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A STUDY TO DETERMINE THE APPLICABILITY OF NOISE ABATEMENT APPROACH PROCEDURES TO MCDONNELL DOUGLAS AIRCRAFT

by

John A. Painter and James H. Shannon

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16. Abstract

Analyses of McDonnell Douglas DC-8, DC-9, and DC-10 jet transports were conducted to investigate the applicability of two segment approach noise abatement procedures to these airplanes. All models had the required glide slope capability at the certified landing flap settings. The DC-8 models would probably be limited to an upper segment glide slope of 5.5 degrees and would probably not be suitable for the two segment procedure in icing conditions. The DC-8 would not be compatible with this procedure at a reduced landing flap setting.

This report also discusses the feasibility of installing a two segment approach system in the Douglas-built fleet of commercial jet transports from a hardware viewpoint. The candidate system consists of a "two segment computer" plus the necessary peripheral equipment interfaced with the existing autopilot and associated avionics. The required modifications and additions to existing equipment are described and the attendant costs estimated. Potential problems which may be encountered are also discussed.

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Approach Noise Reduction
Retrofit Requirements

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CONTENTS

FIGURES

FIGURES (continued)

A STUDY TO DETERMINE THE APPLICABILITY OF NOISE ABATEMENT

APPROACH PROCEDURES TO MCDONNELL DOUGLAS AIRCRAFT

By:

John A. Painter and James H. Shannon

SUMMARY

Typical models of the McDonnell Douglas DC-8, DC-9, and DC-10 jet transports have been examined to determine their suitability for two segment, noise abatement approach procedures. All models were found to have adequate glide slope capability in the full flap landing configurations. At reduced landing flap settings, an upper segment glide slope of approximately five degrees would be possible on DC-9 and DC-10 models. Adequate glide slope for a two segment approach is not available on the DC-8 in the reduced flap landing configuration.

The pneumatic manifold temperatures required for anti-ice makes operation on steep glide slopes unlikely for DC-8 and marginal for DC-9. The DC-10 is certified for operation at idle in icing conditions and its capability is, therefore, not affected.

Adapting a two segment approach system to mate with the autopilot and related avionics on DC-8's and DC-9's was determined to be relatively straightforward and simple. However, to provide a dual system installation, as is necessary to permit extension of CAT II weather minimums certification for two segment approaches, requires dual air data sources. Since DC-8's and DC-9's are in general equipped with a single air data computer, additional expense is involved in providing this capability. Another required input for the two segment system which is not standard on DC-8's and DC-9's is a baro-correction setting. This can be obtained by modifying existing altimeters or replacing them with more sophisticated units. Recertification cost associated with these changes to existing avionics is not expected to be a significant factor.

Applying the two-segment system to DC-10's presents a different problem. All necessary inputs to the system are already available from dual sources, but to interface the system with the autopilot requires some modification thereof. This rework can be kept reasonably simple provided that it is not a requirement to make the two segment approach system compatible with the automatic landing mode. The auto-land feature is standard on all DC-10's. Without a requirement to interface with the autoland mode, the necessary autopilot changes may be limited to a change to the mode annunciator and associated control logic.

INTRODUCTION

Two segment approach procedures have been successfully demonstrated in flight test and airline service. In order to evaluate this procedure fleet-wide, it was necessary to examine the individual airplane models to determine if they are compatible with the two segment operation.

This study considered typical models of the McDonnell Douglas DC-8, DC-9, and DC-10 jet transports. Glide slope capabilities were studied to determine if the two segment procedure was within the performance limitations of the airplanes. Approaches at the full landing flap setting and at a reduced landing flap setting have been examined, with and without anti-ice provisions, on all models. Engine thrust data were also generated in terms of the primary thrust setting parameter.

The avionics equipment of the study airplanes were examined to assess the feasibility and cost of integrating the two segment approach system with the existing avionics. Baseline assumptions embodied in this study include a requirement to maintain Category II weather minimums certification and also include a goal of minimizing modifications to existing avionics in order to hold down the retrofit costs. Recertification effort associated with modification of existing equipment was also a factor to be evaluated.

TERMS AND SYMBOLS

a_n	Normal
EPR	Engine Pressure Ratio
FGS	Flight Guidance System
F_n	Net Thrust
GS	Glide Slope
H	Altitude
H_{baro}	Altitude from Barometric Altimeter
KEAS	Knots, Equivalent Air Speed
KIAS	Knots, Indicated Air Speed
M	Mach Number
N_1	Low Pressure Compressor Rotor Speed
100% N_1	3432.5 RPM
$N_1/\sqrt{\theta_\tau}$	Referred Low Pressure Compressor Rotor Speed
n.m.	Nautical Miles
P	Ambient Pressure
PLT	Pre-land Test
Po	Sea Level Standard Pressure
pot	Potentiometer
S	Laplace Variable
T_{amb}	Ambient Temperature (Deg. Abs.)
To	Sea Level Standard Temperature
T_t	Free Stream Total Temperature $[T_{amb}\ (1+.2M^2)]$
V_{REF}	1.3 x Stall Speed at Landing Flap Setting
V_S	Stall Speed
WT	Airplane Gross Weight
δ_a	Ambient Pressure Ratio P/Po
θ_T	Total Temperature Ratio T_T/To
τ	Filter Time Constant

GLIDE SLOPE CAPABILITY

In order to evaluate the two segment approach on any individual aircraft, it is necessary to estimate the steady state glide slope capability of that aircraft. The usual limitation is idle thrust since drag minus idle thrust dictates the maximum attainable steady state glide slope. Airplane drag is usually established within very small tolerances during the certification program. However, idle thrust is not usually critical for certification and, hence, very rarely is there any specific attempt made to determine the idle thrust by flight testing. Consequently, the idle thrust needed for defining the steady state glide slope capability is based on nominal performance estimated by the engine manufacturer with approximate installation effects added. Nevertheless, the maximum glide slope capability estimates should give a reasonable guide to the user who appreciates that some tolerances exist on these data in the idle thrust region.

The glide slope capability curves were produced for the most common versions of the DC-8. Only DC-8 Series 50, 61, 62, and 63, were considered. Generalized engine data for the turbojet powered DC-8's are not readily available but the idle thrust of the JT4A is similar to that of the JT3D and, hence, the glide slope capability of the DC-8 Series 50 should be representative of the earlier models even though the associated EPR levels may be different.

For the DC-9, the Series 10 and Series 30 with JT8D-7 engines cover the vast majority of the domestic fleet. A few DC-9 Series 30 with JT8D-9 engines exist in the domestic fleet and this version has been included.

Only the General Electric powered DC-10 models were considered. These are the DC-10 Series 10 and Series 30. The Series 40, which is powered by the Pratt and Whitney JT9D, is operated by only one airline at this time, but it does represent a significant minority of the present domestic DC-10 orders. Its glide slope capability would not be expected to differ significantly from that of the Series 30, however.

All glide slope charts have been constructed for zero wind, the certified landing flap settings (or possible alternatives in some cases), gear down, and two weights. The weights considered were maximum certified landing weight and a minimum weight approximately corresponding to operator's weight empty plus minimum reserves with zero payload. Three approach speeds are shown on each chart, V_{REF}, V_{REF+10}, and V_{REF+20}. V_{REF} indicates 1.3 V_S for the indicated flap setting.

The effects of wind shear and weather conditions were also considered. Critical wind shears would normally be expected to occur near ground level where ground irregularities may influence wind velocities. These conditions should not affect the two segment approach since they would normally occur on the lower segment which maintains the present glide slope. On the upper segment, the rate of change of wind velocity, for a given wind shear, would nearly double over that experienced with the present glide slopes. However, extreme wind shear conditions are unlikely to occur at heights greater than 500 feet above the runway. Even on the rare occasions when such shears are encountered, the need for accuracy is less acute on

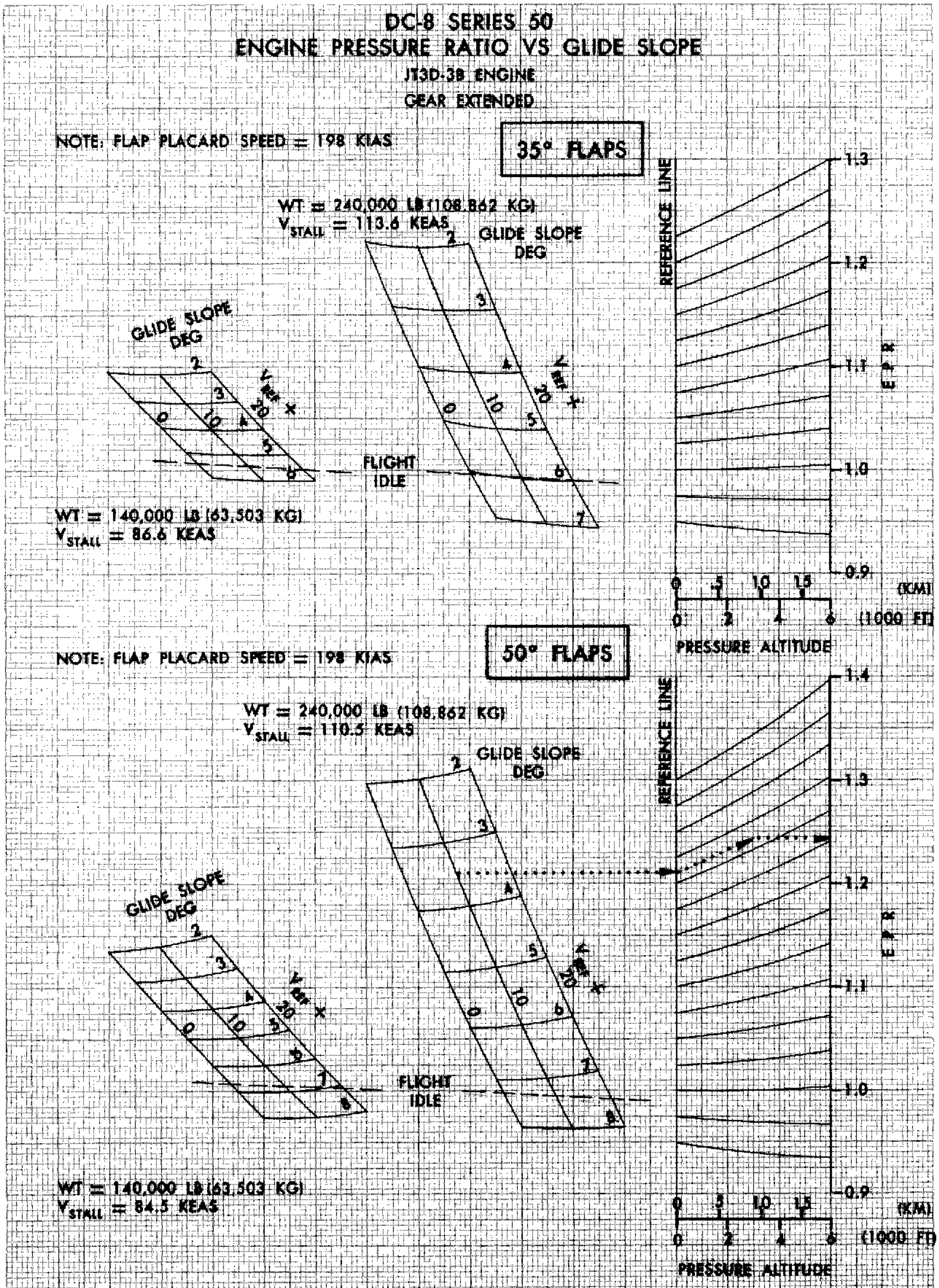

DC-8 SERIES 50
ENGINE PRESSURE RATIO VS GLIDE SLOPE
JT3D-3B ENGINE
GEAR EXTENDED
NOTE: FLAP PLACARD SPEED = 198 KIAS
35° FLAPS
WT = 240,000 LB (108,862 KG)
V STALL = 113.6 KEAS
GLIDE SLOPE DEG
V REF +
WT = 140,000 LB (63,503 KG)
V STALL = 86.6 KEAS
FLIGHT IDLE
REFERENCE LINE
E P R
PRESSURE ALTITUDE
(KM)
(1000 FT)
NOTE: FLAP PLACARD SPEED = 198 KIAS
50° FLAPS
WT = 240,000 LB (108,862 KG)
V STALL = 110.5 KEAS
WT = 140,000 LB (63,503 KG)
V STALL = 84.5 KEAS

FIGURE 1

the upper segment than on the lower segment where a Category II window must be achieved. Therefore, the effects of wind shear is not considered critical for the two segment approach procedure. However, it should be remembered that a ten knot tailwind will reduce maximum glide slope capability by approximately 0.5 degree. If adequate tailwind protection is not established, it is possible to select a low landing flap setting initially which will not provide adequate glide slope capability in an increasing tailwind shear.

The effects of icing conditions present a much larger problem. These effects are discussed in more detail for each airplane but the general conclusions are that the DC-8 is probably not compatible with the two segment approach procedures in icing conditions and the DC-9 is marginal. The DC-10 capability is unaffected by icing conditions.

DC-8 Series 50

The DC-8 Series 50 is the basic fan-powered DC-8. It is powered by four Pratt and Whitney JT3D-3B engines in the short fan duct configuration. Maximum landing weight is 240,000 pounds. The certified landing flap setting is 50 degrees. The 35 degree setting is a possible alternate but not at present certified.

If it is assumed that a minimum of approximately 1.5 degrees of glide slope margin is required to protect against tailwind and provide control margin, the DC-8 Series 50 upper segment should probably be limited to 5.5 degrees for the 50 degree flap setting. A practical two segment approach procedure does not seem possible with the 35 degree flap setting.

The DC-8 airplanes were usually manufactured with "undertemp" lights, which are illuminated when manifold temperatures fall below a given level. If these lights are not installed, the procedure in Section III of the FAA Approved Flight Manual calls for maintaining 190°C in the pneumatic manifold. This temperature is designed to provide adequate anti-icing for operation in temperatures down to -22°F (the FAA required minimum ambient temperature). For this minimum ambient temperature, the DC-8 requires an EPR of 1.35 to 1.40 to attain 190°C manifold temperature. At more normal icing temperature, the EPR requirement drops to 1.2 to 1.25. The DC-8 cannot maintain a steep upper segment at the above EPR's and, hence, a two segment approach is not compatible with the anti-ice procedure in the FAA Approved Flight Manual.

The procedures in Section III of the FAA Manual can be replaced by other satisfactory procedures developed by the operator and accepted by the FAA. If other satisfactory procedures which require less EPR for anti-ice have been developed, the operation in icing conditions can be re-examined by reference to the glide slope capability at these lower EPR levels.

DC-8 Series 61

The DC-8 Series 61 is a stretched version of the Series 50. The fuselage is stretched approximately 47 feet to provide greater passenger capacity but the airplanes are aerodynamically very similar. The limiting weights, power plants, and installations are the same. The Series 61 has slightly less drag in the landing configuration due to the use of a different flap linkage. Apart from the slightly reduced glide slope capability (which may be offset by generally higher weight landings), the Series 50 comments are equally applicable to Series 61.

DC-8 SERIES 61
ENGINE PRESSURE RATIO VS GLIDE SLOPE
JT3D-3B ENGINE
GEAR EXTENDED

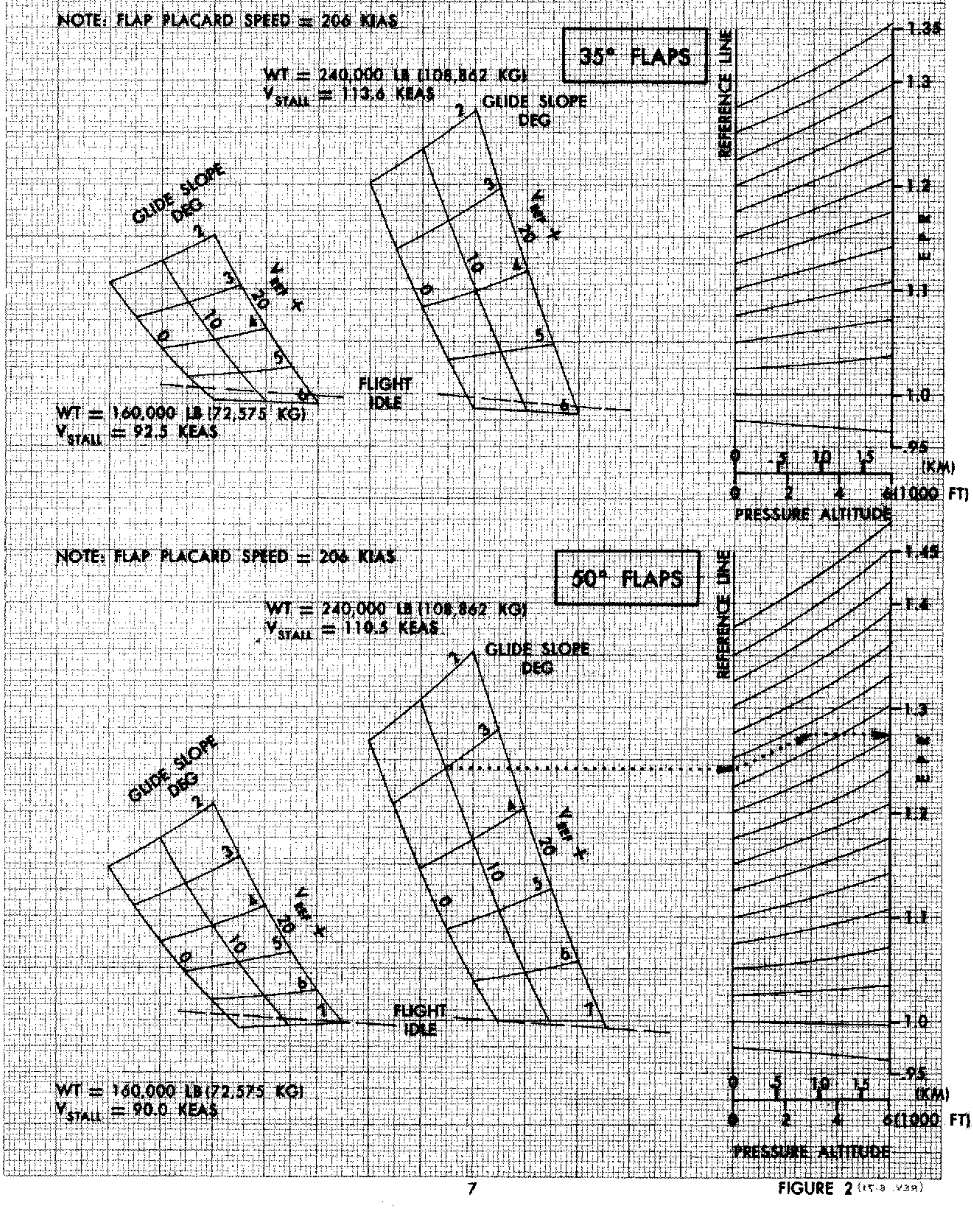
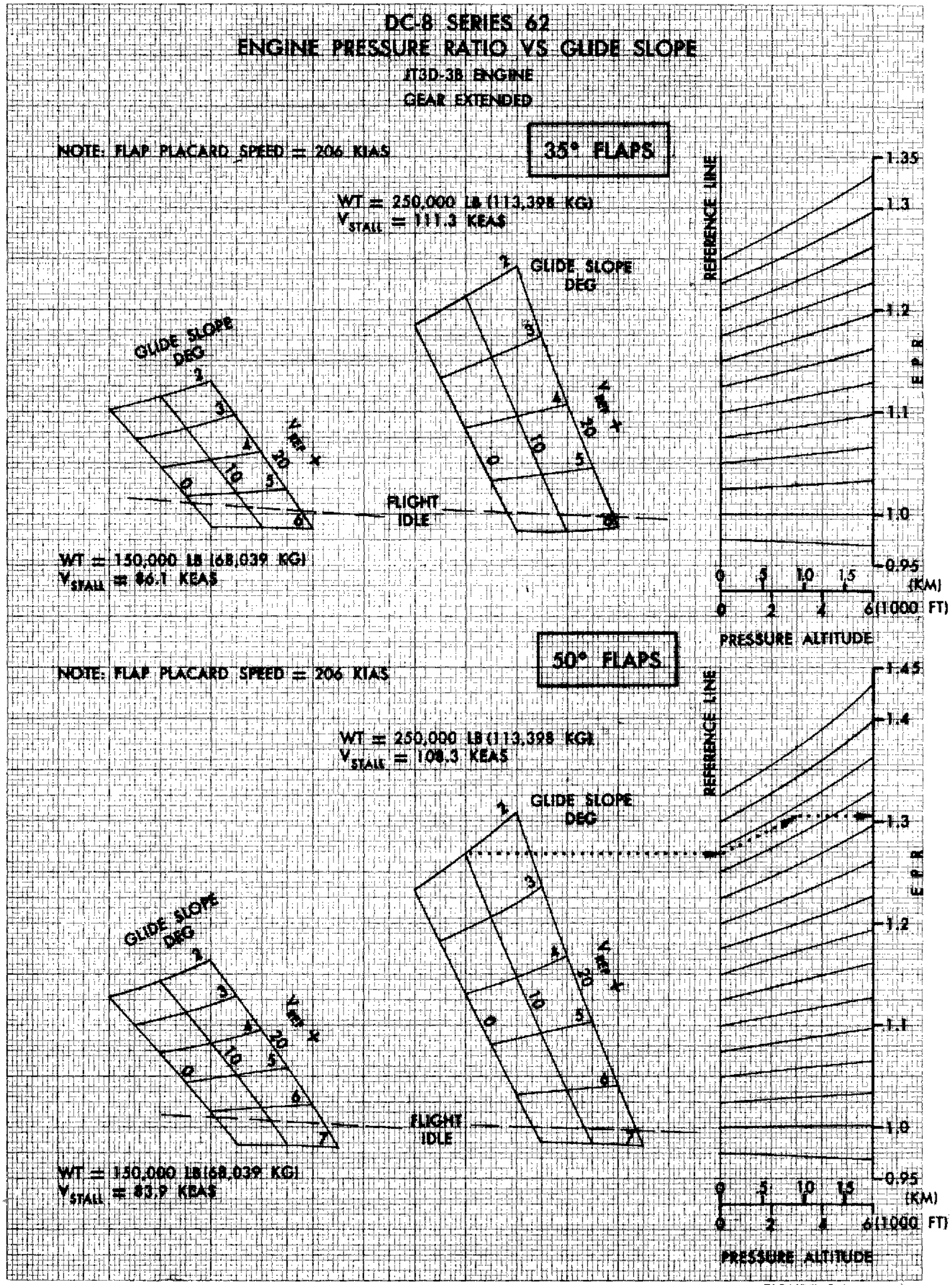


FIGURE 2

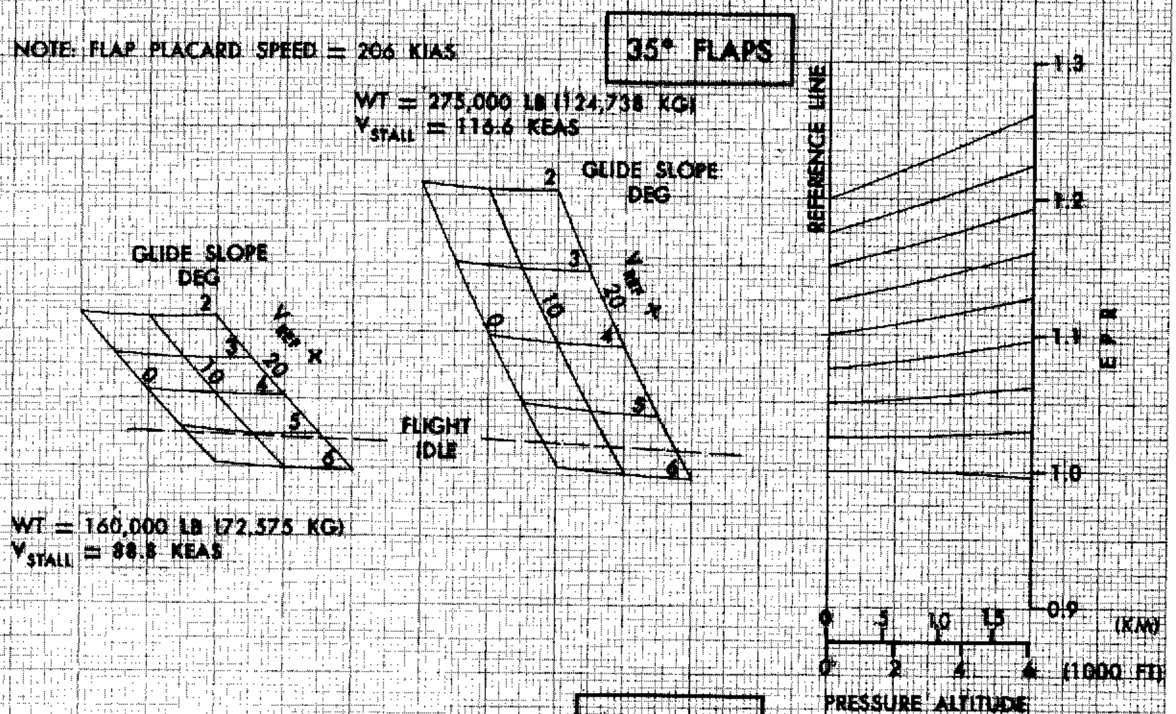


DC-8 SERIES 62
ENGINE PRESSURE RATIO VS GLIDE SLOPE
JT3D-3B ENGINE
GEAR EXTENDED
NOTE: FLAP PLACARD SPEED = 206 KIAS
35° FLAPS
WT = 250,000 LB (113,398 KG)
V_{STALL} = 111.3 KEAS
GLIDE SLOPE DEG
V_{REF} +
FLIGHT IDLE
WT = 150,000 LB (68,039 KG)
V_{STALL} = 86.1 KEAS
REFERENCE LINE
E.P.R.
PRESSURE ALTITUDE
(KM)
(1000 FT)
NOTE: FLAP PLACARD SPEED = 206 KIAS
50° FLAPS
WT = 250,000 LB (113,398 KG)
V_{STALL} = 108.3 KEAS
GLIDE SLOPE DEG
V_{REF} +
FLIGHT IDLE
WT = 150,000 LB (68,039 KG)
V_{STALL} = 83.9 KEAS
REFERENCE LINE
E.P.R.
PRESSURE ALTITUDE
(KM)
(1000 FT)

FIGURE 3

DC-8 SERIES 63
ENGINE PRESSURE RATIO VS GLIDE SLOPE

JT3D-7 ENGINE
GEAR EXTENDED



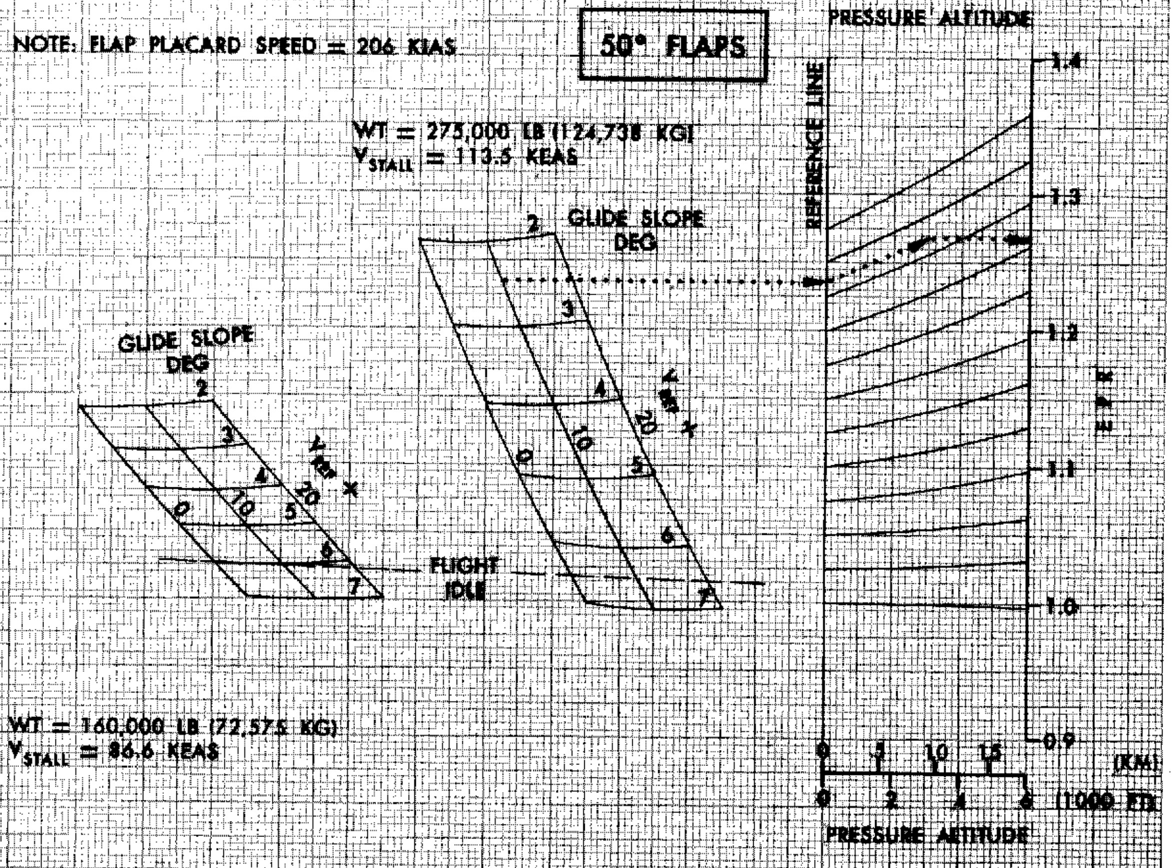


FIGURE 4 (REV. 8-71)

DC-8 Series 62

The DC-8 Series 62 was developed for long range operation. The fuselage was stretched approximately 7 feet over that of the Series 50. It has a 6-foot increase in wing span, long duct nacelles, and redesigned engine pylons to improve cruise efficiency. The usual power plant is the JT3D-3B. The limiting weights have also been increased.

In the landing configuration, new flap linkages have been employed to reposition the flaps and the resulting decrease in drag has caused a further deterioration of the maximum glide slope capability. The Series 62 glide slope capability is approximately 0.5 degrees less than the Series 50. This indicates that the probable upper segment slope should be about 5 degrees for the Series 62. All other Series 50 comments should apply to the Series 62.

DC-8 Series 63

The Series 63 is essentially the same as the Series 62 except for increased fuselage length. The normal power plants are four Pratt and Whitney JT3D-7. Aerodynamically it is identical to the Series 62 at low speeds. Limiting weights have been further increased, however. The higher landing weights almost offset the increased idle thrust of the JT3D-7 and maximum glide slope capability is only marginally decreased. This model seems to be most critical on glide slope capability but, since many DC-8-63 flights are made in the cargo configuration or for charter operations, the generally high landing weights may provide an upper segment capability of 5 degrees with adequate control margins.

All other comments made for the Series 50 would be applicable to the Series 63.

DC-9 Series 10

The DC-9 Series 10 was the original model. It has simple hinged flaps with no leading edge devices. It is powered by two aft-mounted Pratt and Whitney JT8D-7 engines. Maximum landing weight is 81,700 pounds. The certified landing flap setting is 50 degrees. A possible alternate, which is not at present certified, is 30 degrees.

The glide slope capability of this model seems adequate for the two segment approach procedure with either of these flap settings. However, with the 30-degree flap setting, the upper segment slope should probably be limited to 5 or 5.5 degrees.

As on the DC-8, the DC-9 has "undertemp" lights for the anti-ice system. The EPR required to extinguish these under the worst conditions is 1.27 to 1.34. At more usual temperatures, the requirement is 1.08 to 1.14. With the former values of EPR, the two segment approach would not be possible. With the latter values, it may be possible but pilot comment indicates a reluctance to set less than 1.2 EPR. It is, therefore, concluded that two segment approach procedures are marginal on the DC-9 in icing conditions at the full landing flap setting and not possible at the reduced flap setting. Some test data may be necessary to fully determine the capability in ice at full landing flaps.

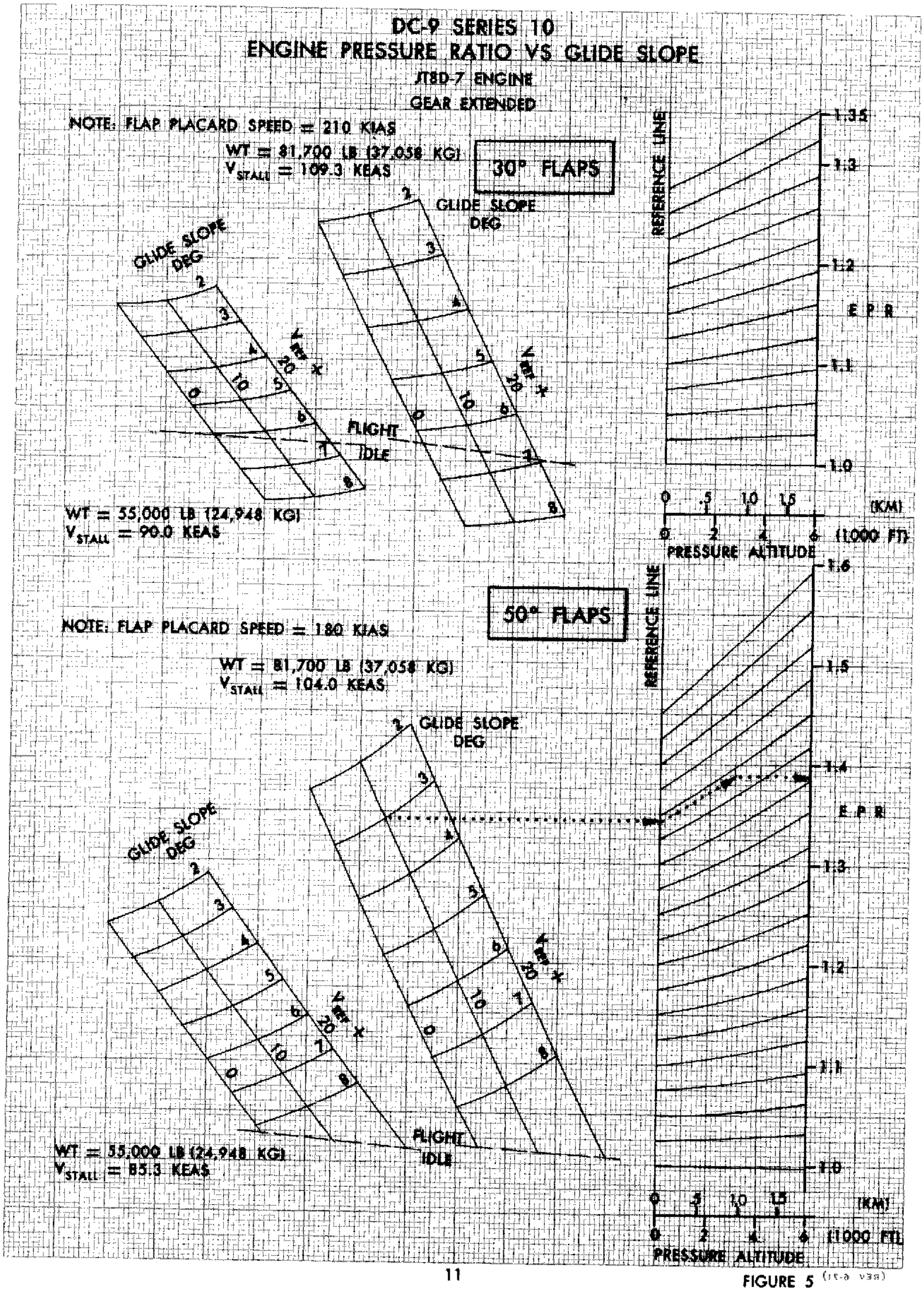

DC-9 SERIES 10
ENGINE PRESSURE RATIO VS GLIDE SLOPE
JT8D-7 ENGINE
GEAR EXTENDED
NOTE: FLAP PLACARD SPEED = 210 KIAS
WT = 81,700 LB (37,058 KG)
V_{STALL} = 109.3 KEAS
30° FLAPS
GLIDE SLOPE DEG
V_{REF} + 20
V_{REF} + 10
FLIGHT IDLE
WT = 55,000 LB (24,948 KG)
V_{STALL} = 90.0 KEAS
REFERENCE LINE
E P R
PRESSURE ALTITUDE
(KM)
(1,000 FT)
NOTE: FLAP PLACARD SPEED = 180 KIAS
WT = 81,700 LB (37,058 KG)
V_{STALL} = 104.0 KEAS
50° FLAPS
WT = 55,000 LB (24,948 KG)
V_{STALL} = 85.3 KEAS

FIGURE 5

DC-9 Series 30

The DC-9 Series 30 is aerodynamically very different from the Series 10. It has a 15-foot longer fuselage, 4-foot greater span, wing leading edge slats, and much higher weights. The vast majority of the domestic Series 30 fleet is powered by two Pratt and Whitney JT8D-7 engines. A few are powered by JT8D-9 engines. The JT8D-7 thrust/EPR relationship is slightly different than that of the JT8D-9 and both versions are presented. The certified landing flap setting is 50 degrees. Thirty-five degrees is not at present certified, but represents a suitable alternate flap setting.

At either flap setting with either power plant, the DC-9 Series 30 is compatible with two segment approach procedures except for icing conditions. As with the Series 10, operation with these procedures in icing conditions is marginal at full flaps and not possible at the reduced flap setting.

DC-10 Series 10

The DC-10 Series 10 is a wide body tri-jet developed for short to medium range operation. It is presently operating on East to West Coast routes, West Coast to Hawaii, and across the North Atlantic, as well as many shorter routes within the United States. It is powered by three General Electric CF6-6D engines. The certified landing flap settings are 35 and 50 degrees.

The glide slope capability curves indicate that the 50 degrees flap setting is compatible with the two segment approach procedures. The glide slope capability is marginal at 35 degrees, however, particularly at light weights. The airplane is certified for operation in icing conditions at flight idle and no change in procedures would be necessary for such conditions.

DC-10 Series 30

The DC-10 Series 30 is a long range development of the Series 10. It has increased gross weights, higher thrust CF6-50A engines, a 10-foot increase in wing span, and an extra centerline main landing gear. The certified landing flap settings of 35 and 50 degrees are presented.

The increased drag, increased weights, and increased idle thrust of the Series 30 counteract one another to produce glide slope capabilities almost identical to those of the Series 10. The 35 degree flap setting has slightly greater glide slope capability than that of the Series 10 but the upper segment would probably be limited to less than 5 degrees. Icing conditions would not affect the glide slope capability.

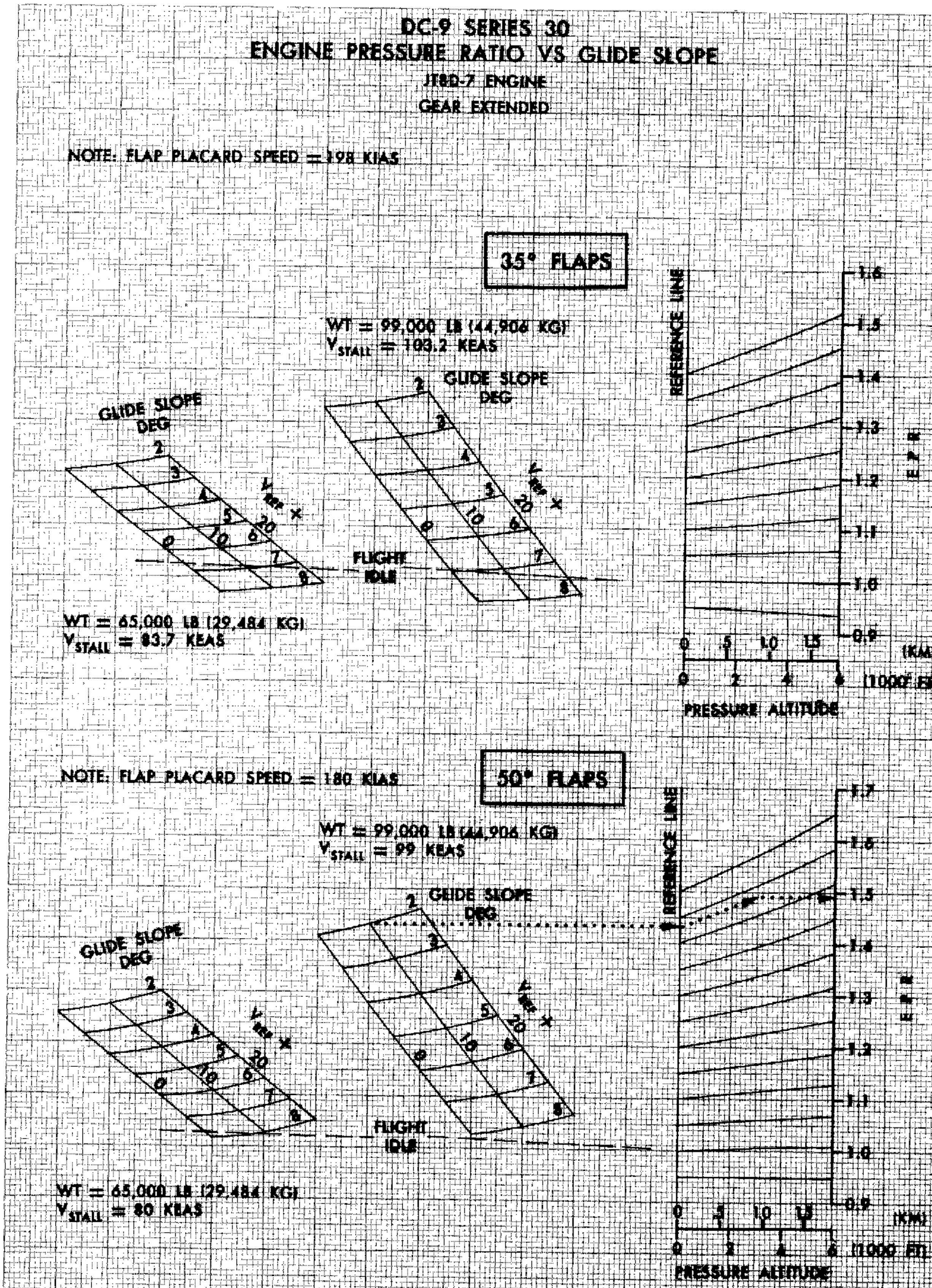
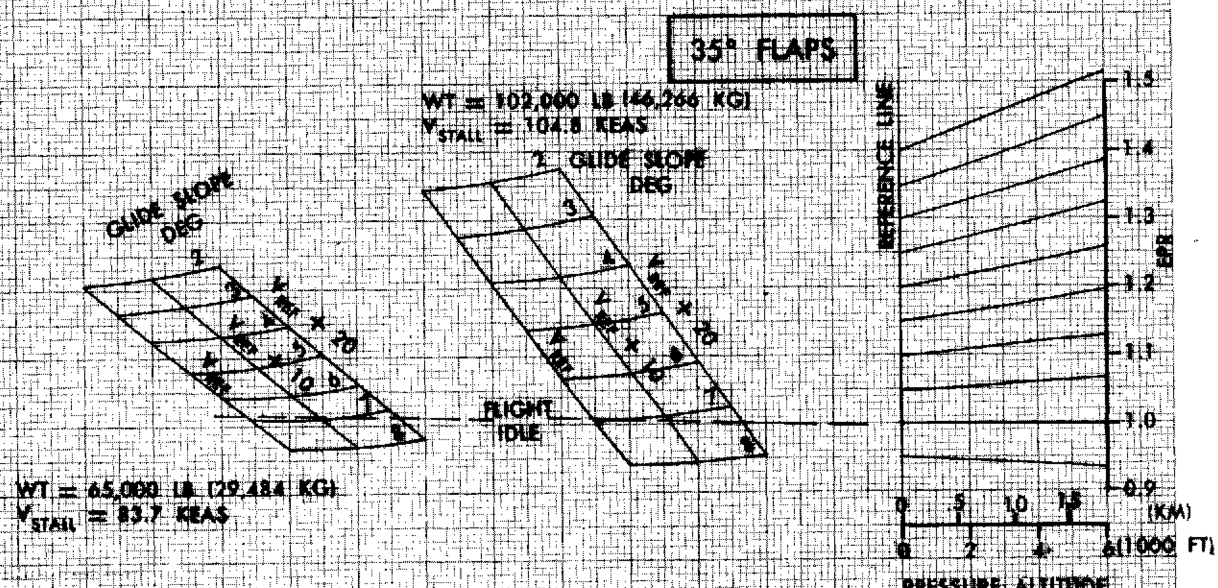

DC-9 SERIES 30
ENGINE PRESSURE RATIO VS GLIDE SLOPE
JT8D-7 ENGINE
GEAR EXTENDED
NOTE: FLAP PLACARD SPEED = 198 KIAS
35° FLAPS
WT = 99,000 LB (44,906 KG)
V STALL = 103.2 KEAS
GLIDE SLOPE DEG
WT = 65,000 LB (29,484 KG)
V STALL = 83.7 KEAS
FLIGHT IDLE
REFERENCE LINE
E.P.R.
PRESSURE ALTITUDE
(KM)
(1000 FT)
NOTE: FLAP PLACARD SPEED = 180 KIAS
50° FLAPS
WT = 99,000 LB (44,906 KG)
V STALL = 99 KEAS
WT = 65,000 LB (29,484 KG)
V STALL = 80 KEAS

FIGURE 6

DC-9 SERIES 30
ENGINE PRESSURE RATIO VS GLIDE SLOPE

JT8D-9 ENGINE
GEAR EXTENDED

NOTE: FLAP PLACARD SPEED = 198 KIAS



NOTE: FLAP PLACARD SPEED = 180 KIAS

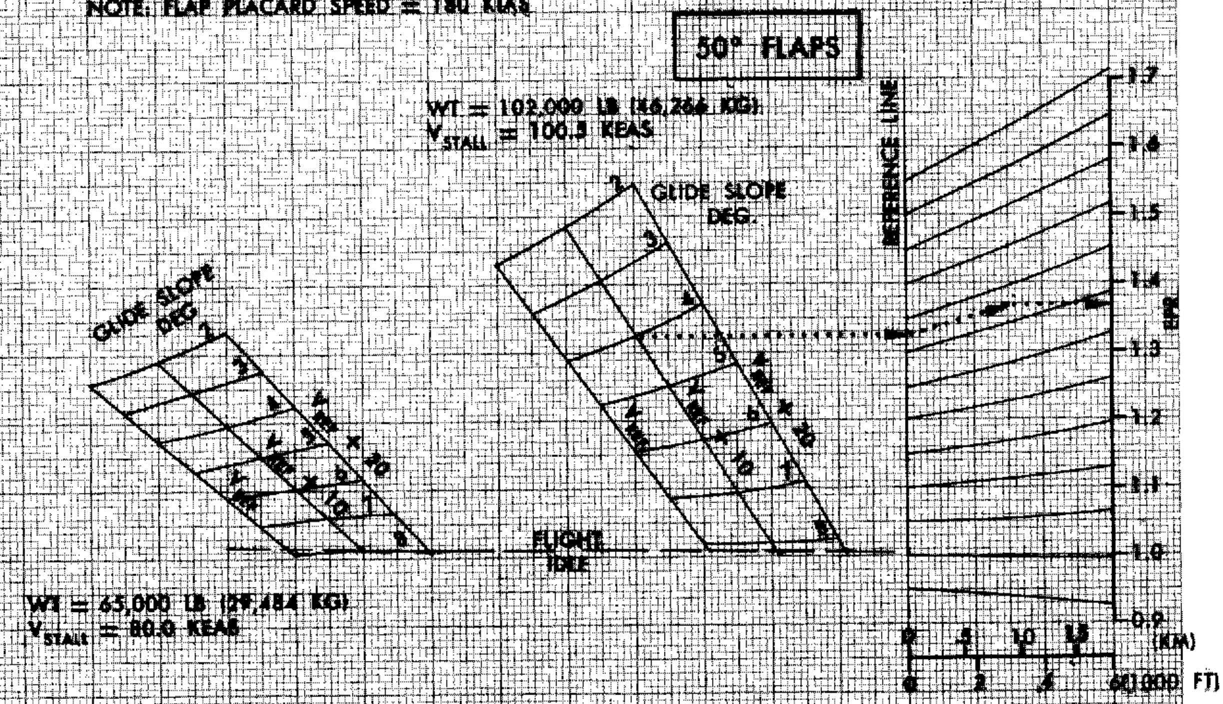


FIGURE 7

DC-10 SERIES 10
REFERRED FAN SPEED VS GLIDE SLOPE

CF6-6D

GEAR EXTENDED

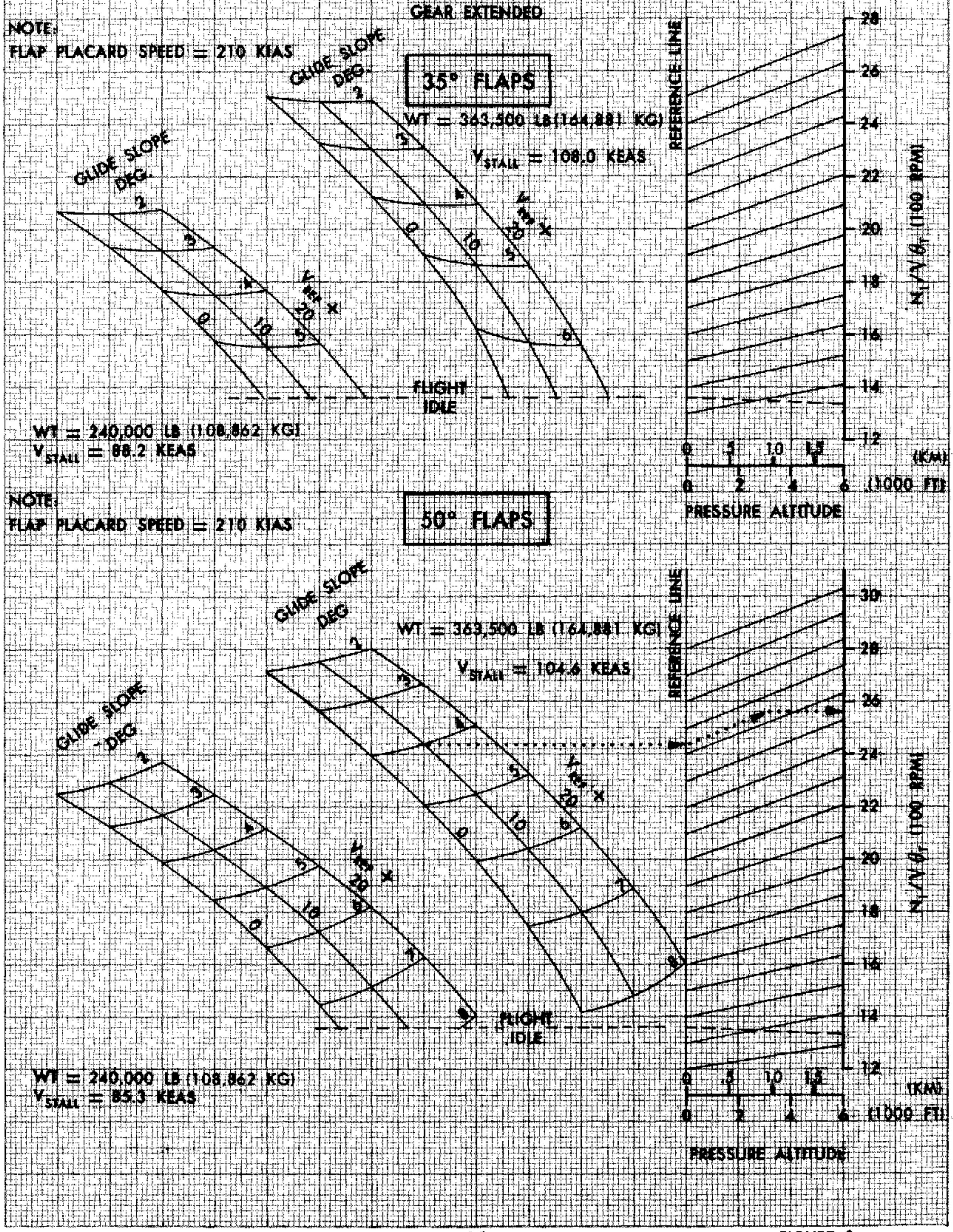
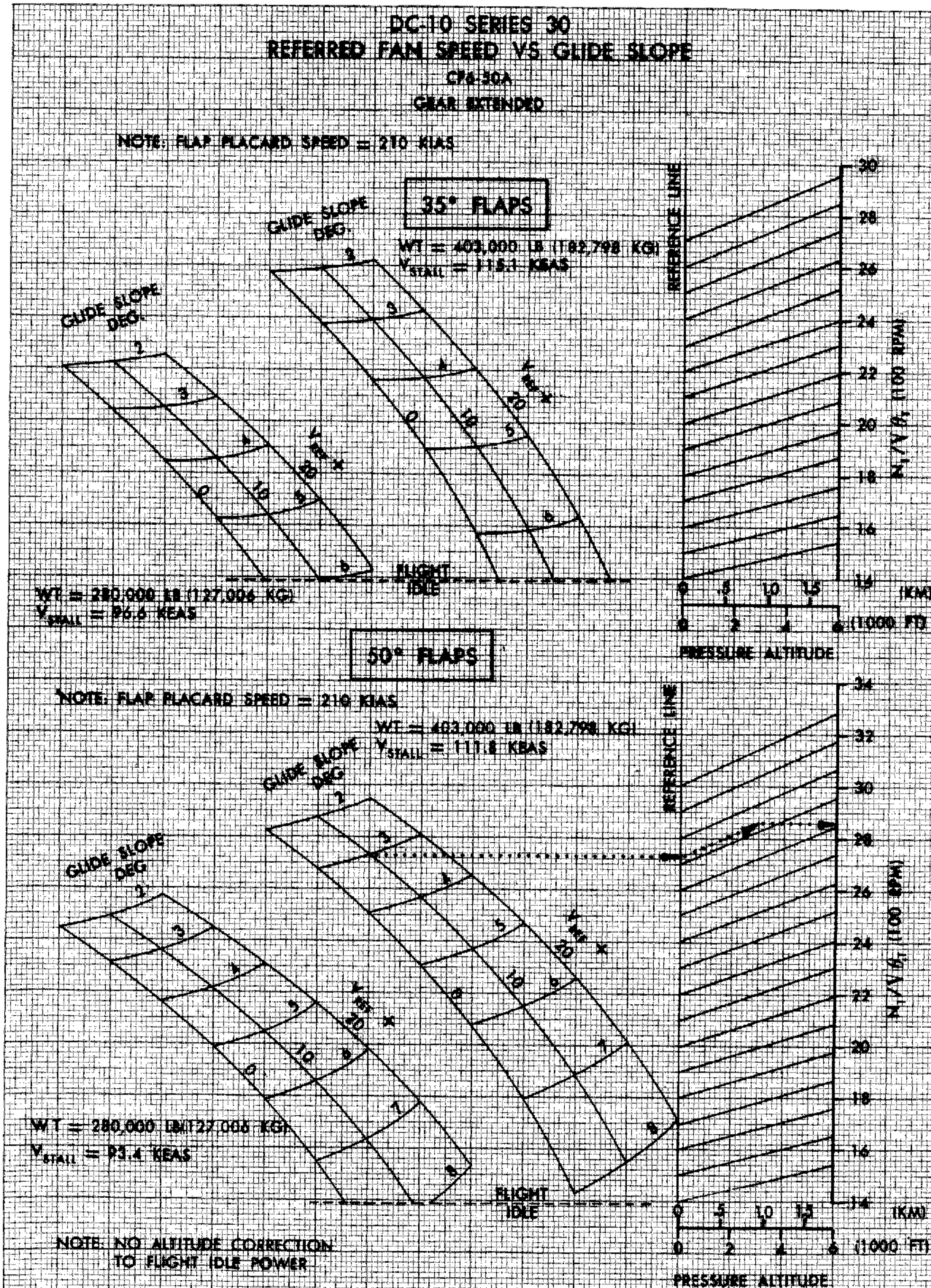


FIGURE 8



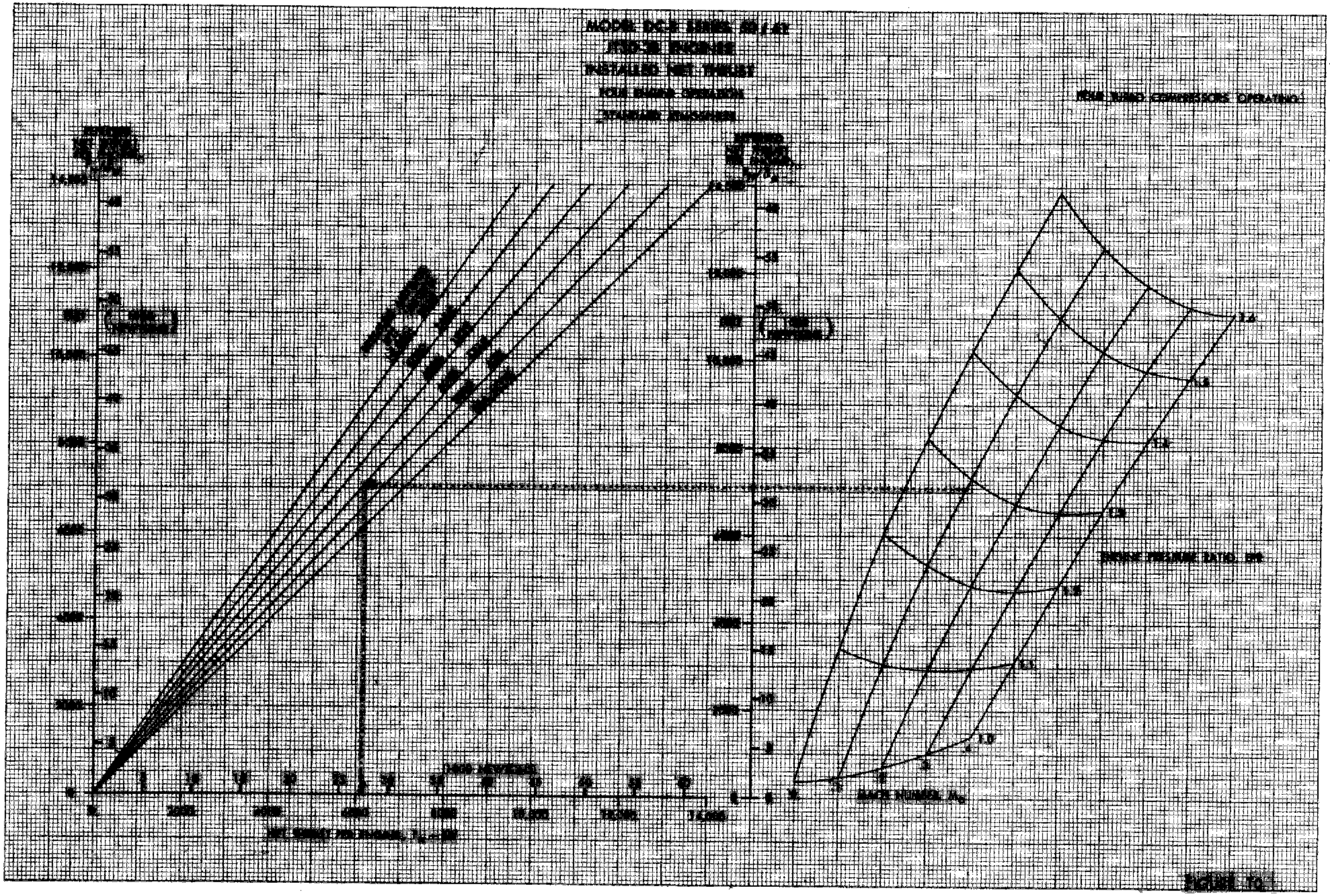
DC-10 SERIES 30
REFERRED FAN SPEED VS GLIDE SLOPE
CF6-50A
GEAR EXTENDED
NOTE: FLAP PLACARD SPEED = 210 KIAS
35° FLAPS
WT = 403,000 LB (182,798 KG)
V_{STALL} = 115.1 KEAS
WT = 280,000 LB (127,006 KG)
V_{STALL} = 96.6 KEAS
GLIDE SLOPE DEG.
FLIGHT IDLE
REFERENCE LINE
PRESSURE ALTITUDE
(KM)
(1000 FT)
50° FLAPS
NOTE: FLAP PLACARD SPEED = 210 KIAS
WT = 403,000 LB (182,798 KG)
V_{STALL} = 111.8 KEAS
WT = 280,000 LB (127,006 KG)
V_{STALL} = 93.4 KEAS
NOTE: NO ALTITUDE CORRECTION TO FLIGHT IDLE POWER
$N_1/\sqrt{\theta_T}$ (100 RPM)

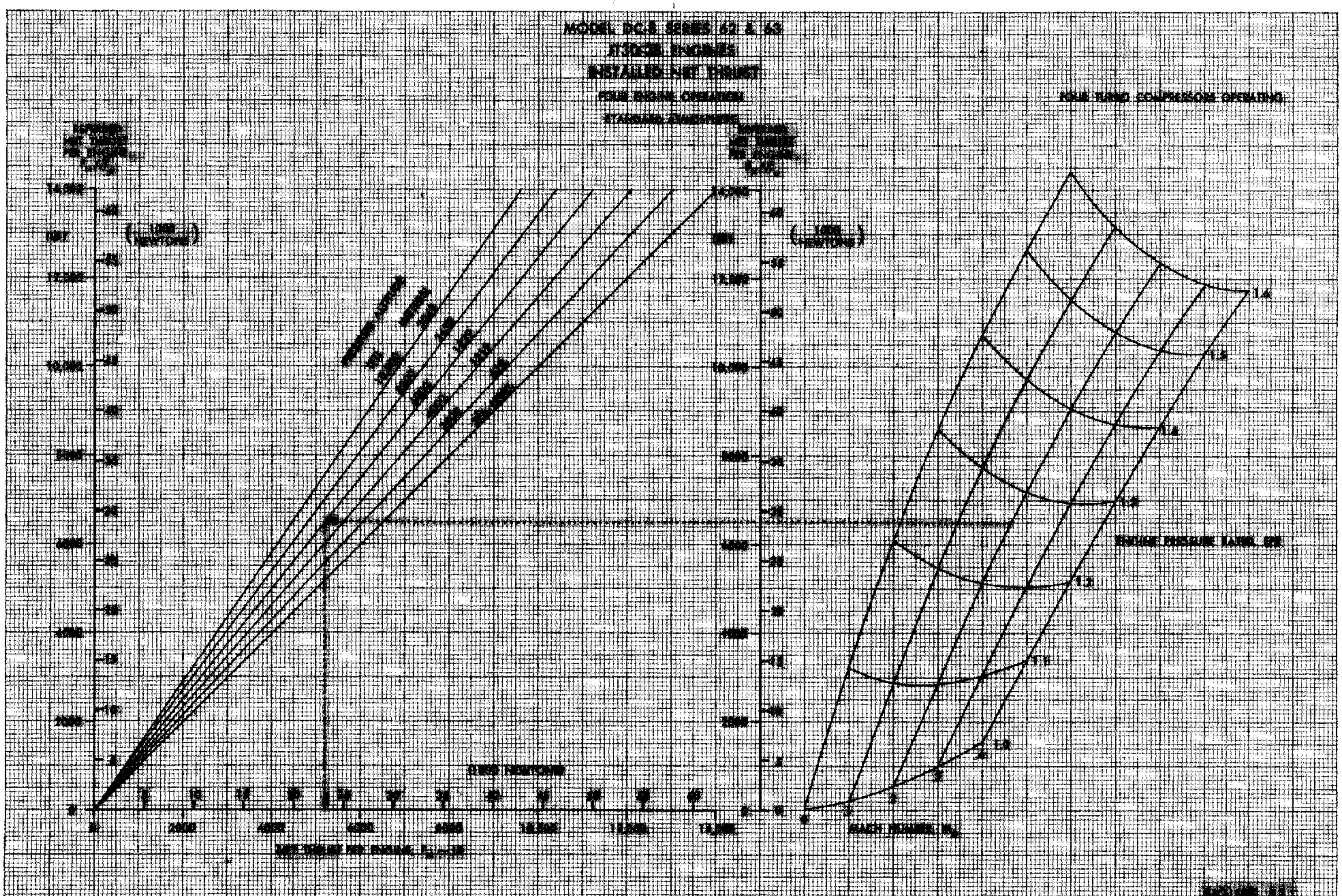
FIGURE 9

INSTALLED NET THRUST

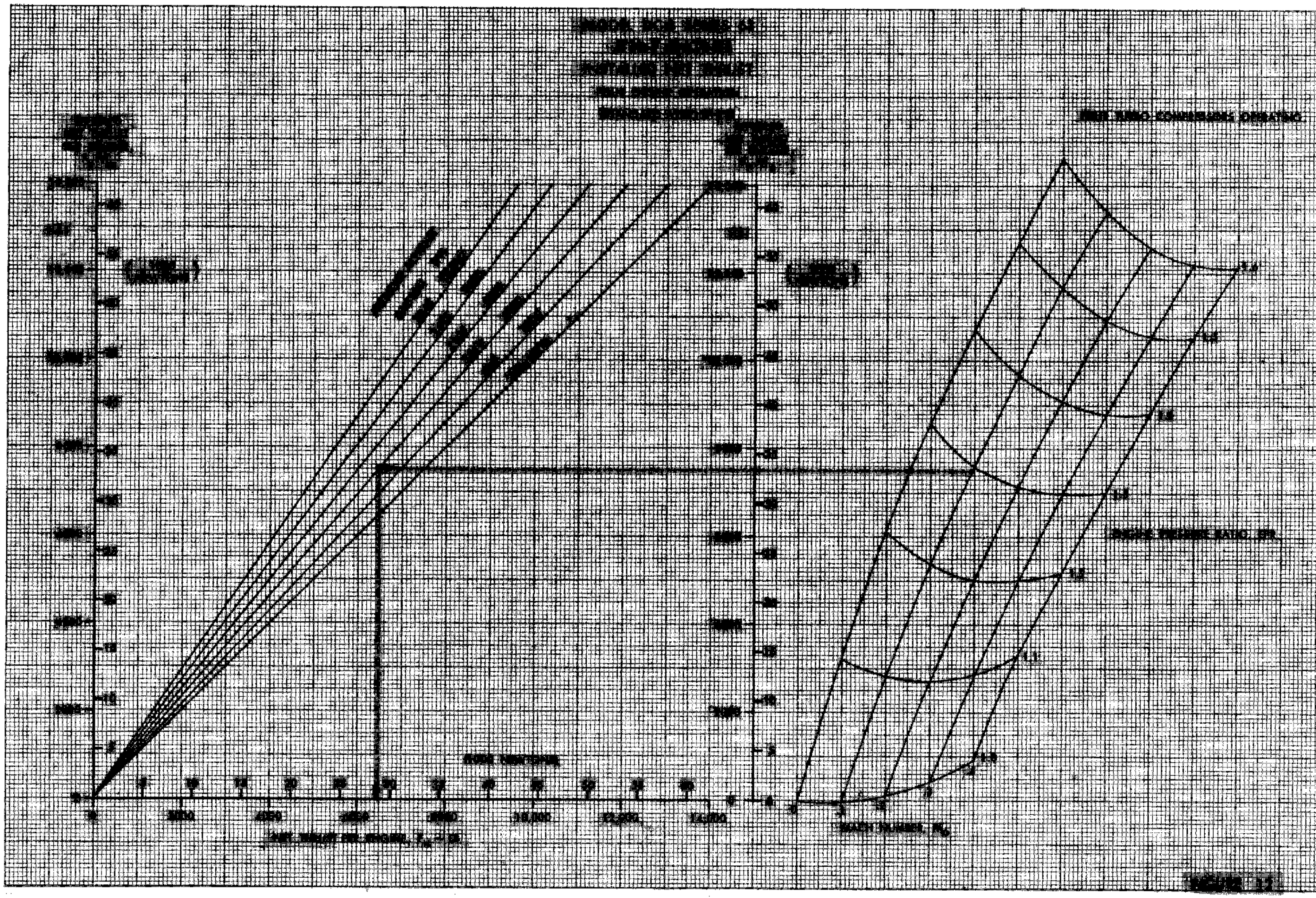
Curves of the installed net thrust versus EPR or $N_1/\sqrt{\theta_T}$, Mach number, and altitude have been prepared for all of the power plants considered for this study. It was agreed with the NASA Program Manager that the original requirement for power lever angle should be deleted due to large tolerances required when using this parameter as a thrust indicator. The range of altitude and Mach number represented cover those expected during a normal approach.

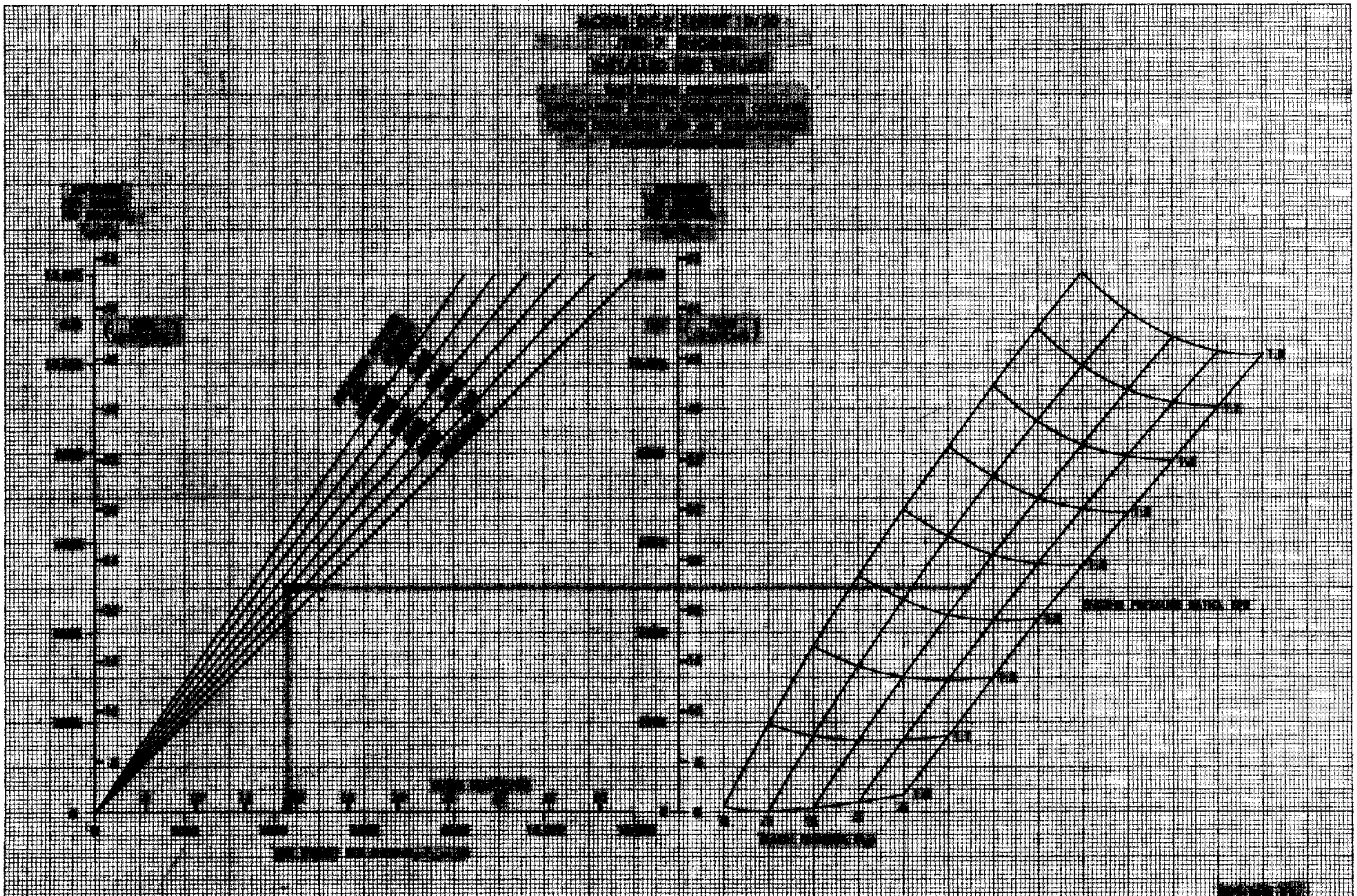
The primary thrust setting parameter for the Pratt and Whitney engines is EPR. For the General Electric engines, thrust is set on the basis of fan speed. The cockpit instrumentation is $\%N_1$. One hundred $\%N_1$ corresponds to an RPM of 3432.5 on both the CF6-6D and CF6-50A engines. The net thrust chart is correlated in terms of referred fan speed, $N_1/\sqrt{\theta_T}$. θ_T is the total temperature ratio T_T/T_0 in degrees absolute. Total temperature, T_T, can be calculated from ambient temperature by the equation $T_T = T_{AMB}\ (1 + 0.2M^2)$.

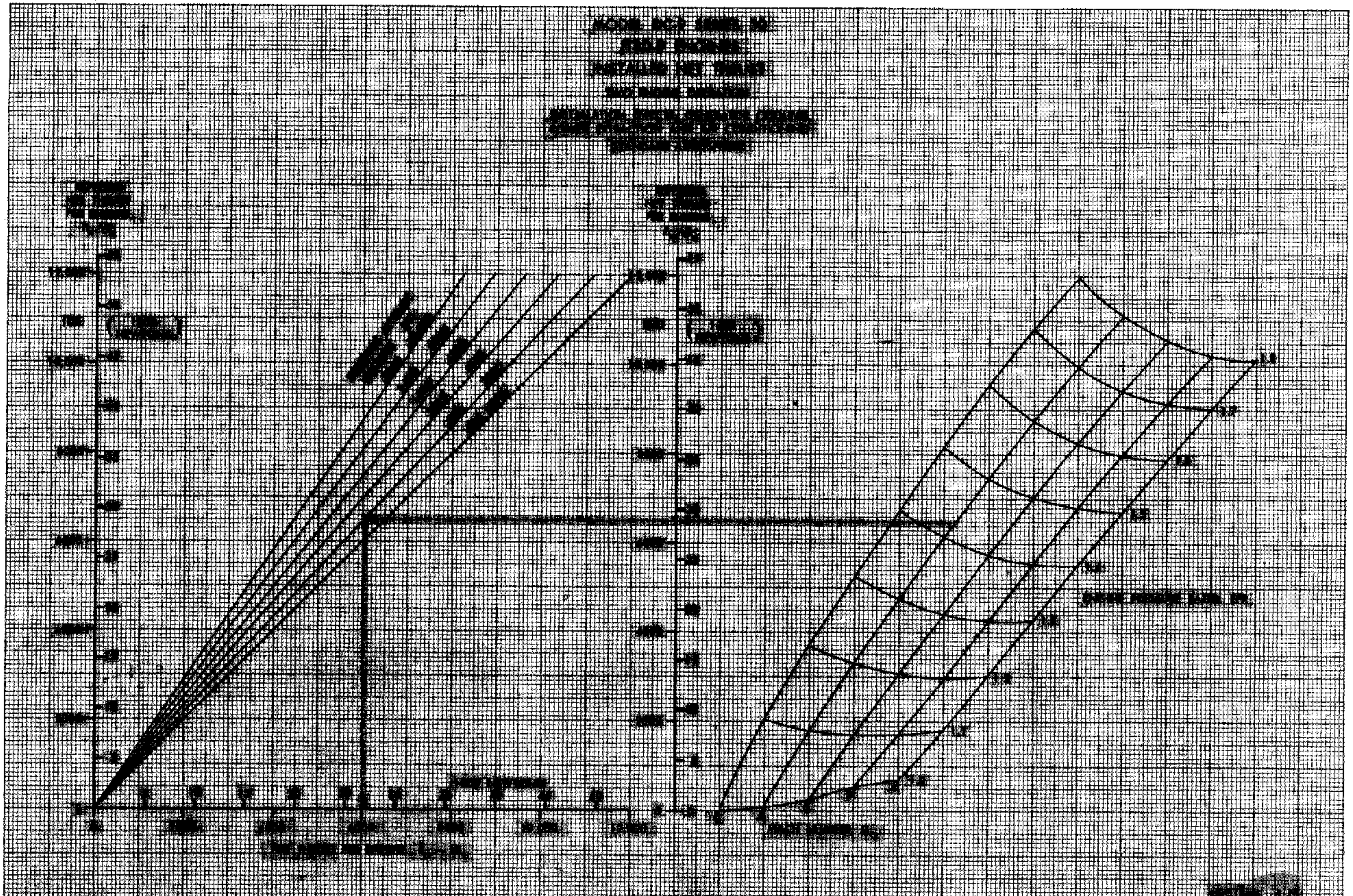

INSTALLED NET THRUST
FOUR TURBO COMPRESSORS OPERATING
ENGINE PRESSURE RATIO, EPR
MACH NUMBER
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
0
2000
4000
6000
8000
10,000
12,000
14,000

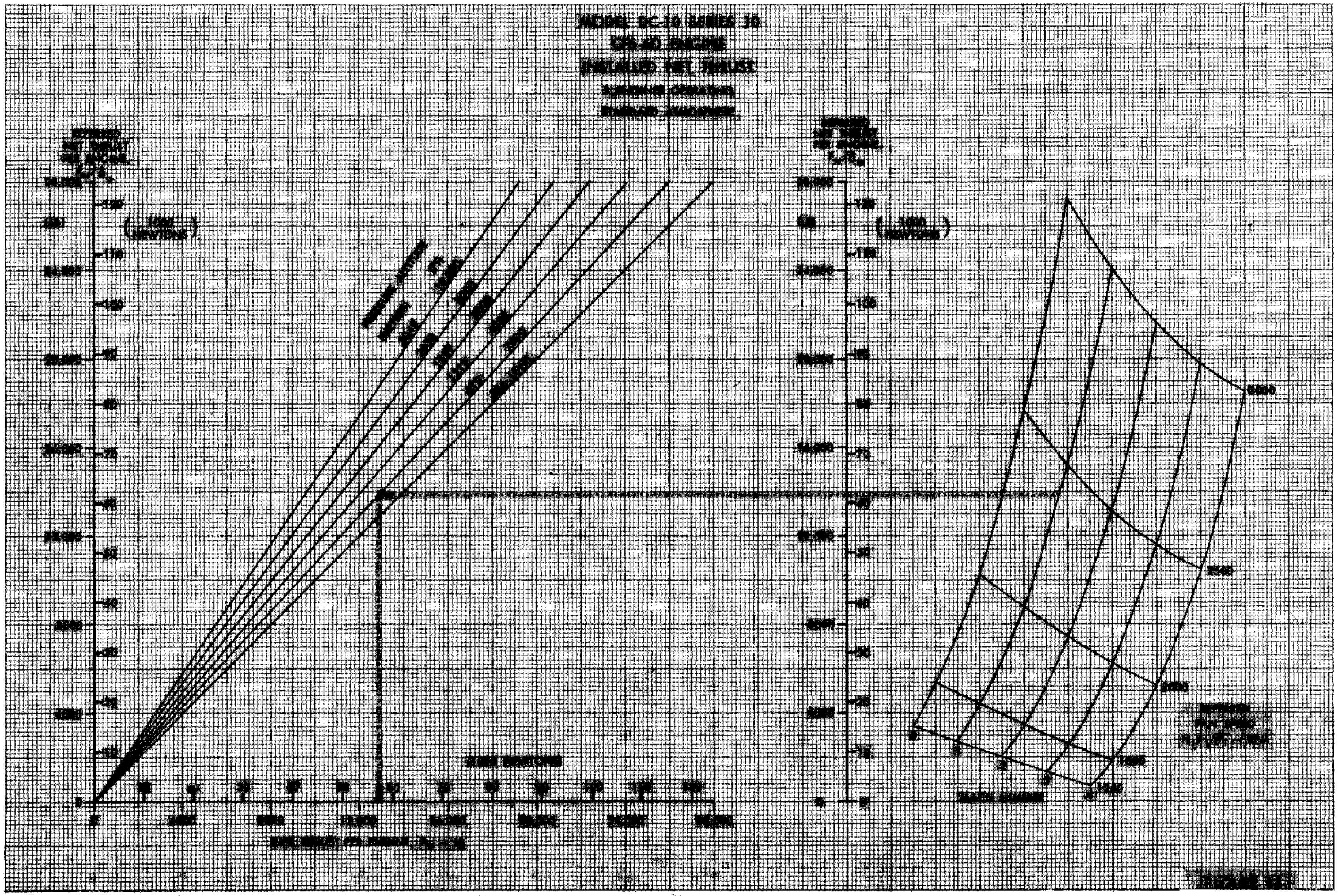


MODEL DC-8 SERIES 62 & 63
JT3D-3B ENGINES
INSTALLED NET THRUST
FOUR ENGINE OPERATION
STANDARD ATMOSPHERE
FOUR TURBO COMPRESSORS OPERATING
ENGINE PRESSURE RATIO, EPR
MACH NUMBER
NET THRUST PER ENGINE
1.0
1.1
1.2
1.3
1.4
1.5
1.6









MODEL DC-10 SERIES 30
INSTALLED NET THRUST

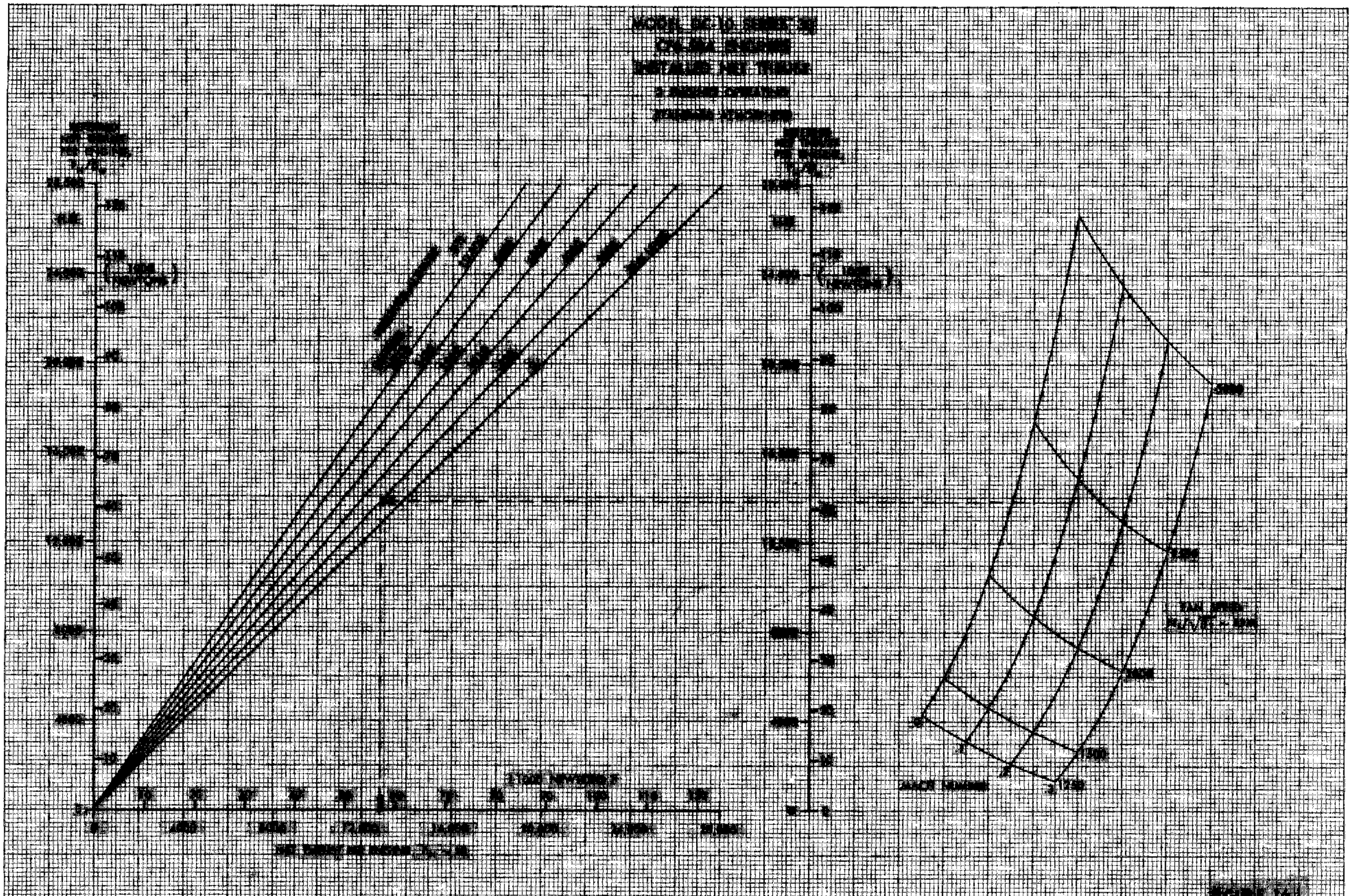

MODEL DC-10 SERIES 30
CF6-50A ENGINE
INSTALLED NET THRUST
MACH NUMBER

FIGURE 16

AIRPLANE SYSTEMS REVIEW

Avionics systems in the subject airplanes must provide guidance commands for the desired two-segment approach either via the flight directors or the autopilot or both. It is also necessary to define or "compute" the upper segment deviation within the onboard equipment since there is no externally generated signal to define the upper segment as there is for the lower segment, which consists of the standard ILS glide slope. Figure 17 depicts the geometry of the two segment approach and defines the method by which the upper segment deviation (ΔH_1) is determined from range and altitude data. Note that the constants K_0 and θ may be adjusted to define the desired upper segment slope and lower seg-upper seg intercept point.

Two Segment Approach System for DC-8 and DC-9 Retrofit

Appendix D contains a preliminary specification which was used as a guide in evaluating DC-8 and DC-9 avionic systems for compatibility with a two segment approach system. Basically, it assumes that dual add-on systems similar to the Collins system used in the 727 will be incorporated (see Fig. 18) to provide the necessary two segment path computations and that the control laws can be formulated to yield satisfactory performance. The latter assumption is supported by the results of the UAL flight evaluations. The problem of adapting this system to the DC-8 and DC-9 aircraft then is one of supplying the necessary sensor inputs, providing means to inject the guidance signal into the autopilot and flight director, and providing mode annunciation means. The following paragraphs address the interface aspects individually.

Input Signals

DME - Dual DME installation is standard and conforms to ARINC 521D. Available signal output is analog A-C with an accuracy of 0.2 nautical miles. It would be advantageous to replace these units with ARINC 568-3 devices to obtain an improvement in accuracy to 0.1 nautical miles.

Air Data - Depending on the customer configuration, the need to supply dual barometric altitude and altitude rate signals can present a problem of varying magnitude. Most customers, however, will find it necessary to install a second air data computer to supply the necessary signals. Since there are a number of relatively recent developments that require altitude signal inputs (namely, altitude alert, automatic altitude reporting, and R-NAV), DC-9 operators may find it advantageous when retrofitting for two segment approaches to install the system described in the next paragraph.

> Add a second air data computer (Sperry) if the airplane has only one installed. Cost would be about 14-20 thousand dollars. Replace both altimeters with Kollsman A4289 type at a cost of 6 thousand dollars. These altimeters will provide up to two outputs each of baro-corrected altitude (two speed synchro) per ARINC 545. Altitude alert could be driven directly from one air data computer. The total of four altitude output signals should meet most or all future requirements for baro-corrected altitude information.

A second possible configuration would be as follows.

> Add the second air data computer. Modify both altimeters to add potentiometer outputs for barometric correction setting. Cost would be about 1 thousand dollars each. Each two segment computer would receive uncorrected

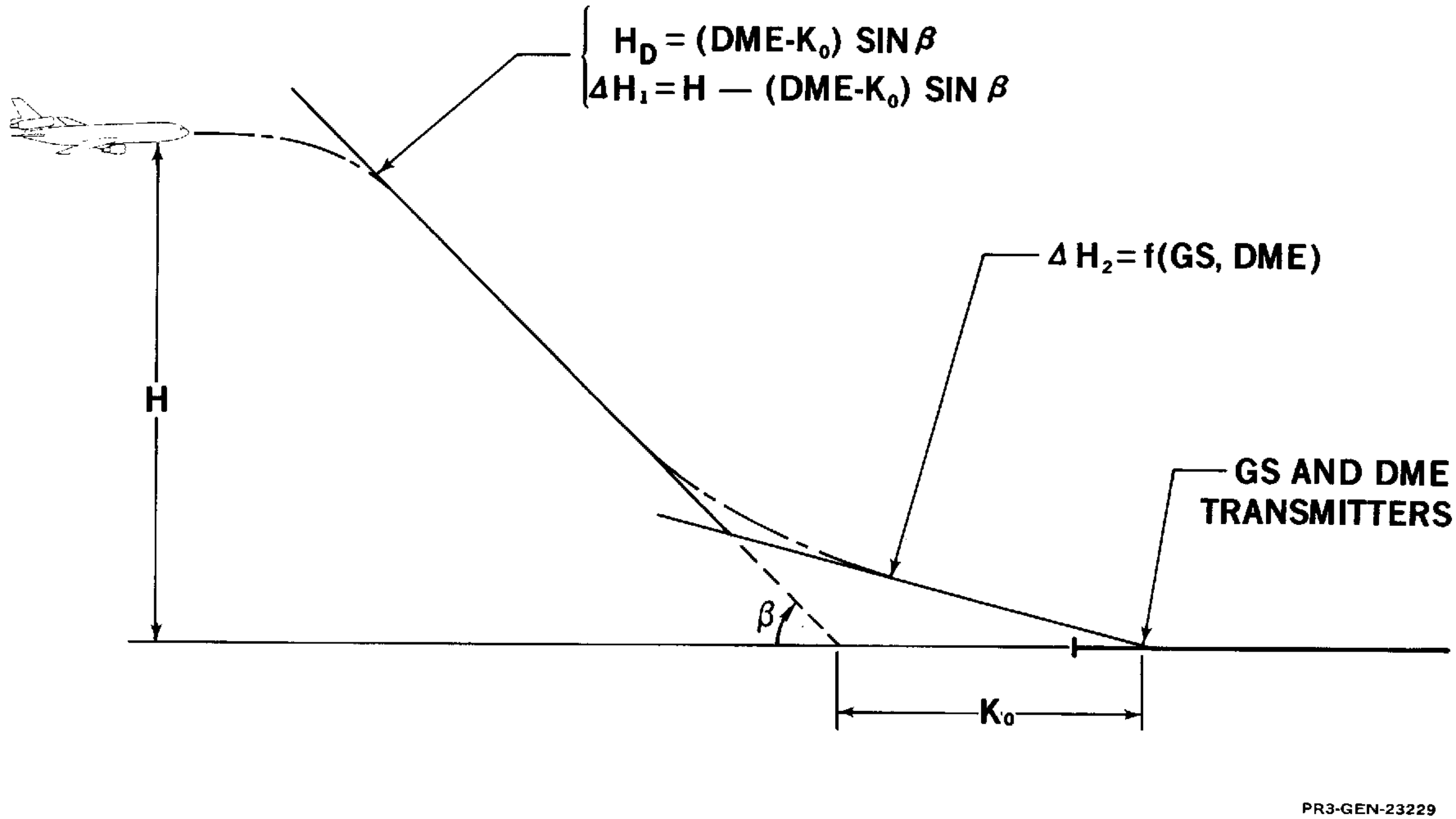


FIGURE 17. TWO-SEGMENT APPROACH GUIDANCE

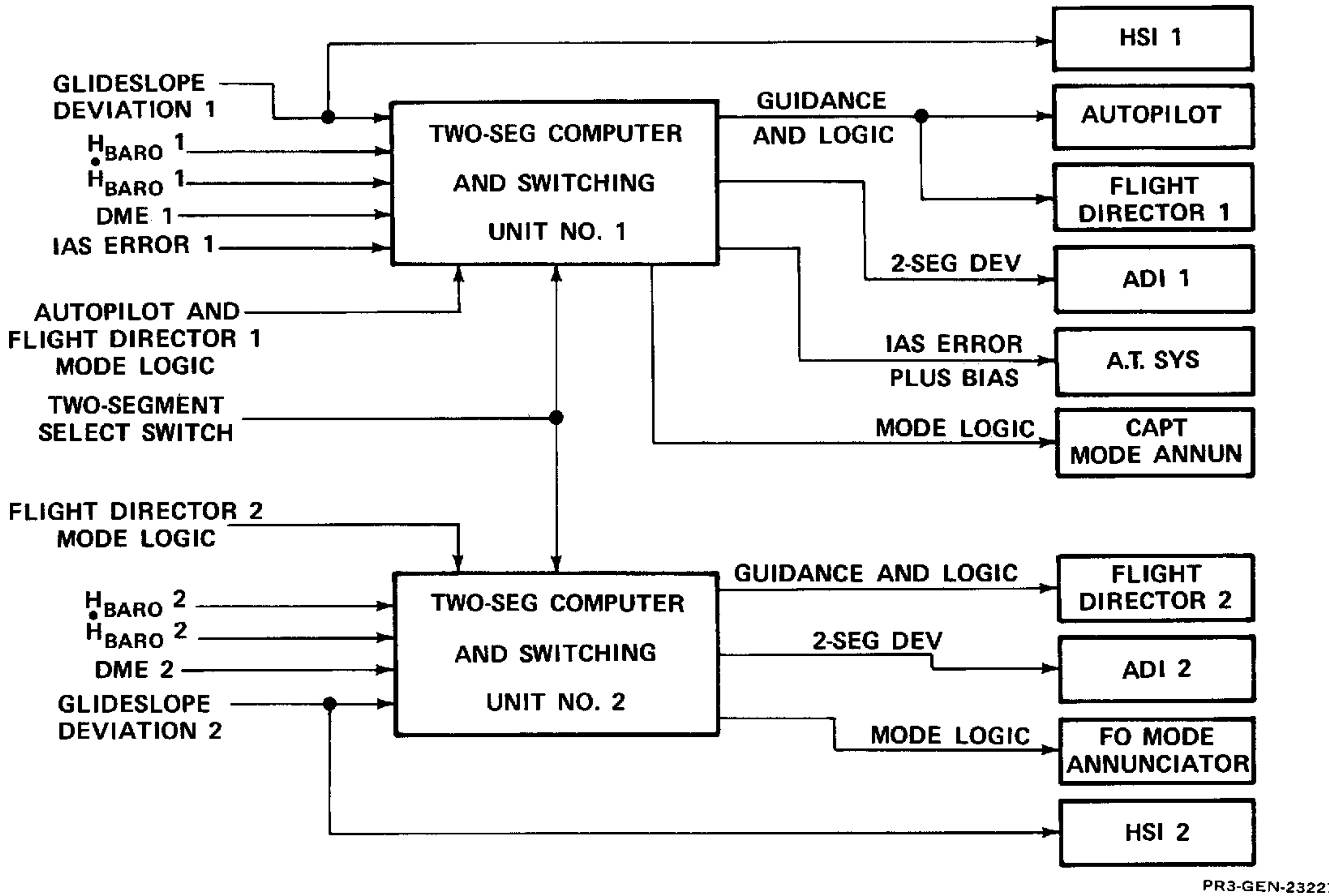
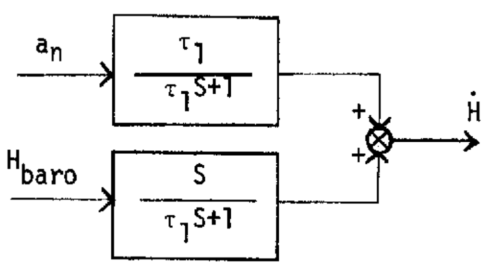


FIGURE 18. TWO-SEGMENT APPROACH SYSTEM

altitude from the air data computer and barometric correction from the altimeter potentiometer. Altitude alert would still be connected directly to one air data computer. This configuration does not provide any spare baro-corrected altitude signals for R-NAV or other uses.

These two air data configurations are illustrated in Fig. 19 with the added components drawn with a dashed line.

In the case of some Series 50 DC-8's, the problem is even more exaggerated, since some of these aircraft do not have any altitude rate signals. In such a situation it may be expedient to limit the required air data signals to dual baro-corrected altitude signals. The need for altitude rate inputs could be avoided by installing a second normal accelerometer and configuring the two segment computer to derive altitude rate from a complementary combination of altitude and normal acceleration (See Fig. 20). This technique which has worked well in a similar (though not identical) application in the DC-10 PAFAM is illustrated below.



$\tau_1 \cong 5$ sec

Assuming $a_n \equiv \ddot{H}$ and $H_{baro} \equiv H$, this filtering produces ideal $\dot{H}$

i.e., $$\frac{\tau_1}{\tau_1 S+1}[S^2H] + \frac{S}{\tau_1 S+1}[H]$$

$$= \frac{S+\tau_1 S^2}{\tau_1 S+1} H = SH \equiv \dot{H}$$

Glide slope signal - not a problem.
Airspeed reference signal for autothrottle - not a problem.

Outputs

Two Segment Deviation Data - Display of two segment data on the ADI and retention of ILS glide slope data on the HSI should present no problem.

Command Guidance Signal - Use of the altitude error signal input to the autopilot as in United's DC-8 installation should be satisfactory for both DC-8's and DC-9's. The pitch authority in altitude hold mode is ±7°. Some differences in the characteristics of the guidance signal that is supplied by the two segment computer will probably be required since the DC-8, unlike the DC-9, uses a lagged normal acceleration term during altitude hold mode to augment the baro-altitude rate. Probably the Two Segment system switching unit should be configured to interrupt the altitude rate input, thereby allowing all "deviation plus rate" terms to be supplied by the Two Segment Computer (with the exception of the lagged normal acceleration term). The normal acceleration signal cannot be interrupted

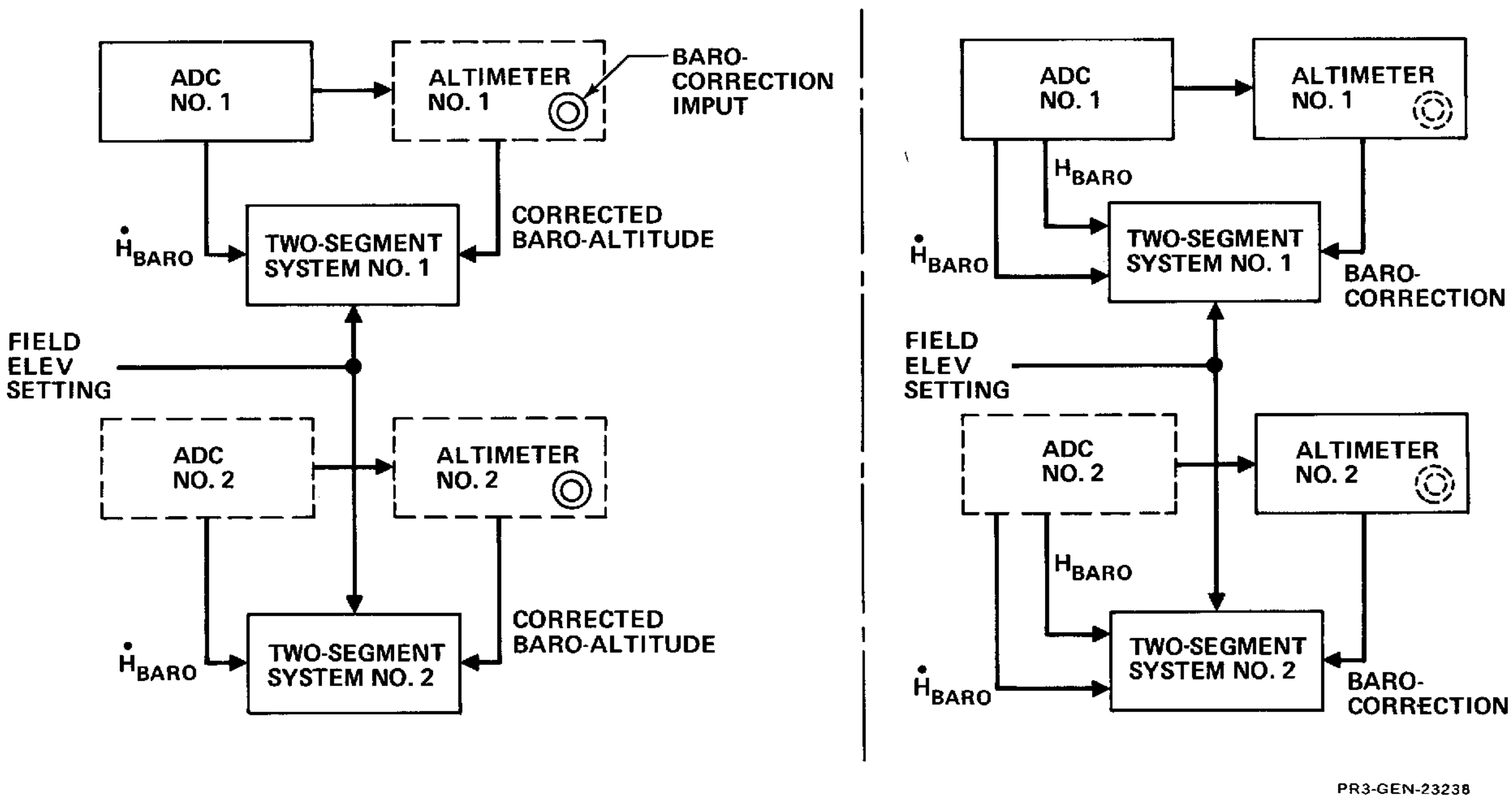


FIGURE 19. AIR DATA CONFIGURATIONS

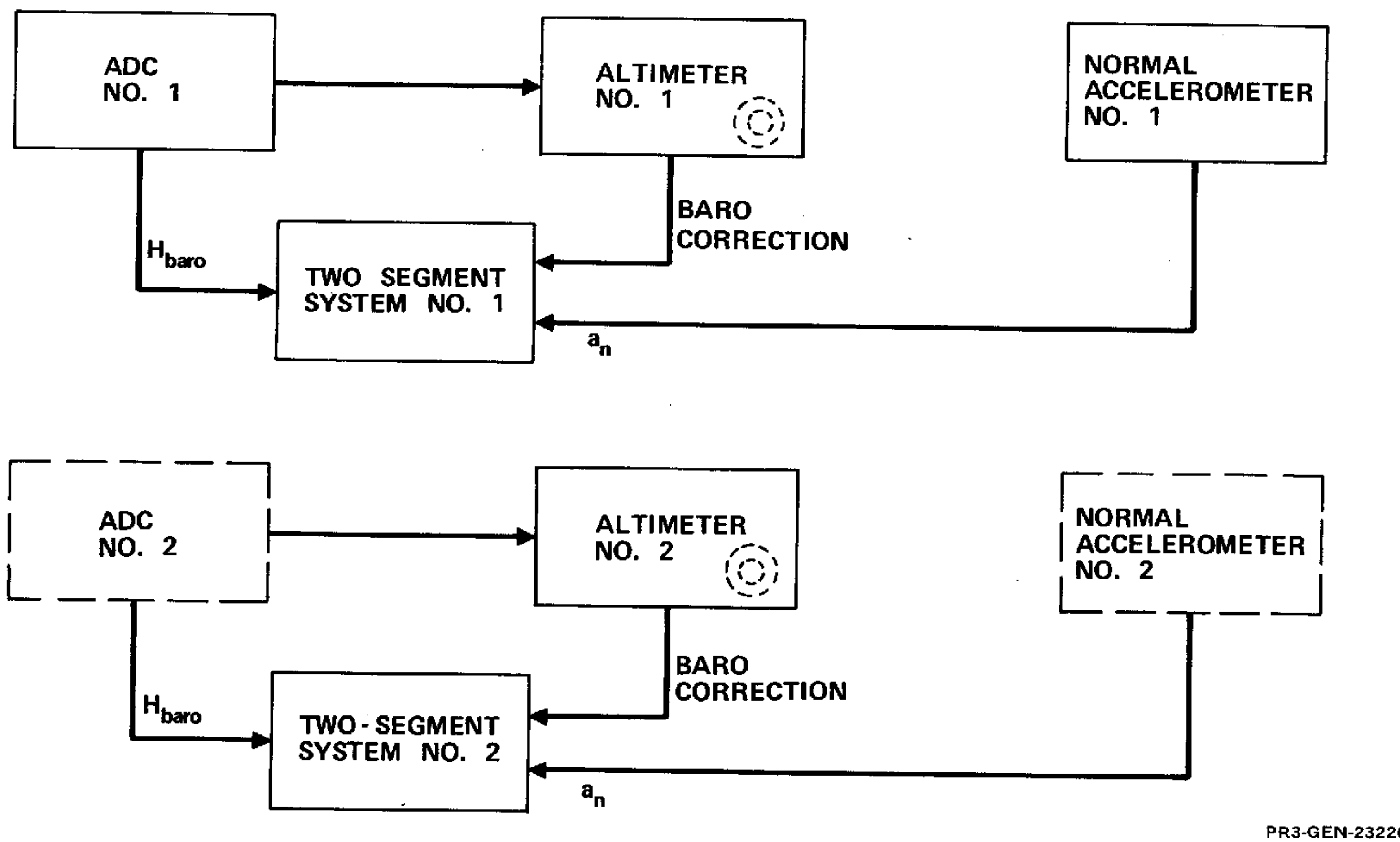


FIGURE 20. ALTERNATE AIR DATA CONFIGURATION FOR APPLICABLE SERIES 50 DC-8'S

externally since this signal is required (in conjunction with a forward-mounted accelerometer) for derivation of pitch rate.

In any event, if United's DC-8 flight testing confirms that satisfactory control is achieved in this manner, there is no reason to think that similarly satisfactory results could not be achieved on DC-9 as well.

Autothrottle Speed Bias - Interfacing the Two Segment Computer with the autothrottle system should not present a problem; however, it is expected that the aft limit switch on the throttle quadrant would have to be bypassed to permit the necessary thrust reduction. There may be some reservation among operations personnel or regulatory agencies aginst allowing this much retard authority.

Mode Annunciation - Addition of the necessary annunciations should not present a significant problem since existing annunciations are minimal and are individually driven.

Interlocks - Autopilot engage lever interlock and flight director flag circuit are accessible for routing through the two segment switching unit.

Logic Switching - Altitude hold select logic can be routed through the Two Segment switching unit to allow this line to be triggered when the Two Segment maneuver is begun, thereby activating the appropriate signal paths in the pitch computer. Since altitude hold mode is not annunciated, no action is required to prevent erroneous mode displays.

Two Segment Approach System for DC-10 Retrofit

Appendix B contains a preliminary specification which was used as a guide in evaluating the applicable systems. The system defined for DC-10 retrofit differs from that discussed for the DC-8 and DC-9 in that control on the ILS Glide Slope is to be provided by the existing autopilot. This change is felt to be necessary in order to allow the automatic flare to be initiated and properly accomplished by the existing autopilot when operating in the LAND mode. Also to delay transfer of control any further would require a fail-operational two segment system. The following paragraphs address the interface aspects individually.

Input Signals

DME-Dual DME installation is standard and conforms to ARINC 521D or 568-3. The former provides an A-C analog signal output and the latter provides a pulse-pair format. Again it would be advantageous in all cases to use the ARINC 568 units to obtain the improved accuracy.

Air Data - Dual central air data computers are standard providing both the needed altitude rate signal and corrected altitude.

G-S Receivers - Dual high level sources are available.

Airspeed Reference Signal - Since the speed command and autothrottle functions are contained in a single unit, the speed reference signal which drives the autothrottle is not directly accessible. However, "selected IAS" signal from the control panel is accessible and should serve the same purpose.

Outputs

Two Segment Deviation Data - Display of data on the HSI and ADI should present no problem.

Command Guidance Signal - Guidance for the upper segment and for transition to the lower segment (ILS glide slope) can be provided by the add-on Two Segment Computer via the IAS error input to the autopilot/flight director computer. Pitch authority in this mode is only 2.5°. However, the "Two Seg" logic input could be used to modify the time constant of the attitude washout circuit to essentially remove this pitch constraint.

The Two Segment Computer must give control to the GS mode of the pitch computer as early as possible to allow proper transition to the flare. Furthermore, prior to engaging the redundant actuator channels, the autopilot must conduct a preland test.

Note that several problems are involved in the transfer of control.

a. The path damping term in the autopilot during GS control is primarily lagged normal acceleration. Proper use of this signal requires that several time constants (τ = 20 seconds) have elapsed after glide slope capture to allow the steady state sink rate term to wash out. This problem can probably be solved by interrupting the normal acceleration signal input during the lower transition and reapplying this signal at a time when glide slope rate is zero.

b. The IAS hold mode of operation employs a forward loop integrator term, whereas glide slope track mode in the autopilot does not. During glide slope track mode, a feedback path around the integrator is closed allowing the integrator to slowly synchronize. The transfer from IAS mode to glide slope track mode could result in upsetting the aircraft (with respect to beam center) if the integrator had acquired a significant value during the upper segment control. A possible solution is to modify the pitch computer such that a logic signal from the two segment computer could be used to close the integrator feedback path during the two segment mode.

c. The switching involved in re-transfer of control must be carefully devised. Any switching that involves a single channel per autopilot should be simple enough since a failure of this switch would be picked up by the autopilot channel comparison monitors. However, switching common to both channels (such as normal acceleration signal switching) would have to be designed with some sort of positive check. This would probably take the form of an added step in the preland test.

Annunciation means and mode logic - Mode annunciation in the DC-10 is accomplished by the flight mode annunciators (FMA) which are projection devices. To add new legends requires a change to the "tapes" in the FMA and also a change to the pitch or roll computer to supply the coded logic necessary to command the new tape position. Each FMA contains four "windows" to display the selected legends. The first window is assigned to annunciate "arm" logic, the second window annunciates the current pitch mode, the third window annunciates the current roll mode, and the fourth window annunciates the current autothrottle/speed command mode.

The new mode annunciation requirements consist of two new legends in the "arm window" (Two Seg/ILS and Two Seg/Land) and a new legend for the "pitch window" (upr seg cap). Details of the modification required to achieve this annunciation change, as well as the other logic changes mentioned below, are described in detail with corresponding diagrams in Appendix C.

Re-transfer of control to the pitch computer occurs when the Two Segment Computer triggers the glide slope track logic. The Two Segment computer must contain sufficient logic to generate this transfer signal after the aircraft is well stabilized on the beam and at a time when the glide slope deviation rate term approaches zero.

When the glide slope track logic is issued the pitch computer initiates its preland test (PLT). At completion of the PLT, the flare and align functions are enabled and all actuators are engaged. Presently the preland test requires about 30 seconds to conduct. Since the PLT would not be initiated until the aircraft was at an altitude of 400-500 feet, 30 seconds would probably be too long a time to utilize during the two segment approach. This implies a need for further extensive changes to the autopilot.

PAFAM compatibility with the Two Segment Approach - A device called PAFAM (acronym for Performance and Failure Assessment Monitor) is standard equipment on all DC-10's as a part of the CAT III Autoland System. Basically, the PAFAM provides an added level of confidence to the autoland maneuver by independently checking performance levels and registering a warning if necessary. In addition, it also provides an override for automatic disconnect of the autopilot down to an altitude of 115 feet. The two segment approach system would inhibit the PAFAM from beginning to function until the relatively low altitude of 300 - 400 feet. Even so, a modification to PAFAM or signal switching of the radio altimeter signal inputs to PAFAM (replacing the actual signals with a fixed bias) would be required to prevent false annunciation on the PAFAM display prior to completion of the lower segment capture. This switching of altimeter signals is very undesirable because the radio altitude signals are critical to proper operation of the autopilot (and PAFAM) and because this circumstance would in effect defeat part of the PAFAM function; namely the NO TRACK mode warning function.

In light of the numerous problems confronting the task of making the two segment approach compatible with the autopilot LAND mode without massive redesign of the existing avionics, consideration of an alternate scheme may be warranted.

A logical alternative is to configure a system similar to the one considered for the DC-8 and DC-9 in which the Two Segment Computer provides the guidance for both segments and no transfer of control is required. The two segment approach mode would be selectable only in conjunction with the ILS mode and signal interface to the pitch computer could be accommodated via the IAS error input path. Modification to existing avionics would be limited to a change to the FMA and to the pitch computer. The change in the pitch computer would consist of the addition of three relays driven by logic generated in the Two Segment Computer to control the new FMA legends and select a shorter time constant for the pitch washout circuit. Modification to the FMA would consist of adding the following legends.

Arm Window - Two Seg

Pitch Window - UPR Seg Cap

Appendix C contains applicable logic diagrams and a more complete description of these changes.

CONCLUSIONS

The DC-8 airplanes are compatible with a two segment approach procedure using approximately 5.5° upper segment slope when landing with flaps fully extended. The DC-8 is not suitable for a two segment approach procedure with a lower landing flap or if operating in icing conditions.

The DC-9 is suitable for two segment approach procedures when landing with the certified landing flap setting. It would also be suitable with a reduced flap landing except that the Series 10 would be limited to approximately 5° on the upper segment. A two segment approach procedure is not recommended for the DC-9 in icing conditions.

The DC-10 is compatible with two segment approach procedures in the full flap landing configuration. Glide slope capability would be marginal for the 35° flap configuration, however. Icing conditions do not affect the glide slope capability on the DC-10.

An examination of the aircraft systems revealed the following:

DC-8 and DC-9

Both aircraft types in all applicable series represent a similar problem and a retrofit system for these aircraft will vary only in details of the interface.

Basically, no change to the autopilot or flight director should be required to adapt a Collins (or equivalent) Two Segment Approach system to these aircraft. It would appear that the only significant problem area is in supplying dual, baro-corrected altitude signals and dual baro-altitude rate signals for a dual, CAT II certificable Two Segment Approach system. In most configurations, only a single air data computer is provided, with the altitude display for the First Officer being provided by a pneumatic uncorrected altimeter which in most cases cannot provide an electrical output.

DC-10

Existing avionics on the DC-10 can provide all necessary signals for a dual installation; however, two new problems are presented by this aircraft.

First is the relatively minor problem of approach progress (mode) annunication. The DC-10 contains dual integrated autopilot/flight director systems including a common mode annunciation means. The mode annunciation is accomplished by the flight mode annunciators (FMA) which are projection devices that can display up to 30 different legends in each of four different windows. However, to change or add new legends requires not only a change to the FMA, but also a change to the pitch computer and/or roll computer which supply the "Gray coded" logic to select a given legend.

The second and far more complex problem is that of configuring the two segment system in such a way as to be compatible with the autopilot "LAND" mode, There are at least three aspects to this problem which require careful attention.

1. The transfer of control from the two segment system to the autopilot at some point on the final approach to allow the flare maneuver to be accomplished.

2. Compatibility of the two segment system with autopilot preland test and autopilot fault monitoring schemes.

3. Compatibility of the two segment approach system with the DC-10 Performance and Failure Assessment Monitor (PAFAM).

These problems are elaborated elsewhere in the report and a possible method of providing a LAND mode compatible two segment system is discussed. In view of the potential difficulties and expense involved in mechanizing such a system an alternate configuration has been defined for consideration. This alternate system will permit two segment approaches to be flown as long as the autopilot LAND mode is not used. The only equipment modification involved in such a configuration is a change to the FMA and pitch computer to provide the necessary mode annunciation.

One other problem that applies to the DC-10 regardless of the mechanization is that of compatibility with the ground proximity warning system. Present thresholds appears to be beyond the range of two segment approach sink rates; however, changes presently being proposed would reduce the threshold to a level within the range of sink rates existing on the upper slope. This subject is discussed more fully in Appendix B.

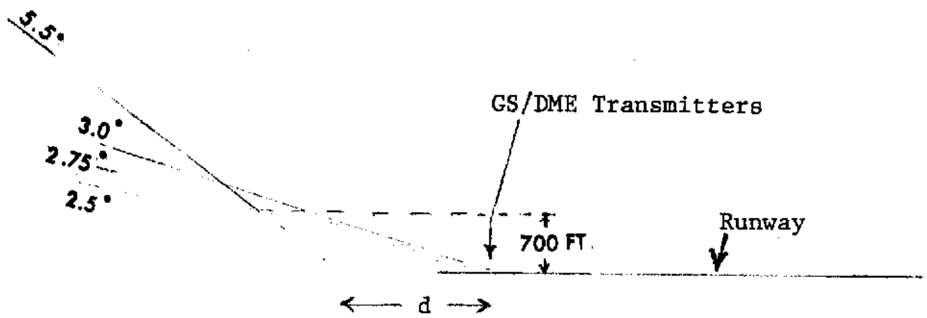
In summary, the conclusion is that no modification to the autopilots will be required on DC-8's or DC-9's. However, installation of a second air data computer will be required on most of these aircraft at an estimated cost of 20 - 30 thousand dollars.

A change in the air data system does involve recertification. However, this can easily be handled by the airline and the cost associated therewith should be considerably less than the cost of the equipment. The effort involved consists of submitting the necessary data to the FAA and conducting a demonstration flight.

For the DC-10, a two segment system can be adapted with only minimal autopilot changes providing that two segment approaches are not required to be flown in conjunction with autoland. Cost of the noted changes is estimated to be 5 thousand dollars. Recertification of the modified equipment will be required. Most likely this would be a simple ground test to show that the proper annunciations appear.

APPENDIX A

SENSOR ACCURACY REQUIREMENTS



To arrive at a crude estimate of sensor accuracy required for two segment approach work, the following rationale is applied.

Based on reports from the 727 flight program the nominal intersect altitude of the upper and lower segments is assumed to be ≅ 700 feet. Furthermore, it is assumed that GS stabilization can be achieved by the time the aircraft is at an altitude approximately 100 feet lower than the intersect altitude. Defining the minimum altitude for achieving GS stabilization as 400 feet sets the minimum acceptable intersect altitude at 500 feet and defines a tolerance of not more than 200 feet of altitude for sensor errors and glide slope angle variations. If the value, d, used to bias the DME signal in the two segment computer, is adjusted to define a 700 ft. intersect altitude for a nominal GS beam angle of 2.75°, the intersect altitude when landing at an airport with a 2.5 degree angle will be 583 feet.

This leaves only 83 feet tolerance for the combination of altitude and DME sensors. The best DME receivers are estimated to provide an accuracy of 0.1 nm = 608 feet. For the 2.5° GS angle, a 608 ft. error in range is equivalent to an altitude change of 608 x .0436 = 26 feet. This leaves a margin of 57 feet for the altitude source. If the less accurate DME unit is used (0.2 nm), the tolerance assignable to the altimeter system becomes only 30 feet.

A 60 feet tolerance on the baro-altitude reading is probably realizable, but the 30 feet number is not. This tolerance would include not only altimeter equipment, but also ground personnel reporting of the baro set figure.

APPENDIX B

COMMENTS RELATIVE TO THE COMPATIBILITY OF THE TWO SEGMENT APPROACH AND THE DC-10 GROUND PROXIMITY WARNING SYSTEM

The sink rate thresholds which are presently incorporated in the proximity warning system appear to be high enough to tolerate the sink rate associated with the two segment approach. However, this system is presently under review with the intent of tightening these thresholds. The proposed thresholds would be low enough to trigger an alarm in some cases during the final portion of the upper segment. This is evident from inspection of the data tabulated below.

Max. DC-10 upper segment sink rate: 32 fps

[Series 30, 400,000 lbs G.W., $\delta_f = 35°$, 10 kt. tailwind, IAS = $V_{ref} + 20 = 170$ kts]

Proximity Warning Threshold	Present	50 fps	45 fps	38 fps
	Proposed	28-38 fps	25-34 fps	23-32 fps
Altitude		900 ft	700 ft	500 ft

Although the 32 fps number quoted for upper segment sink rate is an extreme case, it is entirely possible that this level could exist momentarily in other cases due to maneuvering or sensor noise.

APPENDIX C

DC-10 FLIGHT GUIDANCE SYSTEM (FGS) LOGIC MODIFICATIONS

The following description and associated figures relate to a modification to the autopilot logic which permits proper mode switching and mode annunciation during a two-segment approach terminated by an automatic landing. Required switching in the signal circuits and modifications to the preland test sequence are not addressed here.

Figure C1 shows the new relays which are required to be added to the pitch and roll computers. The wiring of the contacts (those that relate to "logic" circuits) of these relays is shown in Figures C3, C4, and C5.

ARM Sequence:

Either the LAND pushbutton or the ILS pushbutton may be depressed and the two-segment switch actuated, resulting in either a 2 SEG-LAND or 2 SEG-ILS arm annunciation respectively.

i. If the LAND button is depressed, an arm code of 01011 (see Figure C2) is generated to cause the FMA to display a 2 SEG-LAND in the "arm" window. Figure C-3 shows the "2 SEG" contact driving the "B" bit to change the normal LAND arm annunciation code of 00011 to the 2 SEG LAND code of 01011.

ii. If the ILS button is pushed, an arm code of 01111 is produced to cause the FMA to read 2 SEG-ILS in the arm window. The code for ILS is 01110. Figure C-3 shows the 2 SEG relay contacts driving the "E" bit to produce the last 1 digit in the code 01111.

iii. In either case, the pitch computer may be operating in any normal mode such as ALT HOLD at the same time it is armed for the two-segment approach. The 2 SEG relay in the pitch computer also prevents the autopilot GS Eng relay from being activated as shown in Figure C-4.

Upper Segment Capture:

i. The UPR SEG CAP logic is sent to the pitch computer resulting in UPR SEG CAP annunciation in the pitch mode window of the FMA. The code for UPR SEG CAP is 10011 as shown in Figure C2. Figure C-5 shows the contact closures forcing this annunciation, no matter what the pitch computer mode is.

ii. The UPR SEG CAP logic is also sent to the pitch computer IAS pushbutton input J3B-77, putting the pitch computer into IAS hold mode to allow processing of the two segment guidance command via the IAS error input path.

GS Capture and Transfer of Control:

i. The LWR SEG CAP logic is sent to the pitch computer, forcing the pitch annunciation to read GS CAP with a code of 00011 (Fig. C-5).

ii. After completion of GS capture the two segment computer returns control to the autopilot by energizing the GS Eng-1 relay. As shown in Figure C-4, closing the GS Eng-1 contacts energizes the GS Eng and GS TRK relays, which are then latched in the energized state. This action effectively bypasses the 20 second delay normally required between GS Eng and GS TRK. Note in Figure C1 that the GS Eng logic of the autopilot resets all relays driven by logic from the two-segment computer.

The remaining paragraphs and associated figures relate to the alternate configuration which does not permit autolanding in conjunction with a two segment approach. As shown in Figure C6, no modifications is required to the roll computer and one less relay is required to be added to the pitch computer.

ARM Sequence:

The ILS pushbutton is depressed and the two segment switch actuated. At this time the two segment computer sends the 2 SEG logic signal to the pitch computer, resulting in a 2 SEG annunciation in the ARM window of the FMA. Figure C-8 shows the 2 SEG contact driving the "E" bit to produce the 2 SEG code of 01111 (see Figure C7). Without this last "1" the code 01110 would produce the arm legend ILS.

At this time the pitch computer may be operating in any normal mode such as altitude hold.

Upper Segment Capture:

The UPR SEG CAP logic signal is sent to the pitch computer IAS Pushbutton input J3B-77, putting the computer into IAS HOLD.

The 2 SEG relay contacts of figure C-9 prevent the GS Eng relay from being energized. The UPR SEG CAP logic also causes the legend UPR SEG CAP to be annunciated in the pitch window of the FMA. Figure C-5 shows the contact closures changing the annunciator code from 10010 to the UPR SEG CAP code of 10011.

Lower Segment Capture:

When the lower segment (GS) capture begins, the LWR SEG CAP logic is sent to the pitch computer to produce a GS CAP annunciation. Figure C-5 shows the LWR SEG CAP contact forcing the pitch mode annunciator code from 10011 to 00011 (GS CAP).

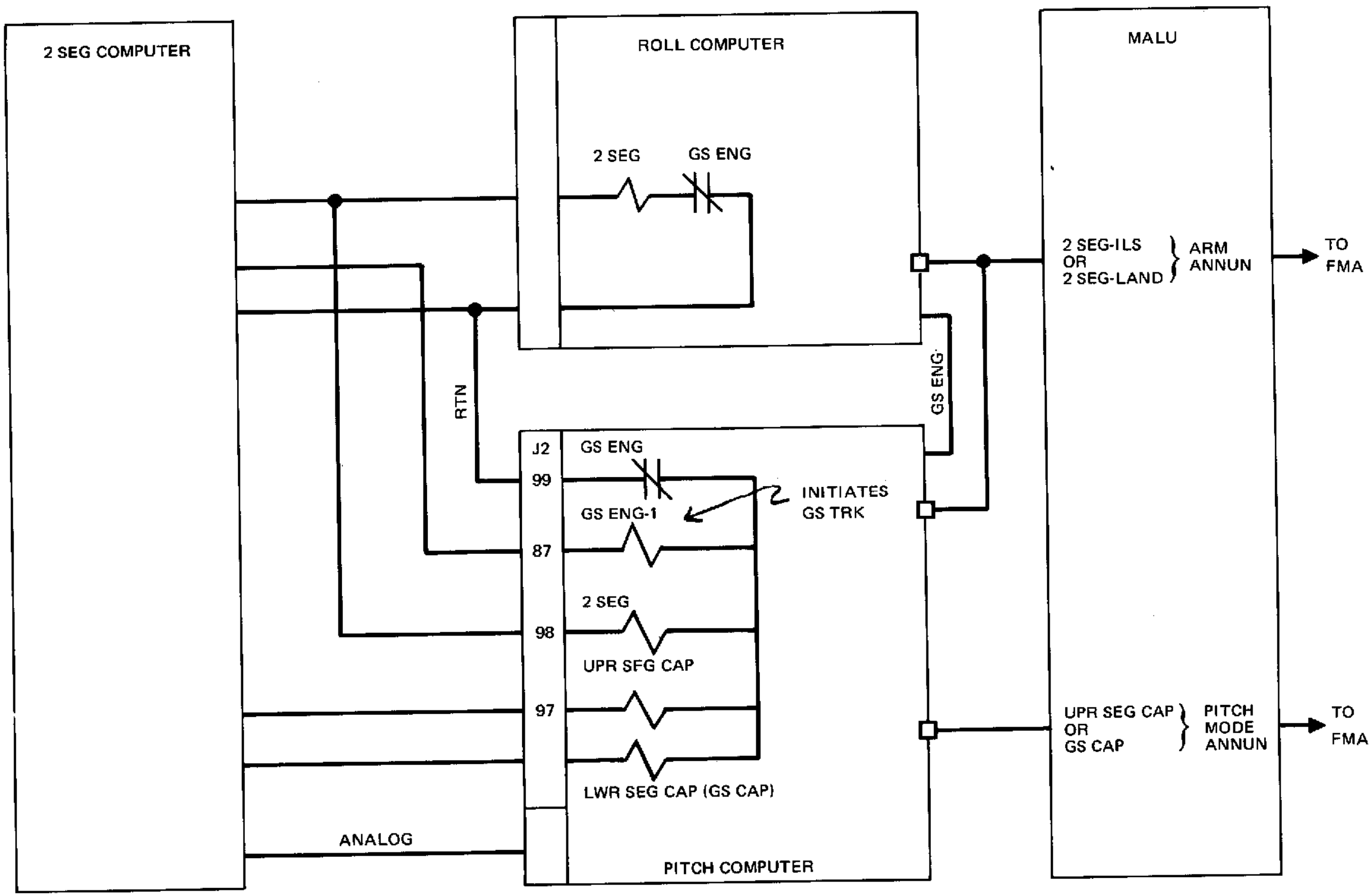


FIGURE C-1. RELAY CONFIGURATION FOR LAND MODE COMPATIBLE SYSTEM

GRAY CODE SEQUENCE							
A	B	C	D	E	ARM	ROLL	PITCH
0	0	0	0	1	DUAL LAND	ROLLOUT	FLARE
0	0	0	1	1	LAND		G/S CAP
0	0	0	1	0	SNGL LAND	ALIGN	G/A
0	0	1	1	0	B/CRS	VOR CRS	
0	0	1	1	1	E	S	T
0	0	1	0	1		TAKEOFF	
0	0	1	0	0	LOC	G/A	TAKEOFF
0	1	1	0	0	INS	CWS G/A	ALT CAP
0	1	1	1	1	2 SEG-ILS	B/CRS TRK	
0	1	1	1	0	ILS	B/CRS CAP	
0	1	0	1	0	APP ONLY	LOC-CAP	CWS G/A
0	1	0	1	1	2 SEG-LAND	LOC-TRK	G/S TRK
0	1	0	0	0	VOR	CWS	CWS
1	1	0	0	0	VOR-ALT	HDG HOLD	VERT SPD
1	1	0	0	1		CWS H/HLD	
1	1	0	1	1		CWS LOC	
1	1	0	1	0		VOR-CAP	CWS IAS
1	1	1	1	0	ILS-ALT	CWS V/CRS	CWS MACH
1	1	1	0	0	INS-ALT	INS-CAP	ALT HOLD
1	0	1	0	0	LOC-ALT	INS TRK	MACH HOLD
1	0	1	1	0	B/CRS-ALT	CWS INS	
1	0	0	1	0		VOR TRK	IAS HOLD
1	0	0	1	1	LAND-ALT	CWS VOR	UPR SEG CAP
1	0	0	0	1		CWS H/SEL	
1	0	0	0	0	ALT	HDG SEL	TURB

FIGURE C-2. FMA DISPLAY LEGENDS

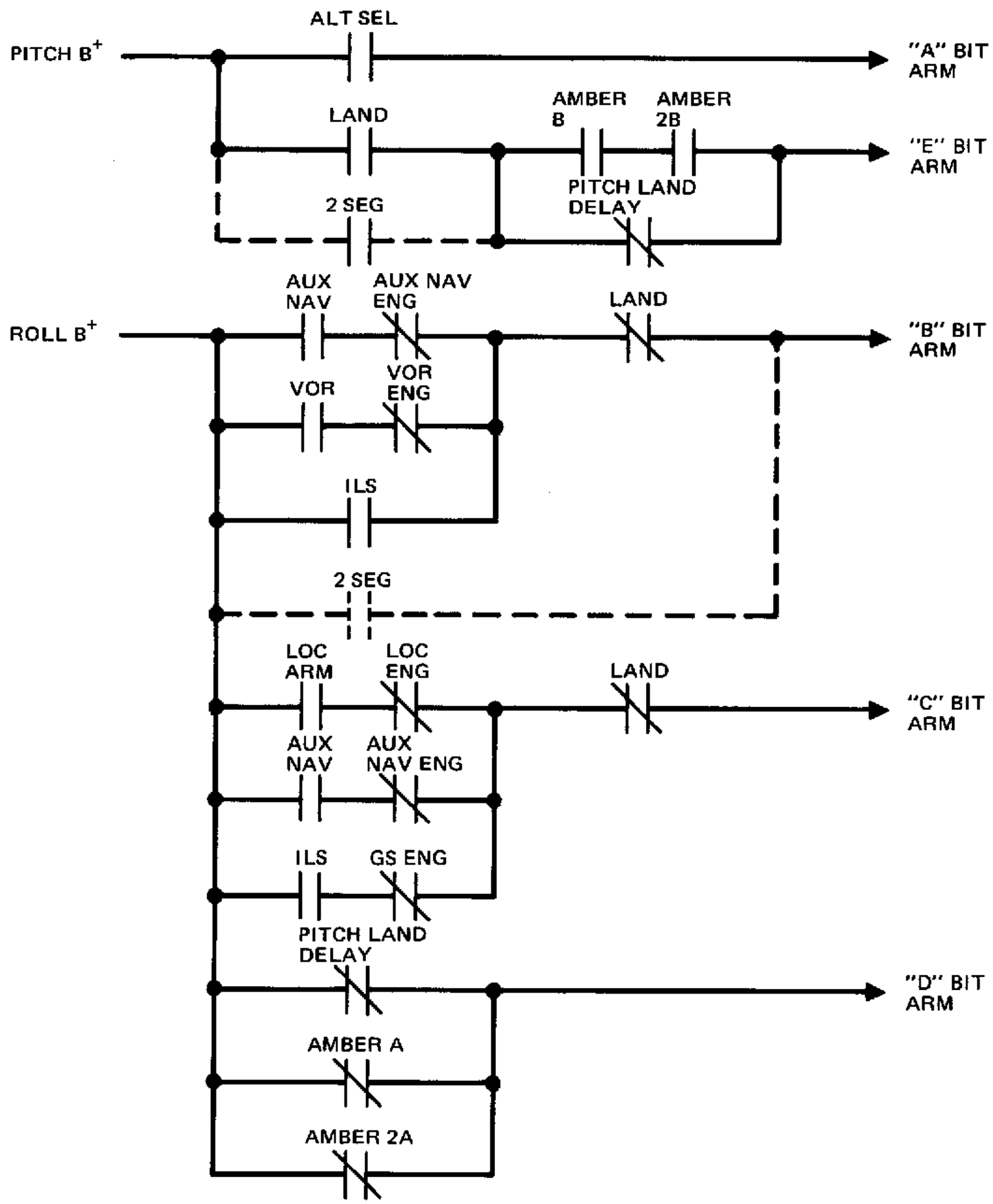


FIGURE C-3. DC-10 FGS ARM MODE ANNUNCIATOR LOGIC

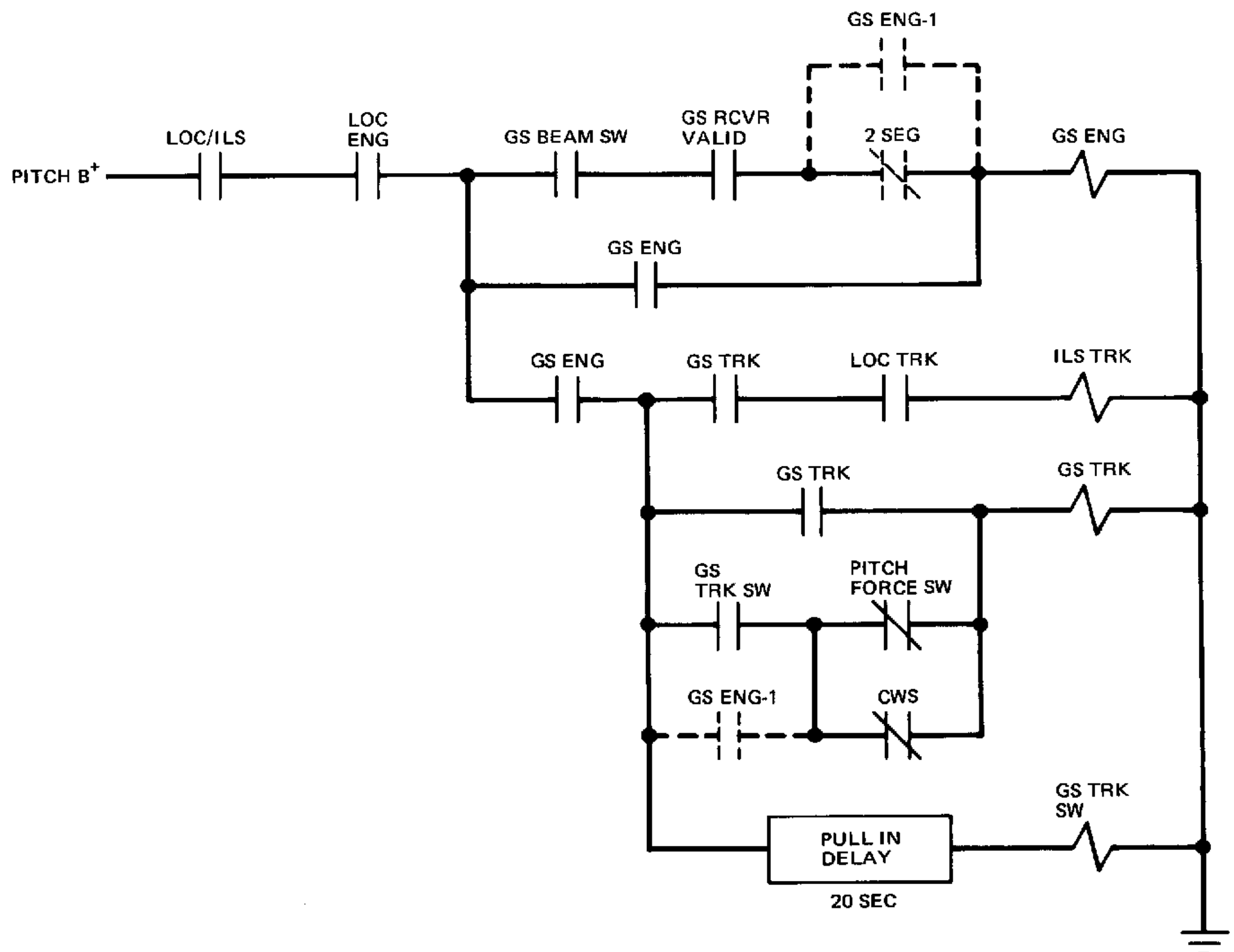


FIGURE C-4. GS MODE RELAYS

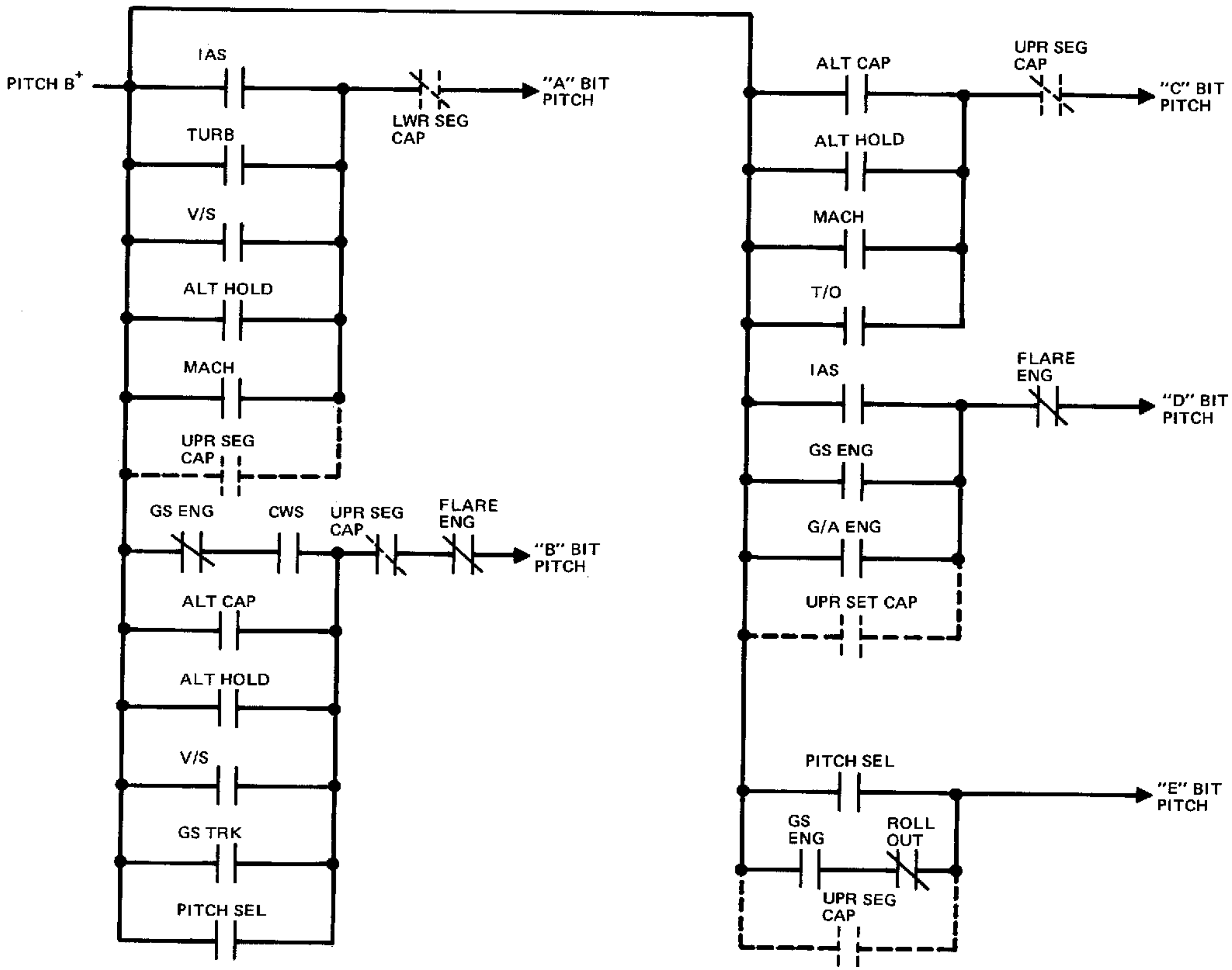


FIGURE C-5. DC-10 FGS PITCH MODE ANNUNCIATION LOGIC

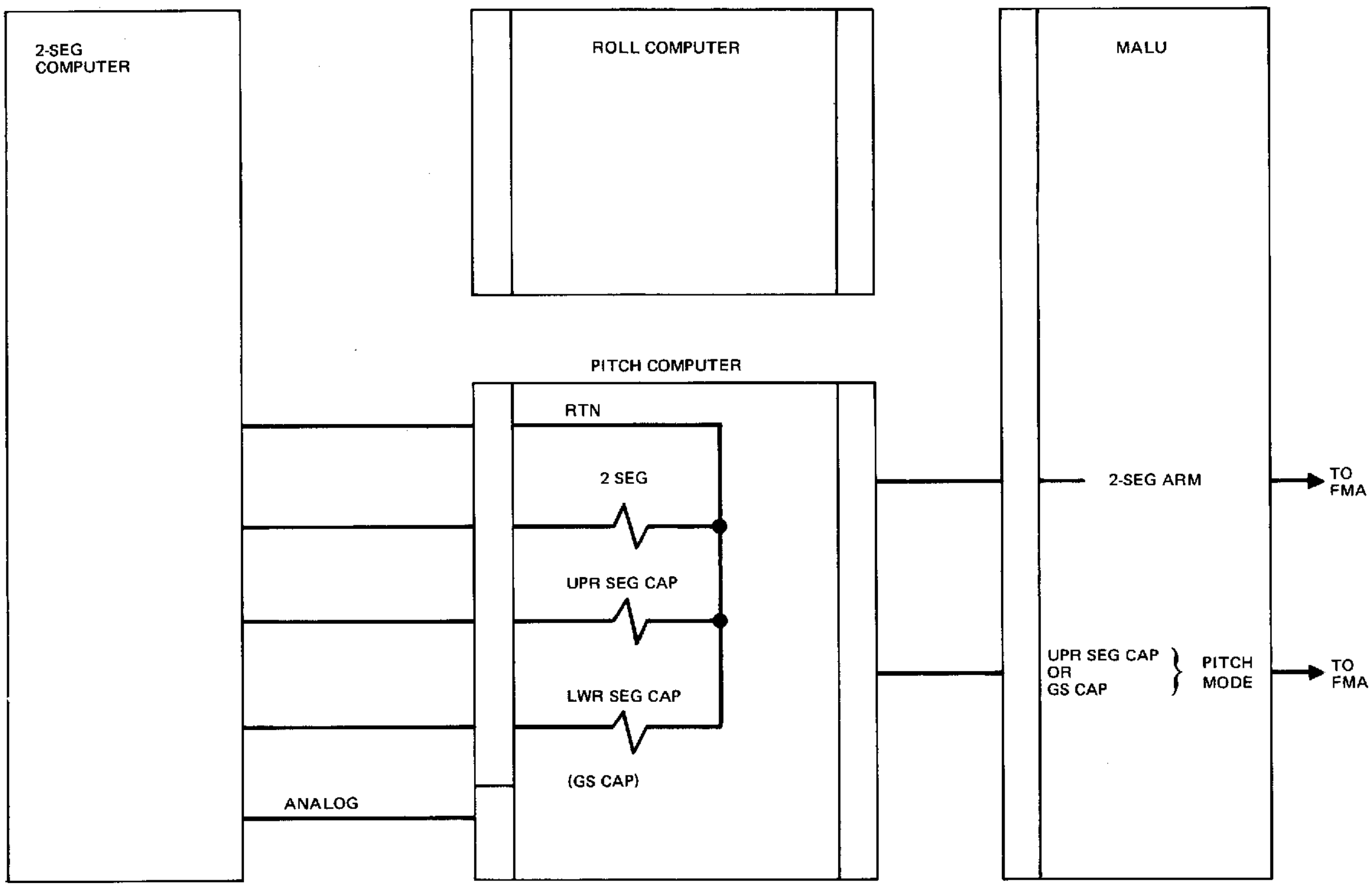


FIGURE C-6. RELAY CONFIGURATION FOR ALTERNATE SYSTEM

GRAY CODE SEQUENCE							
A	B	C	D	E	ARM	ROLL	PITCH
0	0	0	0	1	DUAL LAND	ROLLOUT	FLARE
0	0	0	1	1	LAND		G/S CAP
0	0	0	1	0	SNGL LAND	ALIGN	G/A
0	0	1	1	0	B/CRS	VOR CRS	
0	0	1	1	1	E	S	T
0	0	1	0	1		TAKEOFF	
0	0	1	0	0	LOC	G/A	TAKEOFF
0	1	1	0	0	INS	CWS G/A	ALT CAP
0	1	1	1	1	2 SEG	B/CRS TRK	
0	1	1	1	0	ILS	B/CRS CAP	
0	1	0	1	0	APP ONLY	LOC-CAP	CWS G/A
0	1	0	1	1		LOC-TRK	G/S TRK
0	1	0	0	0	VOR	CWS	CWS
1	1	0	0	0	VOR-ALT	HDG HOLD	VERT SPD
1	1	0	0	1		CWS H/HLD	
1	1	0	1	1		CWS LOC	
1	1	0	1	0		VOR-CAP	CWS IAS
1	1	1	1	0	ILS-ALT	CWS V/CRS	CWS MACH
1	1	1	0	0	INS-ALT	INS-CAP	ALT HOLD
1	0	1	0	0	LOC-ALT	INS TRK	MACH HOLD
1	0	1	1	0	B/CRS-ALT	CWS INS	
1	0	0	1	0		VOR TRK	IAS HOLD
1	0	0	1	1	LAND-ALT	CWS VOR	UPR SEG CAP
1	0	0	0	1		CWS H/SEL	
1	0	0	0	0	ALT	HDG SEL	TURB

FIGURE C-7. FMA DISPLAY LEGENDS

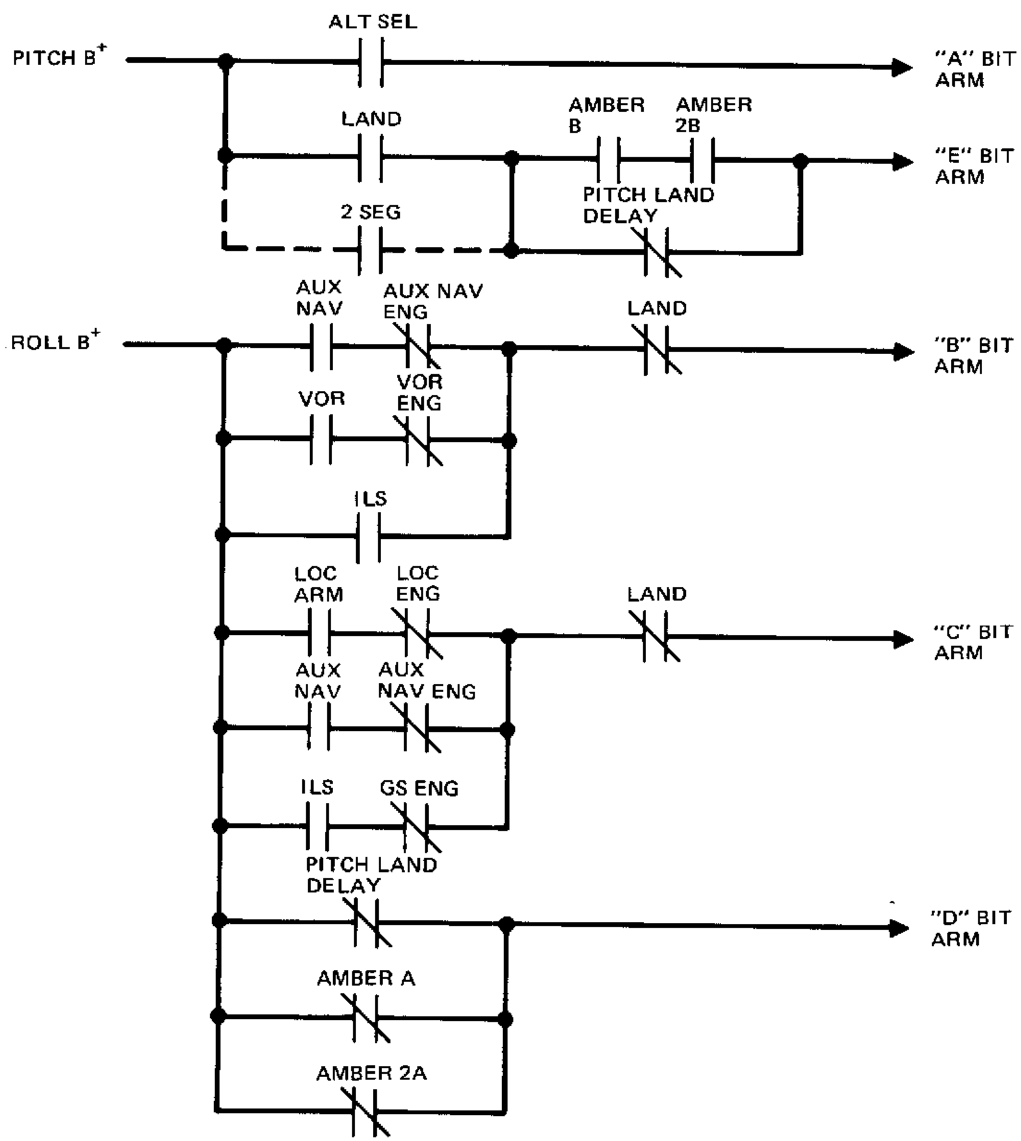


FIGURE C-8. DC-10 FGS ARM MODE ANNUNCIATION LOGIC

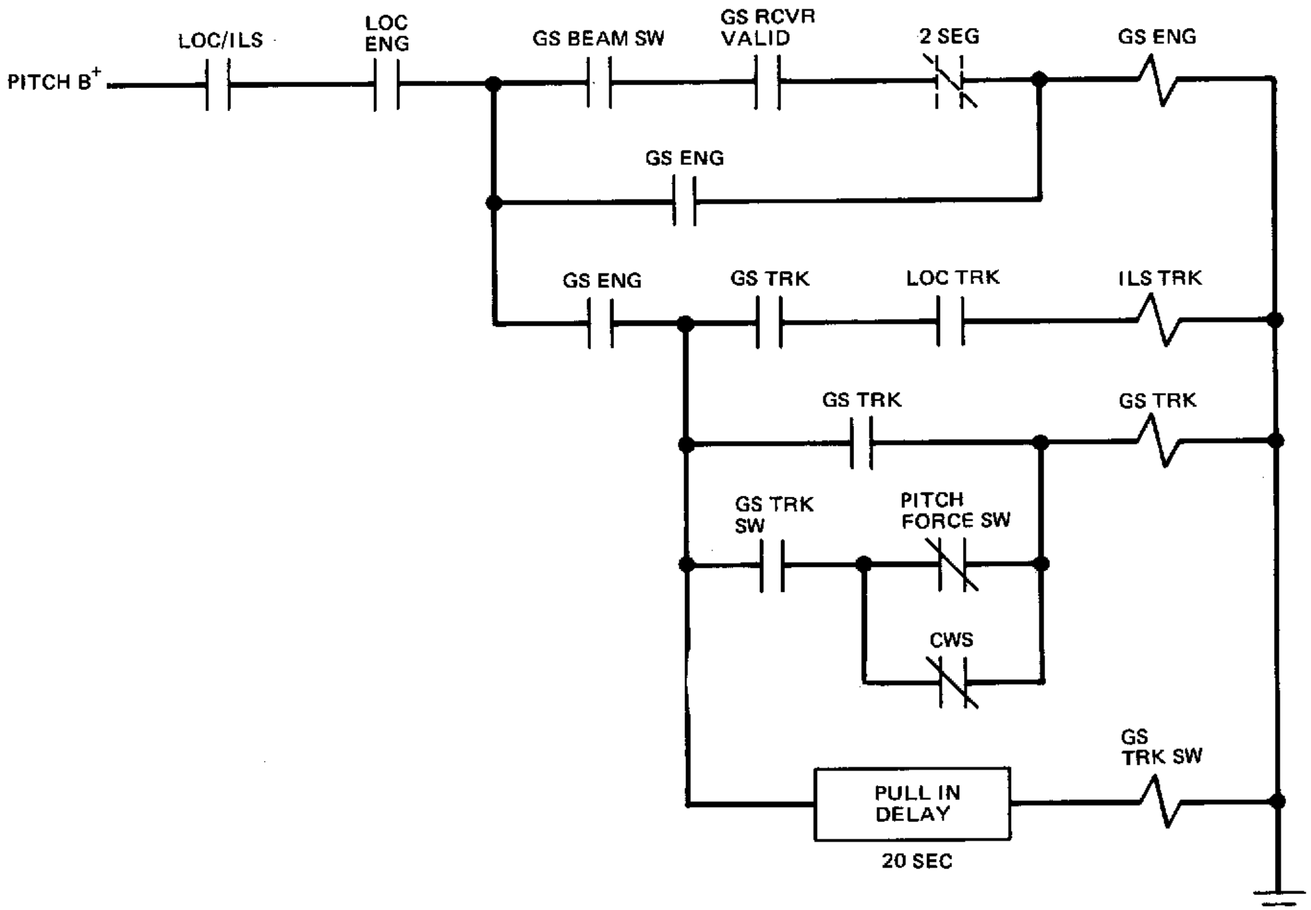


FIGURE C-9. GS MODE RELAYS

APPENDIX D

PRELIMINARY SPEC FOR INTEGRATING THE TWO SEGMENT APPROACH SYSTEM WITH EXISTING AVIONICS IN DC-8'S AND DC-9'S

I. Configuration Outline

A. The two segment approach system shall be a dual system installation to permit certification to CAT II weather minimums. One of the two segment systems will drive both the autopilot and one flight director. The other two segment system will drive the remaining flight director.

B. The two segment approach system shall, where possible, be limited to the following elements:

Two segment computer
Two segment switching unit
Two segment selector switch
Airport Elevation Controller

interfaced with applicable existing avionics.
The functions provided by these four new elements are described below:

1. Two segment computation element will provide:

   a. upper segment deviation
   b. command guidance signal for autopilot (A/P) and Flight Director (F/D) for both segments including capture thereof.
   c. Incremented bias to airspeed reference during upper segment control.

2. Logic Functions:

   a. Means for pilot selection of the two segment approach.
   b. Annunciation logic for
      two segment arm
      upper segment capture
      lower segment capture
   c. Interruption of A/P engage interlock and of F/D flag circuit as necessary.
   d. Necessary logic switching to make A/P and F/D mode and annunciation logic compatible with the two segment approach.

3. Airport Elevation Controller -- will provide means for pilot to input airport elevation data.

C. The four listed components shall (where applicable) be assumed to be sufficiently flexible to accept applicable electrical signal inputs of whatever form available and to provide the applicable electrical outputs of whatever characteristics are required by the existing avionics.

II. INTERFACE REQUIREMENTS

A. General Description

1. Provide necessary sensor input signals.

2. Provide means for mode annunciation.

3. Provide means to display the two segment deviation data.

4. Provide means to insert the command guidance signal into the autopilot and flight director.

5. Provide means to interface the two segment logic functions with existing autopilot and flight director system logic.

B. Signal Interface Requirements

Inputs: (Dual sources required except for No. 5)

1. Provide electrical DME signal. Accuracy required is 0.1 nautical miles.

2. Provide electrical pressure altitude signal and electrical "Baro set" signal or a single signal for corrected pressure altitude. Required accuracy is 60 ft.

3. Provide electrical baro altitude rate signal.

4. Provide G-S deviation signal.

5. Provide airspeed reference signal (in series with autothrottle).

Outputs:

1. Two segment deviation data will be provided by the two segment computer for display on some cockpit instrument. A typical arrangement would be to display this signal on the ADI in place of the normal GS indication.

   NOTE: Display of GS deviation data from the ILS G-S receiver must be retained on some instrument; namely, the HSI.

2. A command guidance signal from the two segment computer will be supplied to the autopilot and flight director for control on both segments, including capture. Ideally, an interface point should be selected so that only the aircraft wiring need be changed to allow the command guidance signal to be inserted into the A/P and F/D. The assumption should be made (unless there are known reasons why this is not feasible) that the command guidance signal provides a "deviation plus rate" signal which can be appropriately scaled to provide satisfactory control (in conjunction with the basic stability loops of the autopilot and flight director) without further modification of the autopilot and

flight director. The signal path selected must not include any limiters that preclude the ability to command pitch changes of $\pm$ 6 degrees from glide slope trim value.

8. The two segment computer will add a bias to the necessary signal to result in a faster reference speed on the upper slope than on the lower slope. For this purpose, the signal must be routed through the two segment computer before being supplied to the autothrottle system.

C. Logic and annunciation interface requirements

1. Provide the following sensor validity logic for inputs to the two segment system:
   GS valid
   DME valid
   Altitude valid (Baro)

2. Provide means to annunciate the two segment system mode logic noted in Paragraph 1B2b. This annunciation means must be properly integrated with normal ILS approach progress annunciation so that no unusual pilot scan procedure is required.

3. Provide means for the autopilot engage interlock and flight director flag circuits to be interrupted by the two segment system.

4. Logic Switching
   Wiring revision is required to allow the two segment system to supply a logic signal to the autopilot and flight director to activate the necessary signal paths to conduct the two segment command signal. Annunciation logic which might normally be outputted in the autopilot and flight director mode selected for two segment operation must be routed through the two segment system to allow it to be interrupted when the two segment mode is selected.

APPENDIX E

PRELIMINARY SPEC FOR INTEGRATING THE TWO SEGMENT APPROACH SYSTEM WITH EXISTING AVIONICS IN THE DC-10

I. CONFIGURATION OUTLINE

A. The two segment approach system shall be a dual system installation designed to be selectable in conjunction with both the "ILS" mode and the "LAND" mode.

B. The two segment approach system shall, if possible, be limited to the following elements:

Two segment Computer
Two segment Switching Unit
Two segment Selector Switch
Airport Elevation Controller

interfaced with applicable existing avionics. The functions provided by these four new elements are described below.

1. Two segment computation element will provide:

    a. Upper segment deviation.

    b. Command guidance signal for autopilot and flight director for capture and tracking of the upper segment and for transition to the lower segment (ILS glide slope).

    c. Incremented bias to airspeed reference during upper segment control.

2. Logic Functions:

    a. Means for pilot selection of the two segment approach.

    b. Annunciation logic for:

        2 seg - LAND (arm)
        2 seg - ILS (arm)
        Upr seg CAP
        GS CAP

    c. Logic to initiate transfer to existing A/P control functions (coincident with GS Track).

    d. Interruption of A/P engage interlock and of F/D flag circuit as necessary.

    e. Necessary logic switching to make the A/P and F/D mode and annunciation logic compatible with the two segment approach.

3. Airport Elevation Controller - will provide means for pilot to input airport elevation data.

C. The four listed components shall (where applicable) be assumed to be sufficiently flexible to accept applicable electrical signal inputs of whatever form available and to provide the applicable electrical outputs of whatever characteristics are required by the existing avionics.

II. INTERFACE REQUIREMENTS

A. General Description

1. Provide necessary sensor input signals.
2. Provide means for mode annunciation.
3. Provide means to display the two segment deviation data.
4. Provide means to insert the command guidance signal into the autopilot and flight director.
5. Provide means to interface the two segment logic functions with existing autopilot and flight director system logic.

B. Signal Interface Requirements

Inputs: (Dual sources required)

1. Provide electrical DME signal. Accuracy required is 0.1 nautical miles.
2. Provide electrical pressure altitude signal and electrical "Baro set" signal or a single signal for corrected pressure altitude. Required accuracy is 60 ft.
3. Provide electrical baro altitude rate signal.
4. Provide G-S deviation signal.
5. Provide airspeed reference signal (in series with autothrottle).

Outputs:

1. Two segment deviation data will be provided by each two segment computer for display on some cockpit instrument. A typical arrangement would be to display this signal on the ADI in place of the normal GS indication.

   NOTE: Display of GS deviation data from the ILS G-S receiver must be retained on some instrument; namely, the HSI.

2. A command guidance signal from the two segment computer will be supplied to the autopilot and flight director for capture and control on the upper segment and transition to the standard ILS glide slope.

The assumption should be made that the command guidance signal provides a "deviation plus rate" signal which can be appropriately scaled to provide satisfactory control (in conjunction with the basic stability loop of the autopilot and flight director) without further guidance computations within the autopilot or flight director. The signal path selected must not include any limiters that preclude the ability to command pitch changes of $\pm$ 6 degrees from GS trim value.

Control of the aircraft will be returned to the existing autopilot control mechanism after the standard ILS glide slope has been captured and the aircraft is well stabilized on the glide slope.

The two segment system will drive a single channel of the engaged autopilot. The switching involved in the transfer of control must be designed so as not to compromise the fail-op and fail-safe characteristics of the LAND mode.

3. The two segment computer will add a bias to the airspeed reference signal used by the autothrottle to result in a faster speed on the upper slope than on the lower slope.

C. Logic and Annunciation Interface Requirements

1. Provide the following sensor validity logic for inputs to the two segment system:

   GS valid
   DME valid
   Altitude valid (Baro)

2. Provide means to annunciate the two segment system logic noted in Paragraph 1B2b. This annunciation means must be properly integrated with normal approach progress annunciation so that no unusual pilot scan procedure is required.

3. Provide means for the autopilot engage interlock and flight director flag circuits to be interrupted by the two segment system.

4. Logic Switching
   Wiring revision is required to allow the two segment system to supply a logic signal to the autopilot and flight director to activate the necessary signal paths to conduct the two segment command signal.

   Annunciation which might normally be provided by the autopilot and flight director in the mode selected for two segment operation must be circumvented when the two segment mode is selected.

   Logic switching is required to allow re-transfer of control to the existing autopilot after G-S stabilization. This switching shall include allowance to initiate the pitch axis Preland Test (PLT).