u}} - M_u & -s\left(M_{\dot{w}} - \frac{1}{U}M_q\right) - M_w \end{bmatrix} \begin{bmatrix} u_g \\ w_g \end{bmatrix} \qquad (10)$$

This gust driving function, together with equations of motion from Reference 36, form the equations to be used to derive the θ/u_g transfer function.

$$\begin{bmatrix} s - X_u & -X_w & g \\ -Z_u & s - Z_w & -Us \\ -M_{\dot{u}}\,s - M_u & -M_{\dot{w}}\,s - M_w & s^2 - M_q s \end{bmatrix} \begin{bmatrix} u(s) \\ w(s) \\ \theta(s) \end{bmatrix} = \begin{bmatrix} -X_u \\ -Z_u \\ -M_{\dot{u}}\,s - M_u \end{bmatrix} \begin{bmatrix} u_g \end{bmatrix} \qquad (11)$$

Solving these equations for the θ/u_g transfer function;

$$\frac{\theta(s)}{u_g(s)} = -\frac{1}{g}\,\frac{s\left[\frac{M_{\dot{u}}}{Z_u M_w - Z_w M_u}\,s^2 + \frac{M_u + Z_u M_{\dot{w}} - Z_w M_{\dot{u}}}{Z_u M_w - Z_w M_u}\,s + 1\right]}{\left[\frac{s^2}{\omega_P^2} + \frac{2\zeta_P}{\omega_P}\,s + 1\right]\left[\frac{s^2}{\omega_{SP}^2} + \frac{2\zeta_{SP}}{\omega_{SP}}\,s + 1\right]} \qquad (12)$$

It can be observed from this transfer function that the pitch response of the uncontrolled airplane to horizontal gusts is a function of the short-period and phugoid roots, together with a forcing function involving $M_{\dot{u}}$, M_u, $M_{\dot{w}}$, M_w, Z_u and Z_w. If $M_{\dot{u}}$ is set equal to zero, the transfer function reduces to the following equation, which is applicable to Groups E, G, H, I, R, S and U.

$$\left.\frac{\theta(s)}{u_g(s)}\right|_{M_{\dot{u}}=0} = -\frac{1}{g}\,\frac{s\left[\frac{M_u + Z_u M_{\dot{w}}}{Z_u M_w - Z_w M_u}\,s + 1\right]}{\left[\frac{s^2}{\omega_P^2} + \frac{2\zeta_P}{\omega_P}\,s + 1\right]\left[\frac{s^2}{\omega_{SP}^2} + \frac{2\zeta_{SP}}{\omega_{SP}}\,s + 1\right]} \qquad (13)$$

If M_u is set equal to zero, the transfer function reduces to the following equation, which is applicable to Groups B, C, O and P

$$\left.\frac{\theta(s)}{u_g(s)}\right|_{M_u=0} = -\frac{1}{g}\,\frac{s\left[\frac{M_{\dot{u}}}{Z_u M_w}\,s^2 + \frac{Z_u M_{\dot{w}} - Z_w M_{\dot{u}}}{Z_u M_w}\,s + 1\right]}{\left[\frac{s^2}{\omega_P^2} + \frac{2\zeta_P}{\omega_P}\,s + 1\right]\left[\frac{s^2}{\omega_{SP}^2} + \frac{2\zeta_{SP}}{\omega_{SP}}\,s + 1\right]} \qquad (14)$$

And if both M_u and $M_{\dot{u}}$ are set equal to zero, the transfer function reduces to the following equation, which is applicable to Groups A and N:

$$\left.\frac{\theta(s)}{u_g(s)}\right|_{M_{\dot{u}}=M_u=0} = -\frac{1}{g}\,\frac{s\left[\frac{M_{\dot{w}}}{M_w}\,s + 1\right]}{\left[\frac{s^2}{\omega_P^2} + \frac{2\zeta_P}{\omega_P}\,s + 1\right]\left[\frac{s^2}{\omega_{SP}^2} + \frac{2\zeta_{SP}}{\omega_{SP}}\,s + 1\right]} \qquad (15)$$

Asymptotic sketches of the amplitude ratio for configurations in Groups A, B, C, E, G, H and I of Table I are drawn in Figure 36. Sketches for Groups N, O, P, R, S and U of Table II are drawn in Figure 37. It must be appreciated that the phugoid mode was either lightly damped or unstable for many of these configurations and therefore the actual amplitude ratio plot would have a high resonance peak at the phugoid break point.

The corresponding phase diagrams have not been included because there were no pilot comments which indicated that the phase of the pitch response to the gusts was important to the pilot. This seems likely, since the gusts were encountered in a random sequence and also the pilot considered all pitch disturbances to be objectionable when he was trying to stay on the glide slope.

From the form of the transfer function and the amplitude ratio sketches, it is seen that the pitch response at low frequency was the same for all of the configurations. However, the response to gusts at high frequency was considerably different for the various configurations.

The pitch response at high frequency is increased by an increase in either the short-period or the phugoid frequency and by a decrease in the frequency at which the factors of the numerator occur.

The order of the numerator is increased from second to third order when $M_{\dot{u}}$ is non-zero. This has a very pronounced effect on the pitch response to horizontal gusts at high frequency. Also, when $M_{\dot{u}}$ is positive, one of the numerator factors is in the right half plane, and the phase at high frequency is altered by 180° from its position for negative values of $M_{\dot{u}}$.

The increased pitch response at high frequency was noted by the pilot for each of these factors. This can be seen by comparing comments in the following Groups:

Short-Period Frequency:	See Group A relative to Group N
Short-Period Frequency:	See Groups E, G and H relative to Groups R and S
$M_{\dot{u}}$ Numerator:	See Groups B and C relative to Group A

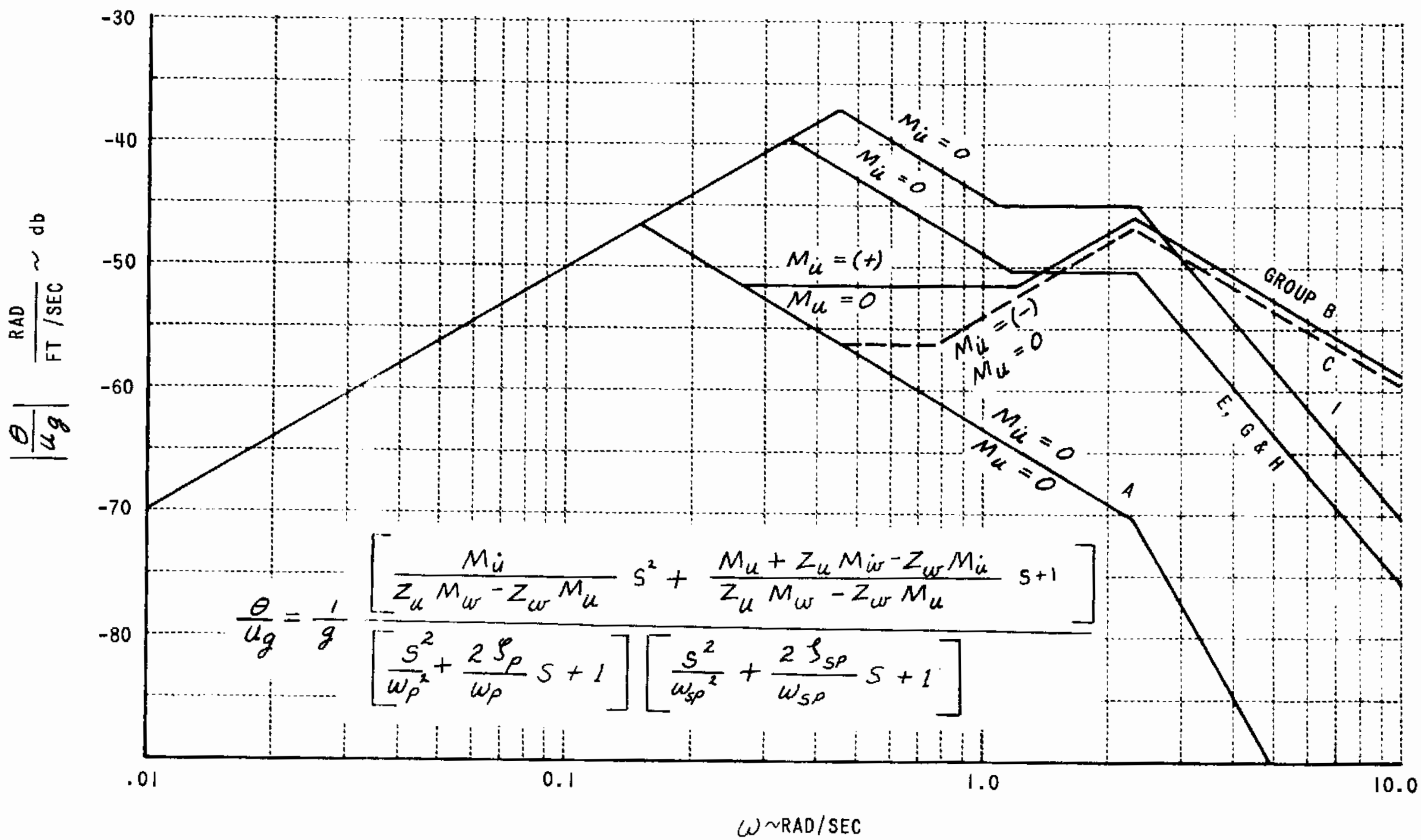


Figure 36. PITCH RESPONSE TO HORIZONTAL GUSTS FOR CONFIGURATIONS IN TABLE I

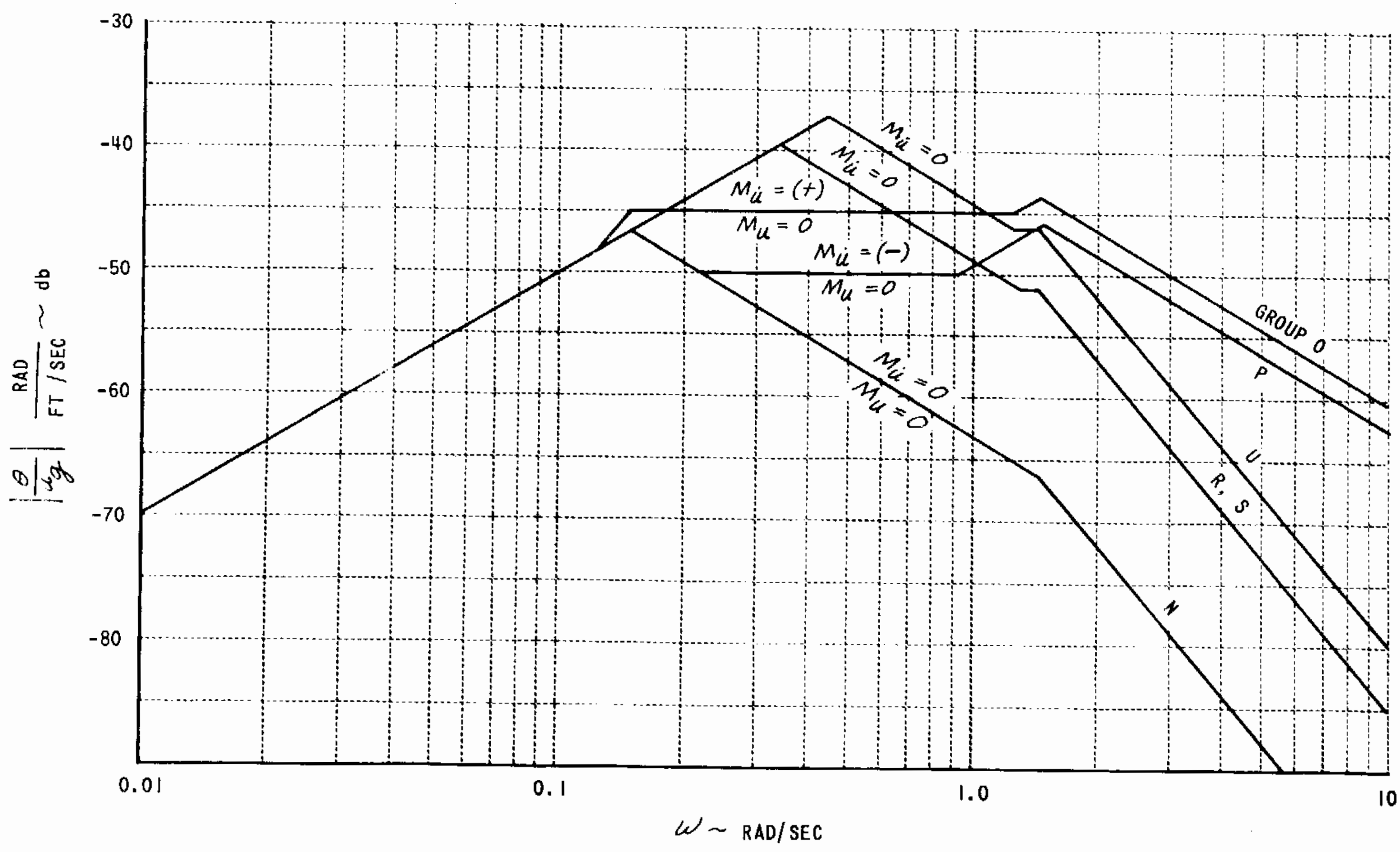


Figure 37. PITCH RESPONSE TO HORIZONTAL GUSTS FOR CONFIGURATIONS IN TABLE II

$M_{\dot{u}}$ Numerator:	See Groups O and P relative to Group N
Phugoid Freq. and M_u Numerator:	See Groups E and I relative to Group A
Phugoid Freq. and M_u Numerator:	See Groups R and U relative to Group N

The turbulence level and the wind conditions which existed for each evaluation are noted in the pilot comment summaries in Paragraph 3.2.2, together with the pilot's remarks about the response of the configuration to these distrubances.

It should be noted that, when M_u was used to increase the phugoid frequency, the numerator forcing function was also altered, both of which cause the pitch response at high frequency to be increased.

If the pitch response at the short-period frequency is taken as a basis for comparison, it is seen in Figure 36 that increasing the phugoid frequency from $\omega_p \doteq .15$ to $\omega_p \doteq .32$ rad/sec caused the magnitude of the pitch response to increase by 14 db and the change in the numerator factor caused an additional increase of approximately 6 db. Also, from Figure 36, when the phugoid frequency was increased from $\omega_p \doteq .15$ rad/sec to $\omega_p \doteq .45$ rad/sec, the amplitude ratio at the short period was increased 18.5 db and the numerator factor caused an additional increase of approximately 6.5 db.

For the cases involving the low-frequency short-period sketched in Figure 37, it is seen that the increased pitch response at the short period results almost entirely from the phugoid frequency increase, since the numerator breakpoint occurs near the short-period frequency.

Thus, increasing the phugoid frequency causes a large increase in the pitch attitude response to airspeed changes at the short-period frequency. When M_u is used to increase the phugoid frequency, there is an additional increase in the attitude response at the short-period because of the effect on the numerator factors of the θ/u_g transfer function.

SECTION IV
CONCLUSIONS

4.1 As in Reference 46, the pilot preferred the higher frequency short period, $\omega_{sp} \doteq 2.46$ rad/sec, to the lower frequency short period, $\omega_{sp} \doteq 1.46$ rad/sec. The configurations with the less stiff short period did not readily maintain the trim angle of attack or attitude; thus, the pilot had to provide nearly continuous attitude stabilization to maintain precise flight path control. In addition, he had to overdrive the airplane to obtain satisfactory attitude response when maneuvering. The tests in this program were conducted at $U = 160$ kts IAS. The value of Z_w ranged from -1.02 to -1.17 for first and second configurations in the flights.

4.2 Increasing the phugoid frequency resulted in increased stick force feel for airspeed deviations from trim. In smooth air this helped the pilot sense airspeed errors without looking at the airspeed indicator. In turbulence, however, the pitch response to airspeed fluctuations (caused by horizontal gusts or wind shear) became detrimental to the task of flight path control and tended to outweigh the advantages of stick feel for airspeed changes.

Limited data obtained for reduced phugoid frequency indicates that the lack of stick force feel for airspeed changes from trim was not a strong factor in pilot rating; however, when the phugoid mode was made statically unstable,the pilot rating degraded sharply because of the amount of closed-loop control required, and because of the danger that errors might grow beyond the control authority available. A configuration with time to double amplitude of $T_2 = 3.57$ sec was rated P.R. = 8.

4.3 The pilot's handling qualities rating of an airplane must consider both the response to his control inputs and the response of the airplane to external inputs such as wind gradients and atmospheric turbulence. For the configurations evaluated in this program, the pilot comments indicated that the most objectionable characteristic was the pitch response to airspeed variations caused by wind shear and turbulence.

The pitch response to airspeed variations is described by the following approximate transfer function.

$$\frac{\theta(s)}{u_g(s)} = -\frac{1}{g}\,\frac{s\left[\dfrac{M_{\dot u}}{Z_u M_w - Z_w M_u}\,s^2 + \dfrac{M_u + Z_u M_{\dot w} - Z\ \ M_{\dot u}}{Z_u M_w - Z_w M_u}\,s + 1\right]}{\left[\dfrac{s^2}{\omega_p^2} + \dfrac{2\zeta_p}{\omega_p}\,s + 1\right]\left[\dfrac{s^2}{\omega_{sp}^2} + \dfrac{2\zeta_{sp}}{\omega_{sp}}\,s + 1\right]}$$

This transfer function shows that the pitch response of the uncontrolled airplane to airspeed disturbances is a function of the short-period and phugoid roots together with a forcing function involving $M_{\dot u}$, M_u, $M_{\dot w}$, M_w Z_u and Z_w.

4.4 For positive values of $1/T_{h_1}$, the pilot accepted (i.e. P.R. = 6.5) unstable phugoid configurations with times to double amplitude of $T_2 \doteq 12$ sec for $\omega_p \doteq .32$ rad/sec and $T_2 \doteq 17$ sec for $\omega_p \doteq .15$ rad/sec.

It must be remembered that attitude stabilization with the elevator is a very powerful way to increase the closed-loop phugoid damping and that the procedure used in this test program permitted the pilot to operate in a continuous closed-loop manner when required. That is, there were no other tasks such as map reading, radio manipulation or extensive check list reading required which would prevent the pilot from closing an attitude-to-elevator loop as required. The level of instability that a pilot can tolerate in the open-loop airplane is closely related to the amount of closed-loop attention that he can devote to the loops required to stabilize the unstable mode. It is also related to the level of external disturbances existing. The pilot rating improved as the phugoid mode was made more stable; however, increasing the phugoid damping ratio beyond $\zeta_p \doteq .15$ did not further increase the pilot rating for the landing approach task.

4.5 The following observation made by the authors of Reference 6 has been verified by the results of this experiment.

"The pilot's acceptance of a certain level of speed stability must be colored by the overall difficulty of controlling the aircraft, which determines the amount of attention he can devote to the speed control problem."

In this experiment, for an otherwise good configuration, the pilot accepted (P.R. = 6.5) a value of $1/T_{h_1}$ = -0.085 1/sec or a time to double amplitude of T_2 = 8.2 sec. See Figure 10a. However, for a configuration with an unstable phugoid and a low short-period frequency, the pilot considered $1/T_{h_1}$ = -0.02 or T_2 = 35 sec to be marginally acceptable. See Figure 10b.

Although definitive absolute limits on the value of the parameter $1/T_{h_1}$ cannot be specified independent of other handling qualities parameters, the results of this experiment have confirmed that when $1/T_{h_1}$ is negative it becomes a primary handling qualities parameter for the landing approach task.

In the literature the parameter $\frac{d(T/W)}{dU} \sim \frac{1}{Kts}$ has been used as a measure of speed stability or degree of "backside" operation. This parameter can be related to $1/T_{h_1}$ by the following expression which is included for the readers convenience:

$$\frac{1}{T_{h_1}} \doteq \frac{g}{1.69} \, \frac{d(\frac{T}{W})}{dU} \sim \frac{1}{sec}$$

4.6 The optimum longitudinal control gain values selected by the pilot have been found to be the result of a compromise which is influenced by the initial pitch response, the steady forces in turns, and the steady forces required to maintain attitude when airspeed changes from the trim speed occur.

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13. ABSTRACT

This is the second in a series of two reports dealing with longitudinal handling qualities in the landing approach. The T-33 variable stability and variable drag airplane was used in a flight program to evaluate various short period dynamics, phugoid dynamics, drag characteristics and elevator control authority levels.

The first phase of the flight program was directed mainly at longitudinal short period dynamics, drag variation with angle of attack and elevator control authority. This work was reported in FDL TDR 64-60.

The second phase of the flight program was directed at phugoid dynamics, short period frequency, elevator control authority and drag characteristics. Drag variations with angle of attack, airspeed and elevator deflection were considered.

Pilot ratings and comments are related to the airplane characteristics tests.

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