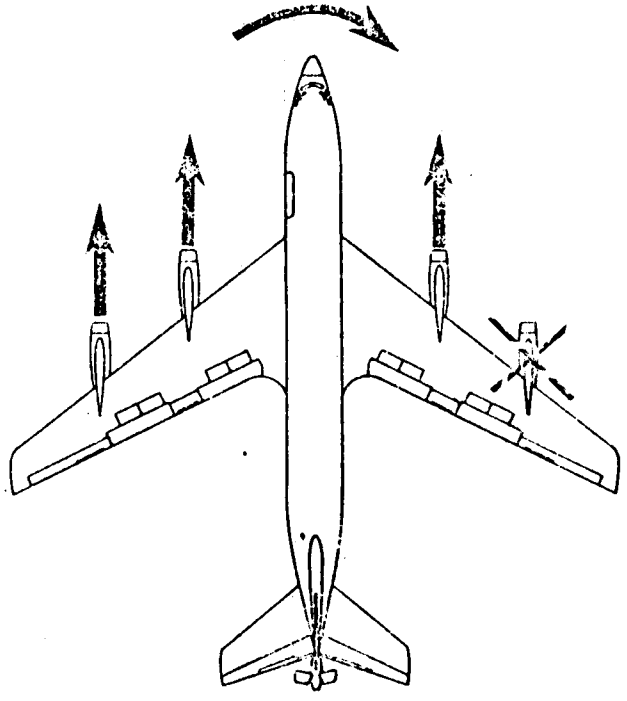
C/KC-135 ASYMMETRIC FLIGHT CHARACTERISTICS



Boeing Military Airplane Company
Wichita, Kansas 67210
D500-10348-1

BP/7570/WL - DISK 1/A1

ASYMMETRIC FLIGHT FACTORS

ENGINE

- o Engine Failure
- o Differential Thrust (split throttles or engine instrument malfunctions)
- o Throttles Missed During Emergency Go-Around or Refused Takeoff

AUTO-PILOT MALFUNCTIONS

FLIGHT CONTROL MALFUNCTIONS

- o Unscheduled Rudder Movement
- o Differential Spoilers (split or spoiler float condition)
- o Jammed or Inoperative Aileron
- o Asymmetric Flap Configuration
  - Fillet flap failure
  - Jammed cove flap
  - Leading edge flap failure

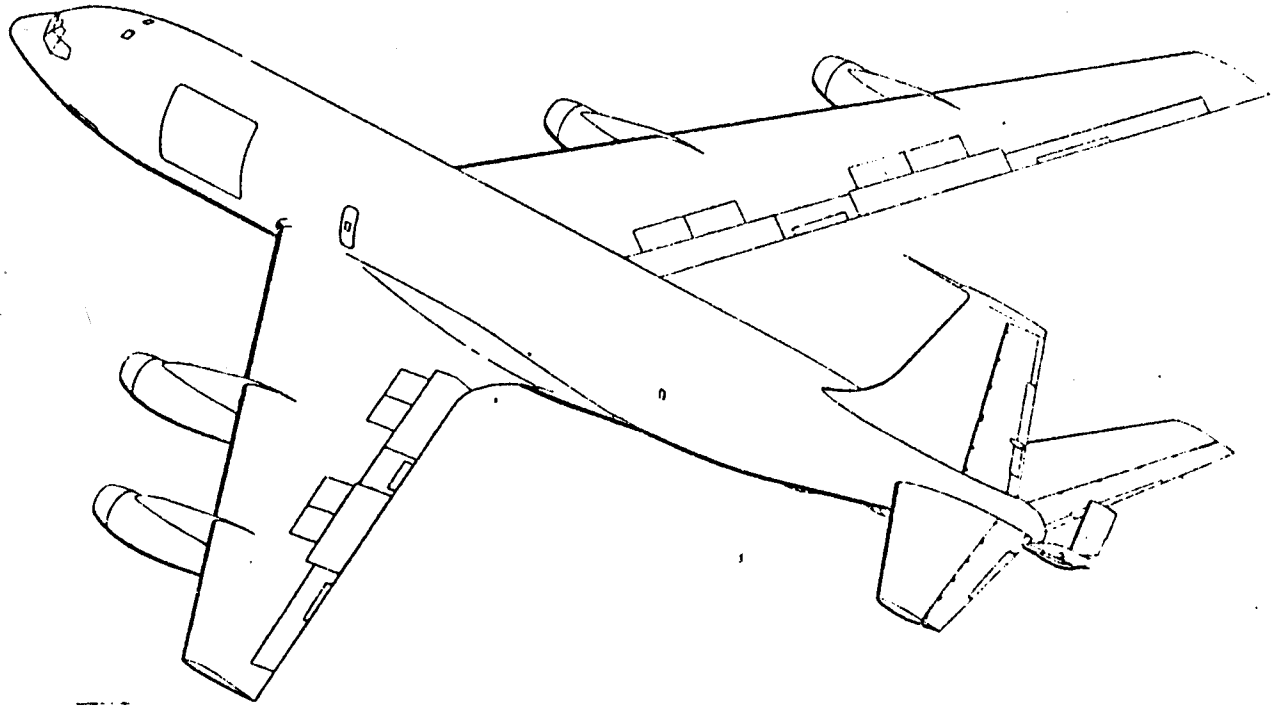
FUEL DISTRIBUTION OR LOADING

- o Lateral Fuel Unbalance
- o Fuel Quantity Gage Errors
- o Incorrect Fuel Panel Setting

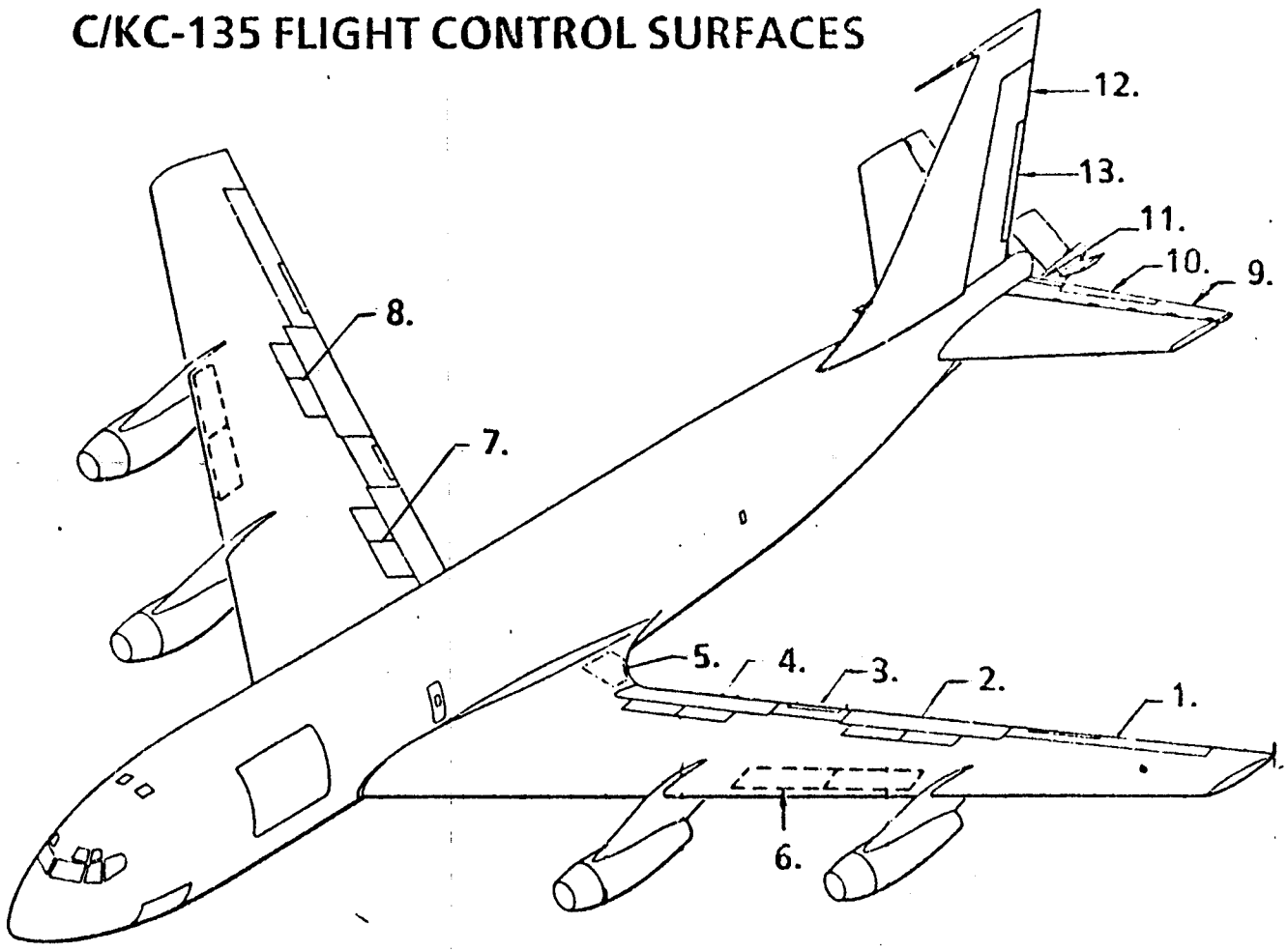
BASIC AIRCRAFT TRIM CHARACTERISTICS

- o Aircraft Alignment and Rigging
- o Missing Seals on Flight Controls or Balance Bays
- o Control Surface Fit and Fair Tolerance
- o Basic Airplane Configuration (camera pods, special antenna and radomes, pods and fairings, side viewing windows, etc.)

2.0 C/KC-135 FLIGHT CONTROL SYSTEM DESCRIPTION



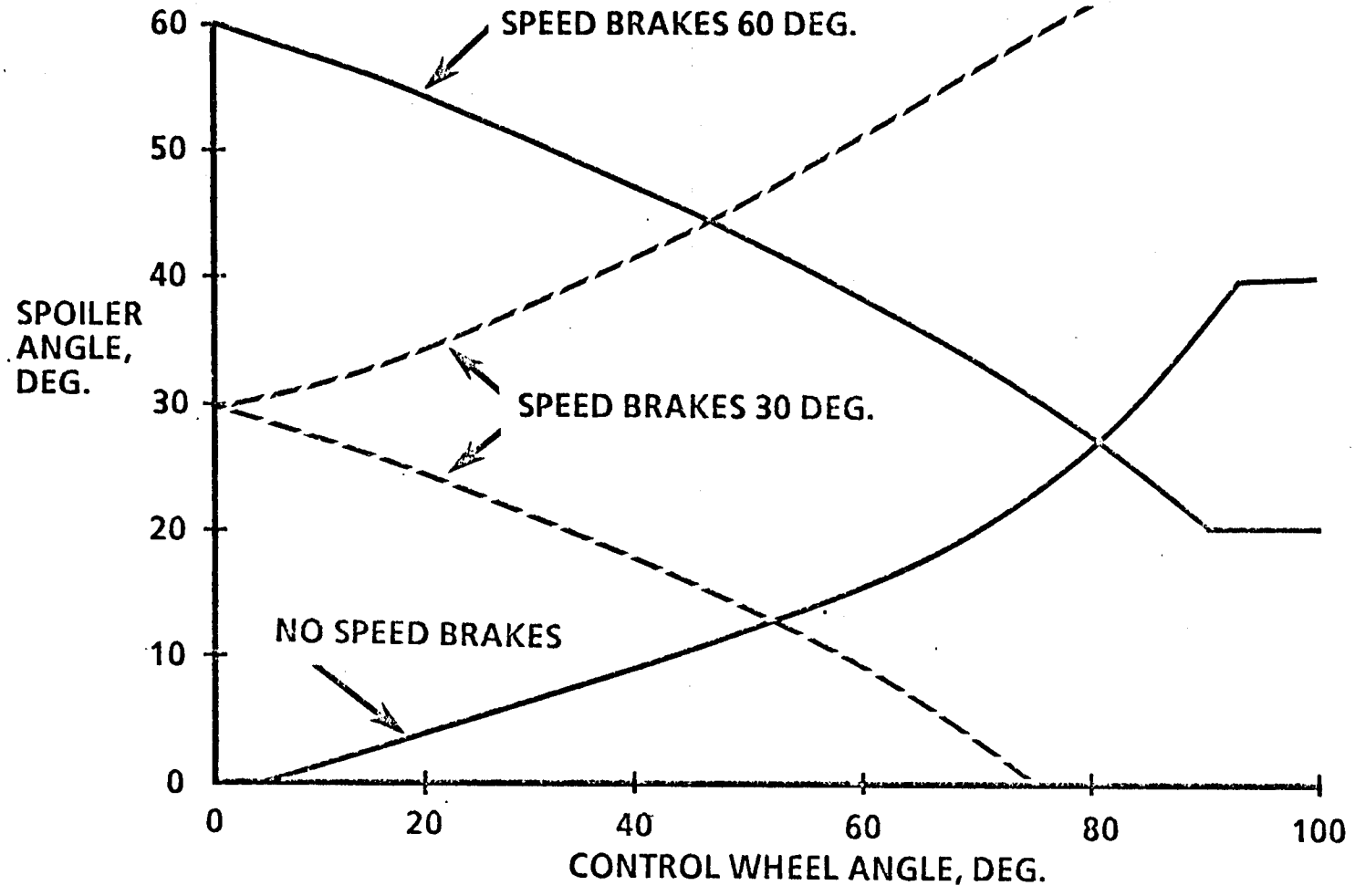
C/KC-135 FLIGHT CONTROL SURFACES



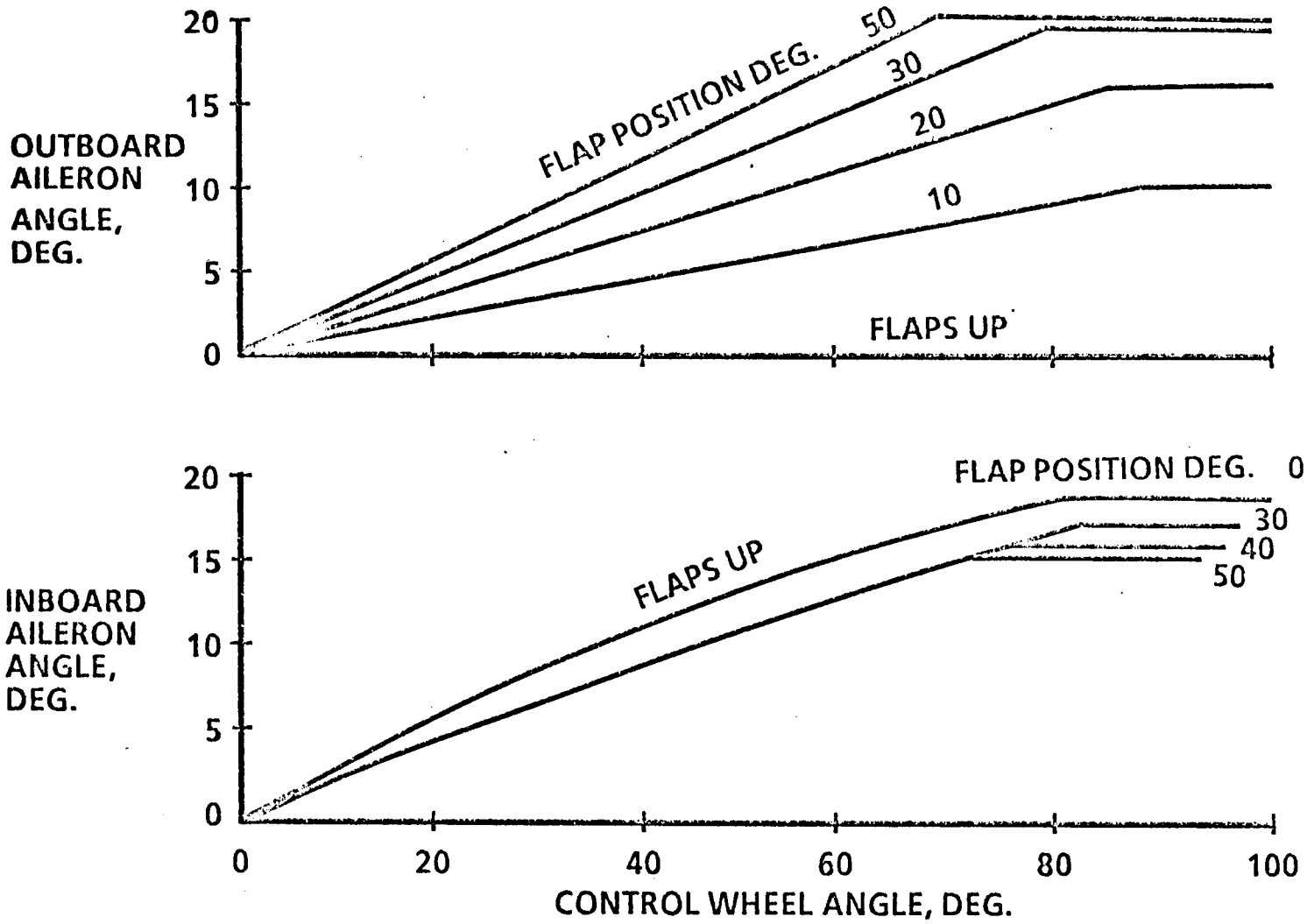
1. Outboard Aileron and Control Tab
2. Outboard Flap
3. Inboard Aileron and Control Tab
4. Inboard Flap
5. Fillet Flap
6. Leading Edge Flap
7. Inboard Spoilers
8. Outboard Spoilers
9. Elevator
10. Elevator Control Tab
11. Elevator Stabilizer Actuated Tab
12. Rudder
13. Rudder Control Tab

FIGURE 2

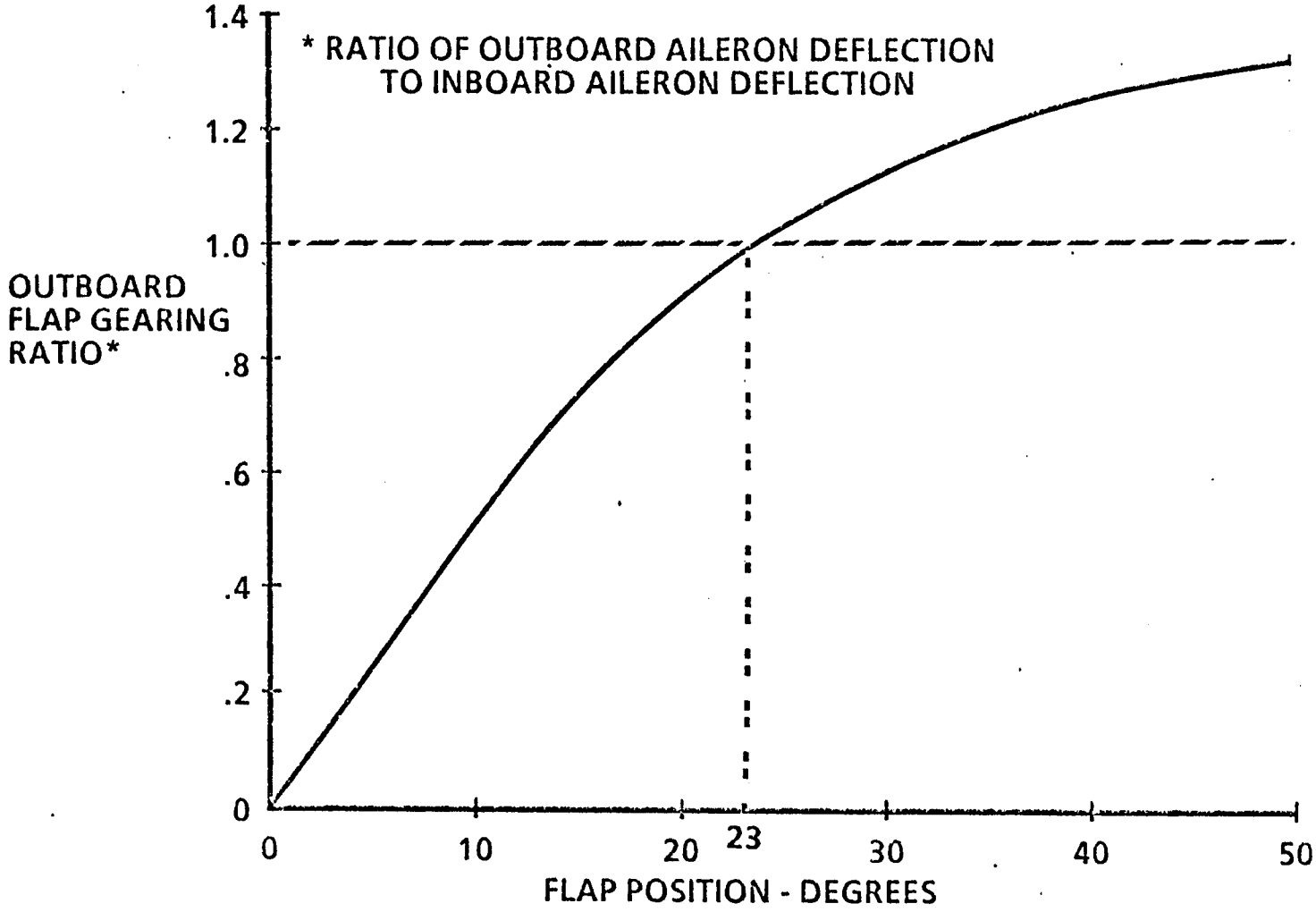
SPOILER DEFLECTION WITH CONTROL WHEEL (SPEED BRAKES DEPLOYED)



AILERON DEFLECTION WITH CONTROL WHEEL



OUTBOARD AILERON GEARING CHARACTERISTICS (AILERON INTERCONNECT WITH OUTBOARD FLAP)



C/KC-135 CONTROL RESPONSE RATES

	CONTROL RATE	TIME TO OBTAIN MAXIMUM AUTHORITY
FLIGHT CONTROLS		
o Rudder Rate		
All C/KC-135	28 Deg/Sec	.9 Sec.
KC-135R (CFM56)	48 Deg/Sec	.5 Sec.
o Spoiler and Aileron Rate		
Full Down to Full Up	60 Deg/Sec	1.0 Sec.
Full Up to Full Down	120 Deg/Sec	.5 Sec.
NOSE WHEEL STEERING	14 Deg/Sec	.6 to 1.0 Sec.*
KC-135R FLIGHT CONTROL AUGMENTATION SYSTEM (FCAS)		
o Rudder Rate - Channel 1 (Engine Failure Assist System Secondary Actuator)	15 Deg/Sec	.4 Sec.
o Rudder Rate - Channel 2 (SYD Secondary Actuator)	15 Deg/Sec	

*Based on typical takeoff conditions with an engine failure near V_{MCG}.

SERIES YAW DAMPER COMPONENTS

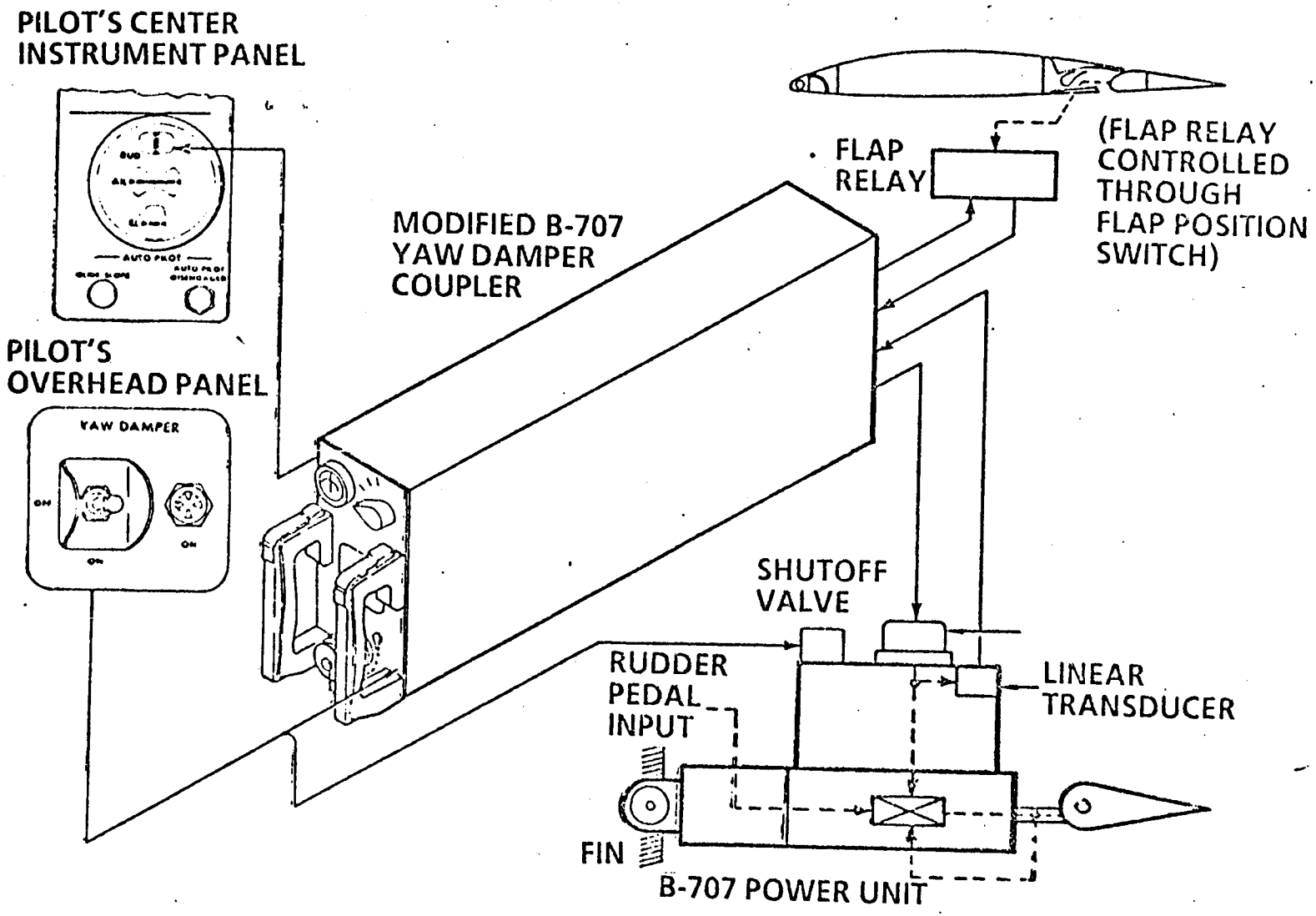
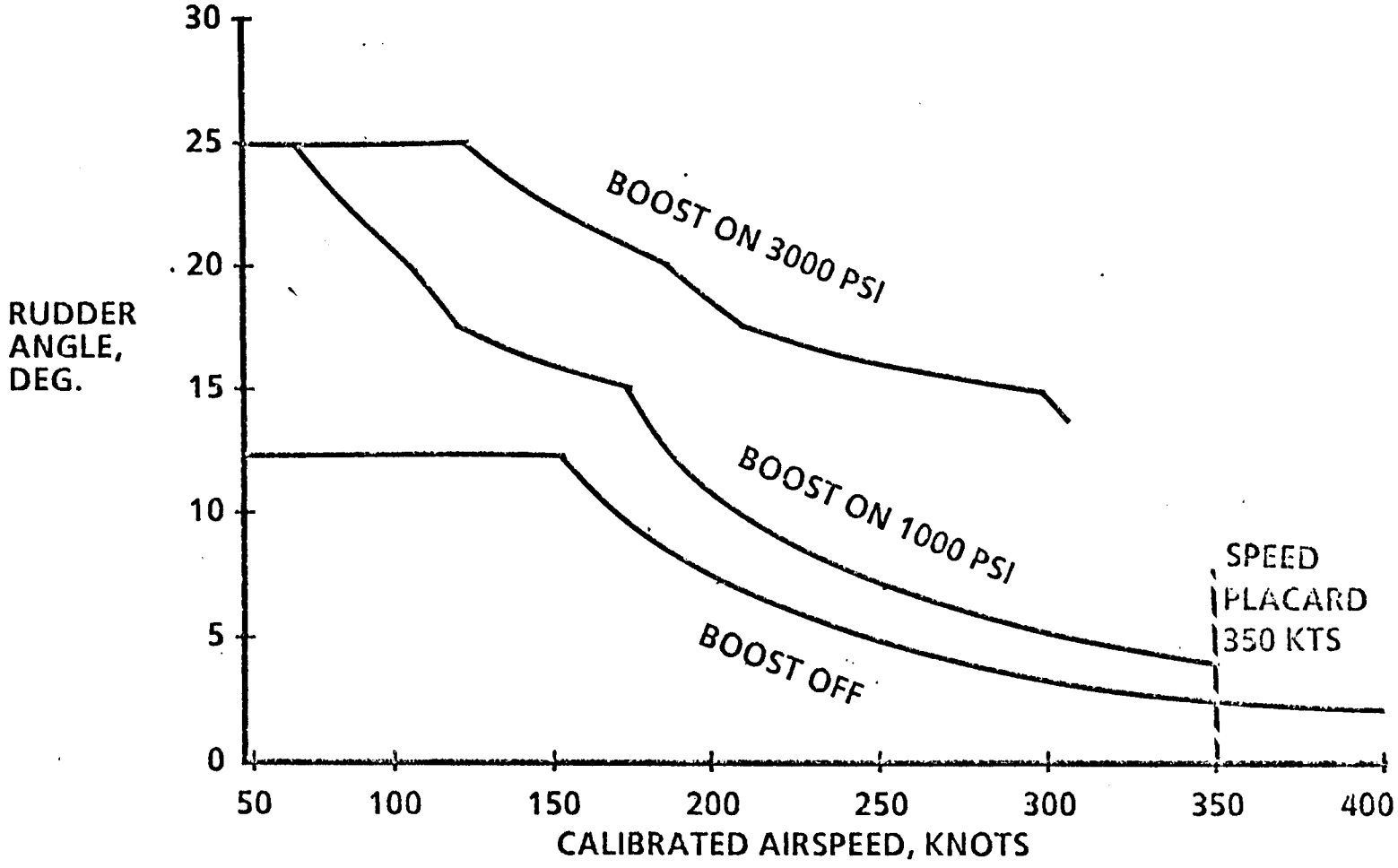


Figure 6

RUDDER BLOWDOWN CHARACTERISTICS
PARALLEL YAW DAMPER - ZERO SIDESLIP



RUDDER BLOWDOWN CHARACTERISTICS
SERIES YAW DAMPER - ZERO SIDESLIP

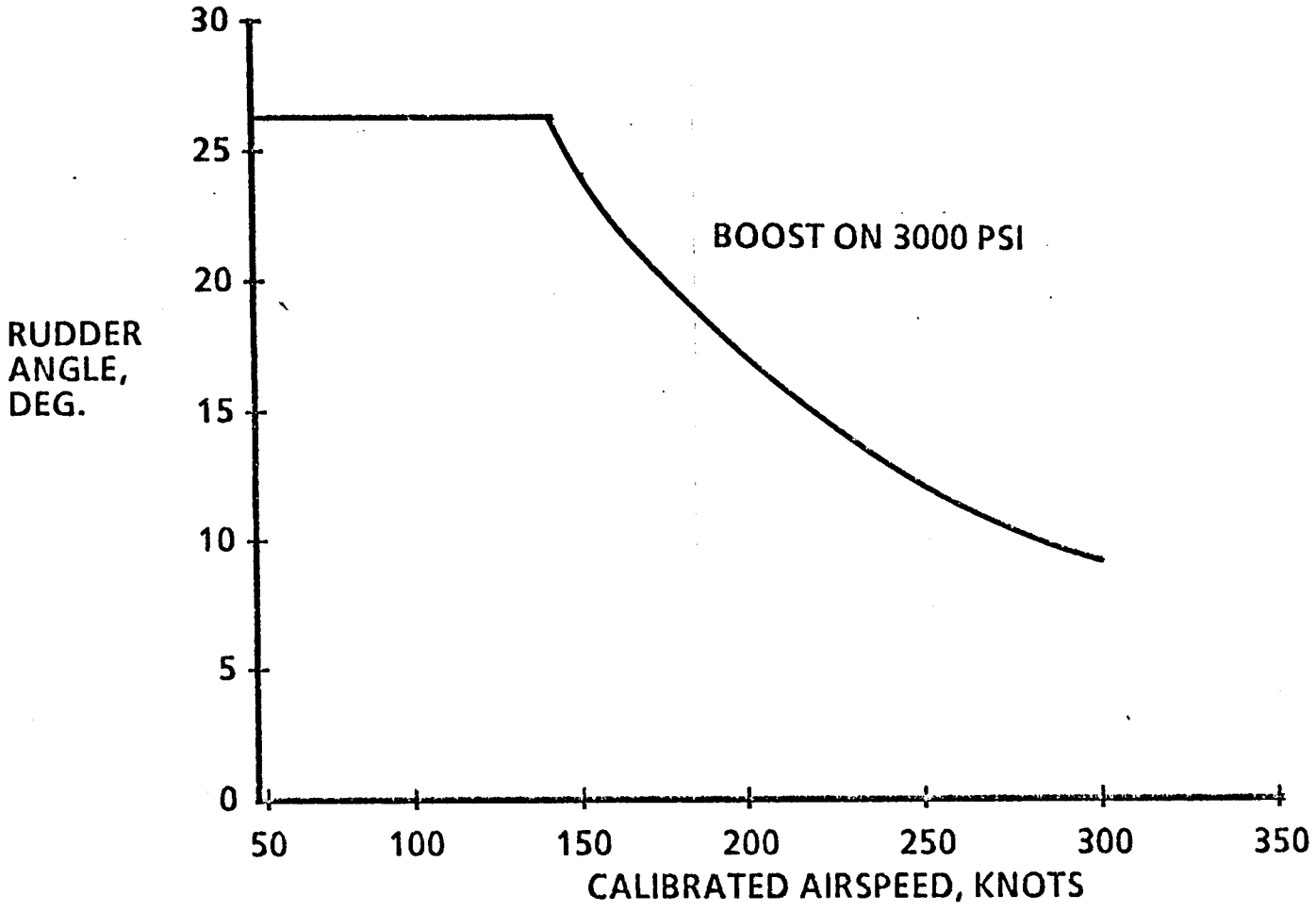


FIGURE 9

RUDDER BLOWDOWN CHARACTERISTICS
PARALLEL YAW DAMPER - WITH SIDESLIP

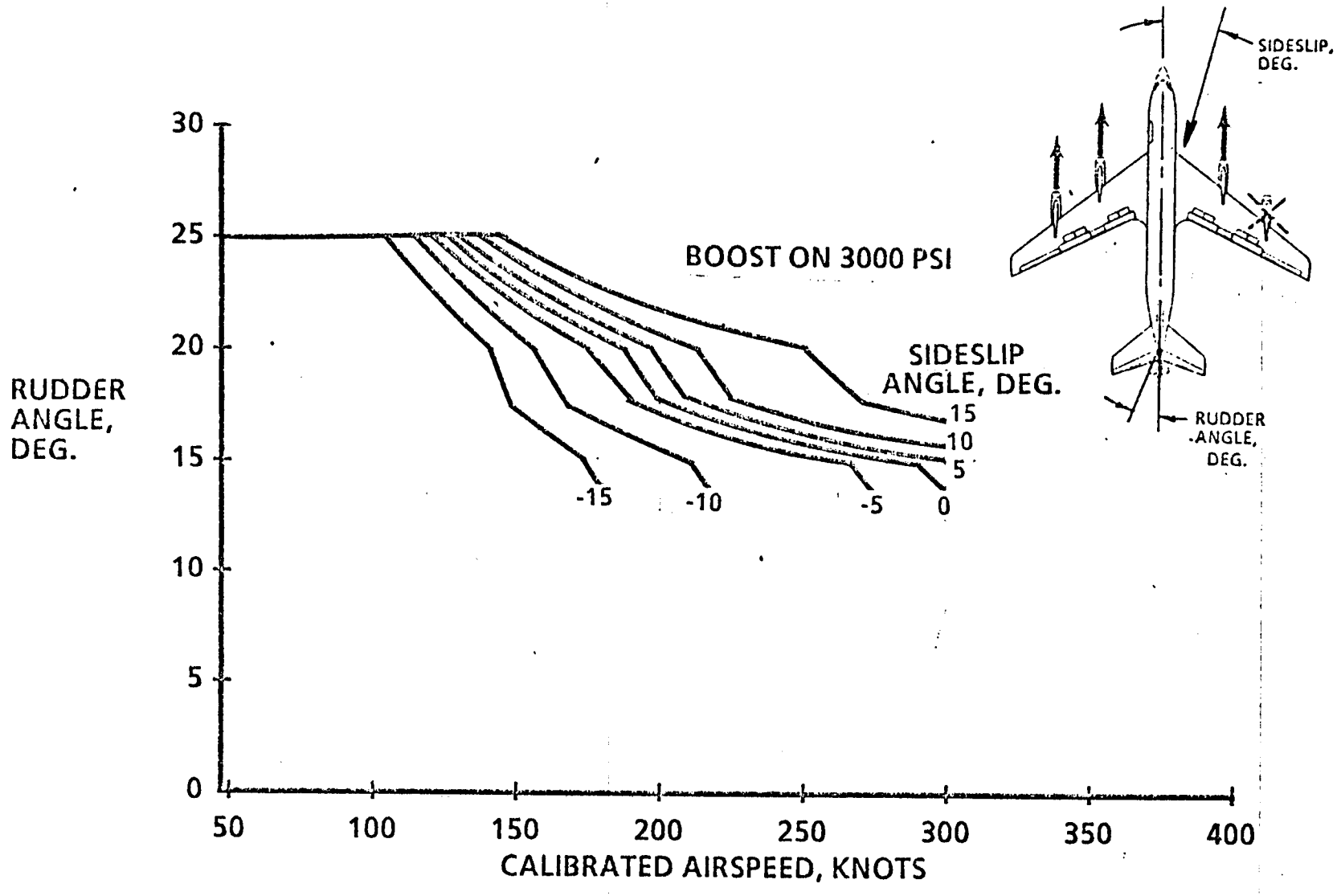


FIGURE 10

SPOILER BLOWDOWN CHARACTERISTICS

MACH NUMBERS LESS THAN .7

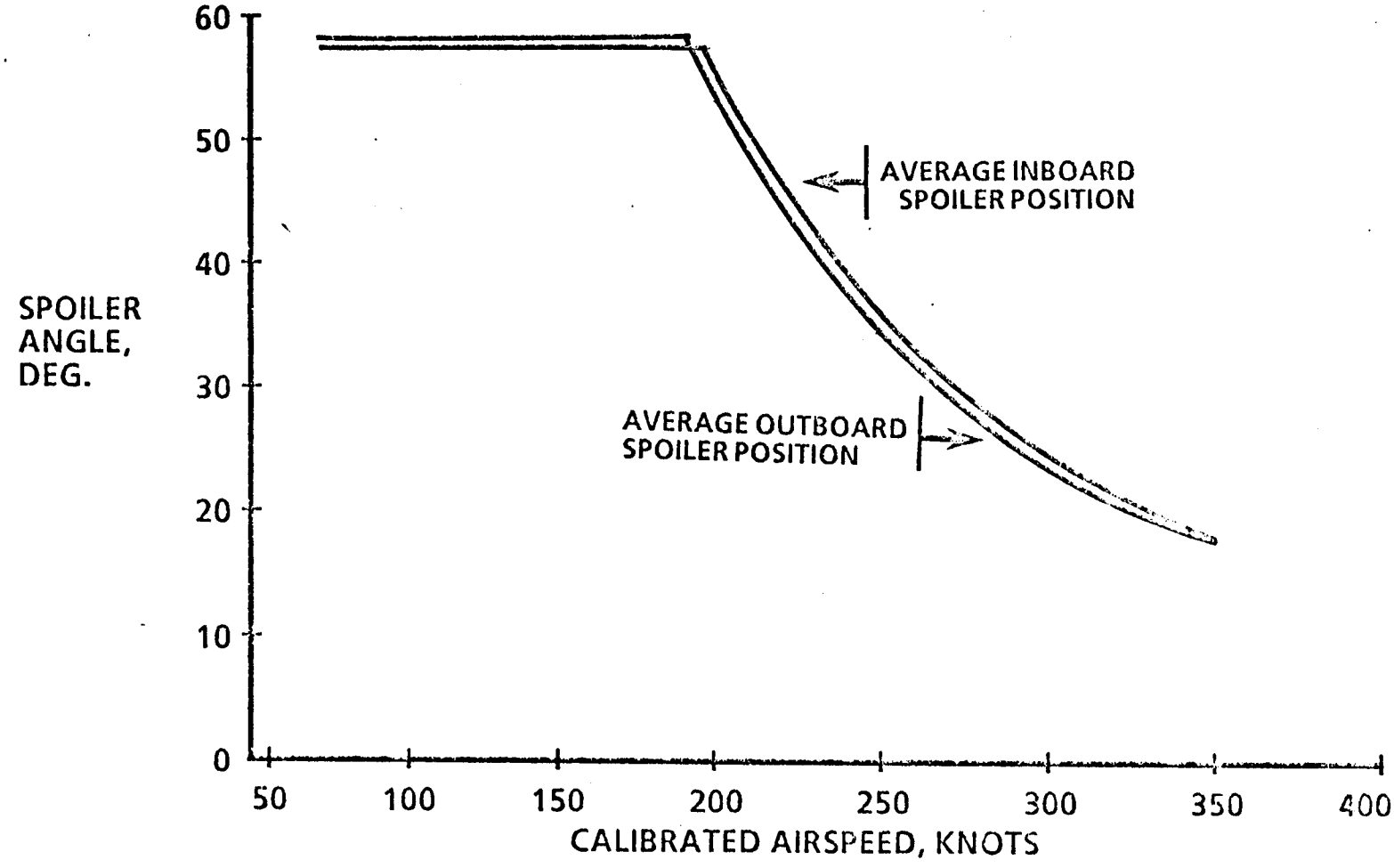


FIGURE 11

EFFECT OF ANGLE OF ATTACK ON ROLL AUTHORITY

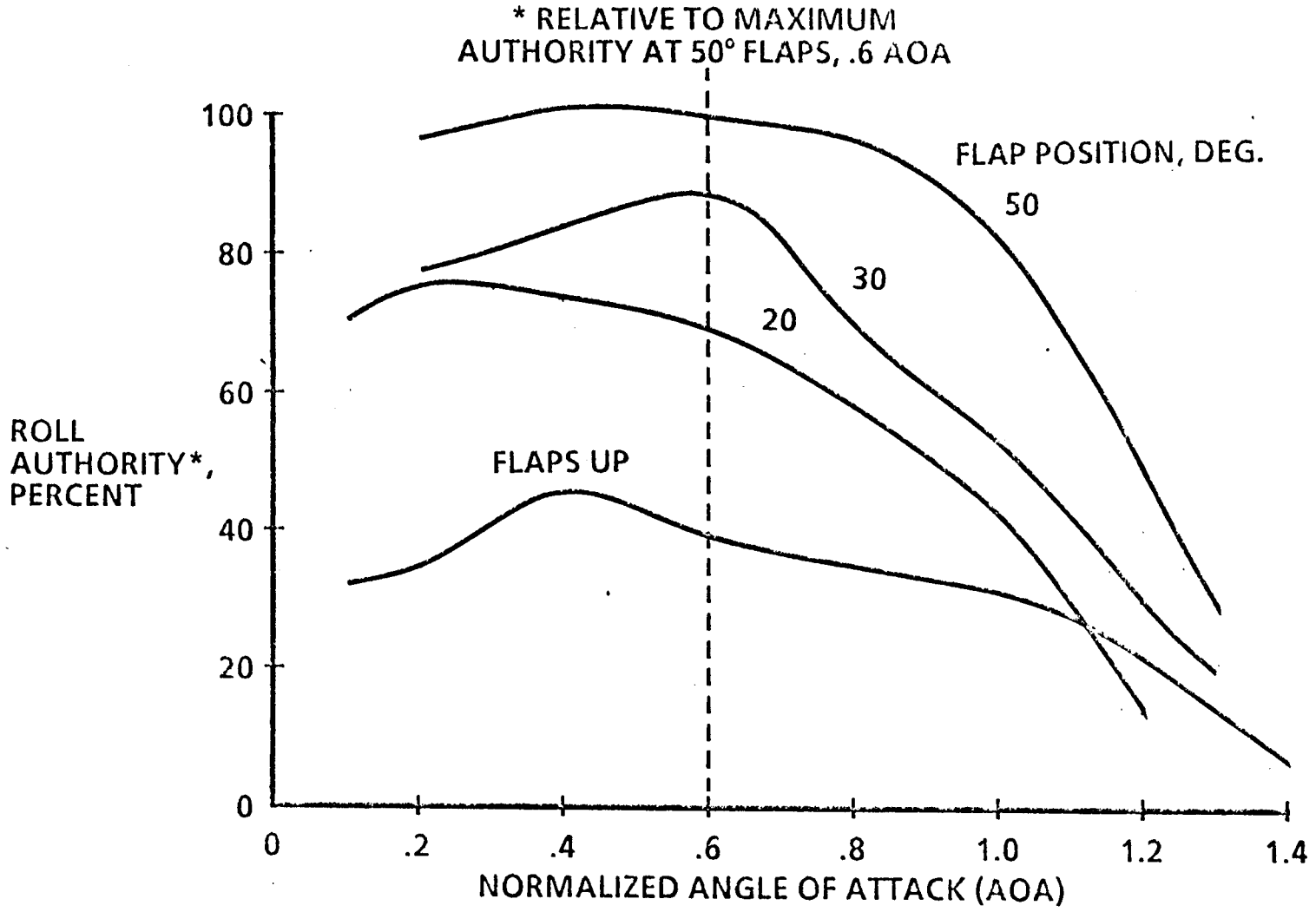
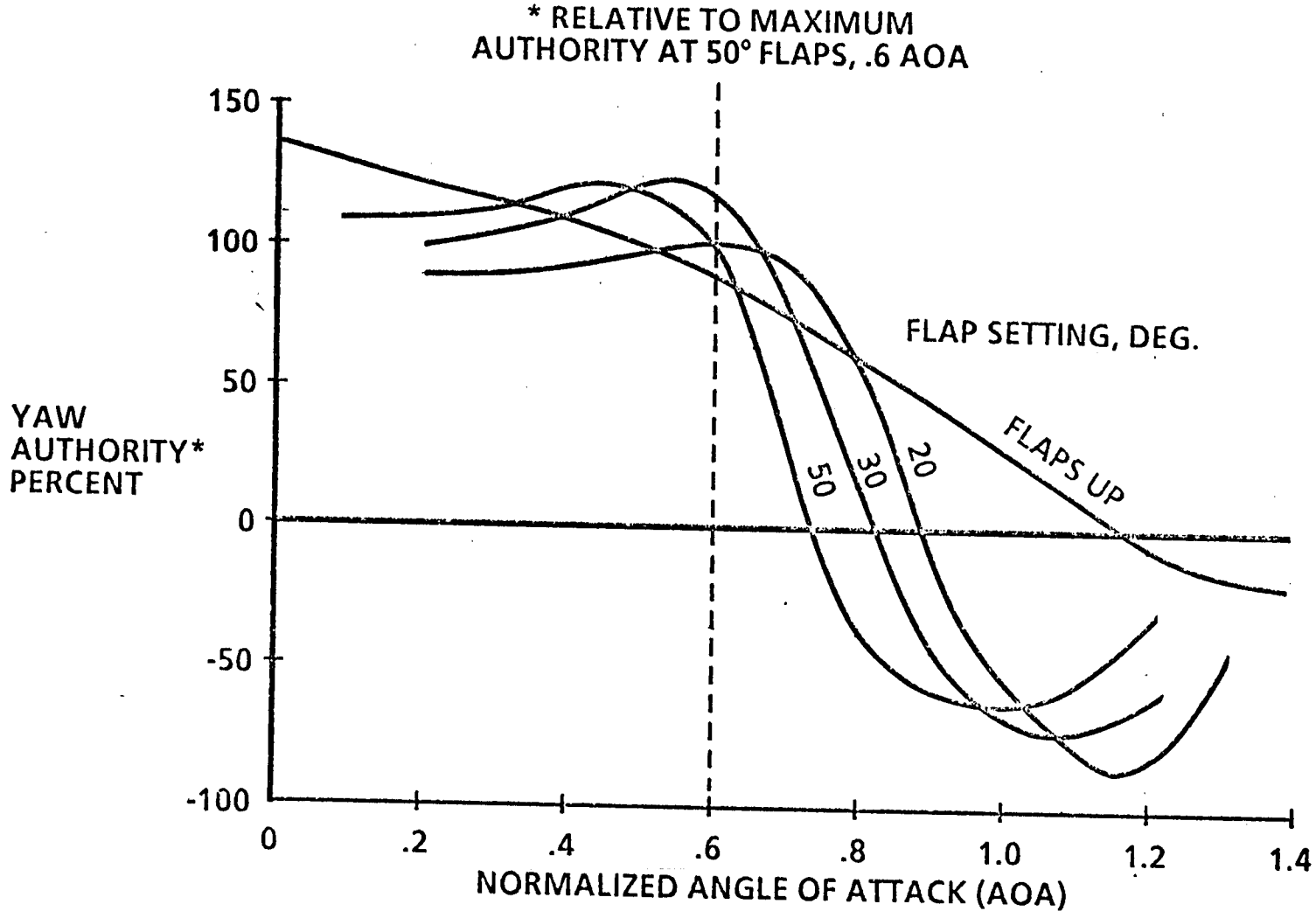


FIGURE 12

EFFECT OF ANGLE OF ATTACK ON YAW AUTHORITY



EFFECT OF SPEED BRAKES ON ROLL AUTHORITY

APPROACH AND LANDING CONDITIONS - .6 AOA

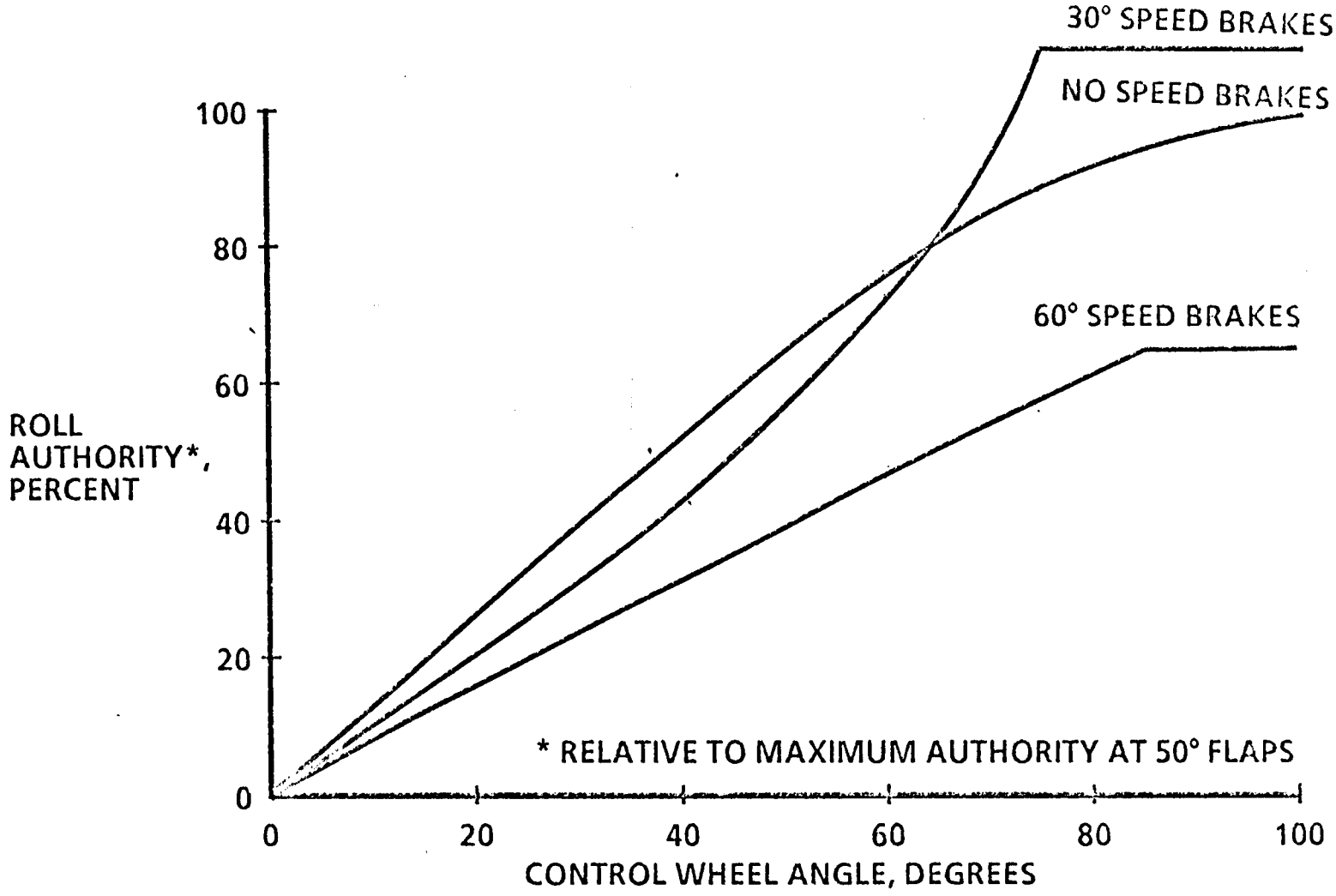
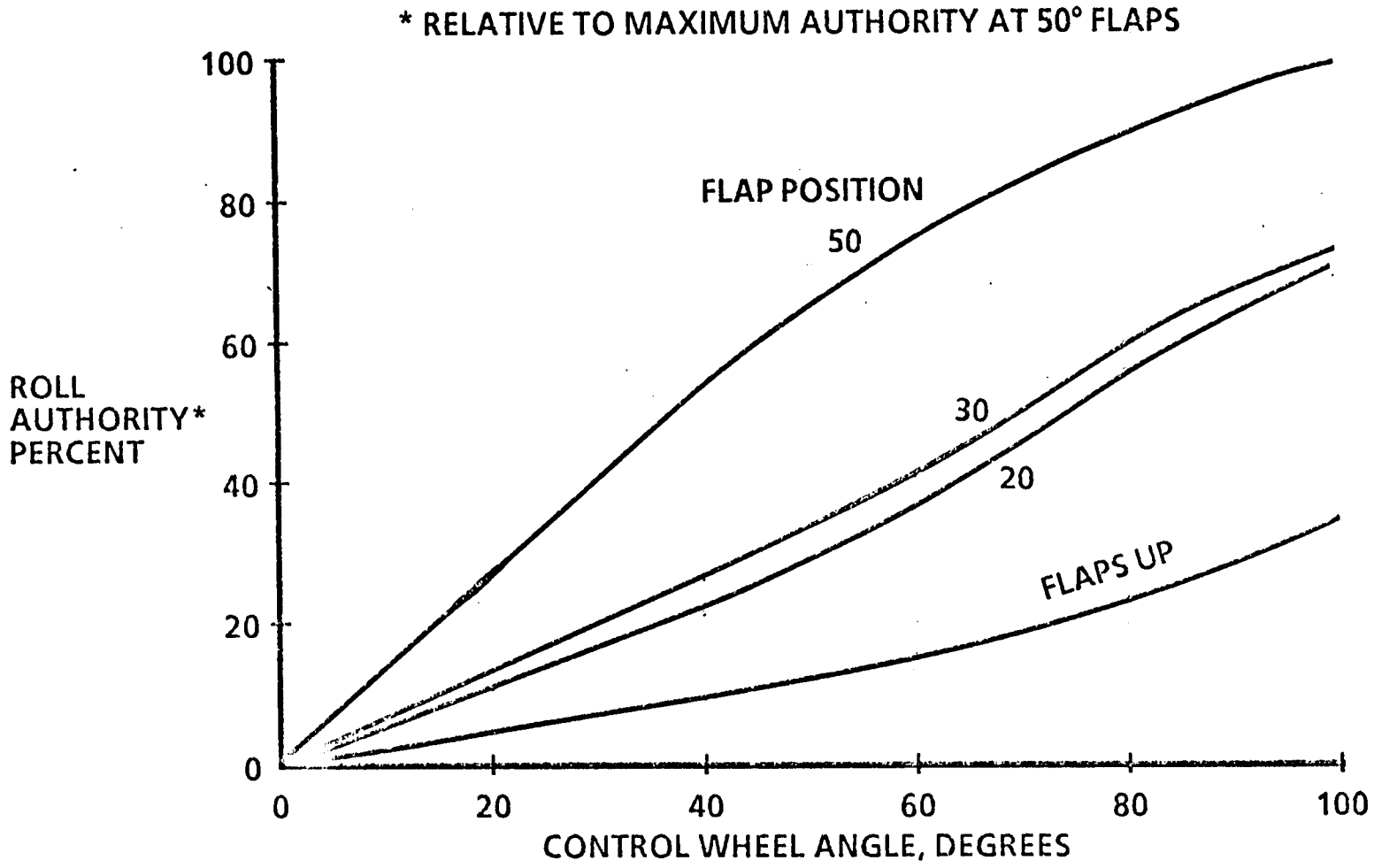


FIGURE 14

EFFECT OF CONTROL WHEEL DISPLACEMENT ON ROLL AUTHORITY

APPROACH AND LANDING CONDITIONS - .6 AOA



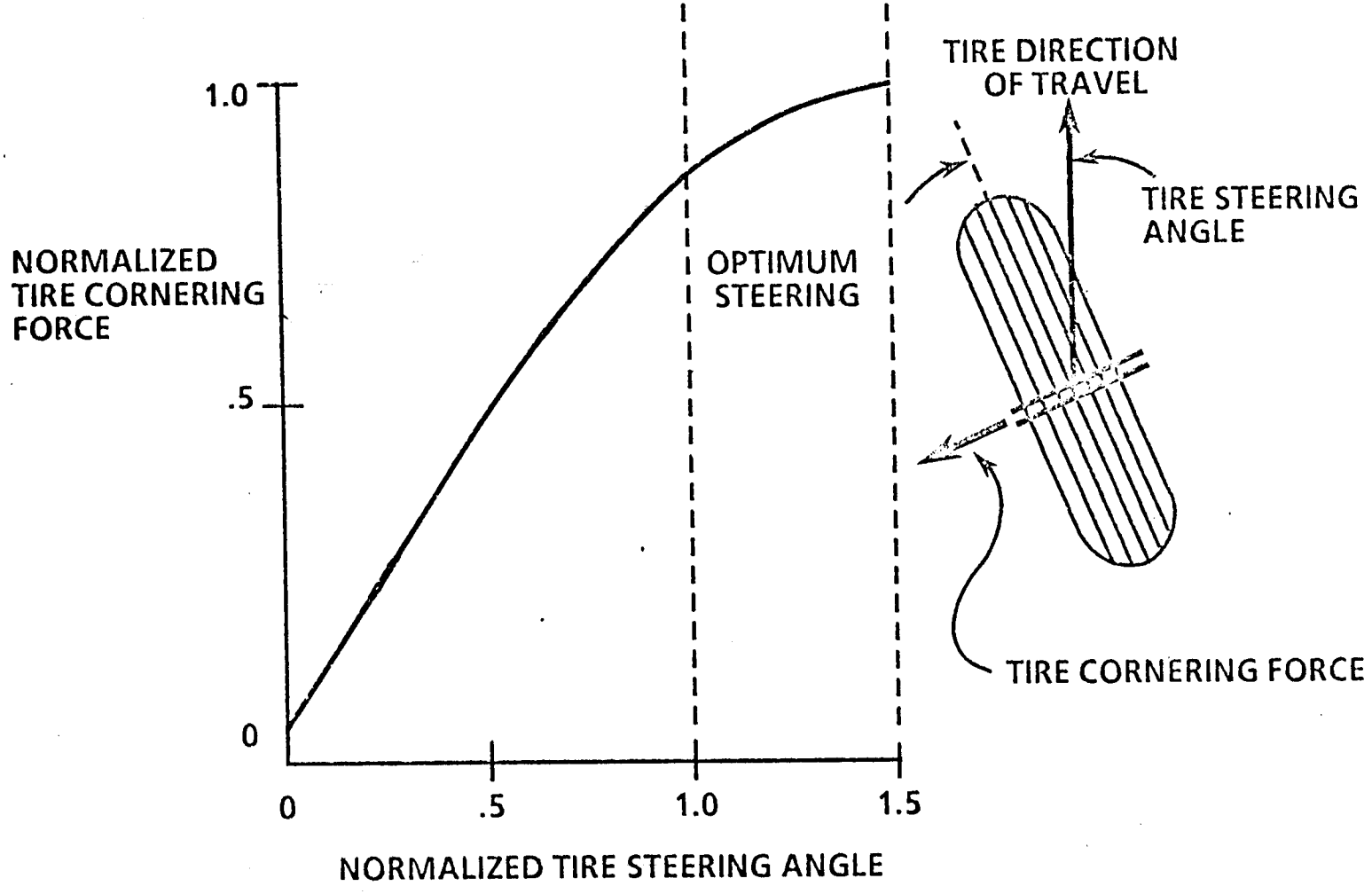
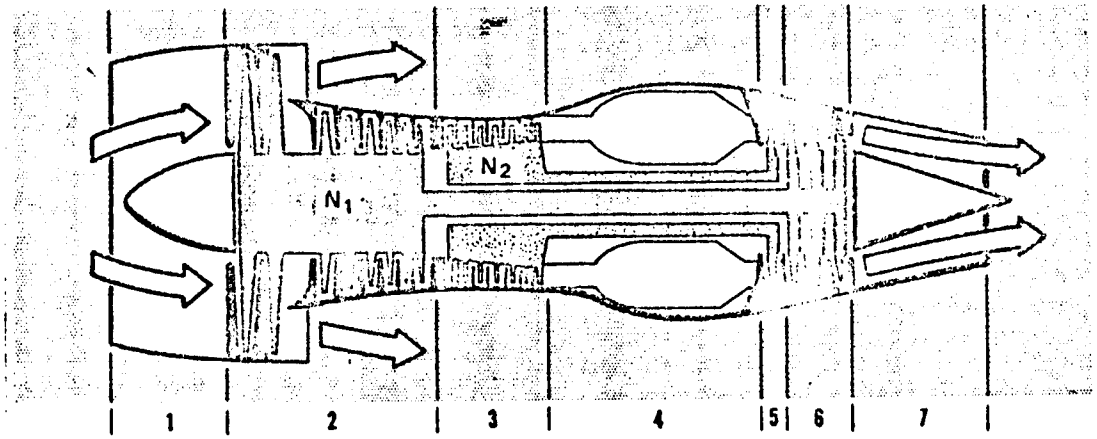

TIRE STEERING CHARACTERISTICS
1.0
.5
0
NORMALIZED TIRE CORNERING FORCE
OPTIMUM STEERING
0
.5
1.0
1.5
NORMALIZED TIRE STEERING ANGLE
TIRE DIRECTION OF TRAVEL
TIRE STEERING ANGLE
TIRE CORNERING FORCE

FIGURE 16

3.0 C/KC-135 ENGINE CHARACTERISTICS



1 INLET
2 LOW PRESSURE COMPRESSOR WITH FAN SECTION
3 HIGH PRESSURE COMPRESSOR
4 COMBUSTION CHAMBER
5 HIGH PRESSURE TURBINE
6 LOW PRESSURE TURBINE
7 EXHAUST

TAKEOFF THRUST COMPARISONS -135 ENGINE INSTALLATIONS

(SEA LEVEL, M = .15)

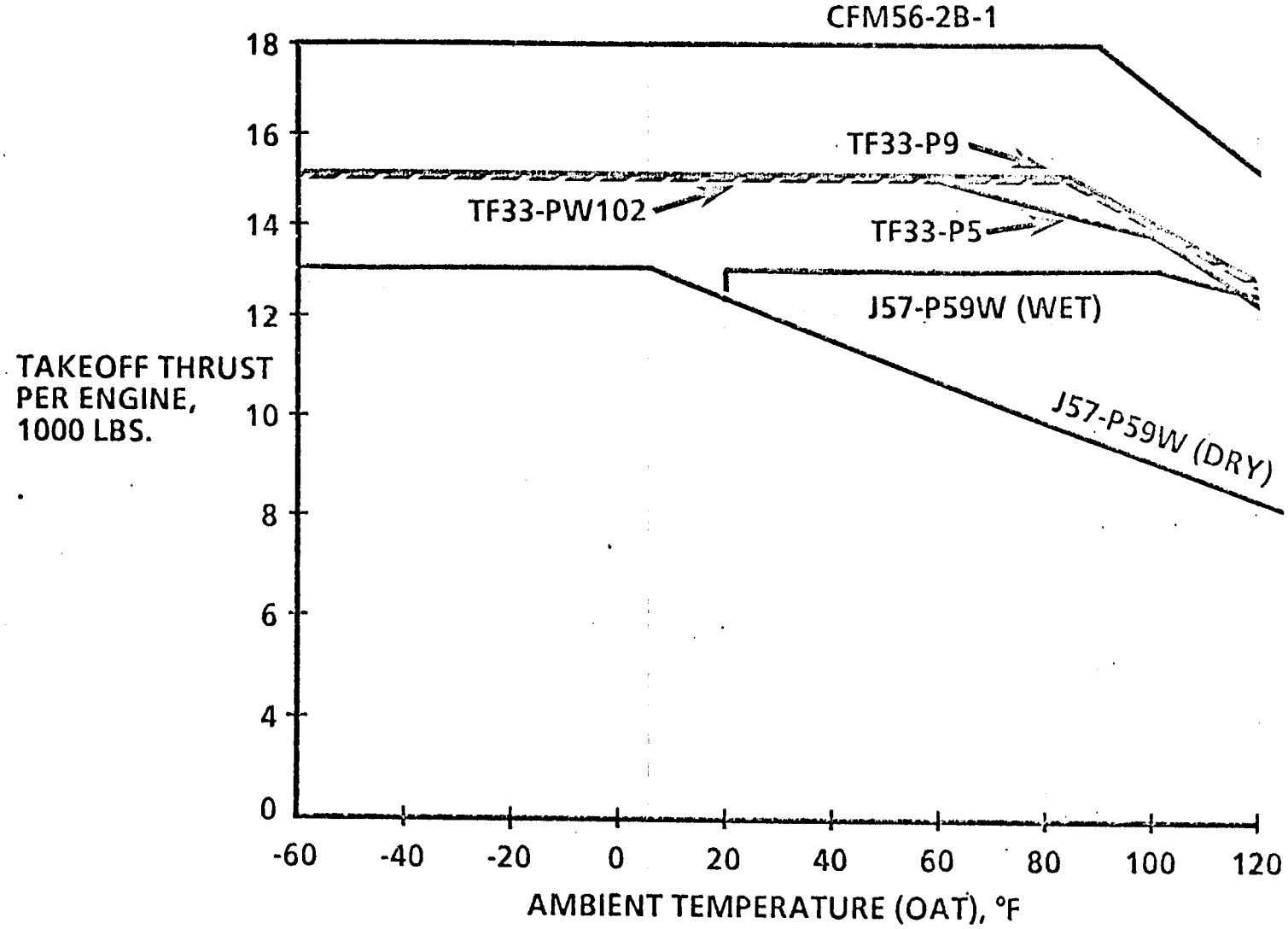
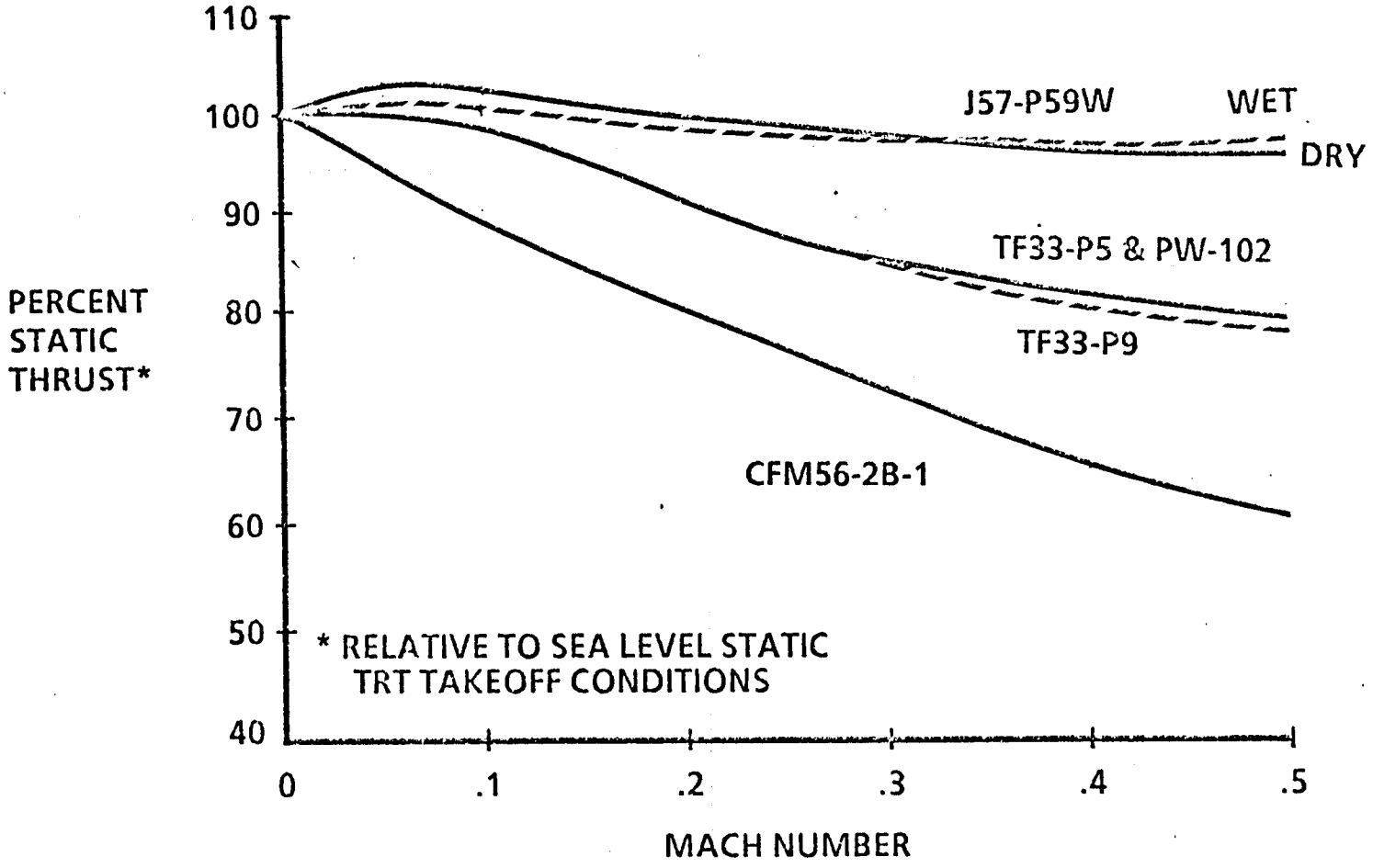
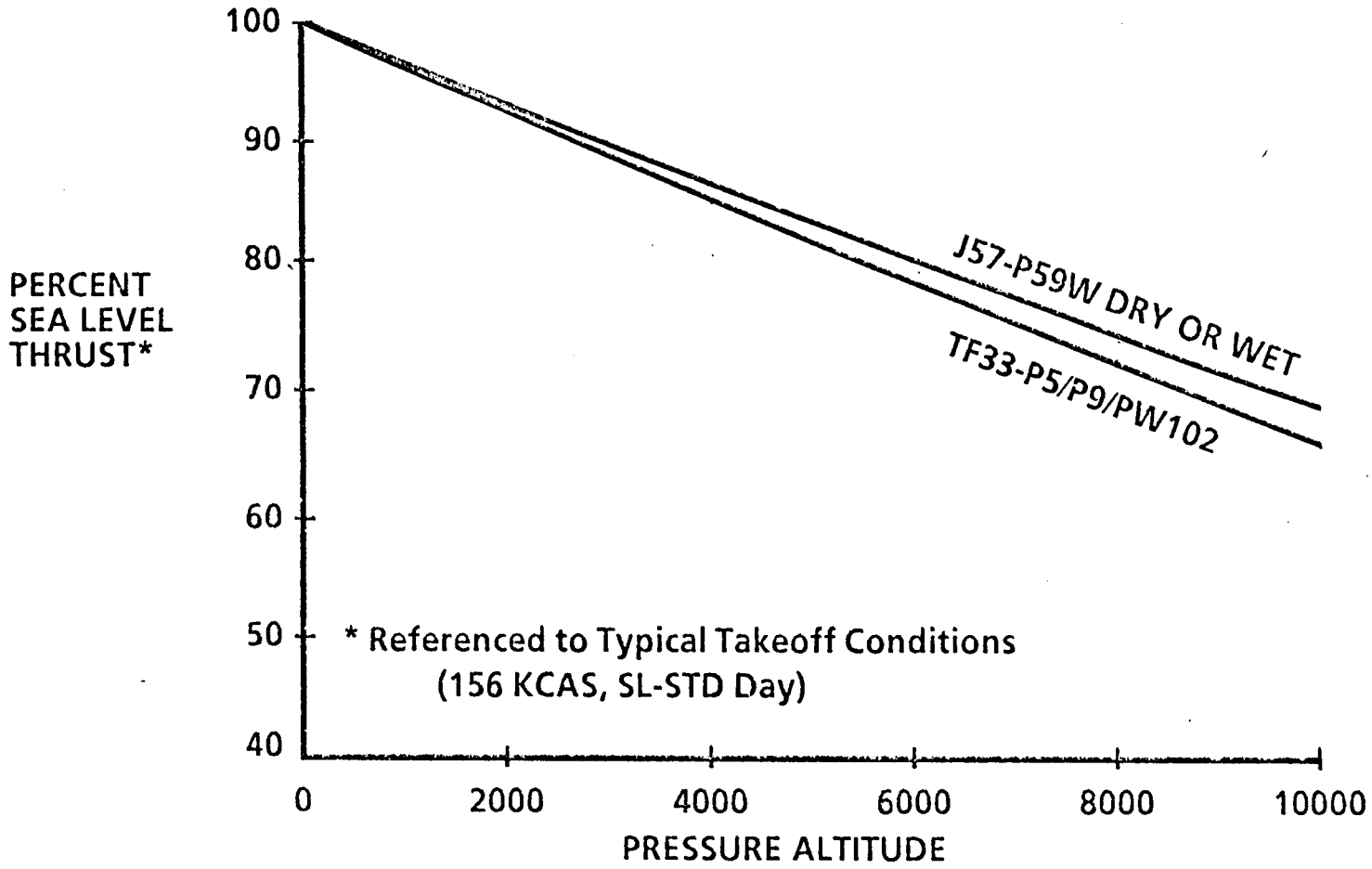


FIGURE 17

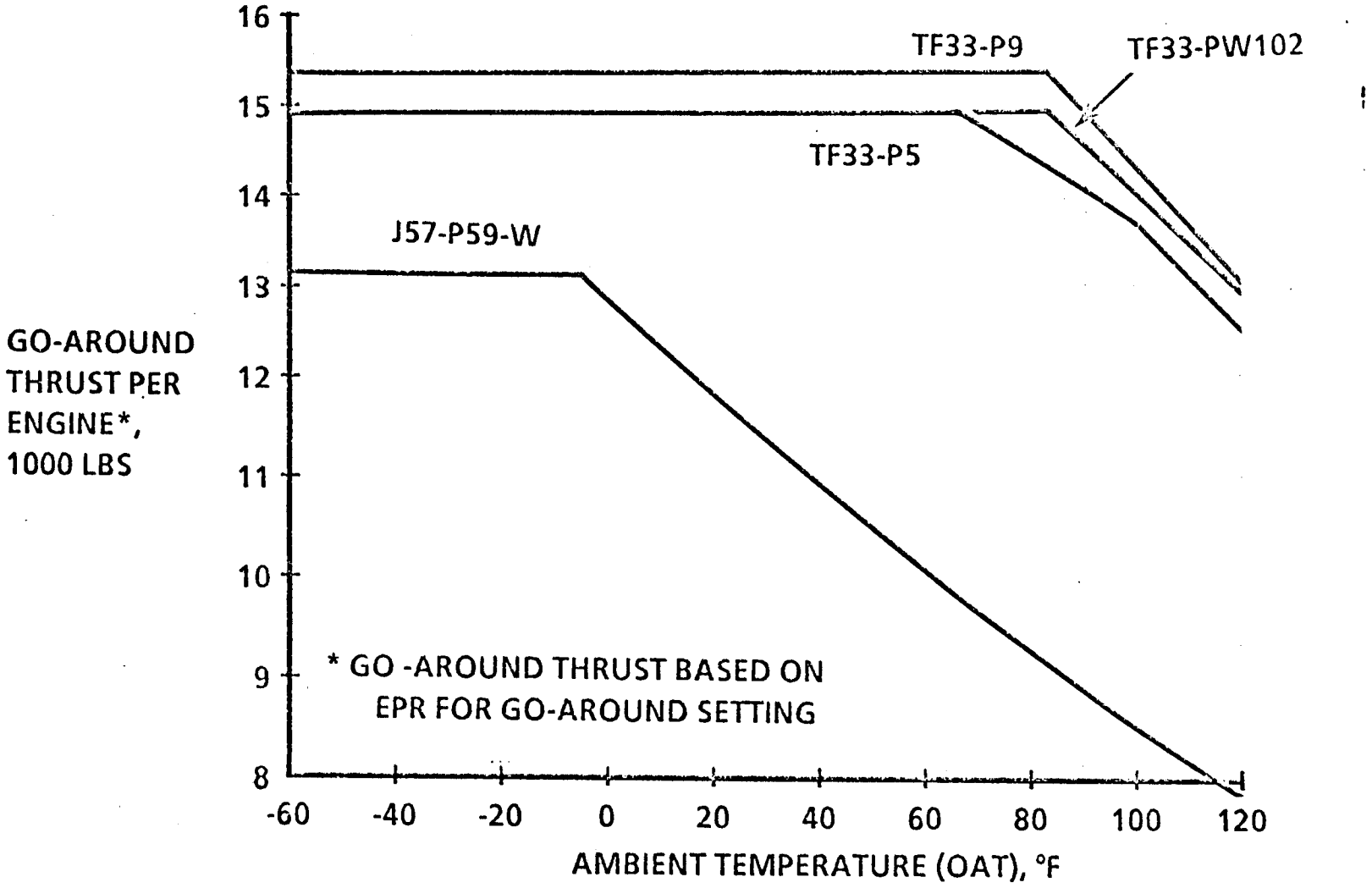
EFFECT OF SPEED ON MAXIMUM AVAILABLE THRUST
(THRUST LAPSE RATE WITH SPEED)



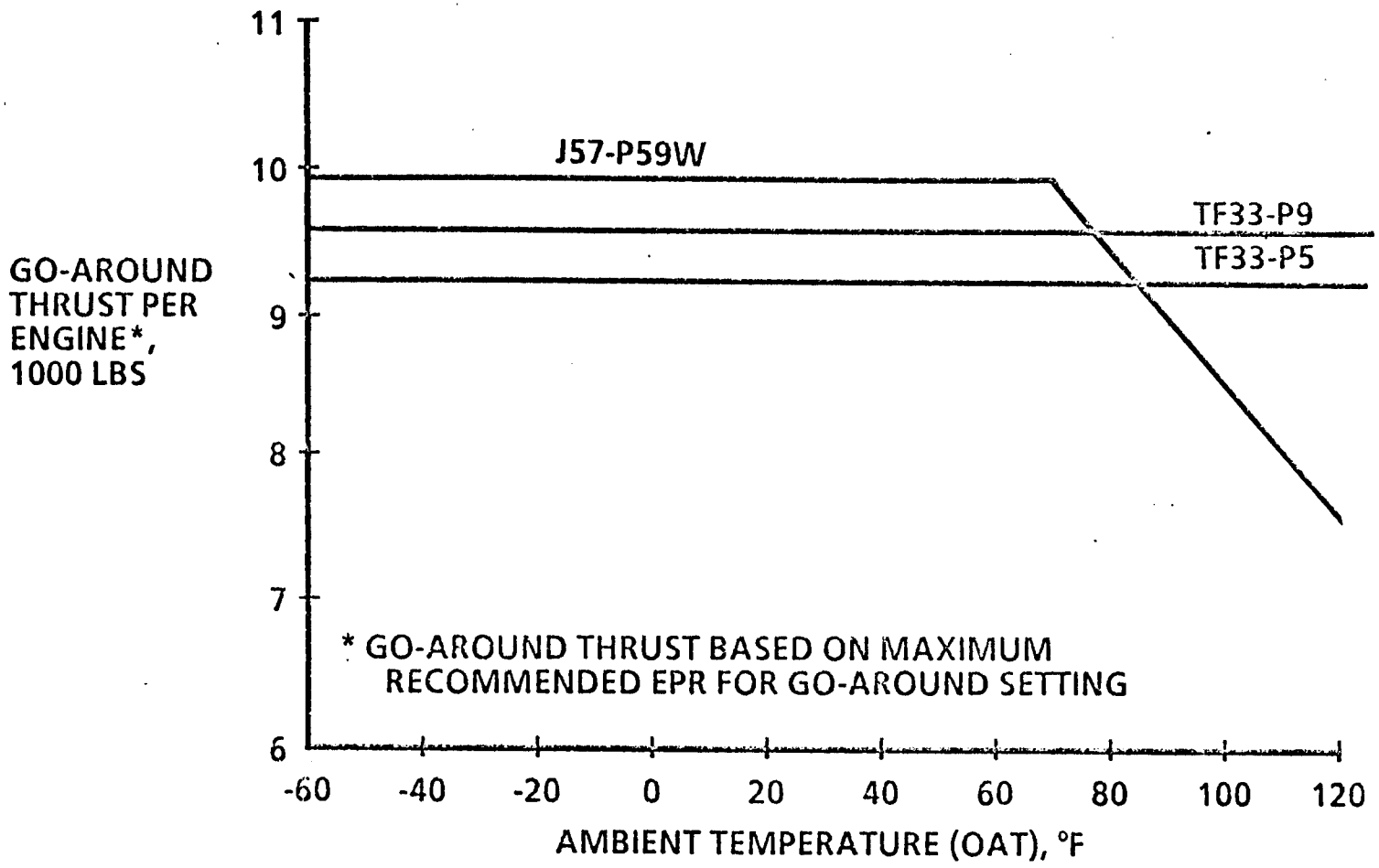
EFFECT OF PRESSURE ALTITUDE ON MAXIMUM AVAILABLE THRUST (THRUST LAPSE RATE WITH ALTITUDE)



GO-AROUND THRUST - SEA LEVEL

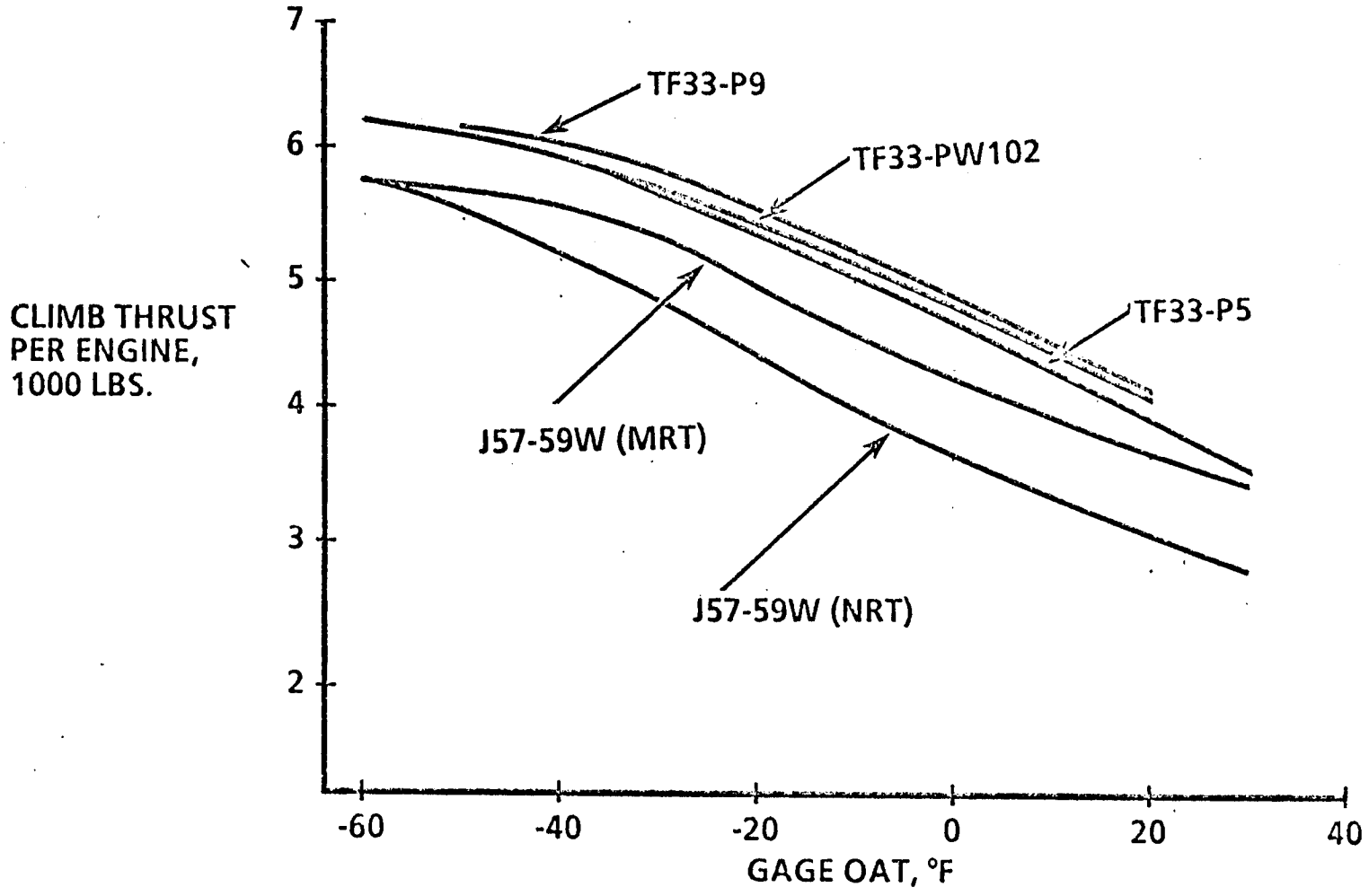


MAXIMUM RECOMMENDED GO-AROUND THRUST - SEA LEVEL

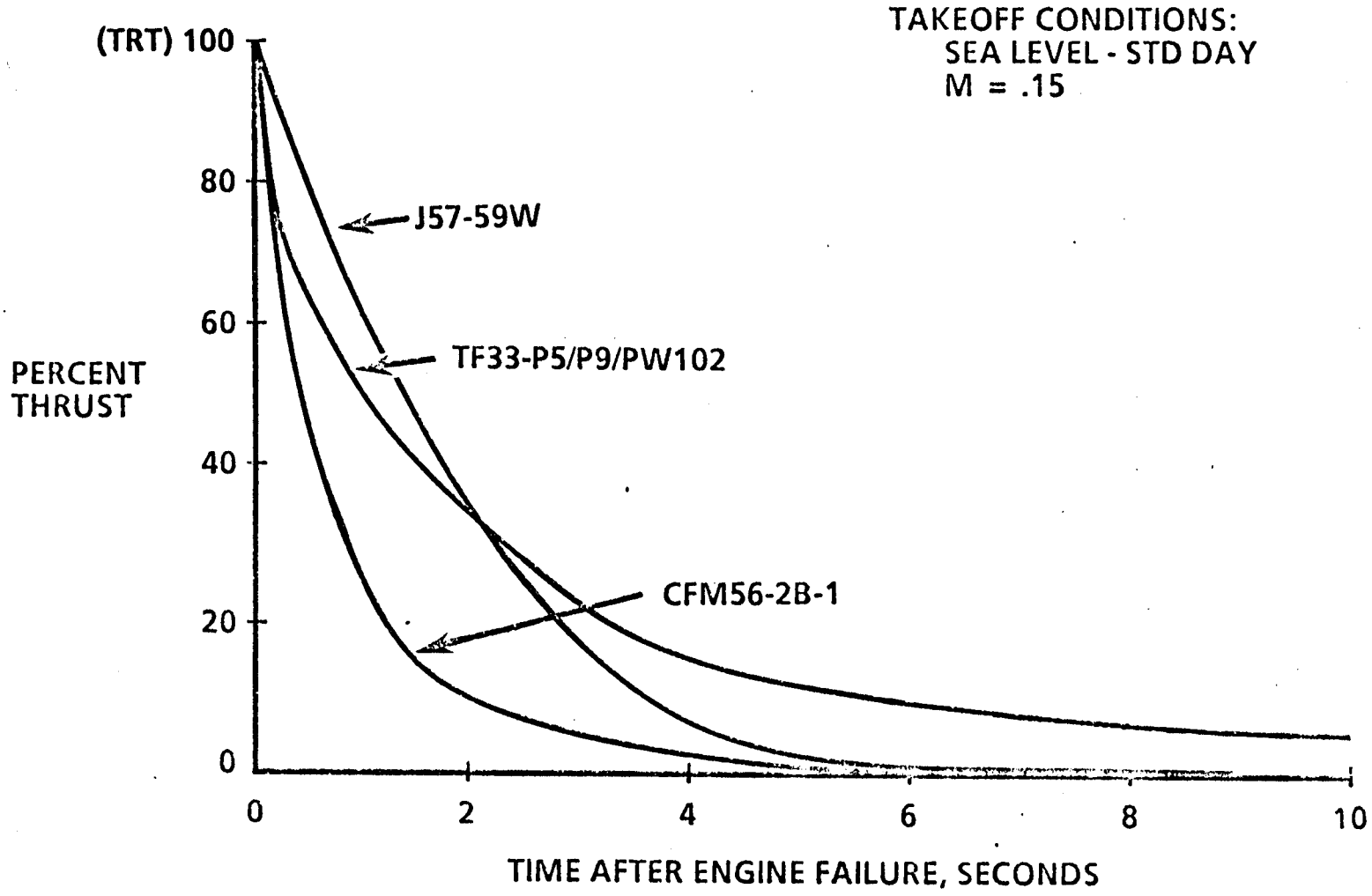


ENROUTE CLIMB THRUST

PRESSURE ALTITUDE 30,000 FT, MACH = 0.80

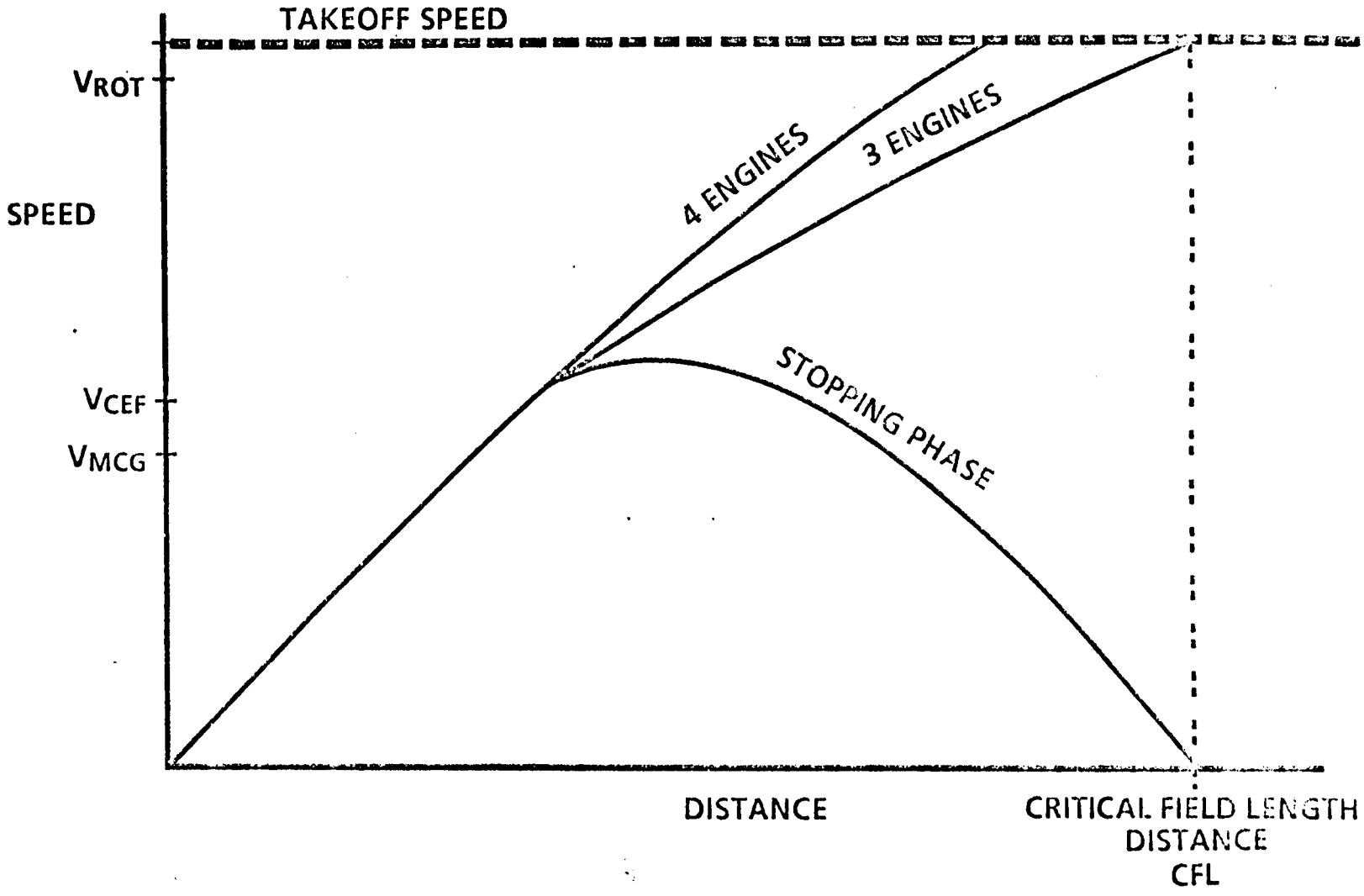


ENGINE SPIN DOWN CHARACTERISTICS
FUEL STARVATION CONDITION AT TRT CONDITIONS



4.0 C/KC-135 ASYMMETRIC FLIGHT CHARACTERISTICS - TAKEOFF AND CLIMBOUT

CRITICAL FIELD LENGTH



ENGINE PARAMETERS

THRUST SETTING FOR TAKEOFF (TRT OR REDUCED)

TYPE OF ENGINE FAILURE

- FUEL STARVATION
- LOSS OF WATER AUGMENTATION
- THROTTLE CHOP
- EXPLOSIVE FAILURE

INBOARD OR OUTBOARD FAILURE

TAKEOFF PARAMETERS

ENGINE FAILURE SPEED

GROSS WEIGHT

STABILIZER POSITION AND CONTROL COLUMN POSITION

CENTER OF GRAVITY

RUDDER BOOST ON OR OFF

RUNWAY CONDITION READING (RCR)

CROSSWIND

PILOT FACTORS

PILOT RECOGNITION/REACTION TIME

ENGINE OUT CONTROL INPUTS

- RUDDER
- NOSEWHEEL STEERING
- CONTROL WHEEL

C/K-135 V_{MCG} CHART FORMAT (KC-135E EXAMPLE)

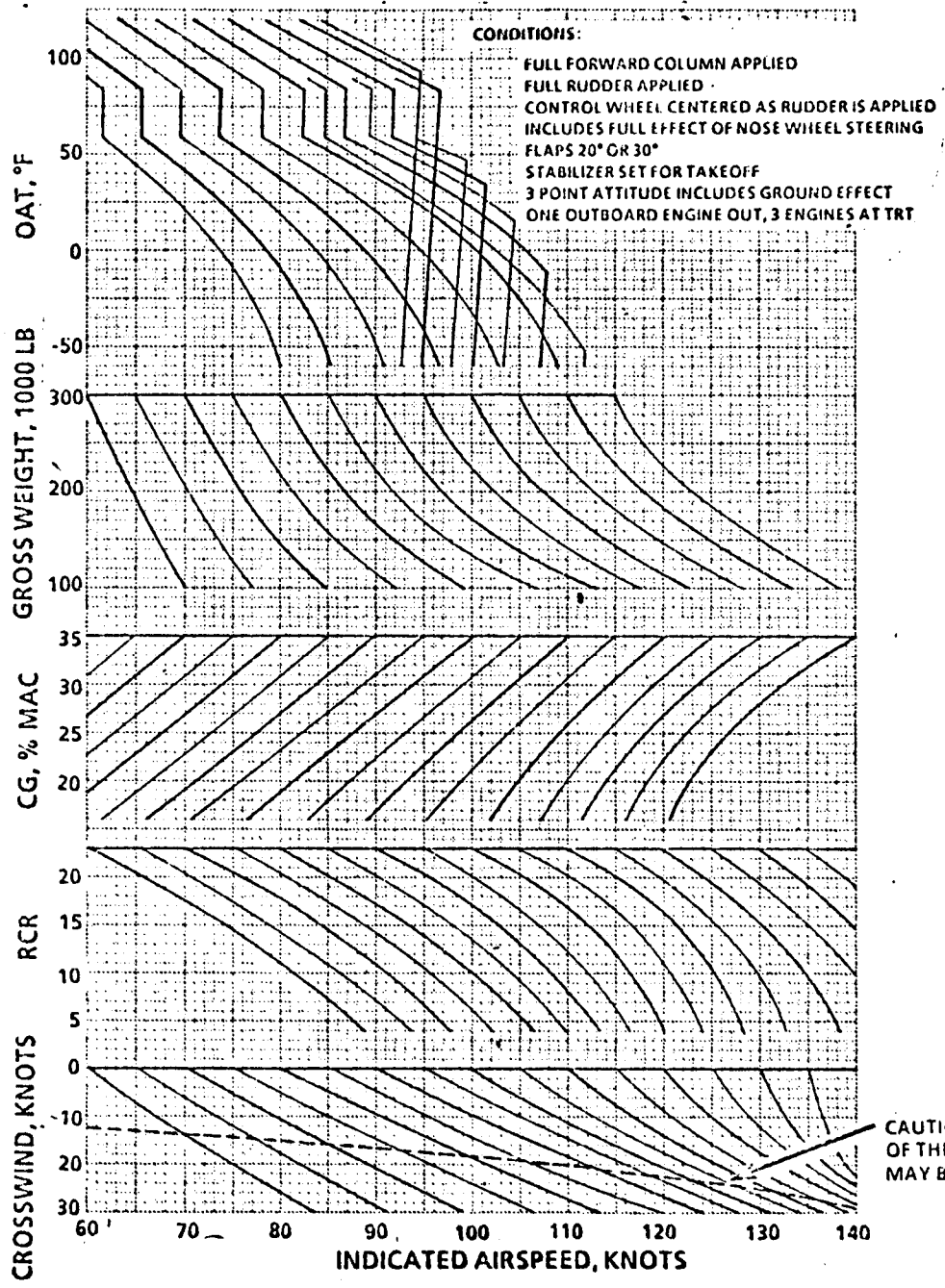
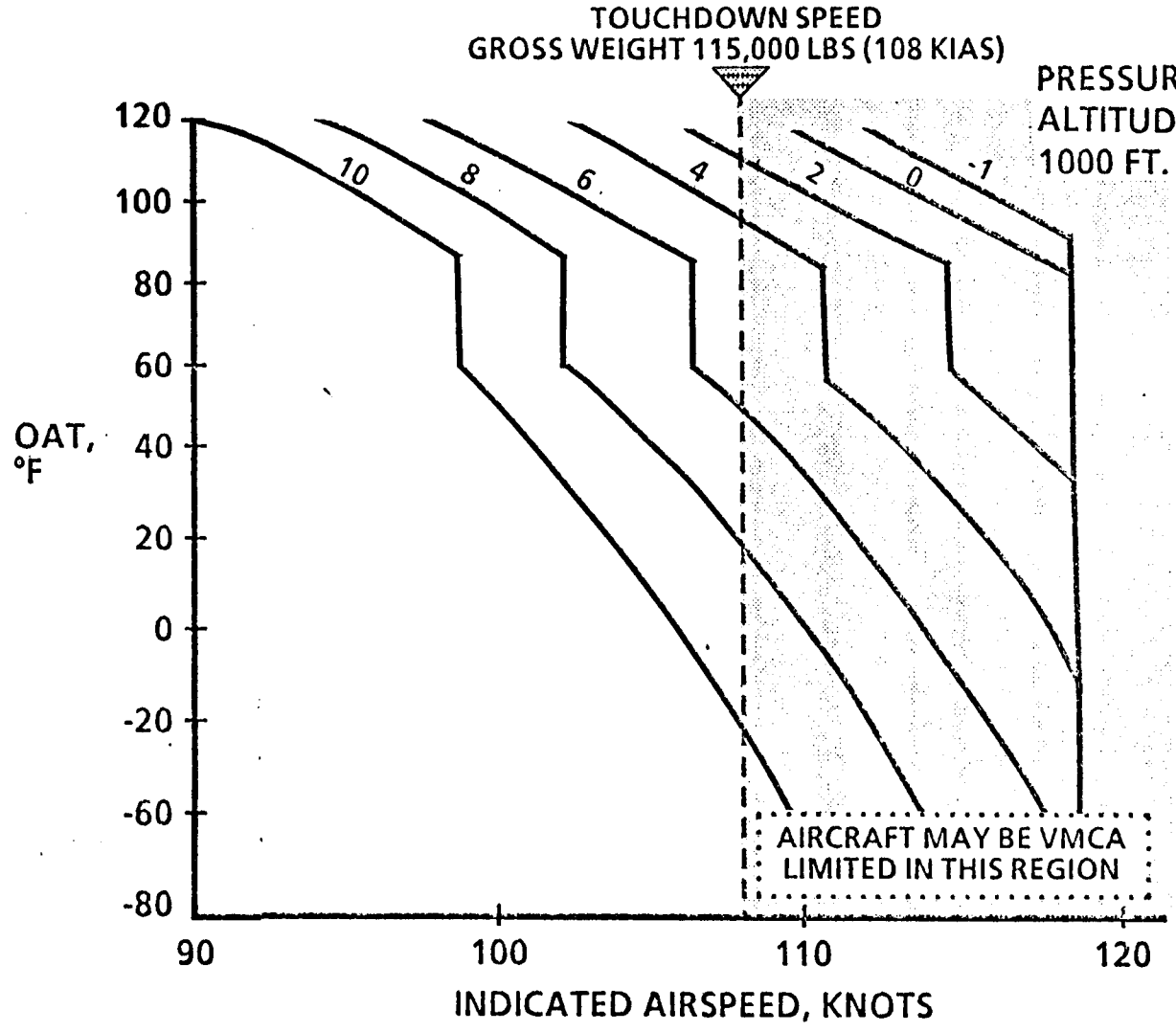


FIGURE 25

KC-135E INFLIGHT MINIMUM CONTROL SPEED



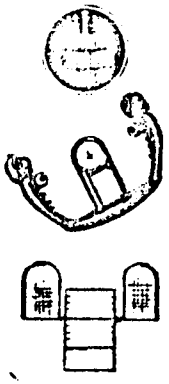
CONDITIONS:

RUDDER POWER ON
ONE OUTBOARD
ENGINE OUT

ENGINE FAILURE CONTROL TECHNIQUE

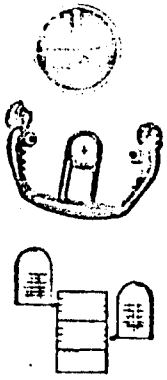
NOTE:
NUMBER 4
ENGINE
INOPERATIVE

INCORRECT TECHNIQUE



WHEEL ONLY
NO RUDDER

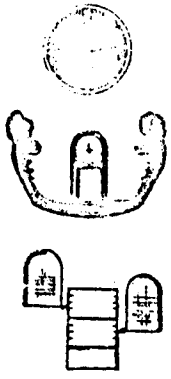
NOT ENOUGH RUDDER



TOO MUCH RUDDER

CORRECT TECHNIQUE

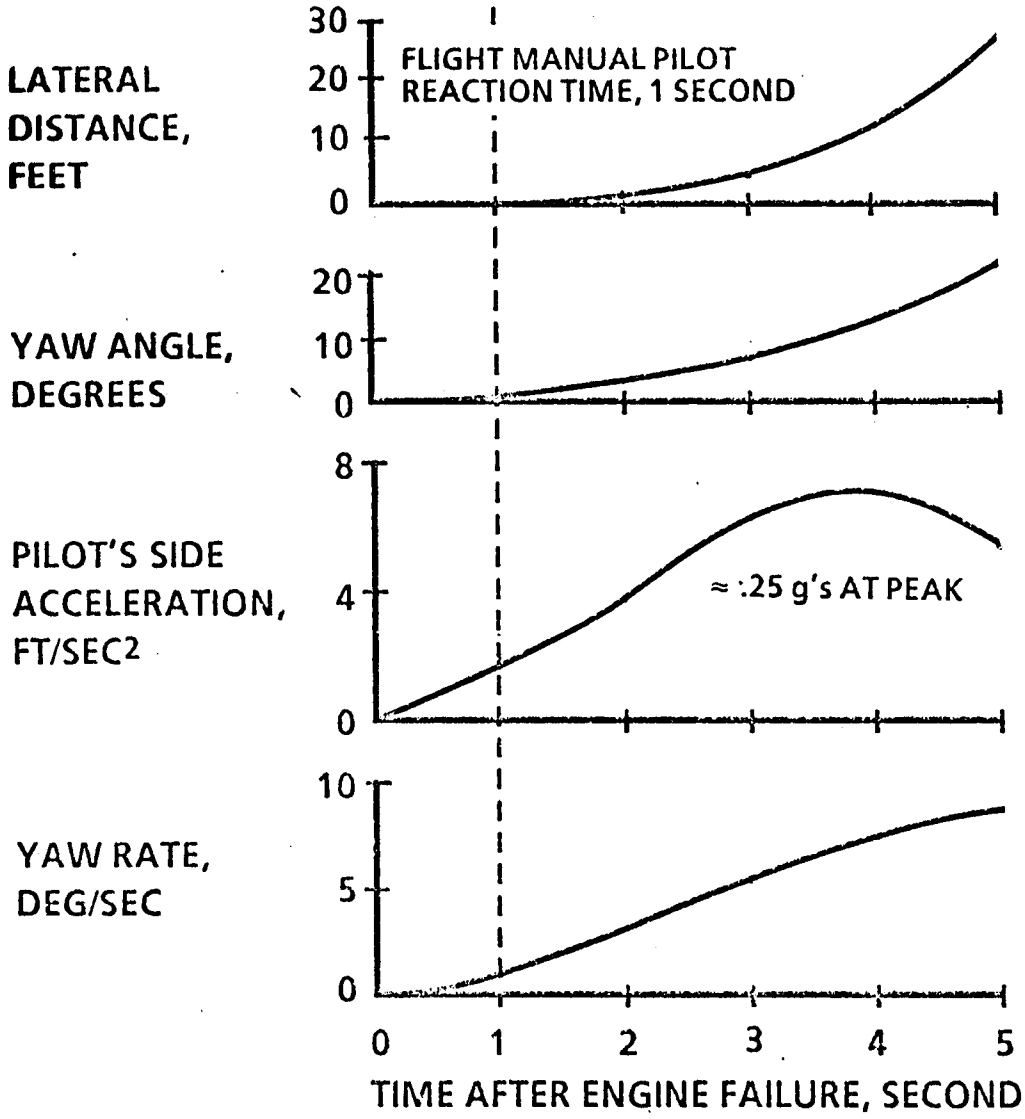
RIGHT SPOILER UP - WINGS LEVEL
BALL CENTERED (CROSS CONTROLS)



CONTROL WHEEL LEVEL
BALL SLIGHTLY OUT OF CENTER
RUDDER ONLY(RECOMMENDED)

FIGURE 27

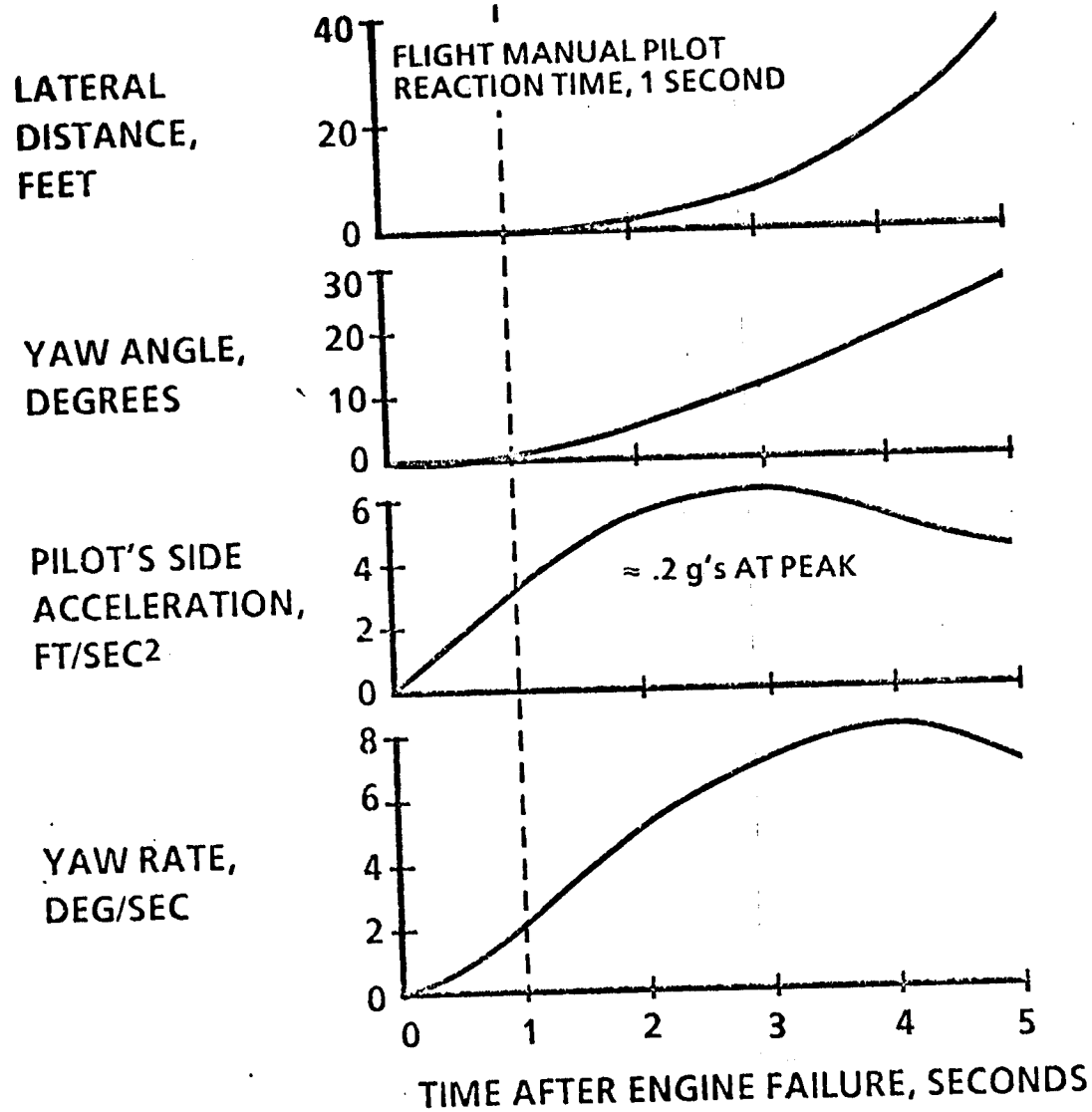
PILOT CUES TO AN ENGINE FAILURE, KC-135A



CONDITIONS

- GROSS WEIGHT 200,000 POUNDS
- SEA LEVEL, 59° F
- AT V_{MCG} SPEED (83.0 KCAS)

PILOT CUES TO AN ENGINE FAILURE, C-135B

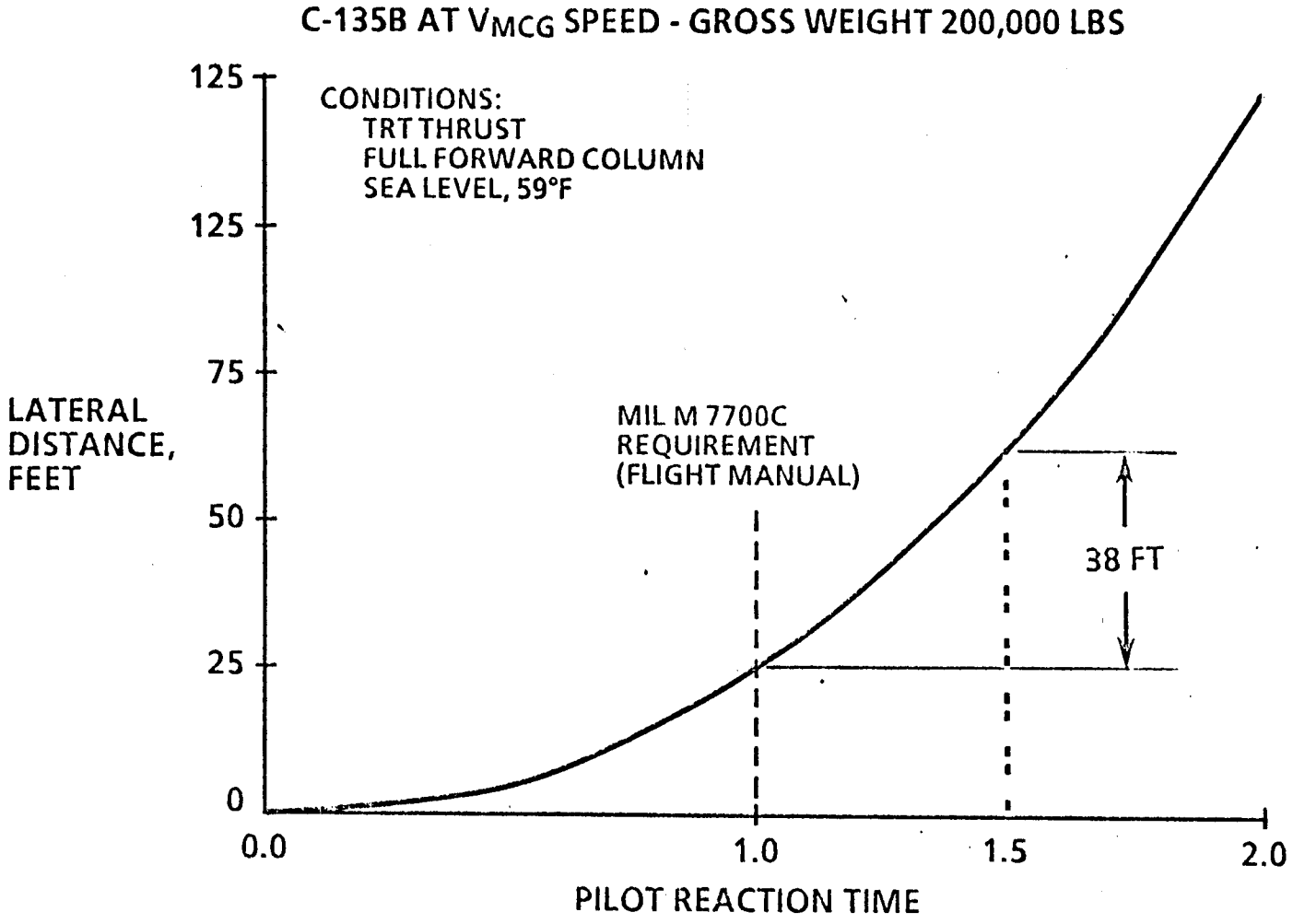


CONDITIONS

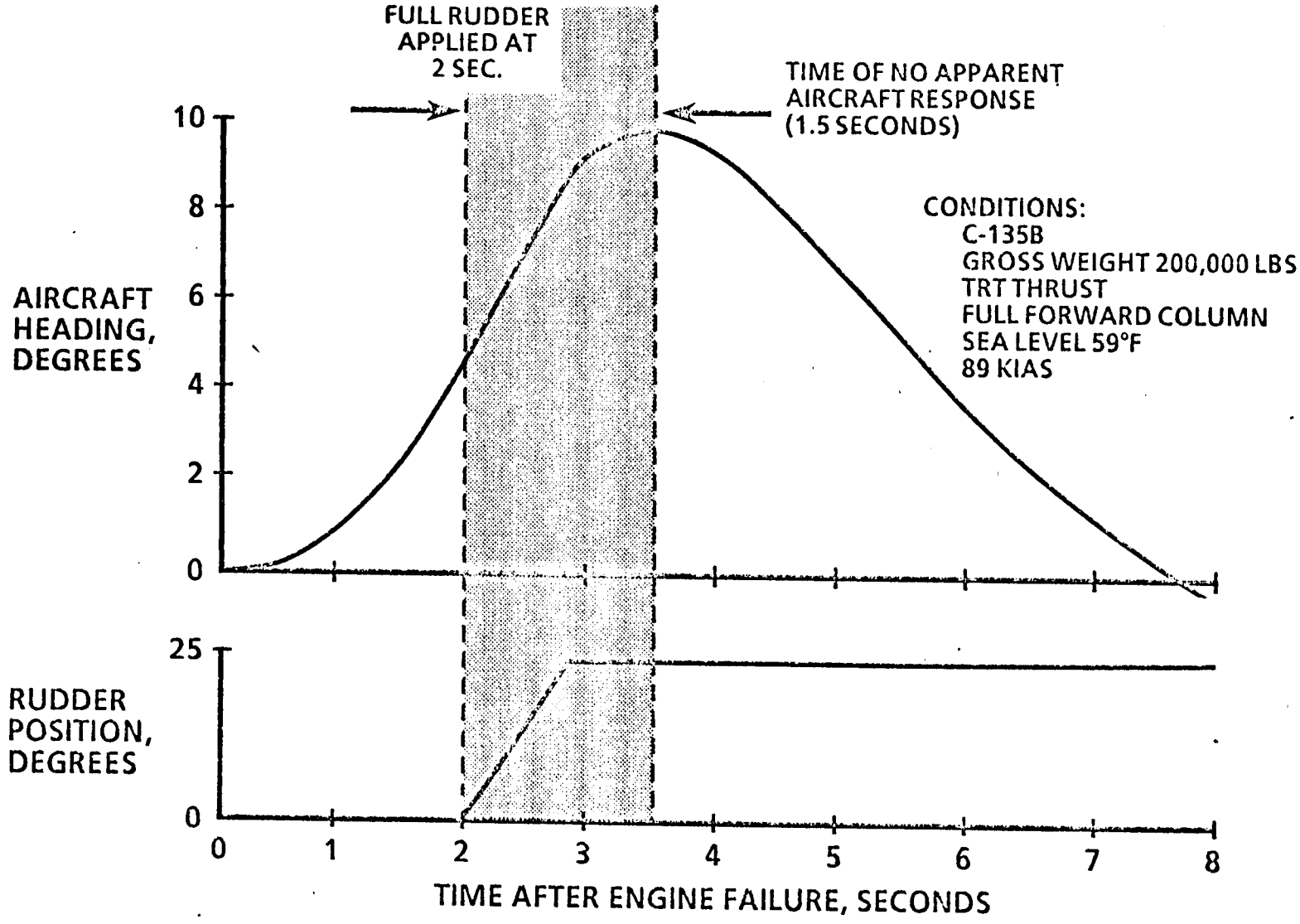
- GROSS WEIGHT 200,000 POUNDS
- SEA LEVEL, 59° F
- AT V_{MCG} SPEED (100.5 KCAS)

FIGURE 29

EFFECT OF PILOT REACTION TIME ON LATERAL DISTANCE



AIRCRAFT RESPONSE TO RUDDER CONTROL INPUTS



EFFECT OF ENGINE FAILURE SPEED ON LATERAL DISTANCE

GROSS WEIGHT 200,000 LBS, DRY RUNWAY (RCR 23)

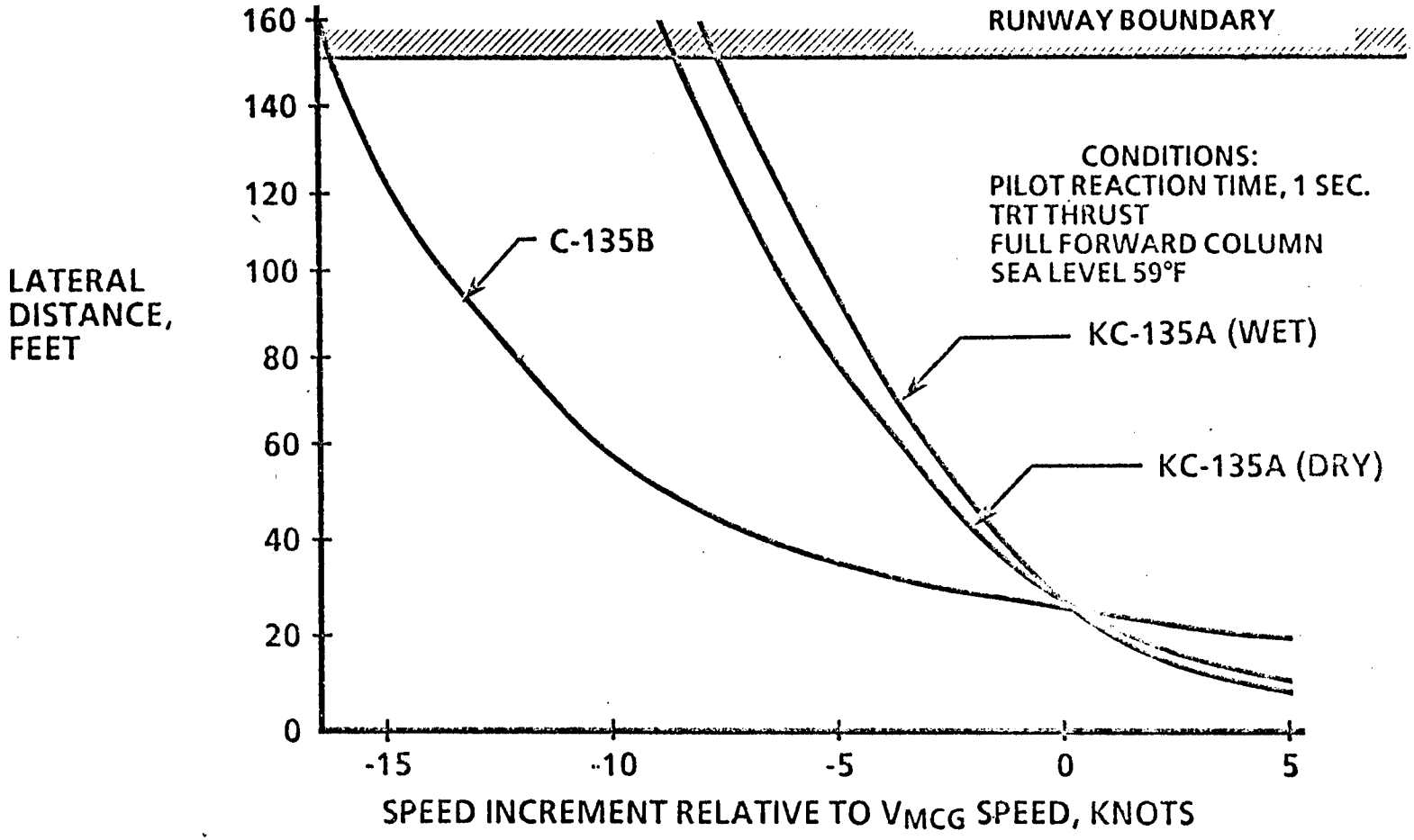
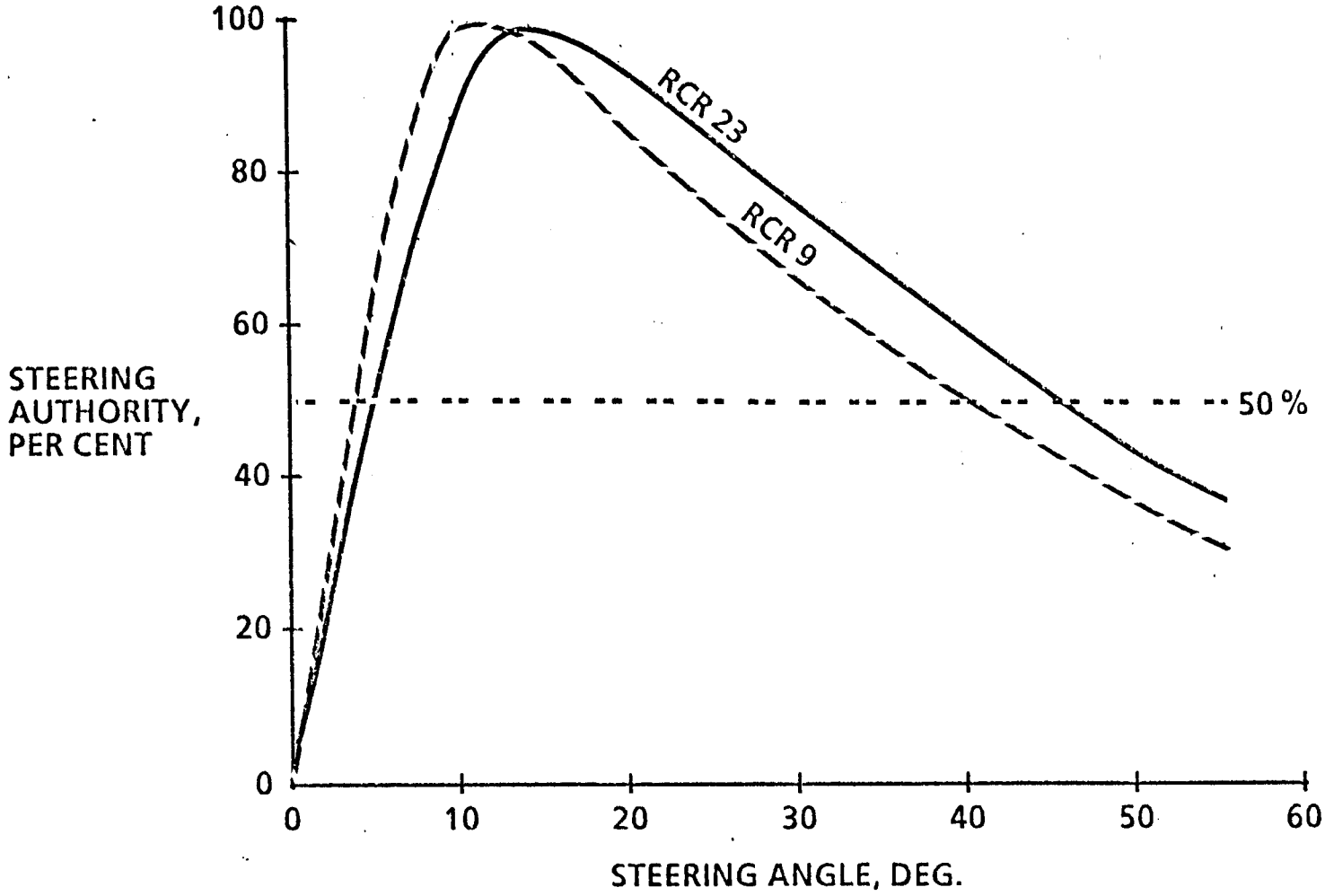


FIGURE 32

STEERING AUTHORITY



OPTIMUM NOSEWHEEL STEERING TECHNIQUE

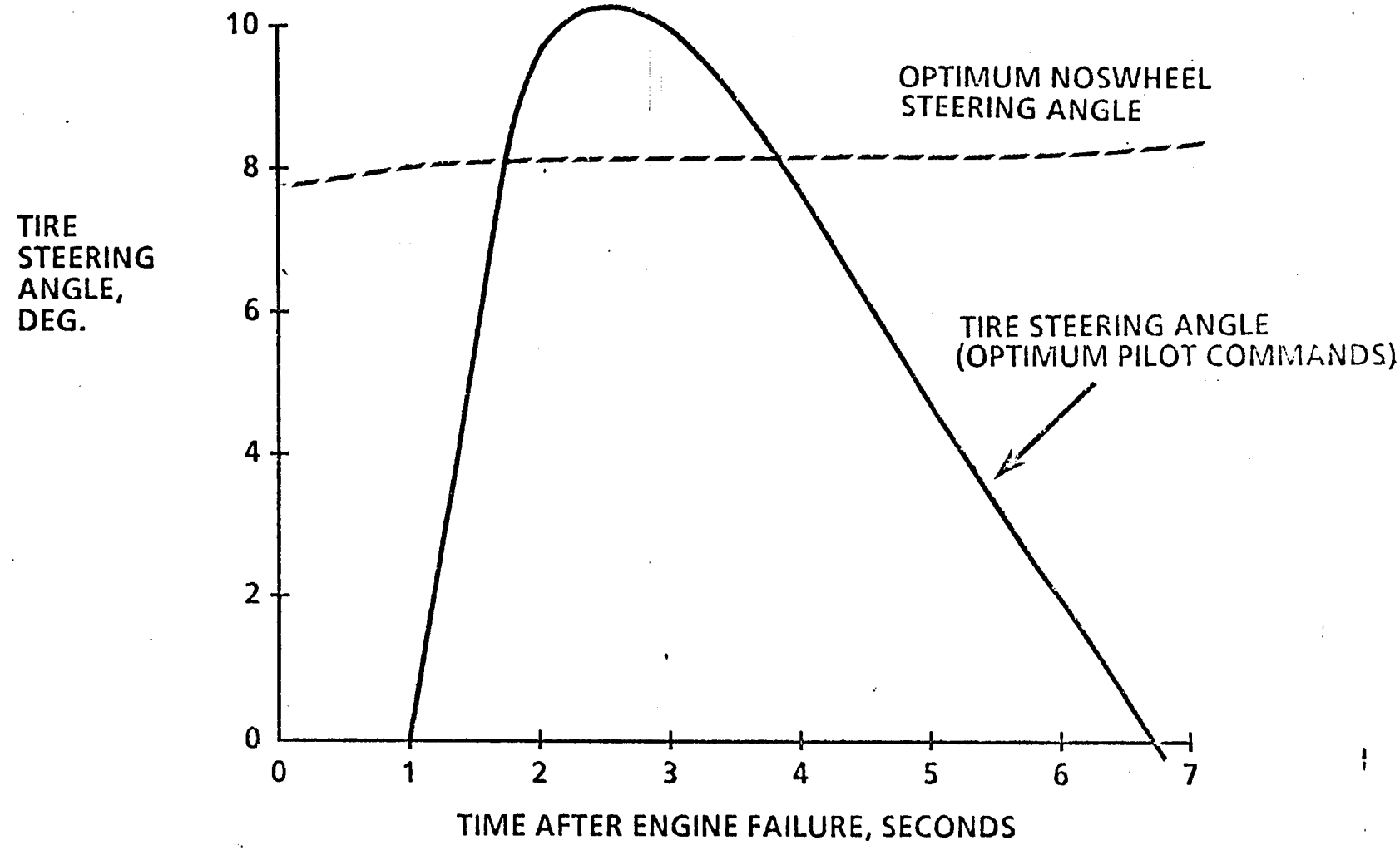
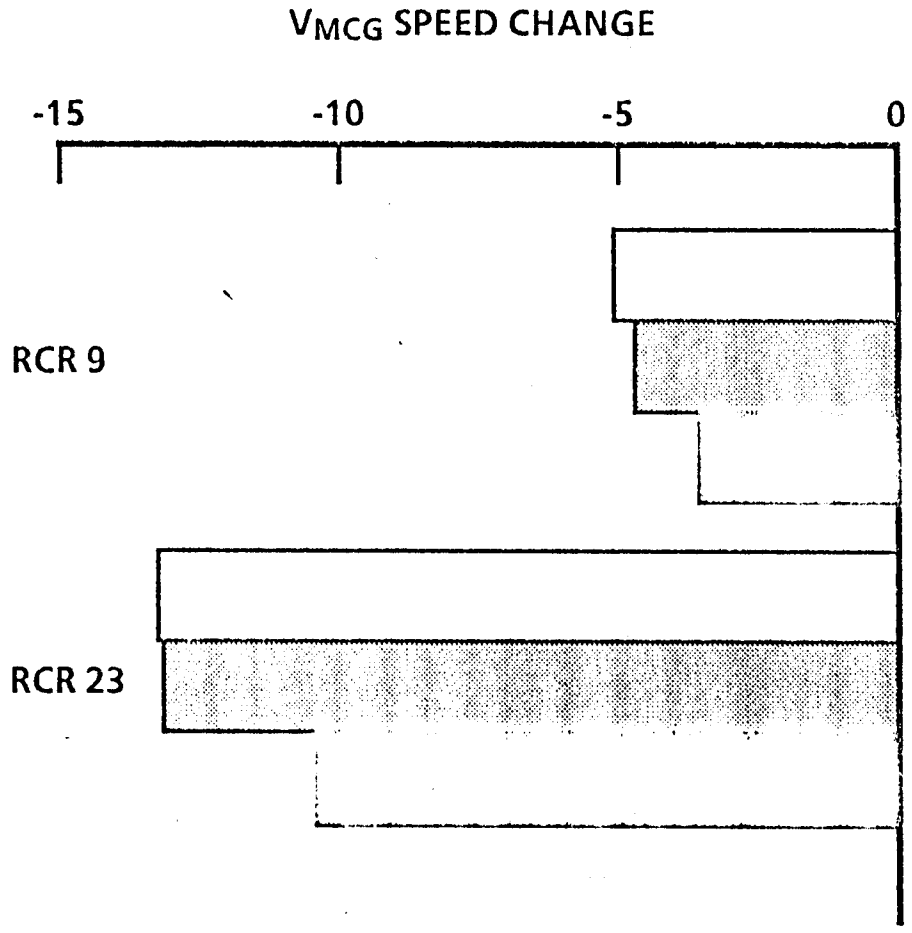


FIGURE 34

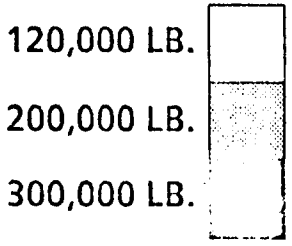
EFFECT OF CONTROL COLUMN POSITION ON V_{MCG} SPEEDS

C-135B - GROSS WEIGHT 200,000 LBS. - FULL FORWARD COLUMN APPLIED

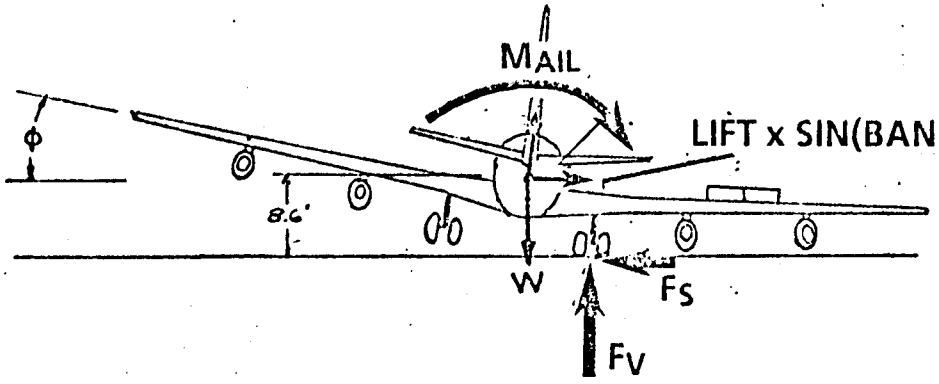


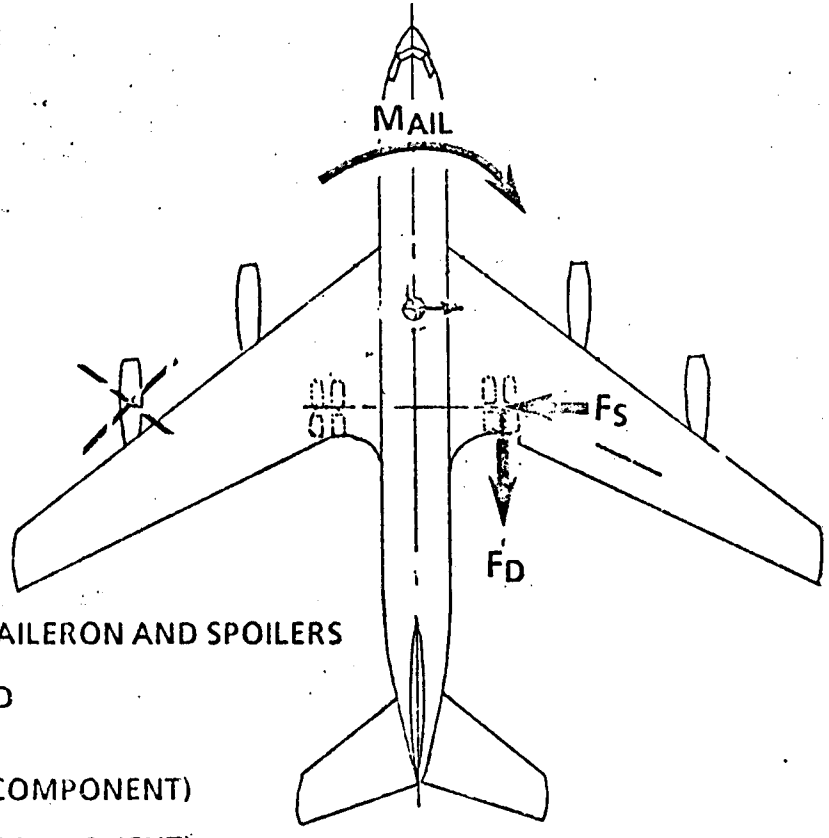
NOTE:

* BASELINE VMCG BASED ON NEUTRAL CONTROL COLUMN POSITION AFTER ENGINE FAILURE



MOMENTS DUE TO BANK ANGLE





M_{AIL} = MOMENT DUE TO AILERON AND SPOILERS

F_V = GEAR VERTICAL LOAD

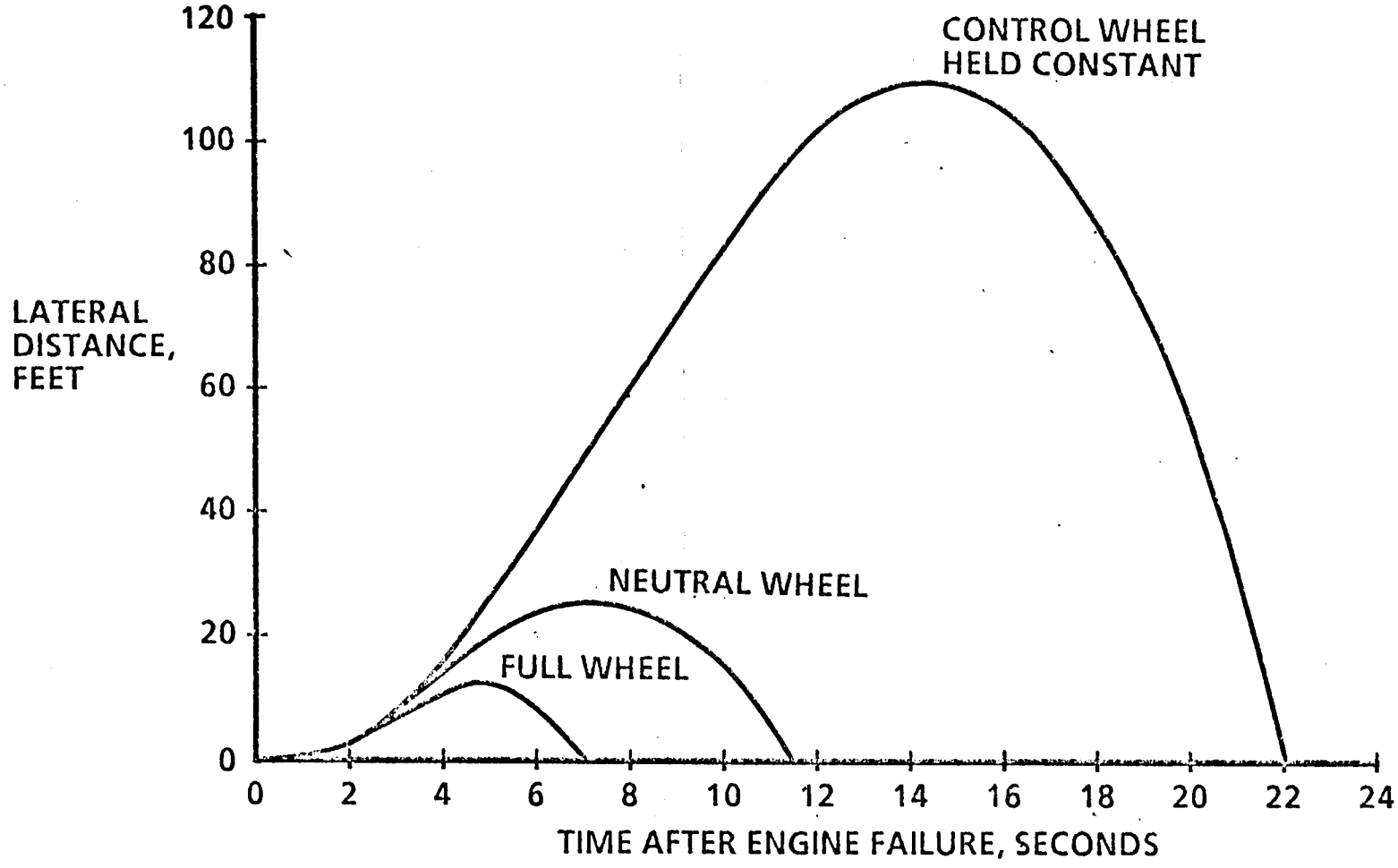
F_S = GEAR SIDE FORCE (CORNERING FORCE COMPONENT)

F_D = GEAR DRAG FORCE (CORNERING FORCE COMPONENT)

FIGURE 36

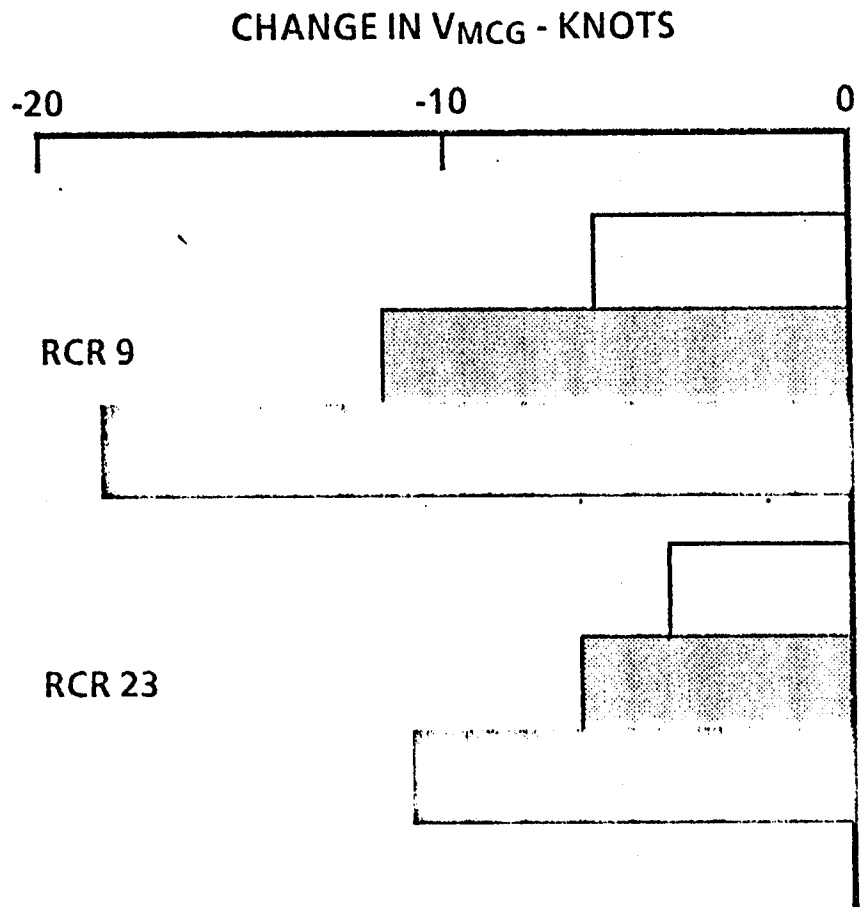
EFFECT OF CONTROL WHEEL TECHNIQUE ON LATERAL DISTANCE

GROSS WEIGHT 200,000 LBS - CROSSWIND 20 KNOTS
C-135B



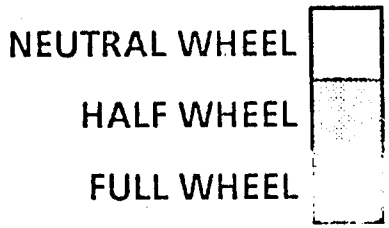
• EFFECT OF CONTROL WHEEL TECHNIQUE ON V_{MCG} SPEED

C-135B - GROSS WEIGHT 200,000 LBS - CROSSWIND 15 KNOTS



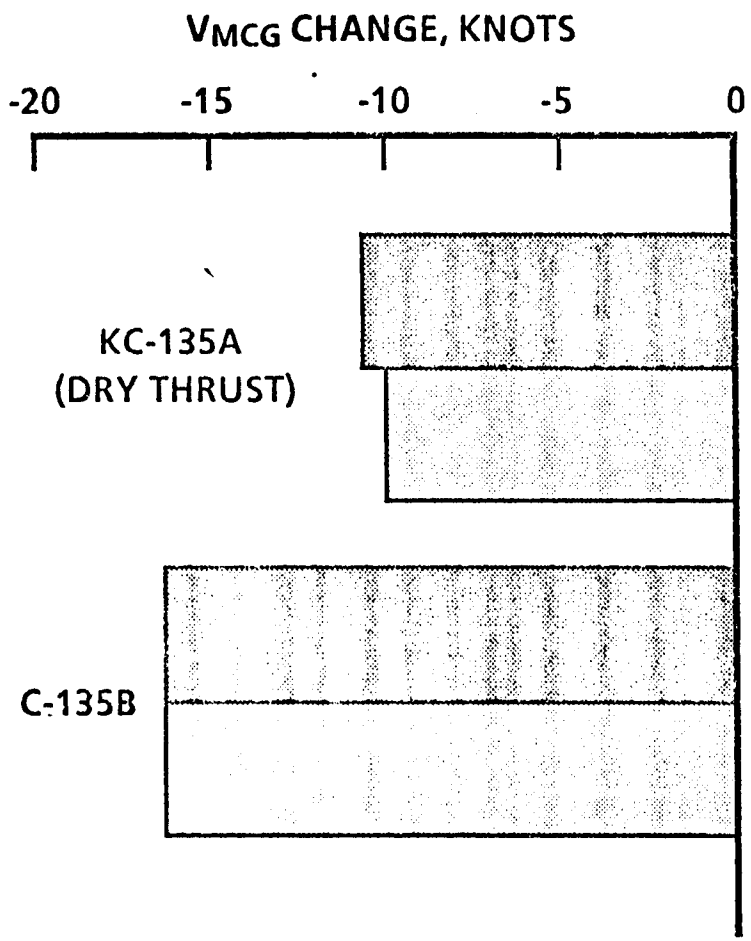
NOTE:

- BASELINE V_{MCG} BASED ON CONTROL WHEEL HELD CONSTANT AFTER ENGINE FAILURE
- CONTROL WHEEL INPUT APPLIED TOWARD RUNWAY CENTERLINE



EFFECT OF REDUCED THRUST ON VMCG SPEED

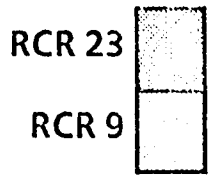
GROSS WEIGHT 200,000 LBS



CONDITIONS:

- SEA LEVEL, 59° F
- FULL FORWARD COLUMN
- EPR REDUCTION (REDUCED THRUST PROCEDURES)

KC-135A	-0.30
C-135B	-0.15



MAXIMUM BANK ATTITUDE - CROSSWIND TAKEOFF

CROSSWIND 20 KNOTS - OUTBOARD ENGINE FAILURE

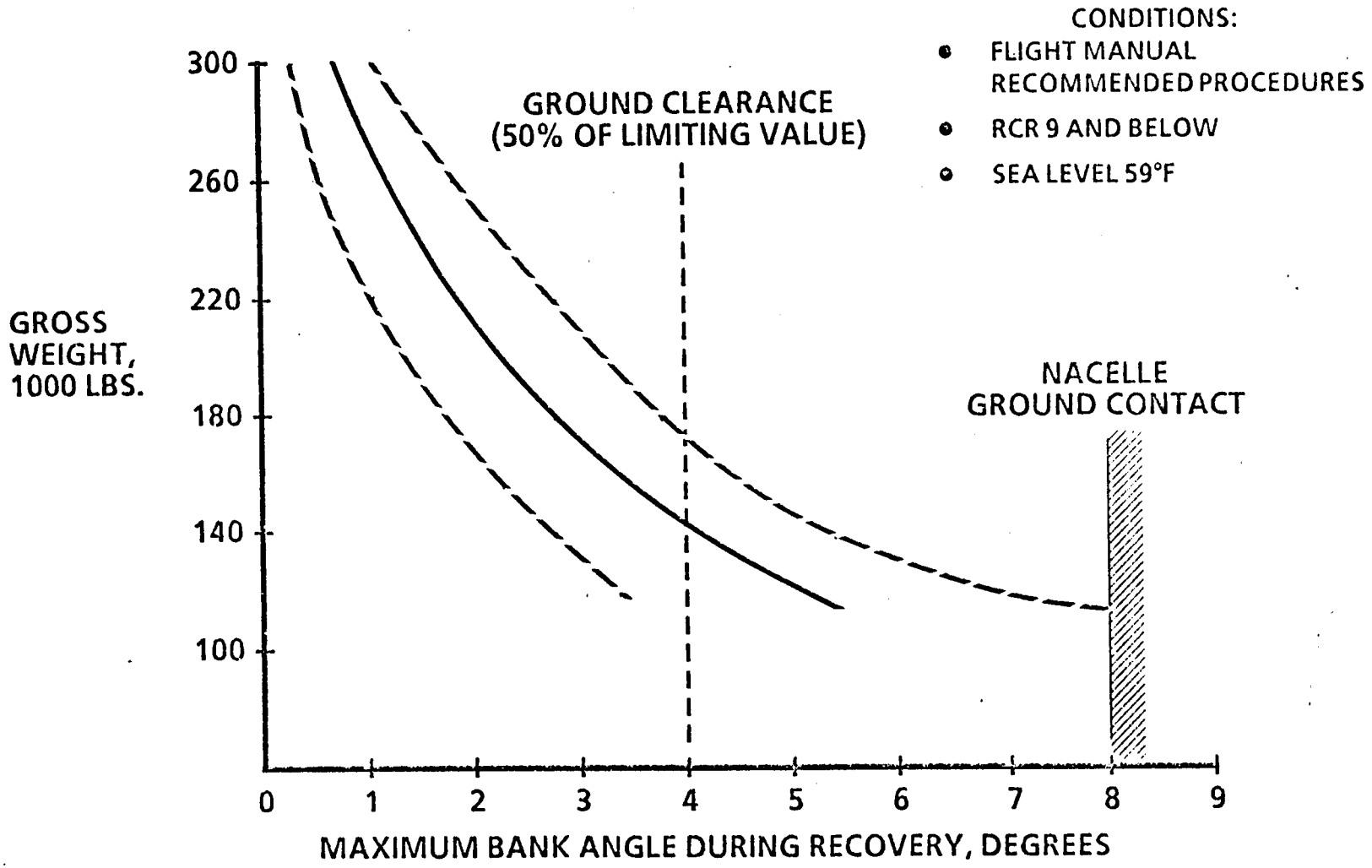
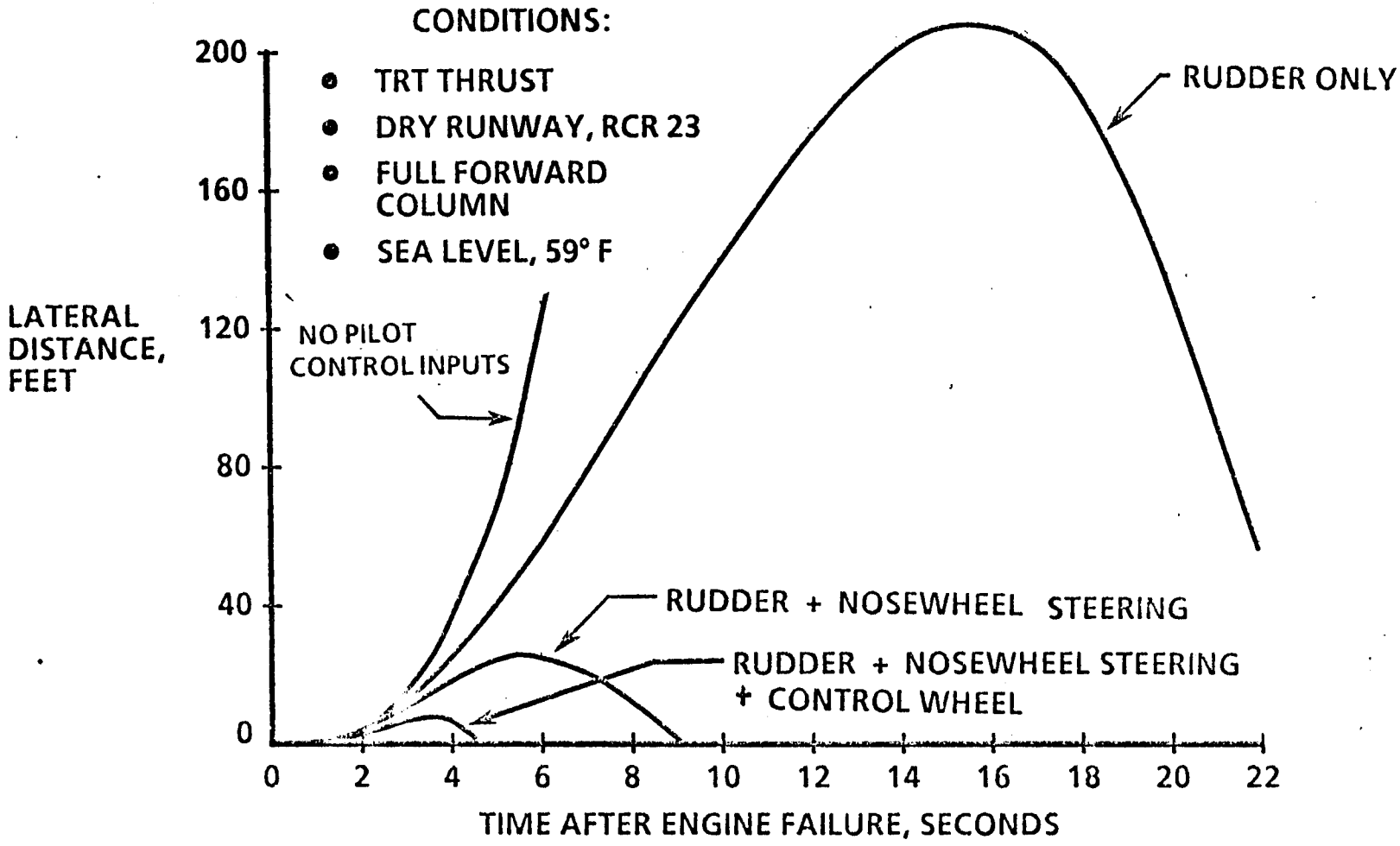


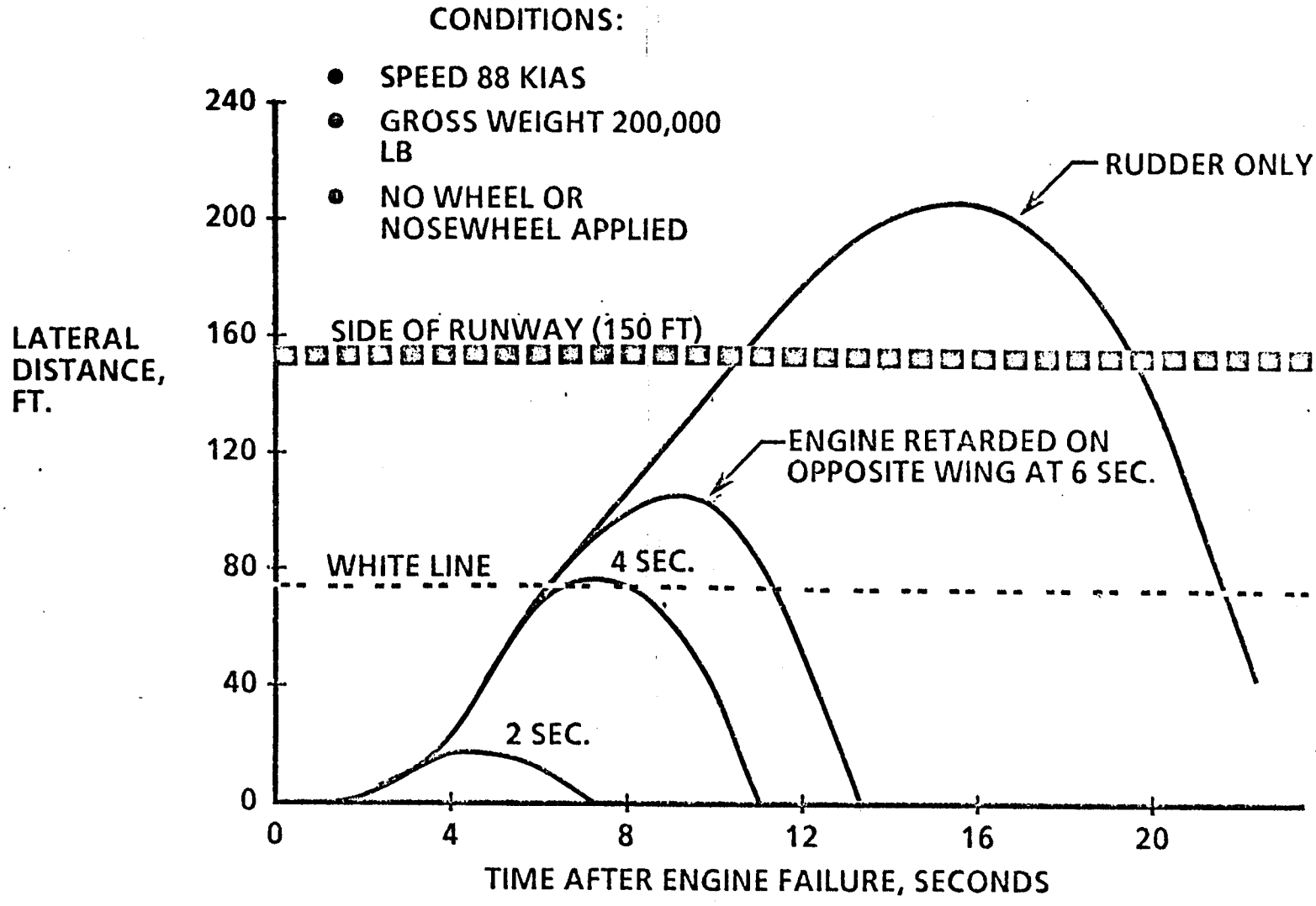
FIGURE 40

EFFECT OF PILOT CONTROL TECHNIQUES ON LATERAL DISTANCE

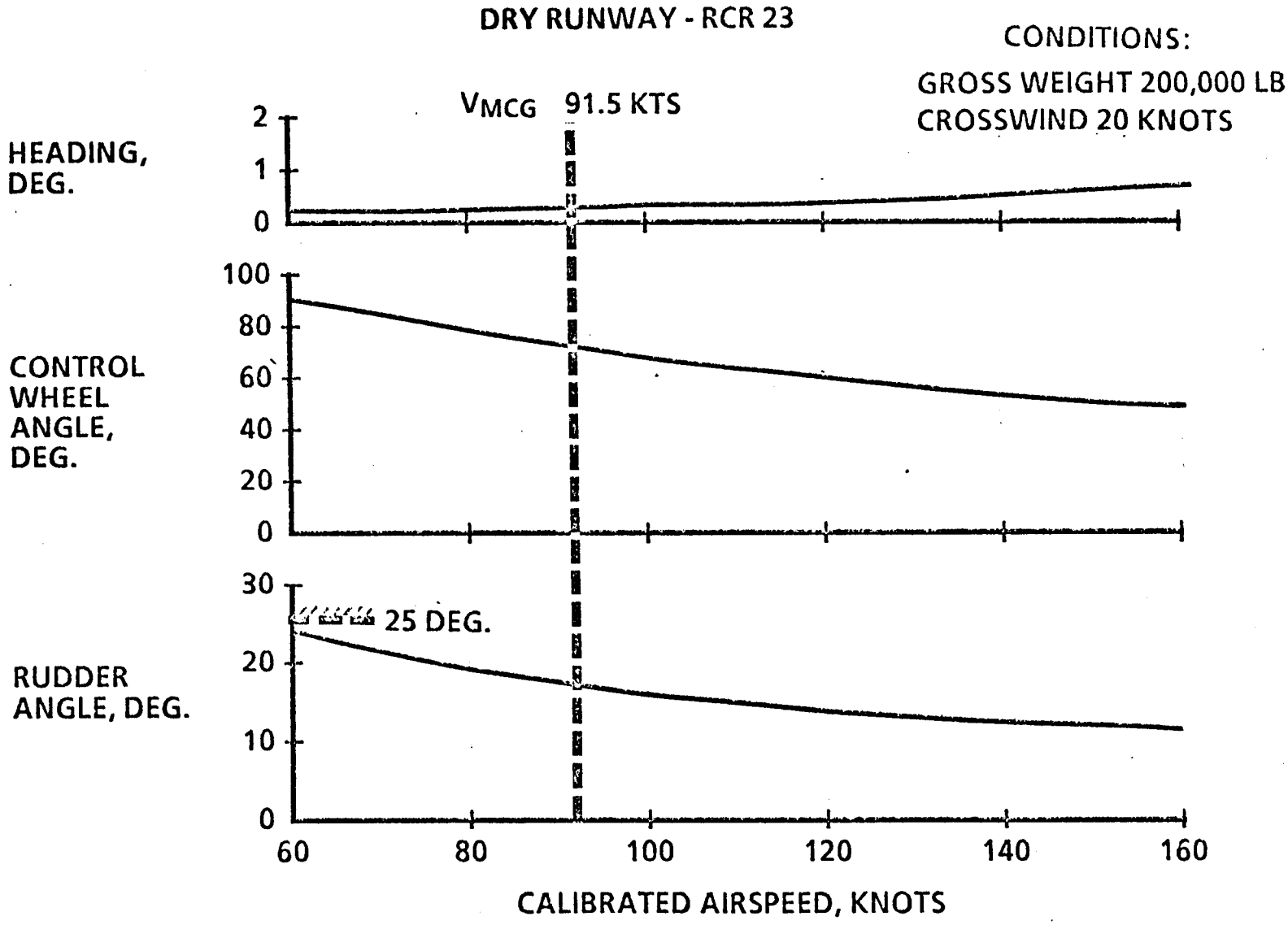
C-135B AT VMCG SPEED - GROSS WEIGHT 200,000 LBS



EFFECT OF RETARDING OPPOSITE ENGINES ON AIRCRAFT CONTROL



TYPICAL PILOT CONTROL INPUTS DURING CROSSWIND TAKEOFF



TYPICAL PILOT CONTROL INPUTS DURING CROSSWIND TAKEOFF

ICY RUNWAY - RCR 4

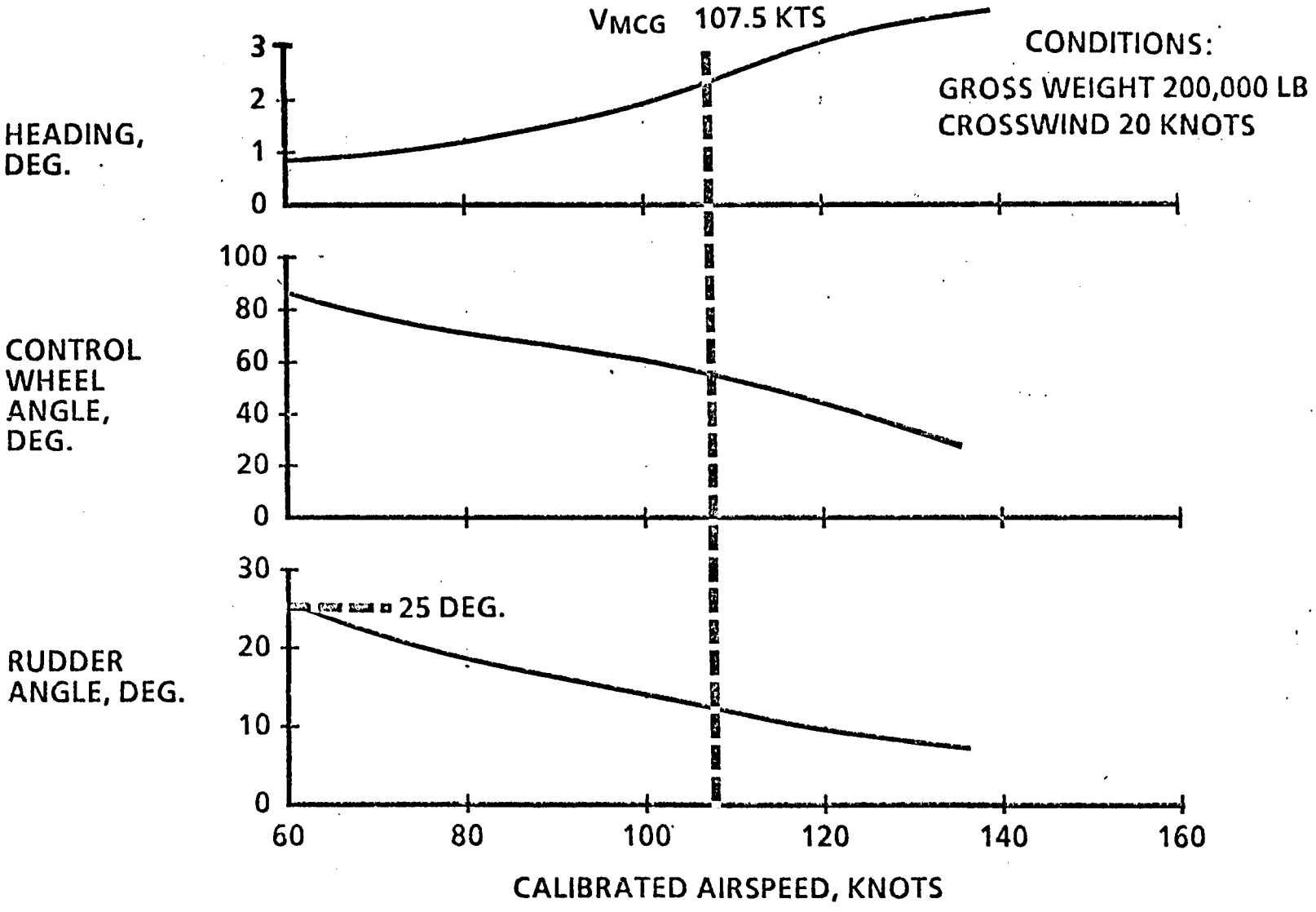
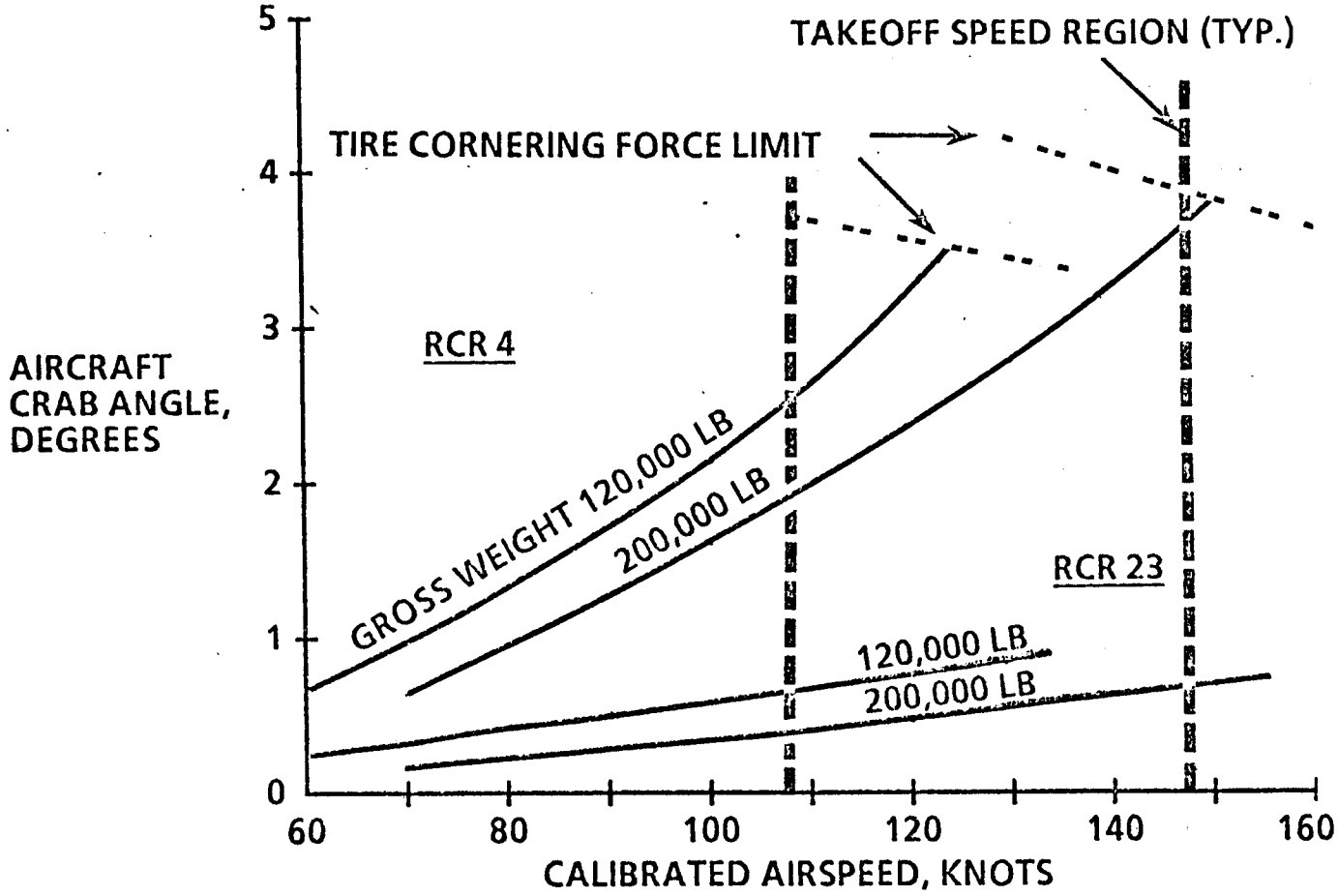


FIGURE 44

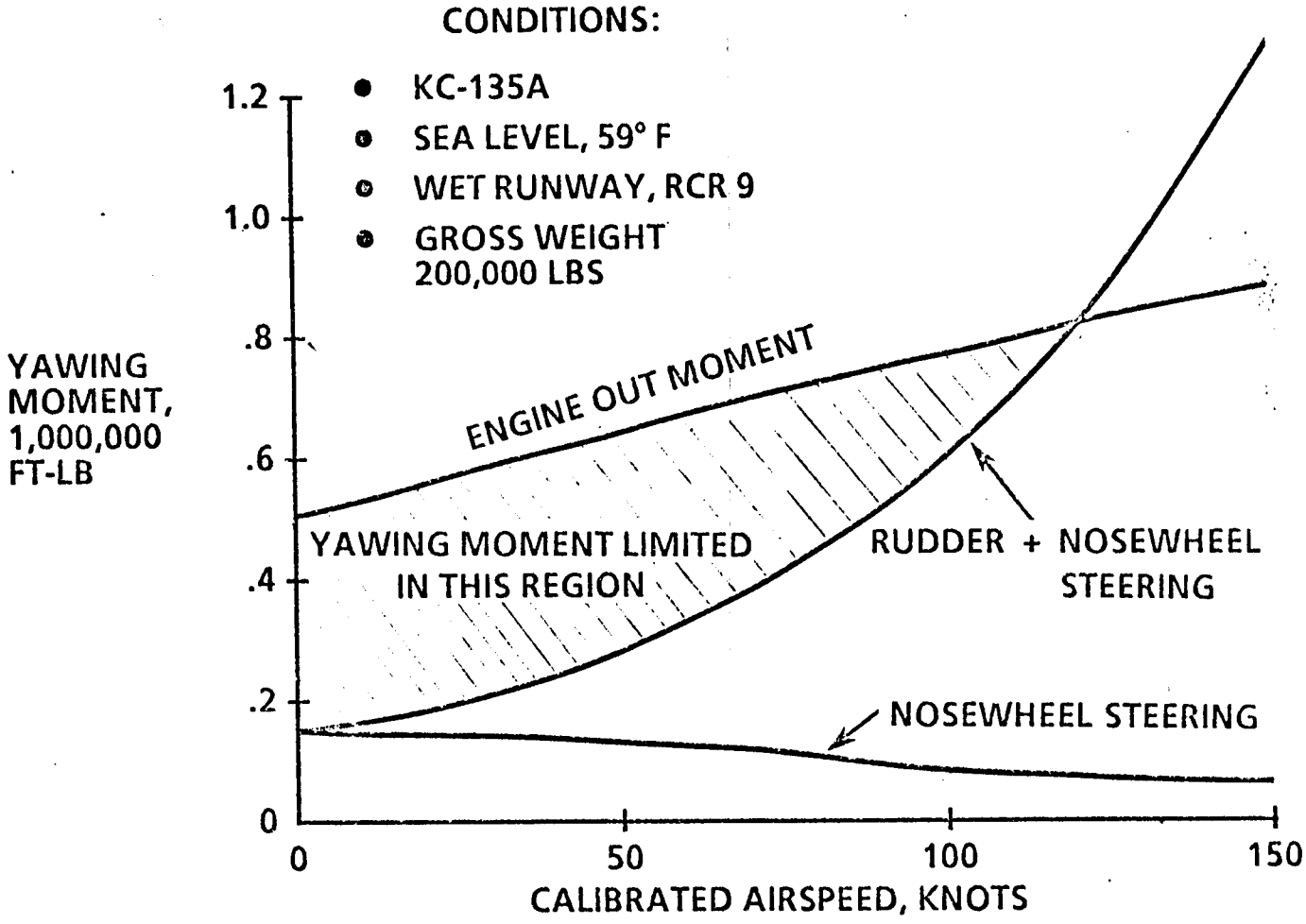
CROSSWIND TAKEOFF - SIDE FORCE LIMITED

CROSSWIND 20 KNOTS - C-135B



ENGINE OUT YAWING MOMENT CHARACTERISTICS

CROSSWIND 20 KNOTS - UPWIND ENGINE OUTBOARD FAILURE



TYPICAL WRONG RUDDER APPLICATION

C-135B 110 KCAS ENGINE FAILURE SPEED (VMCG + 18 KCAS)

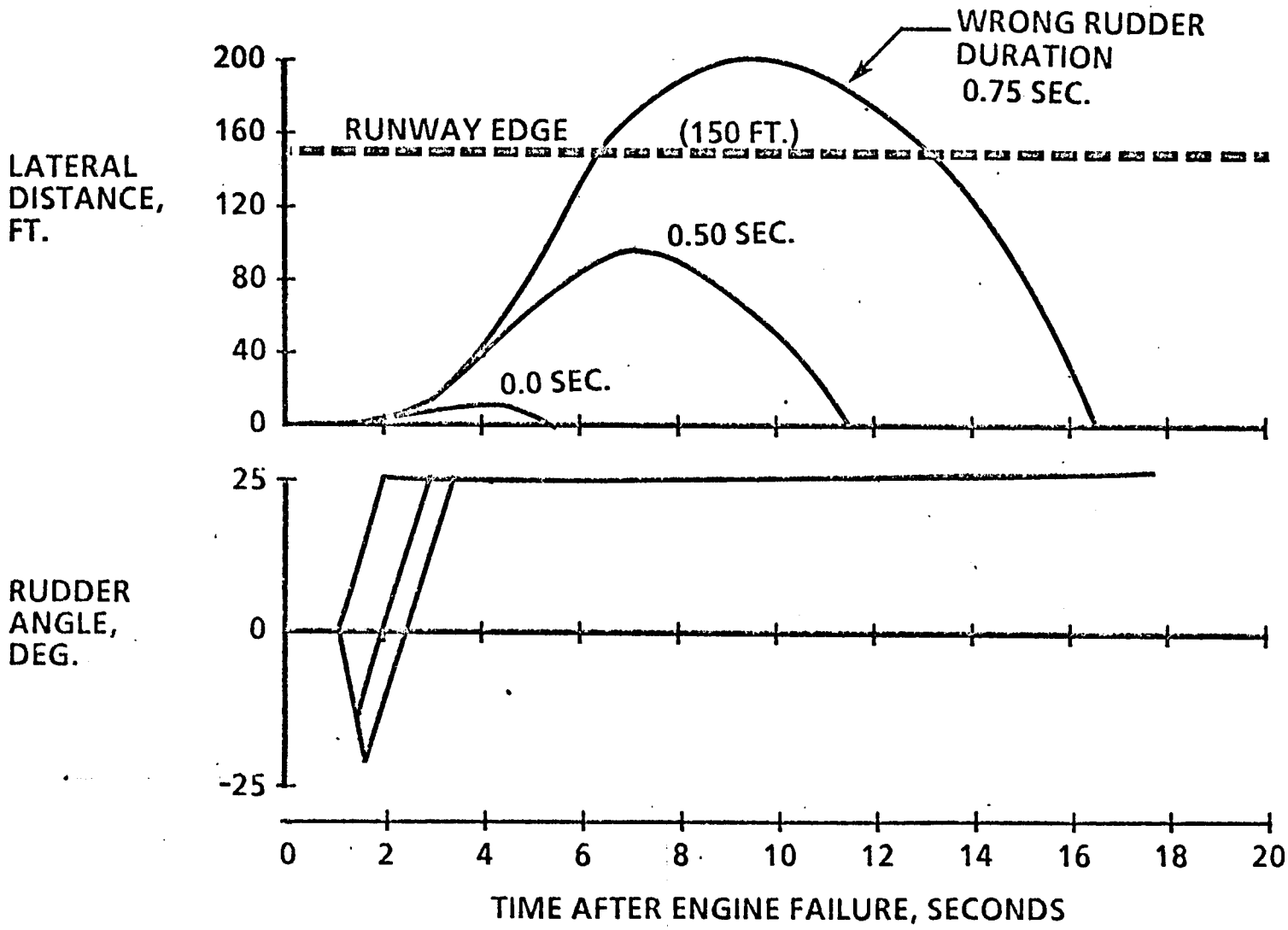
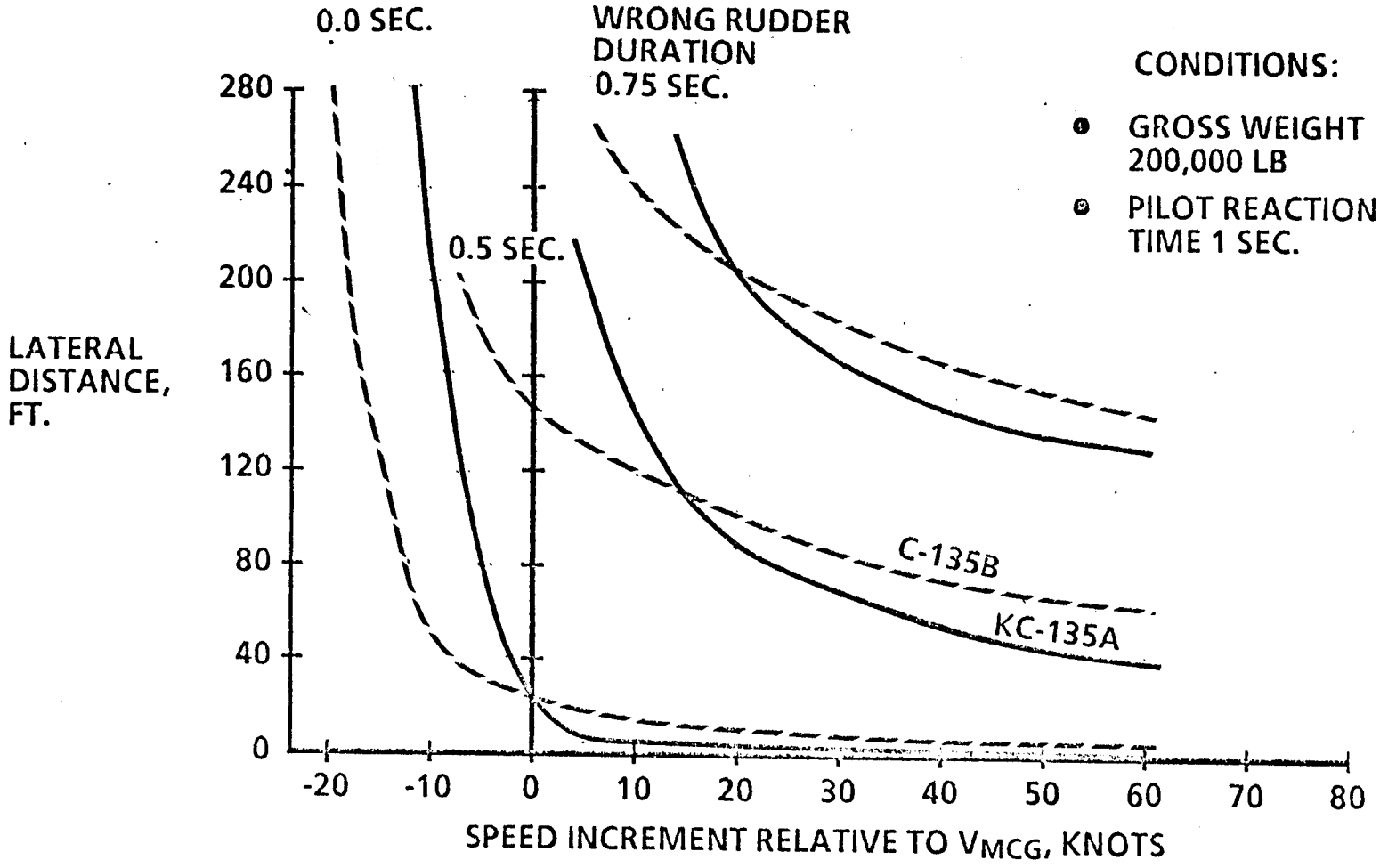


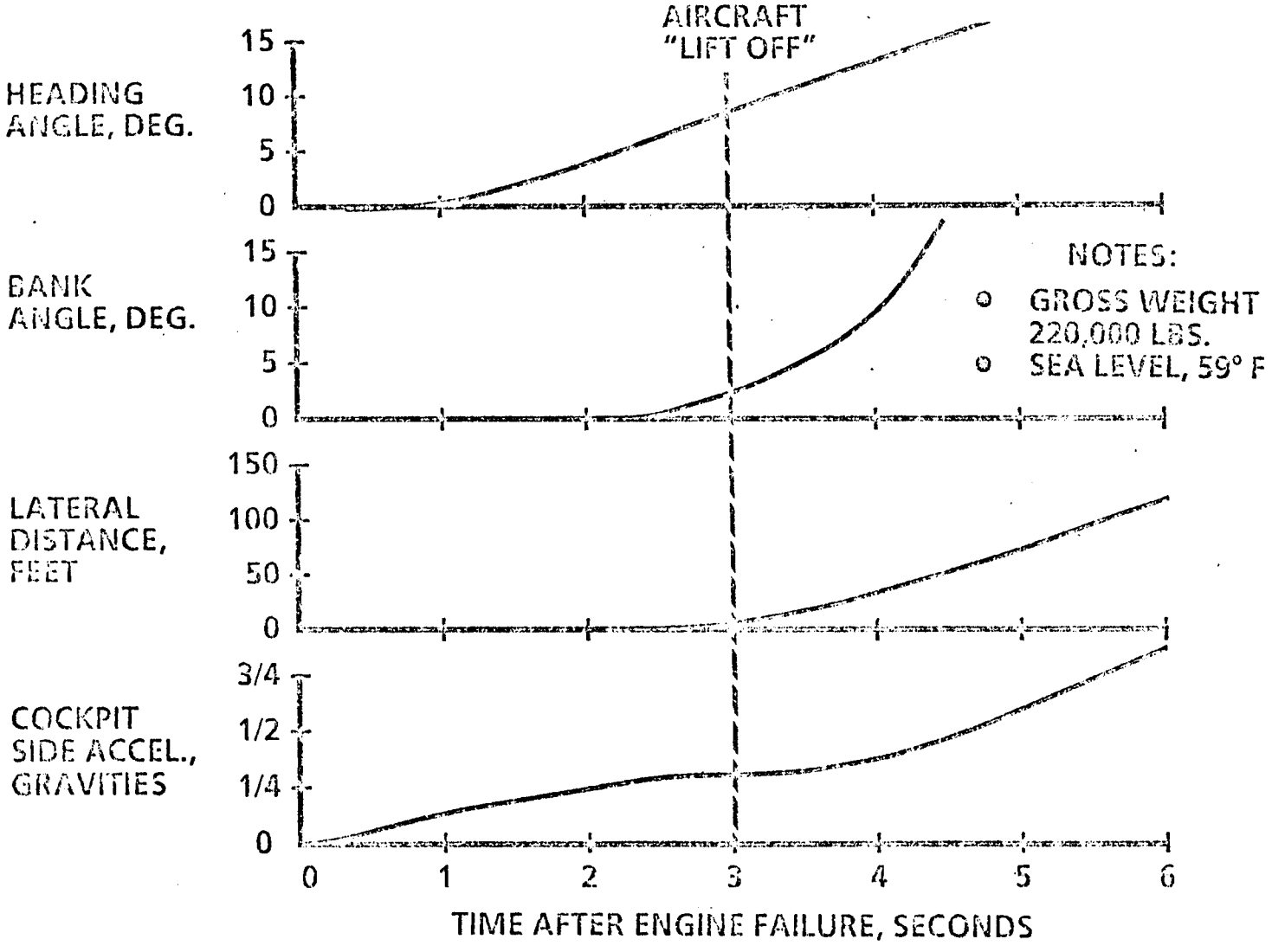
FIGURE 47

EFFECT OF WRONG RUDDER APPLICATION FOR DIFFERENT -135 AIRCRAFT



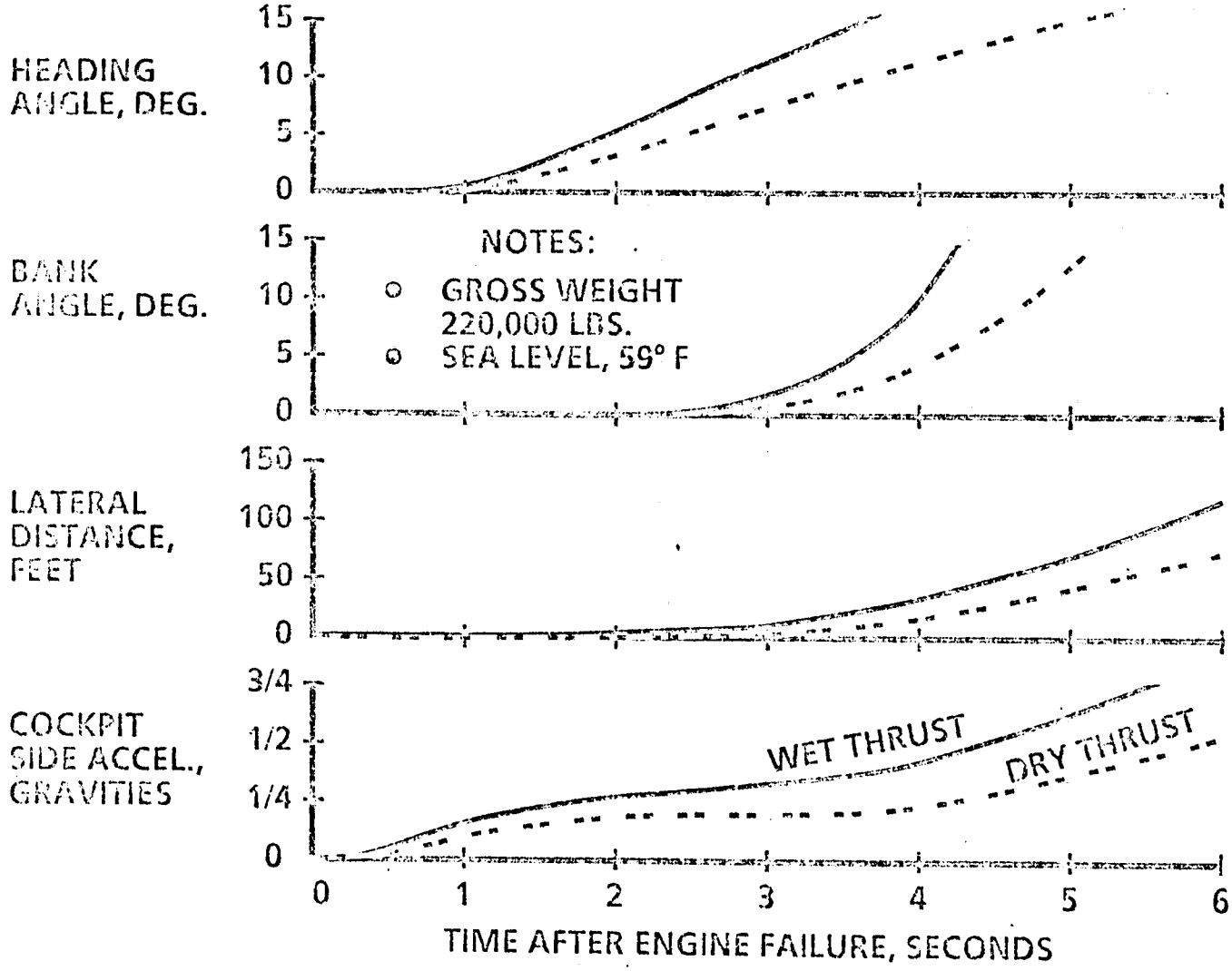
KC-135A RESPONSE TO ENGINE FAILURE DURING ROTATION

NO PILOT CORRECTIVE ACTION - WATER INJECTION



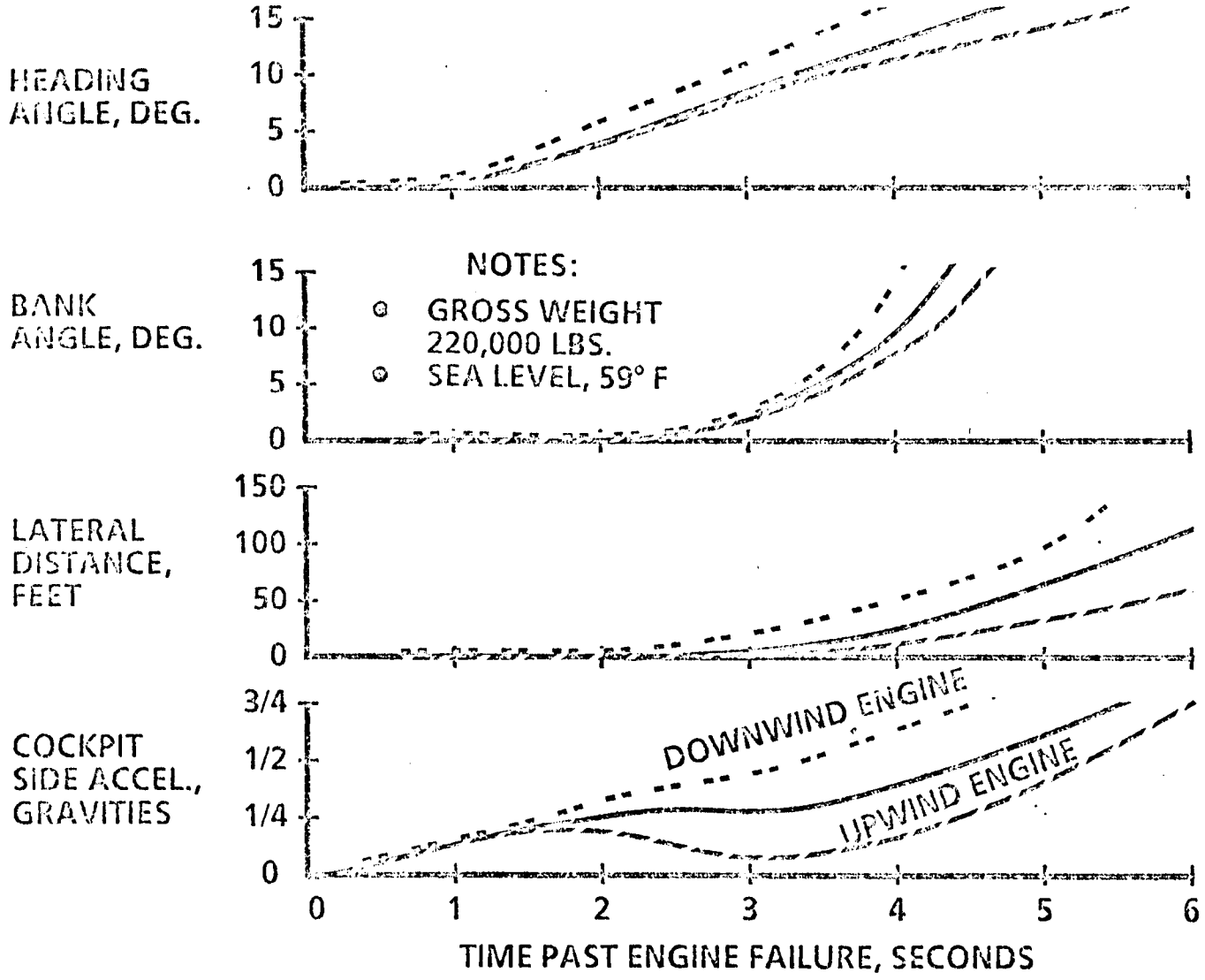
RESPONSE TO ENGINE FAILURE DURING ROTATION

TAKEOFF THRUST VARIATION - NO PILOT CORRECTIVE ACTION - KC-135A

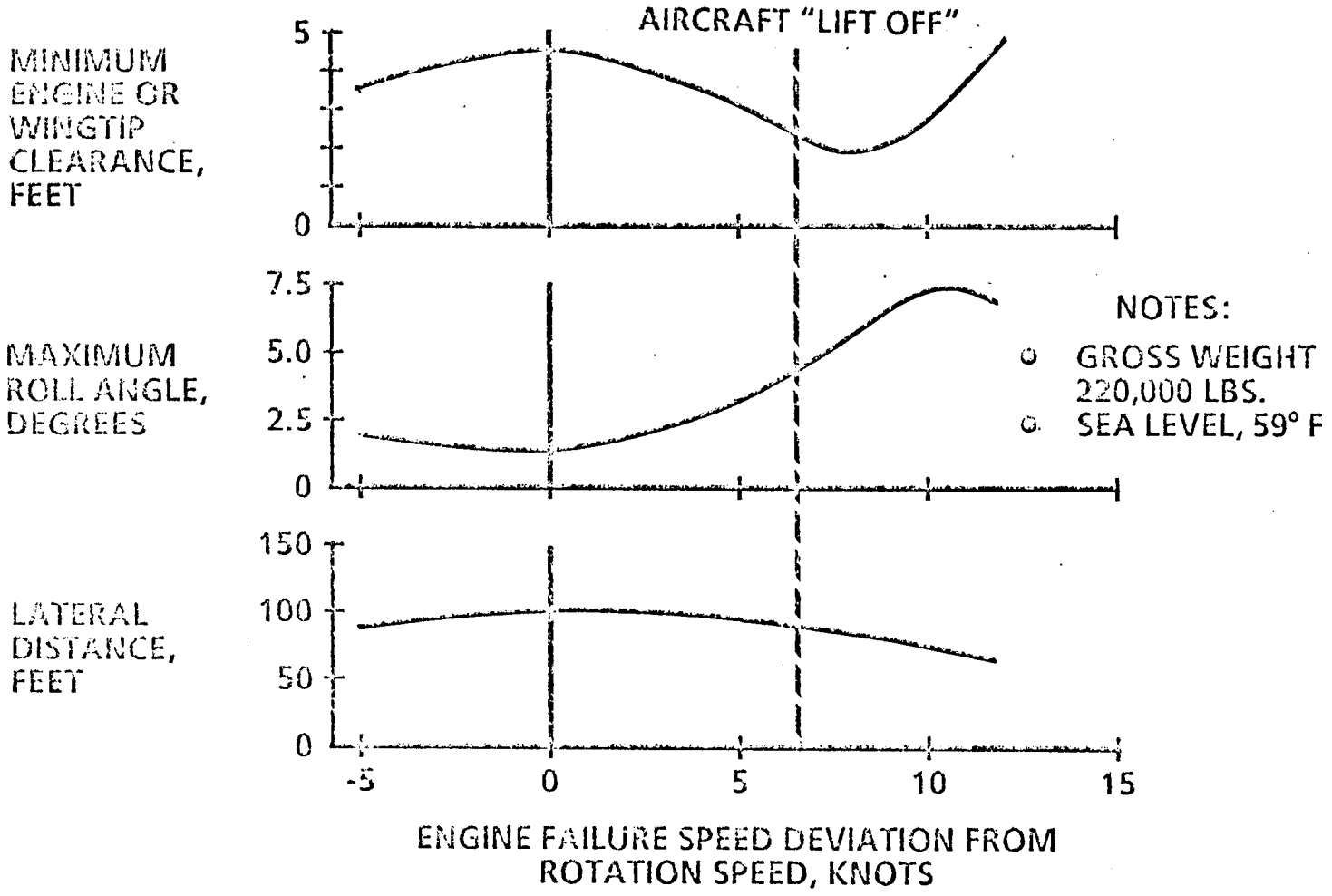


RESPONSE TO ENGINE FAILURE DURING ROTATION WITH A CROSSWIND

15 KNOT CROSSWIND - NO PILOT CORRECTIVE ACTION - KC-135A - WET THRUST

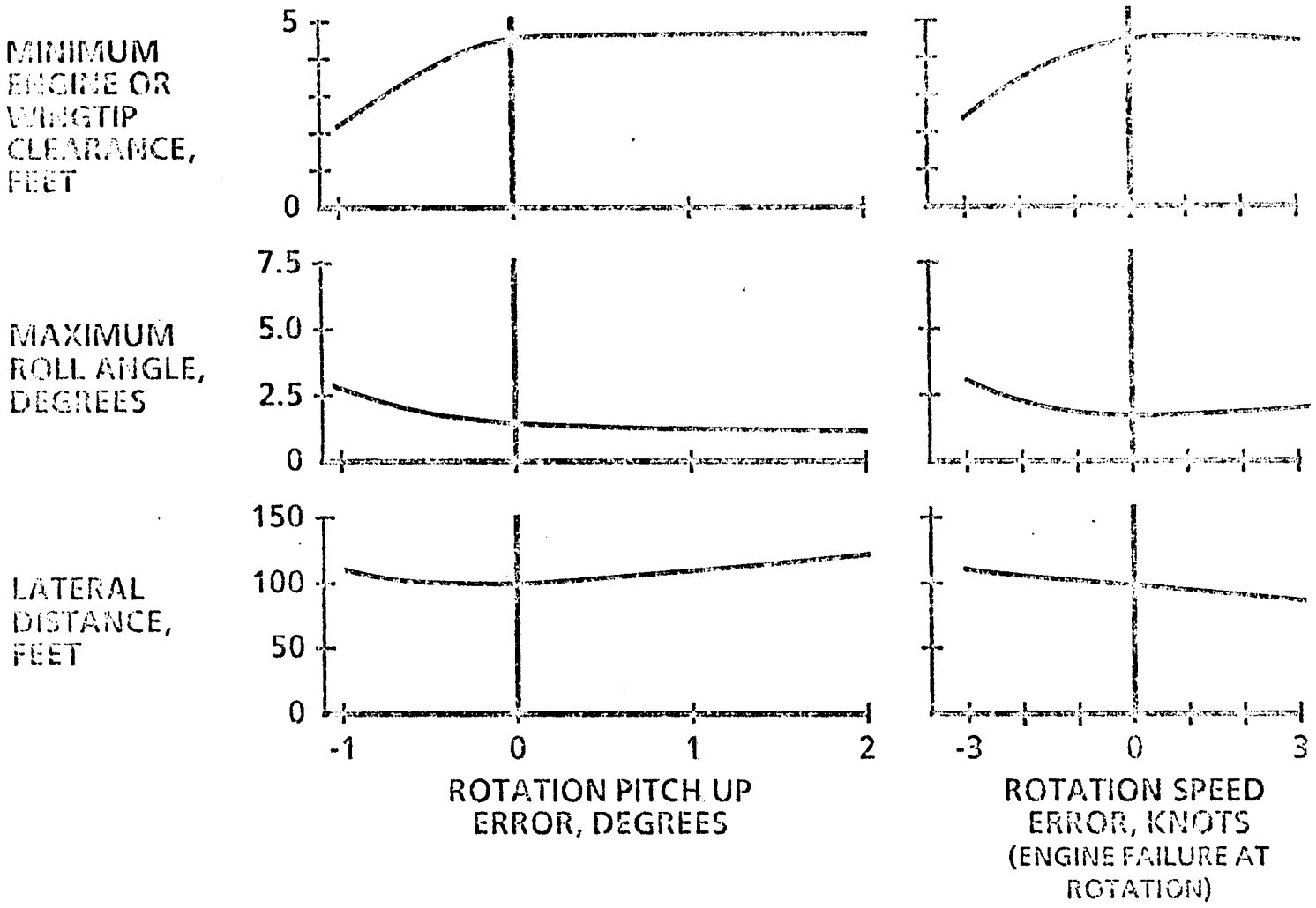


EFFECT OF ENGINE FAILURES SPEED ON AIRCRAFT RESPONSE - KC-135A



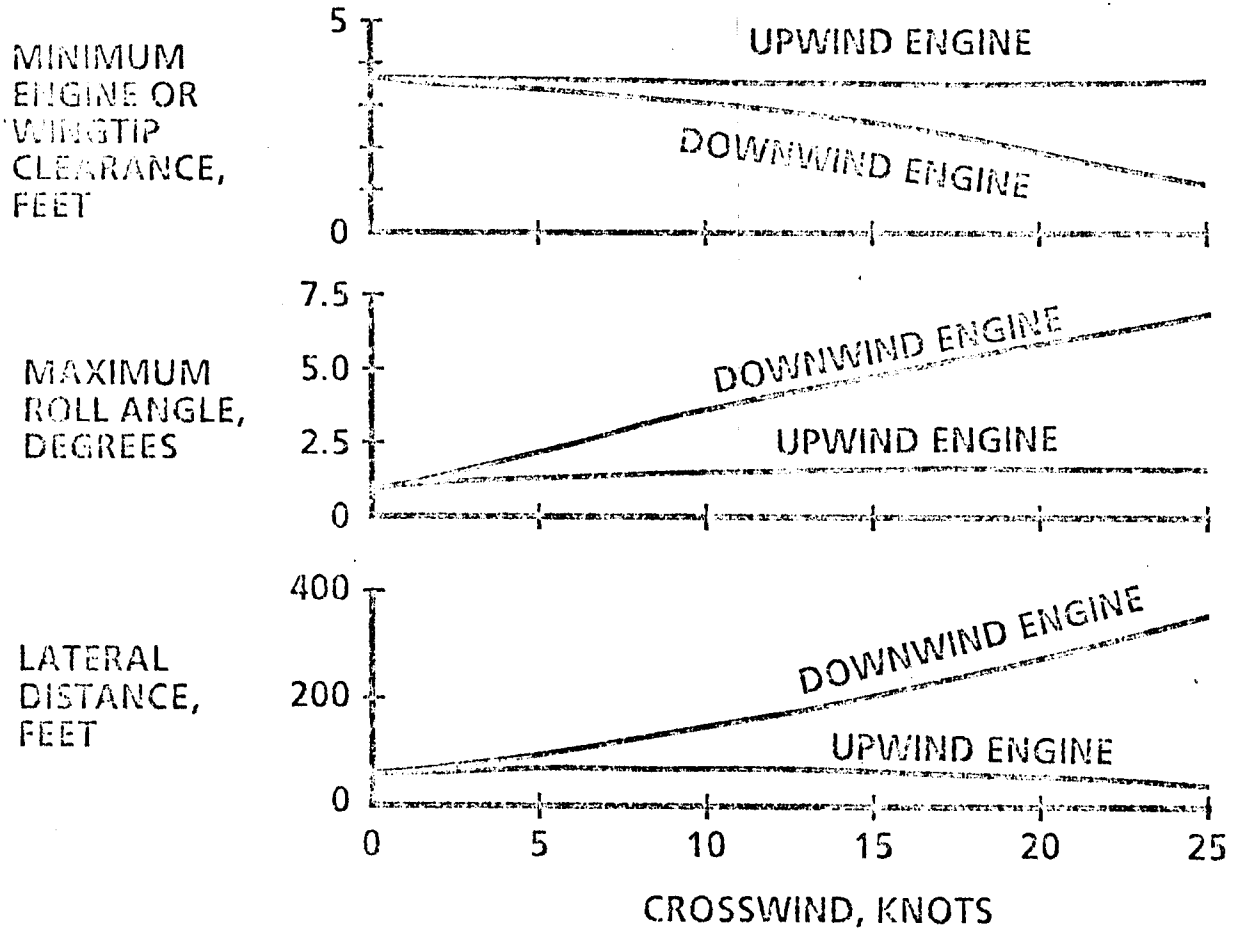
EFFECT OF ROTATION SPEED AND ROTATION ATTITUDE ON AIRCRAFT RESPONSE AFTER AN ENGINE FAILURE

KC-135A - ENGINE FAILURE AT ROTATION SPEED



EFFECT OF CROSSWIND ON AIRCRAFT RESPONSE AFTER AN ENGINE FAILURE - FUEL STARVATION CONDITION

KC-135A - ENGINE FAILURE AT ROTATION SPEED



EFFECT OF CROSSWIND ON AIRCRAFT RESPONSE AFTER AN ENGINE FAILURE - THROTTLE CHOP CONDITION

KC-135A - ENGINE FAILURE AT ROTATION SPEED

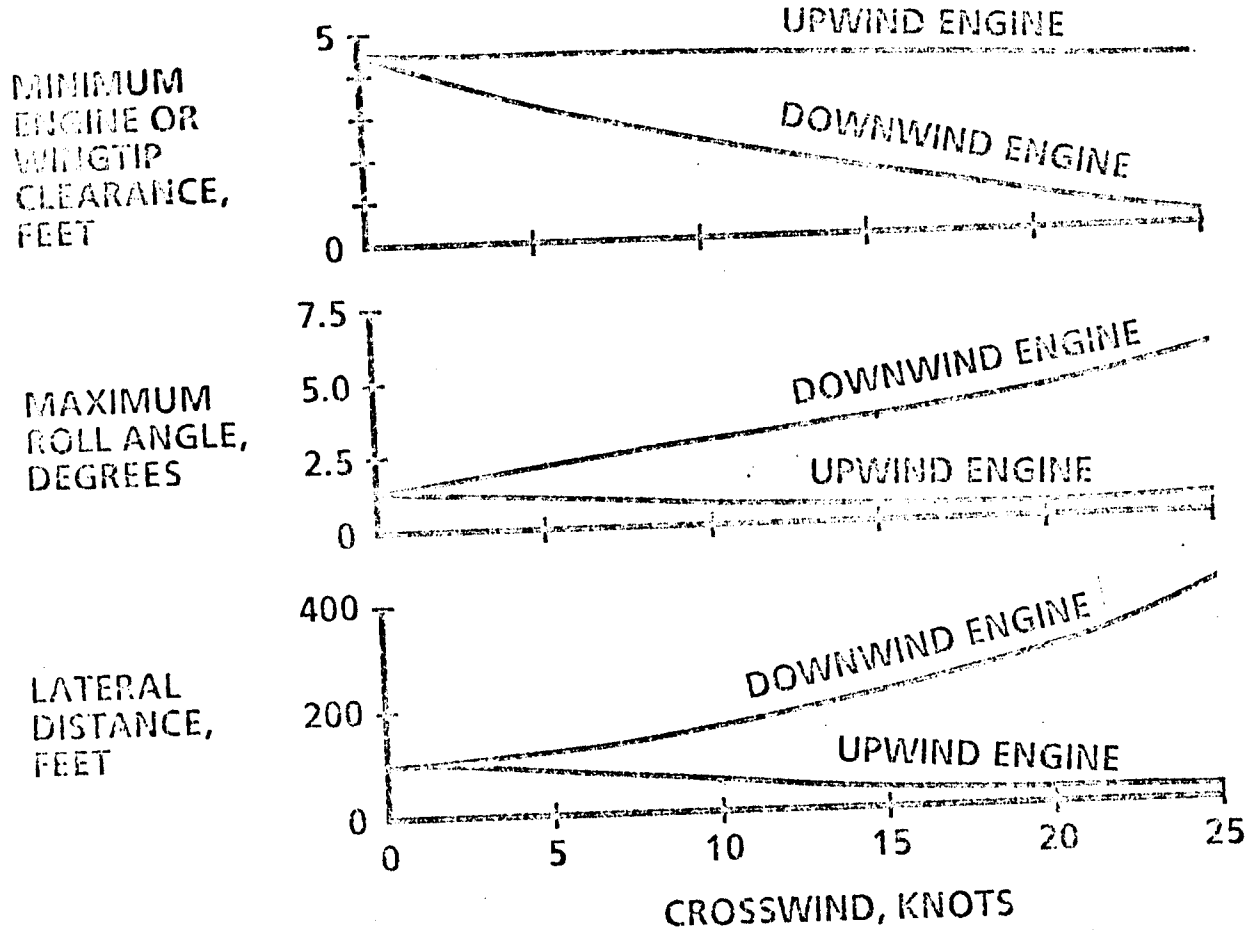
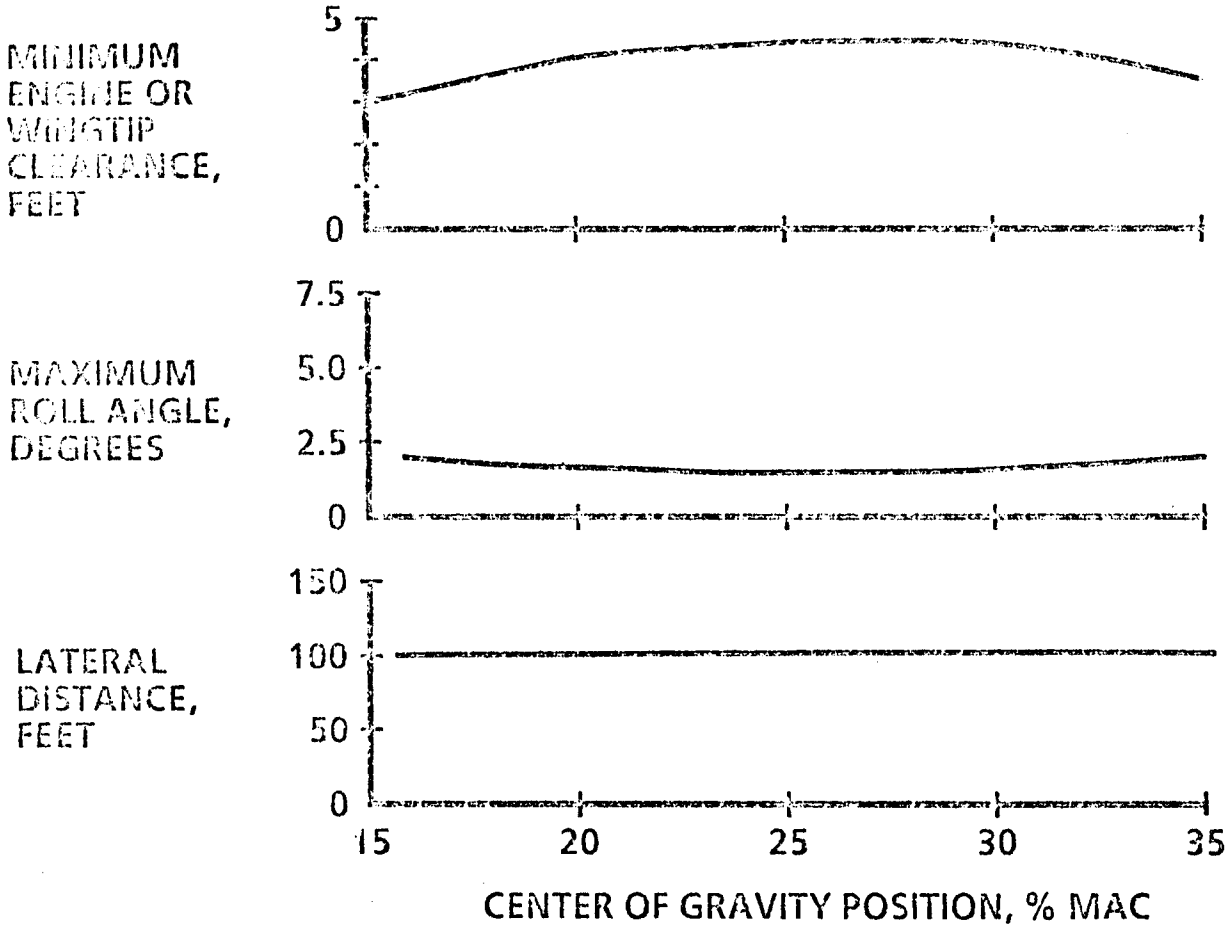


FIGURE 55

EFFECT OF CENTER OF GRAVITY POSITION AIRCRAFT RESPONSE AFTER AN ENGINE FAILURE

KC-135A - ENGINE FAILURE AT ROTATION SPEED



IMPROPER PILOT RESPON[illegible] - DELAYED PILOT REACTION

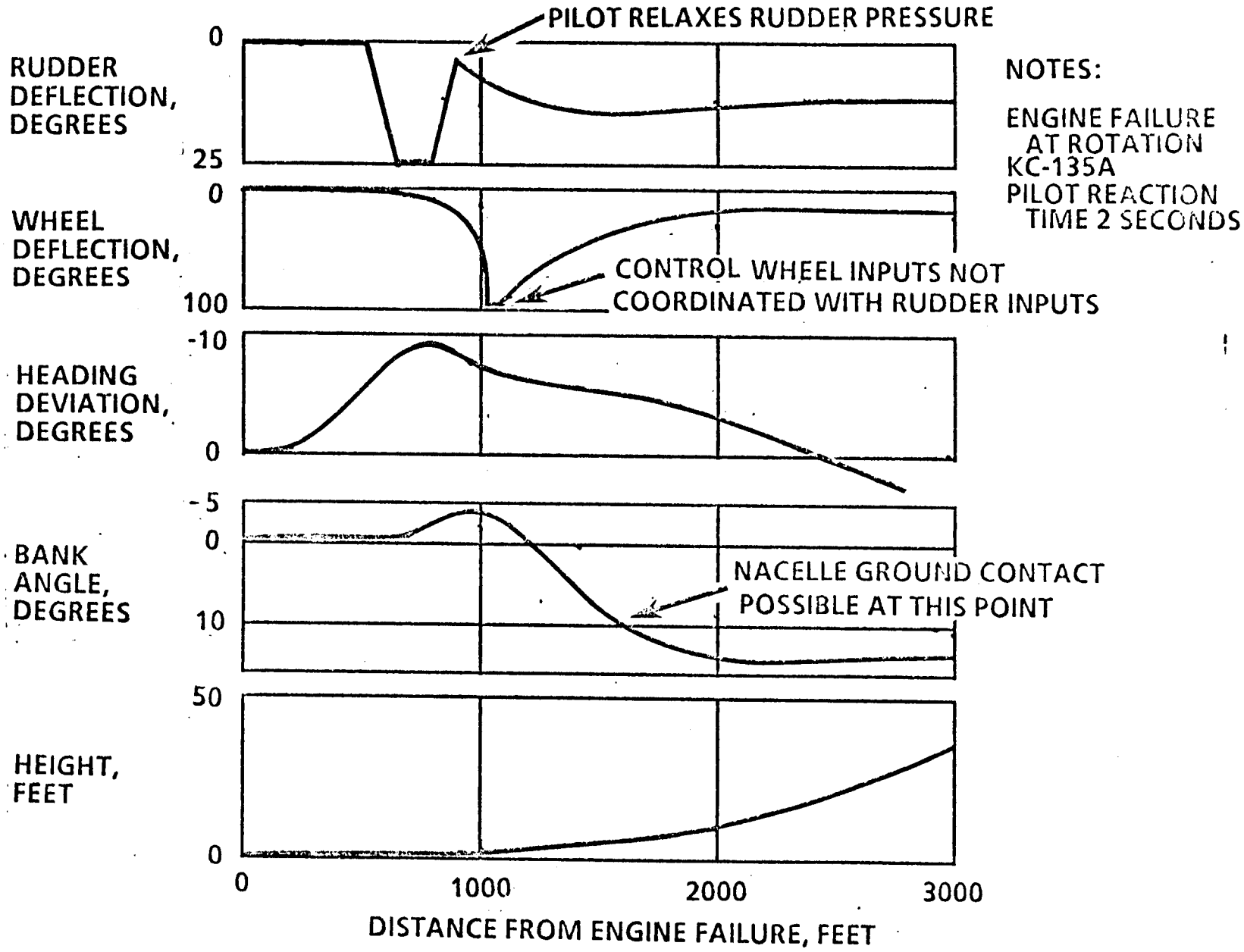
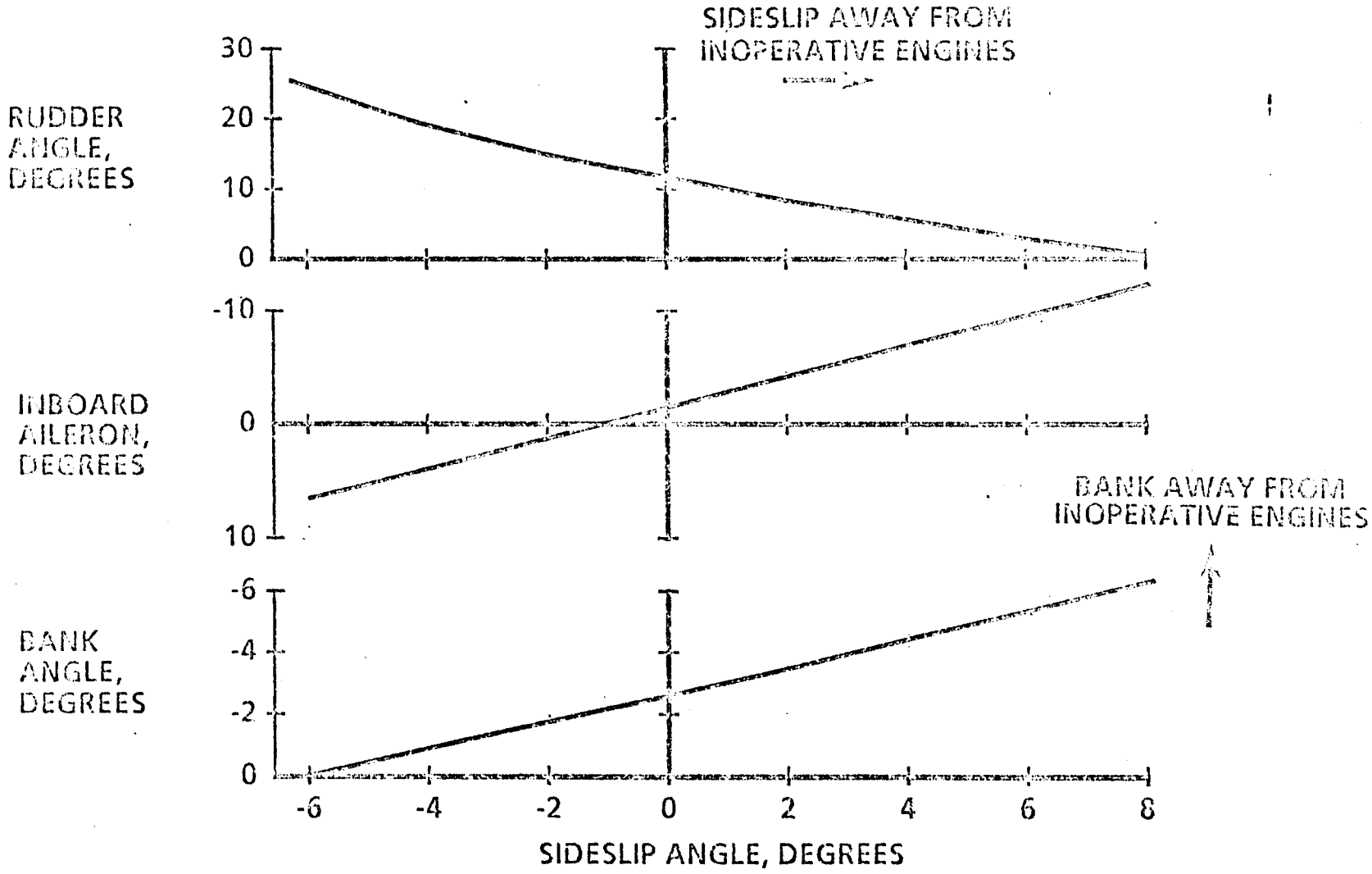
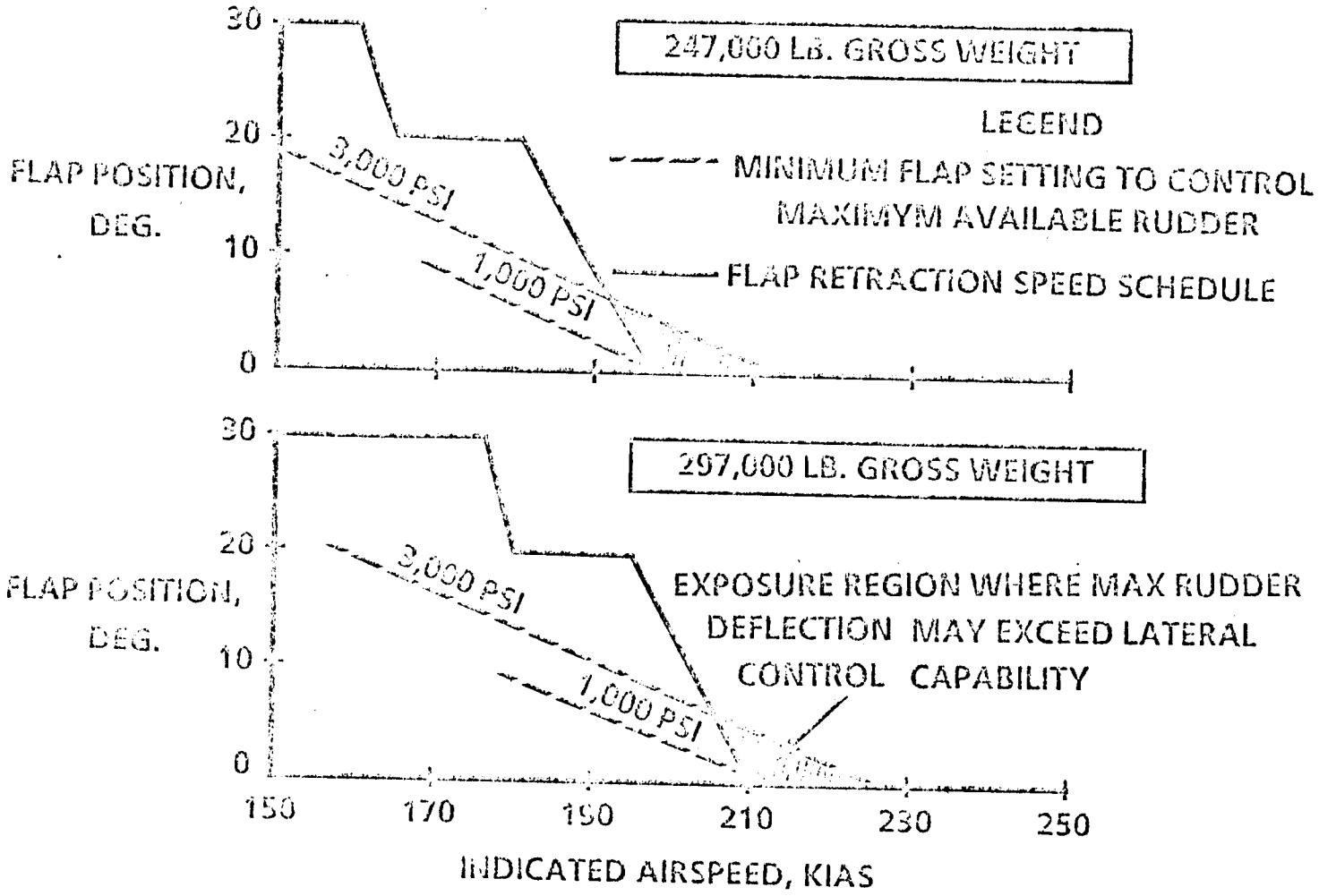


FIGURE 57

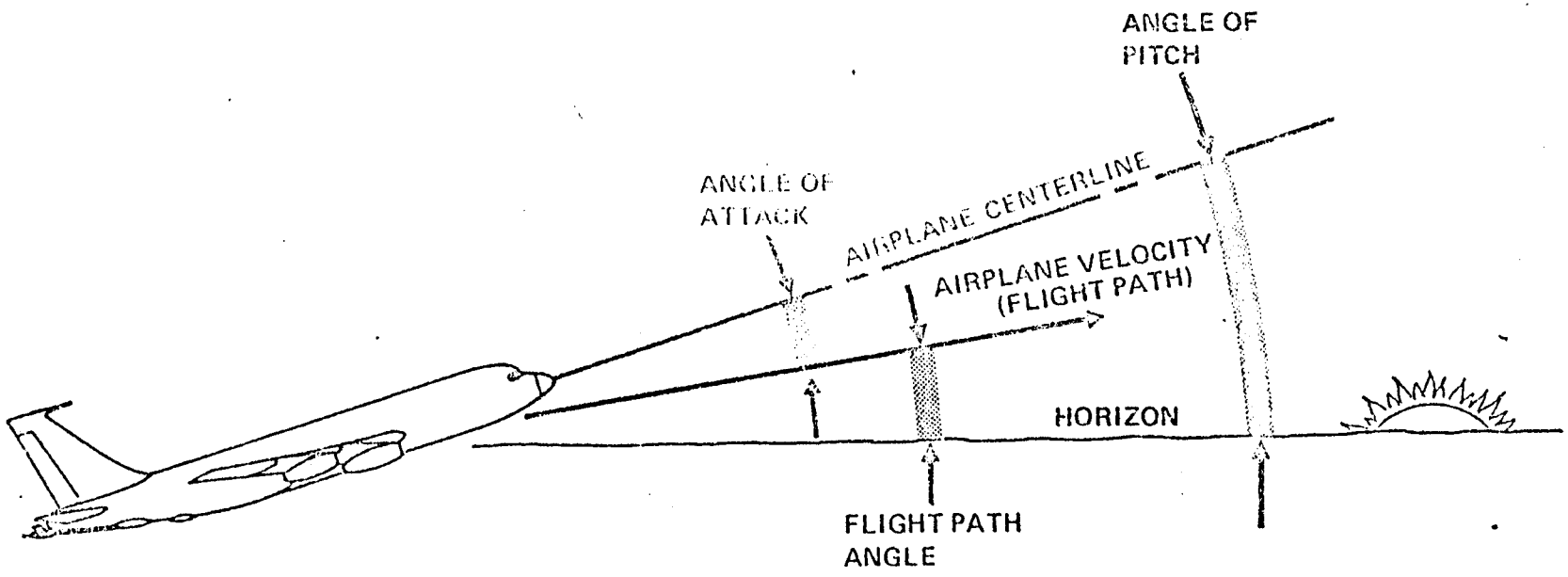
TYPICAL PILOT CONTROL SURFACE TRADES - FLAPS DOWN



LATERAL CONTROL SYSTEM CAPABILITY TO CONTROL UNSCHEDULED RUDDER MOVEMENT



5.0 C/KC-135 ASYMMETRIC FLIGHT CHARACTERISTICS - ENROUTE CLIMB



C/KC-135 ENROUTE CLIMB SPEEDS

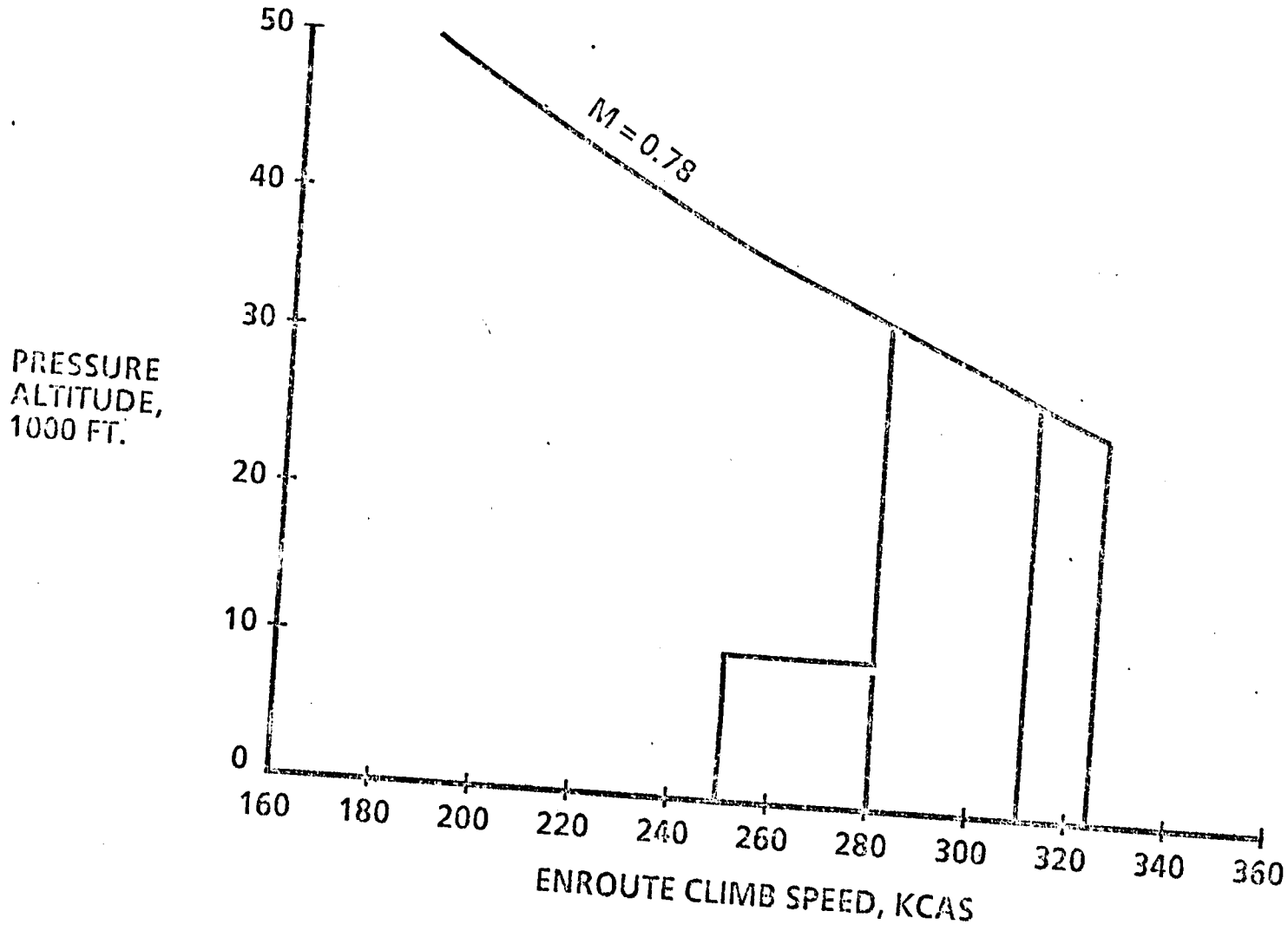
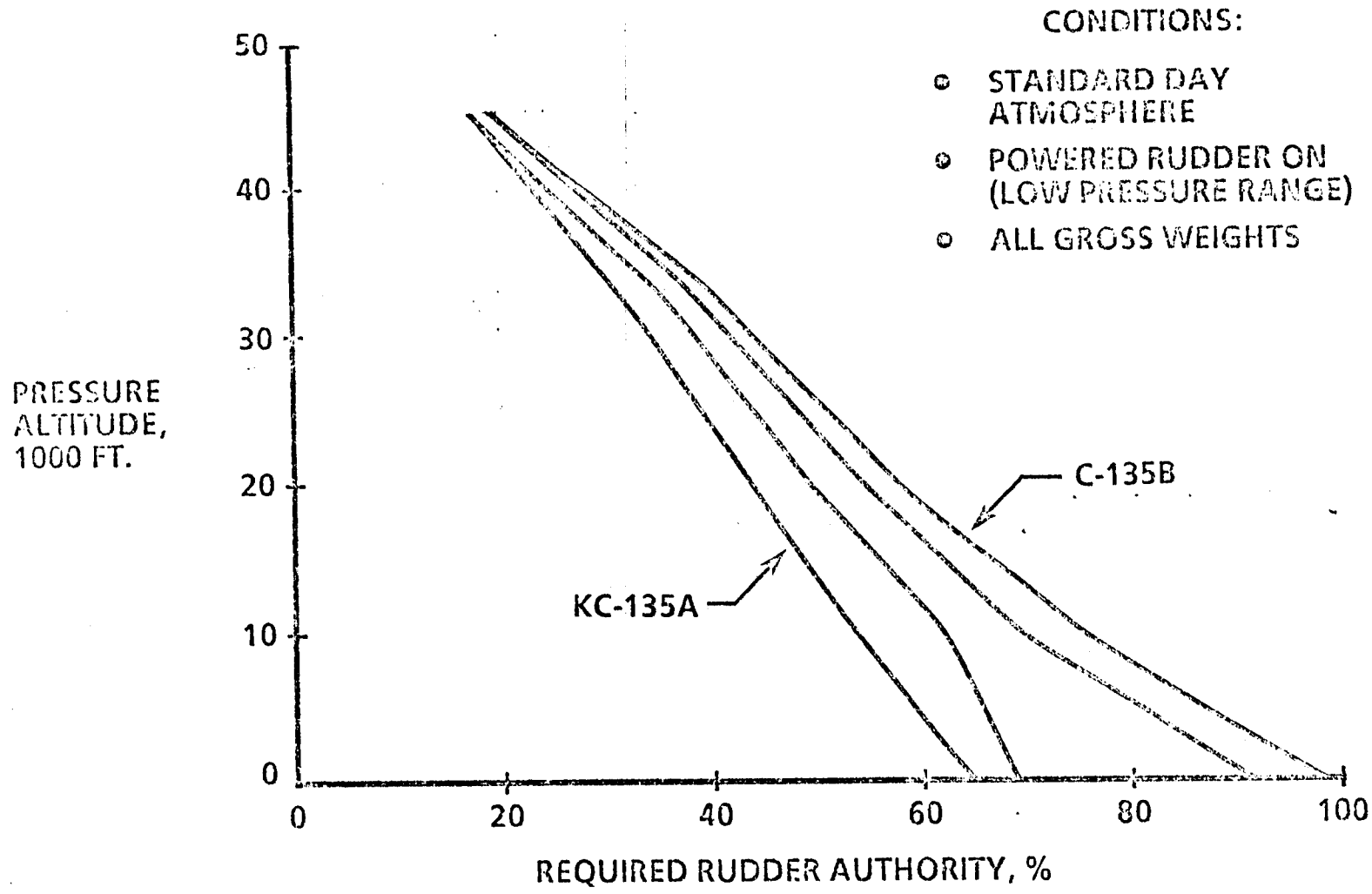


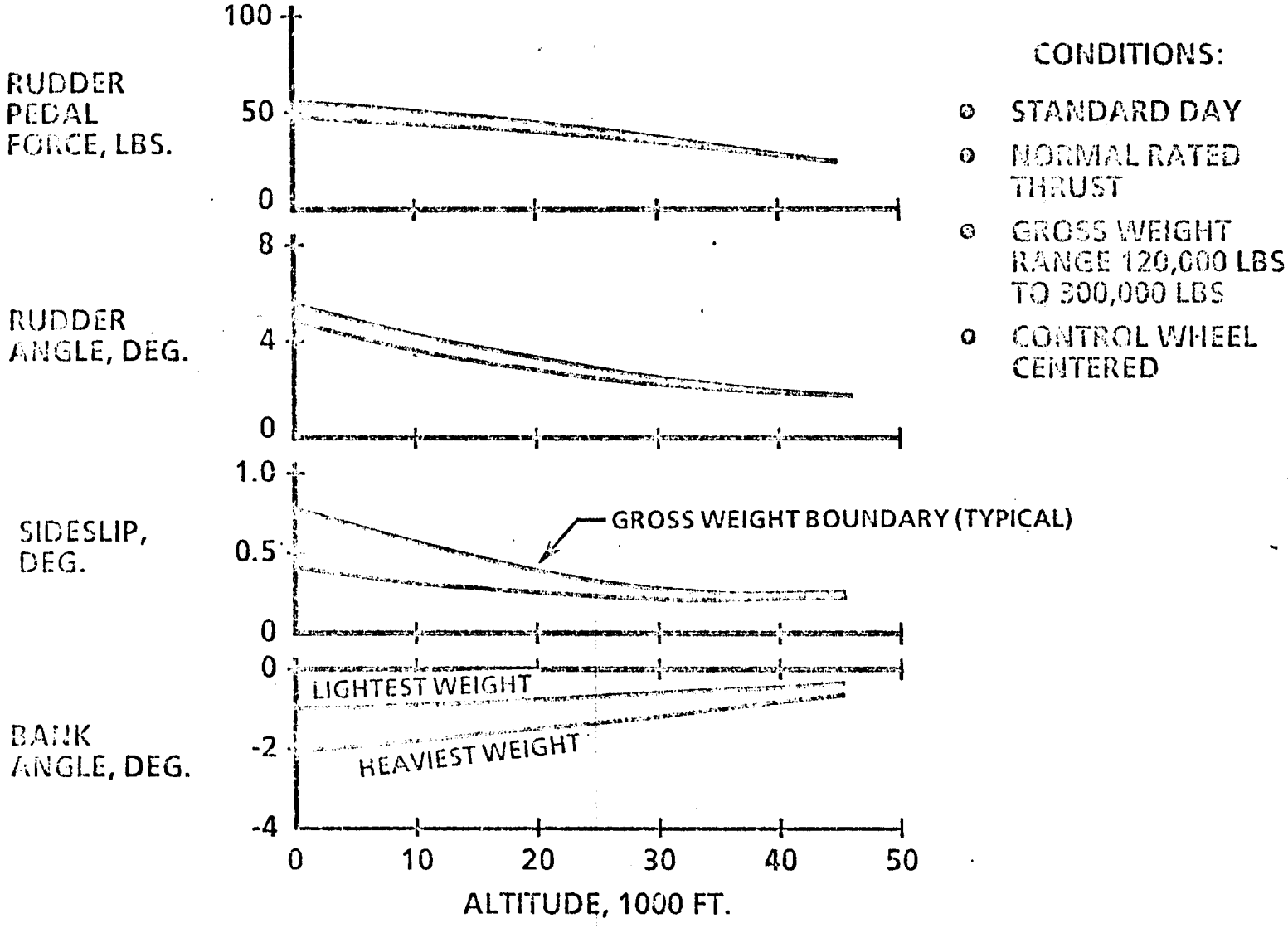
FIGURE 60

ENGINE OUT TRIM REQUIREMENTS DURING ENROUTE CLIMB

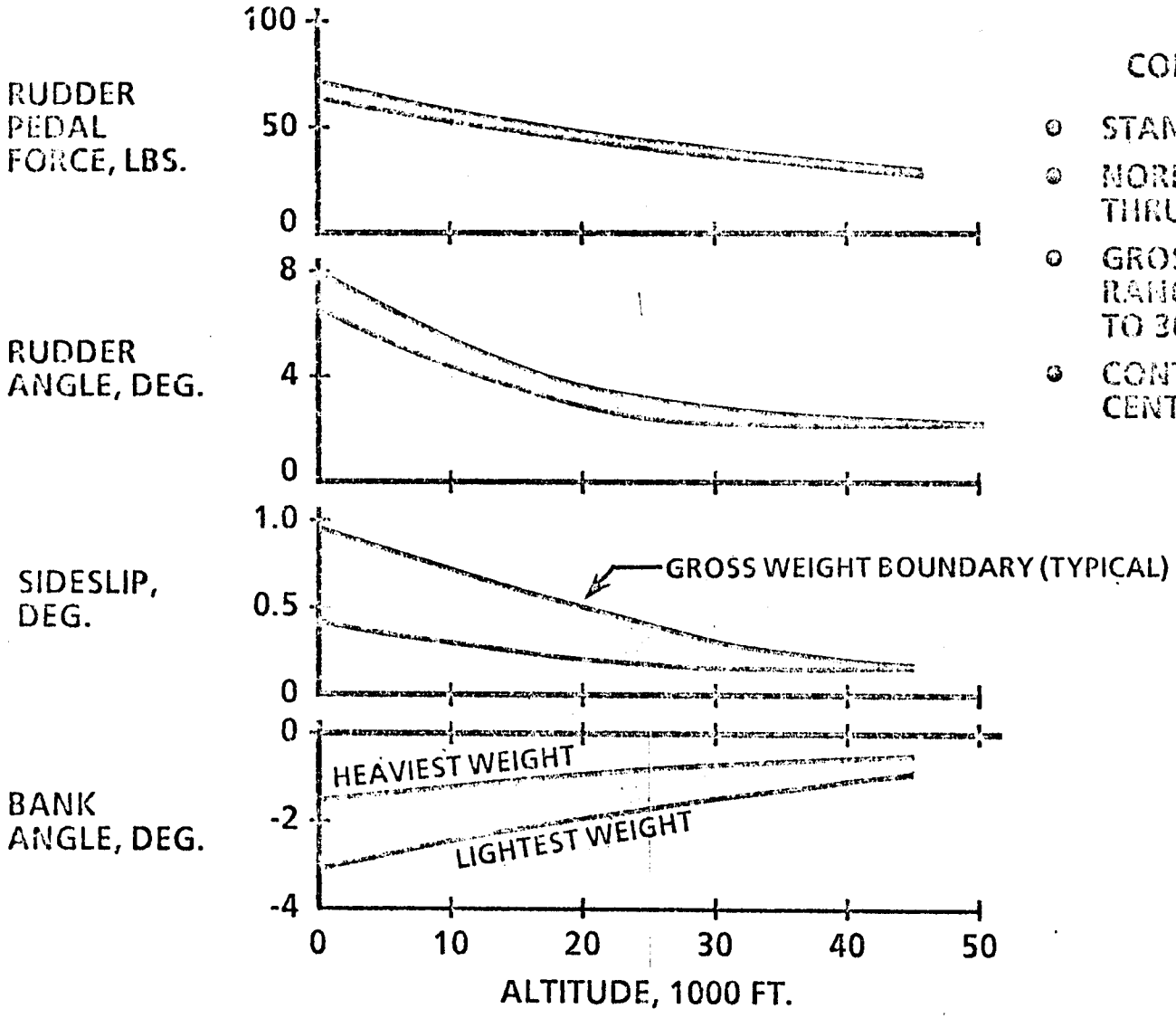
OUTBOARD ENGINE OPERATING AT NRT EPR SETTING



KC-135A ENGINE OUT TRIM CONDITIONS - ENROUTE CLIMB



C-135B ENGINE OUT TRIM CONDITIONS - ENROUTE CLIMB



AIRCRAFT RESPONSE TO AN ENGINE FAILURE - ENROUTE CLIMB CONDITIONS

NO PILOT CORRECTIVE ACTION

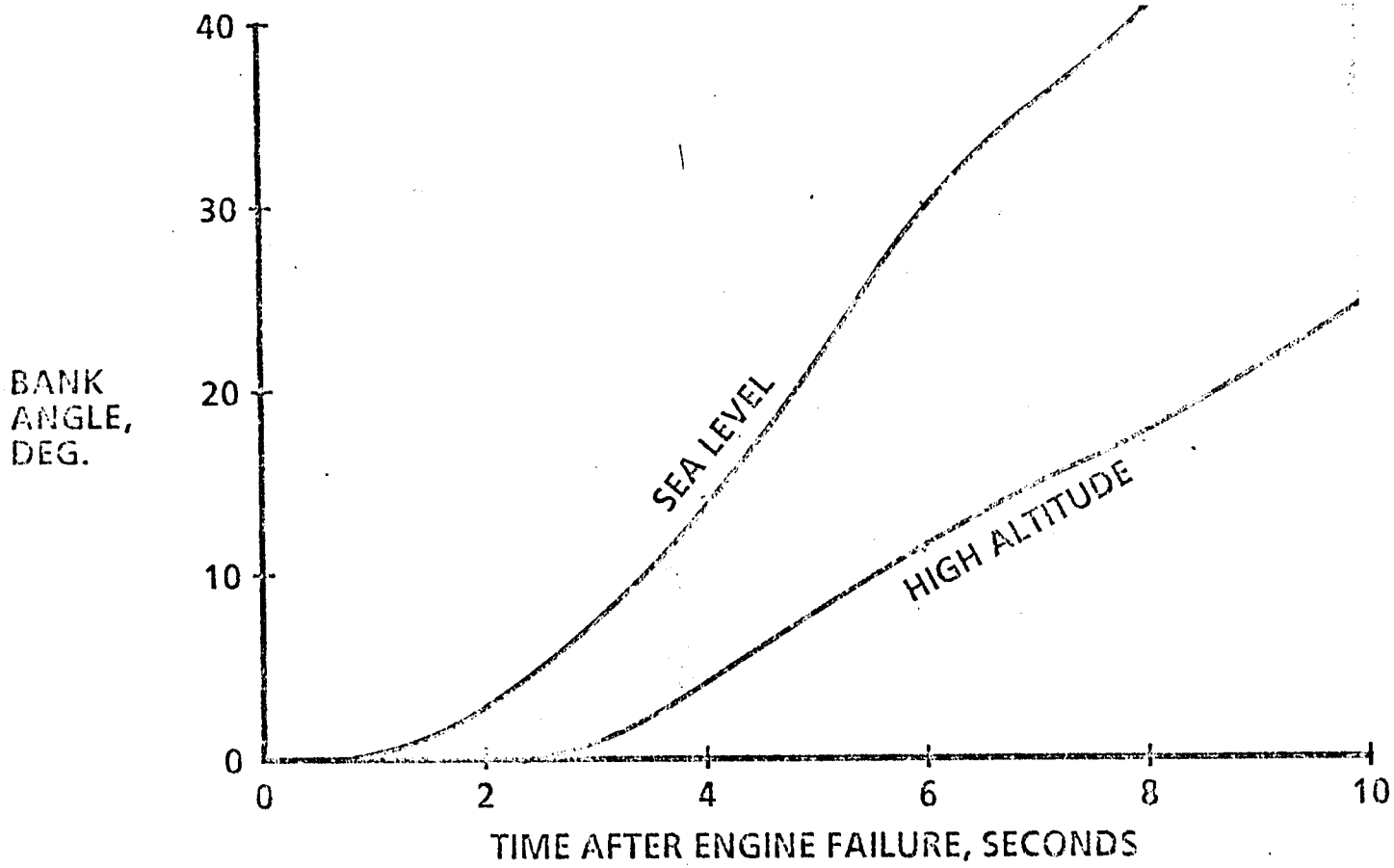
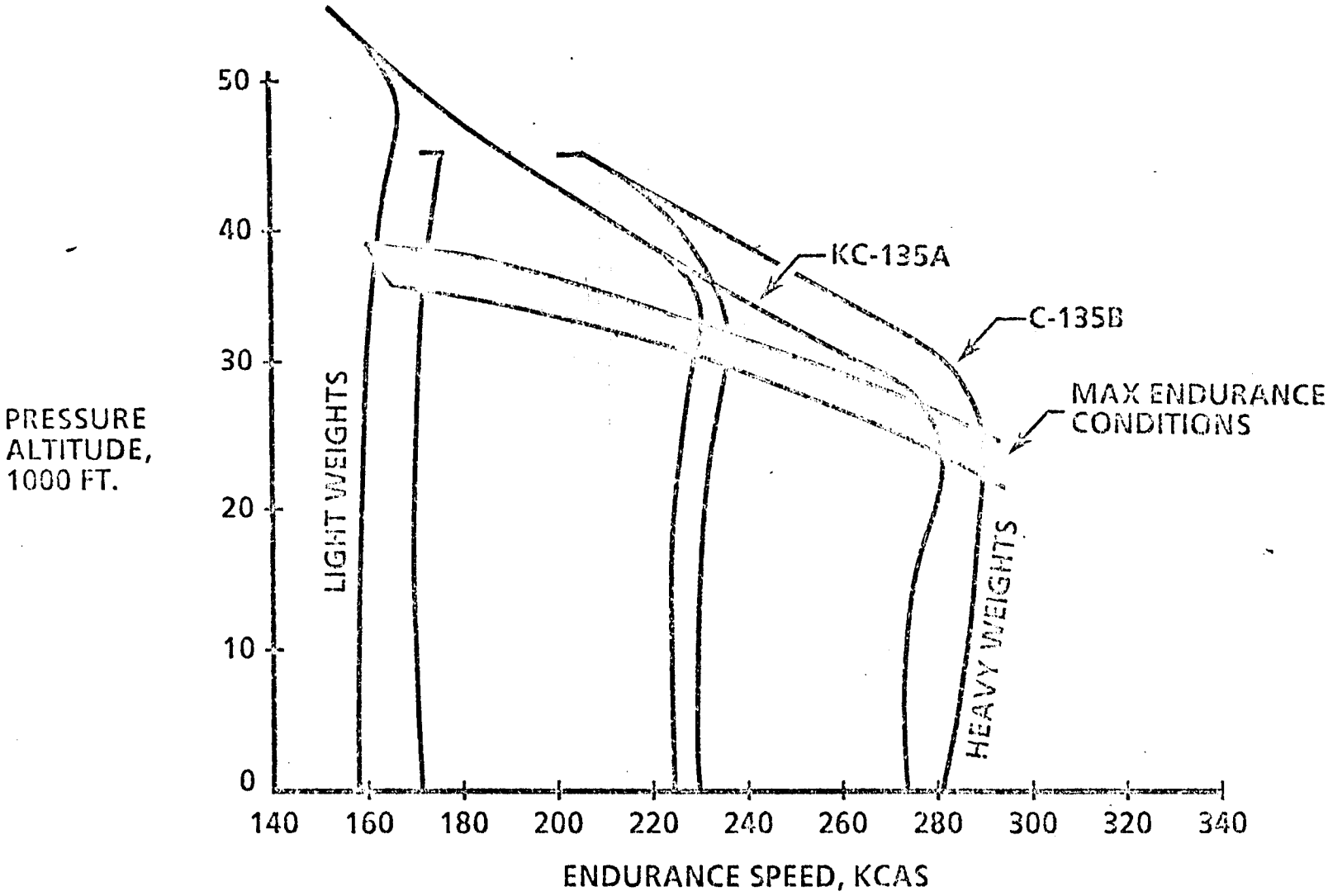


FIGURE 64

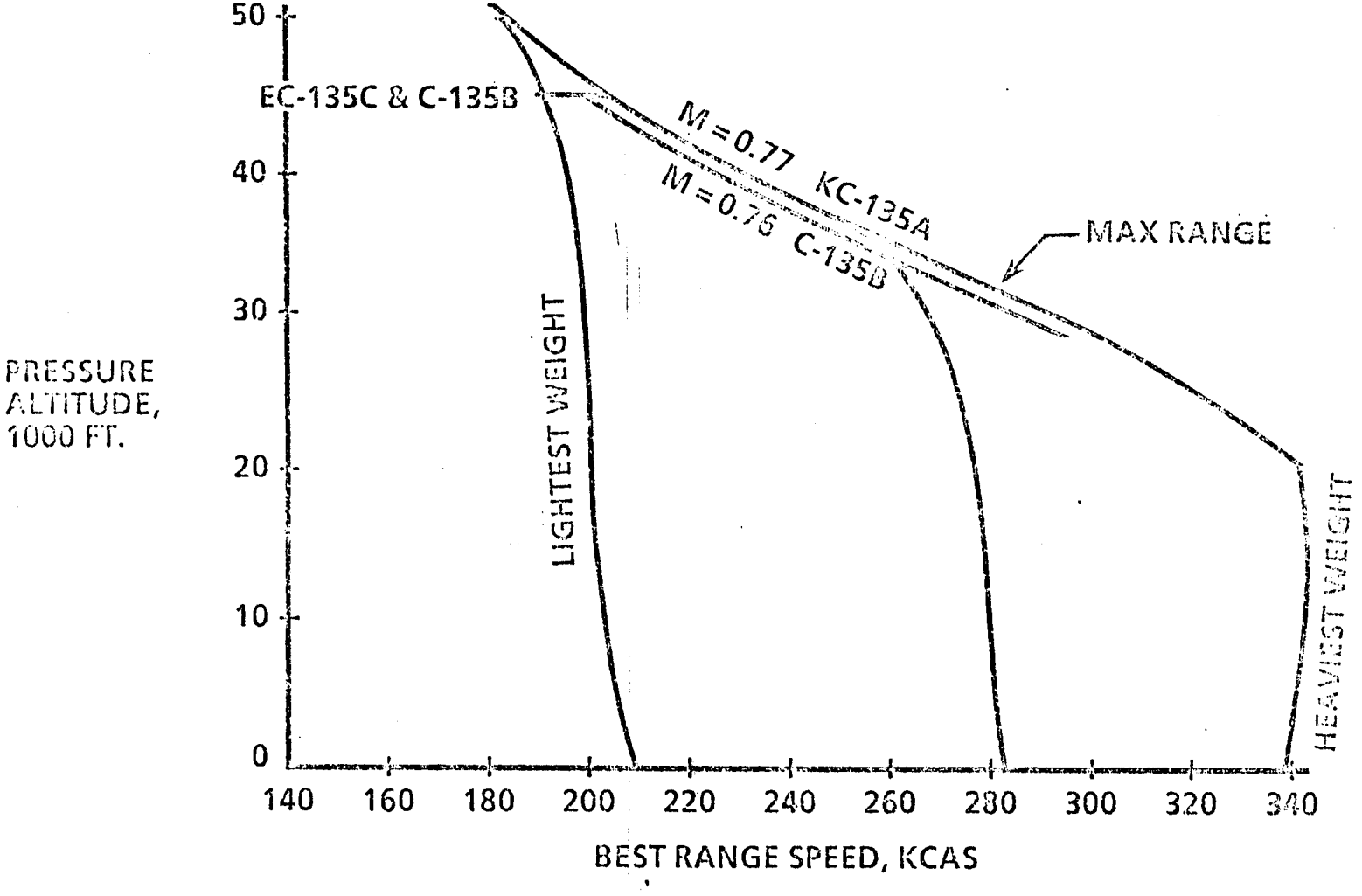
6.0 C/KC-135 ASYMMETRIC FLIGHT CHARACTERISTICS - CRUISE FLIGHT CONDITIONS

RANGE, ENDURANCE, AND AERIAL REFUELING

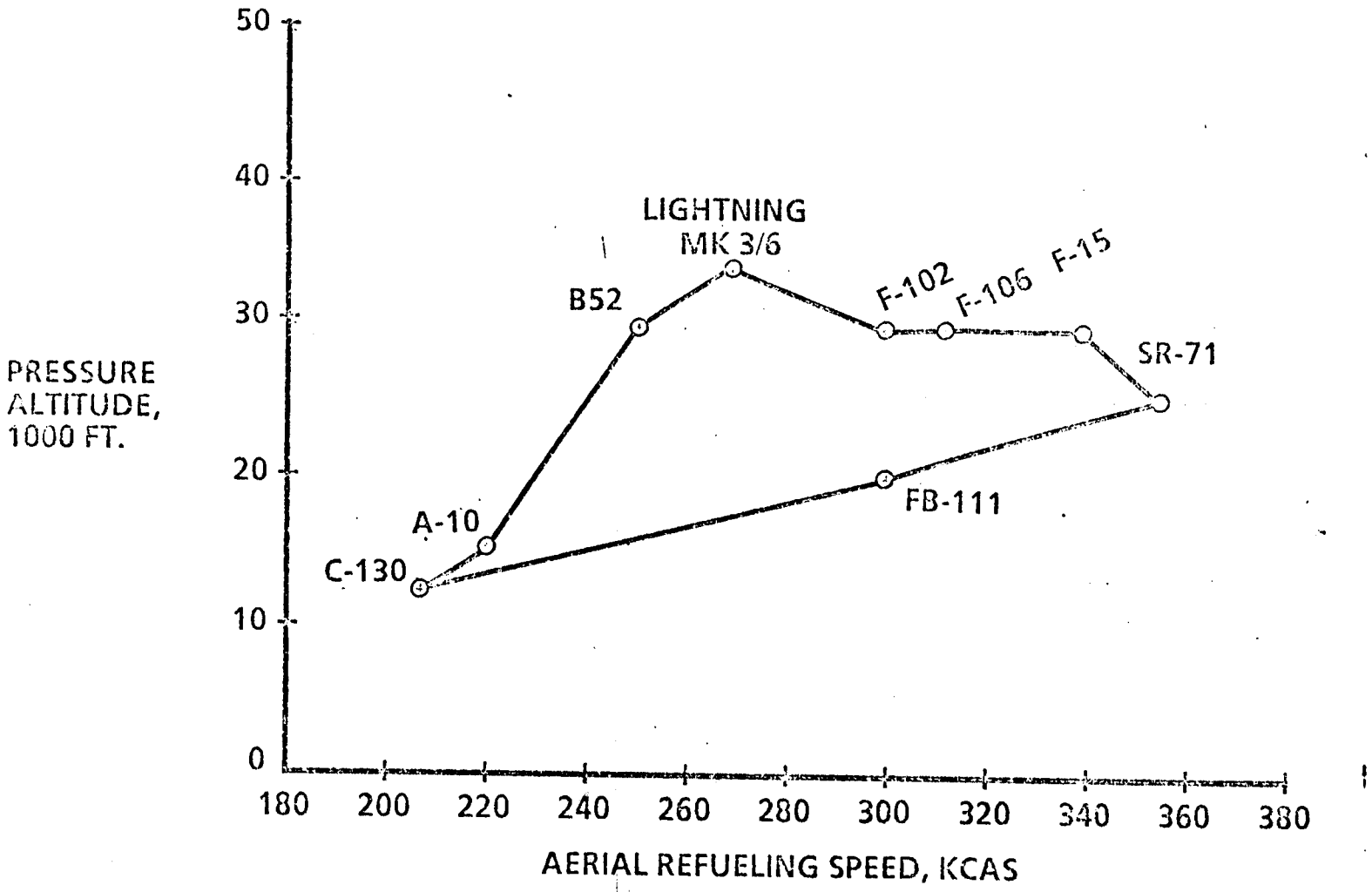
C/KC-135 ENDURANCE SPEEDS



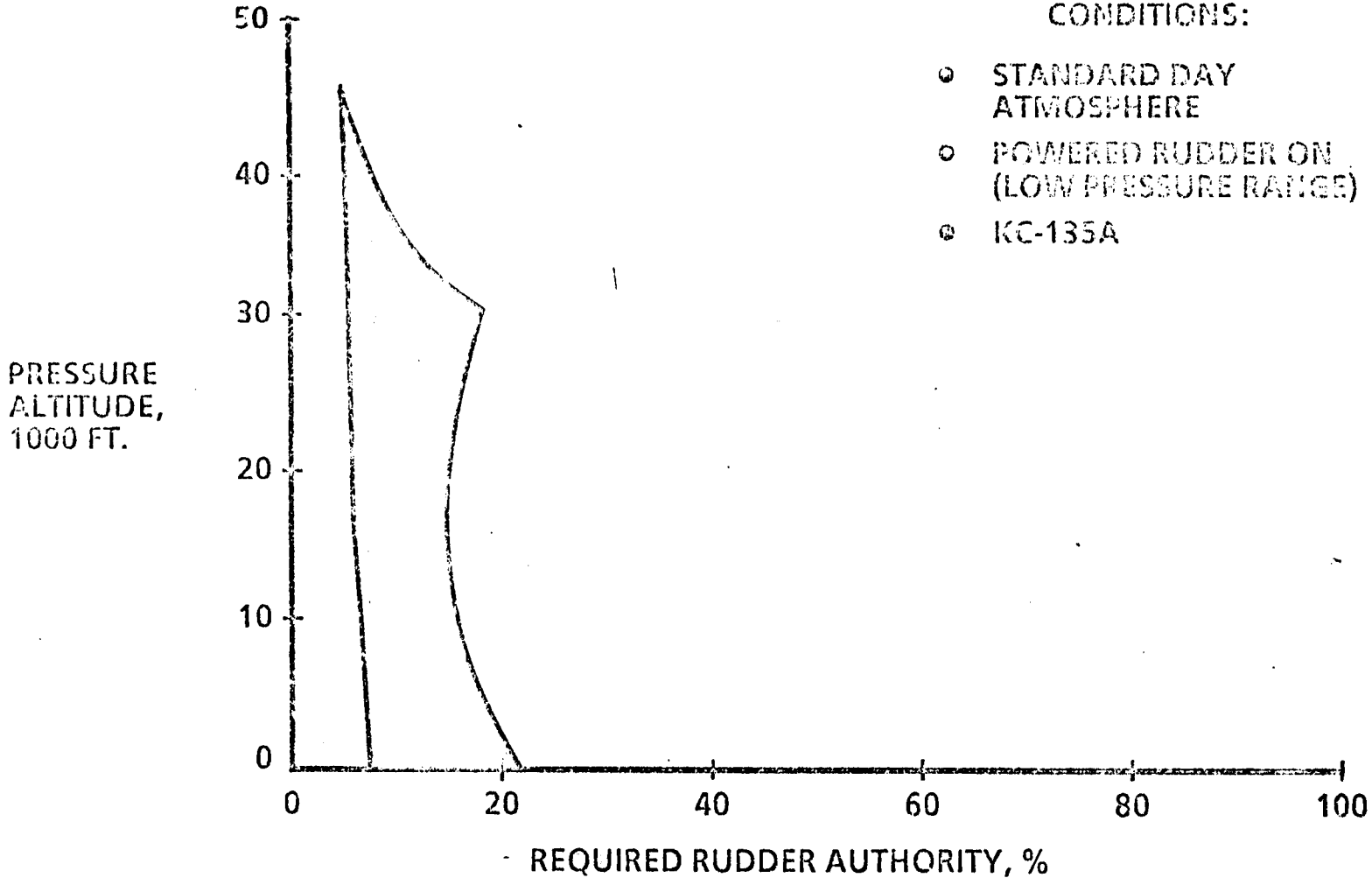
C/KC-135 BEST RANGE SPEEDS



C/KC-135 AERIAL REFUELING SPEEDS

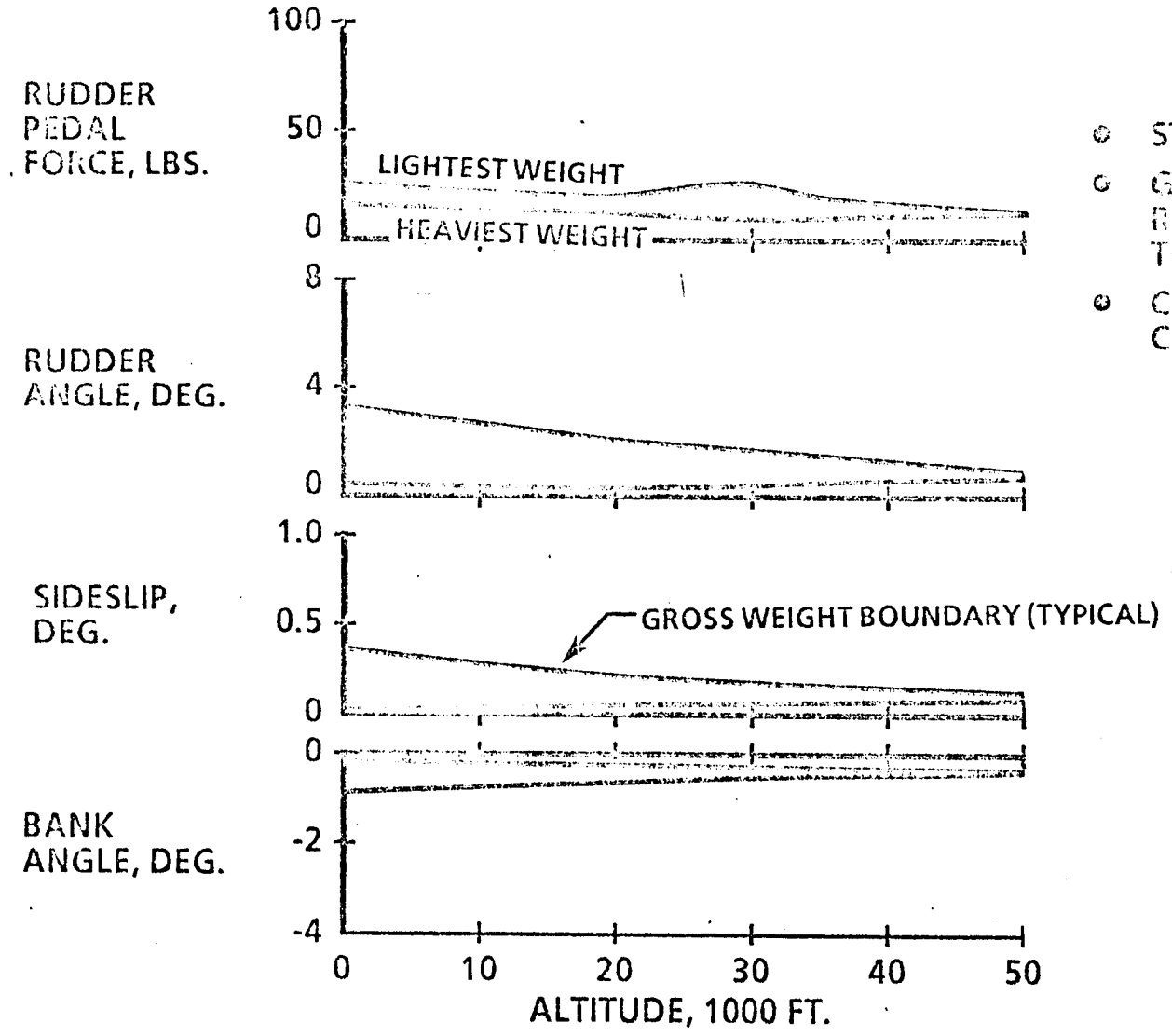


RUDDER TRIM REQUIREMENTS DURING CRUISE FLIGHT



KC-135A ENGINE OUT TRIM CONDITIONS - CRUISE FLIGHT CONDITIONS

COMPOSITE BOUNDARY FOR BEST RANGE, BEST ENDURANCE, AND AERIAL REFUELING

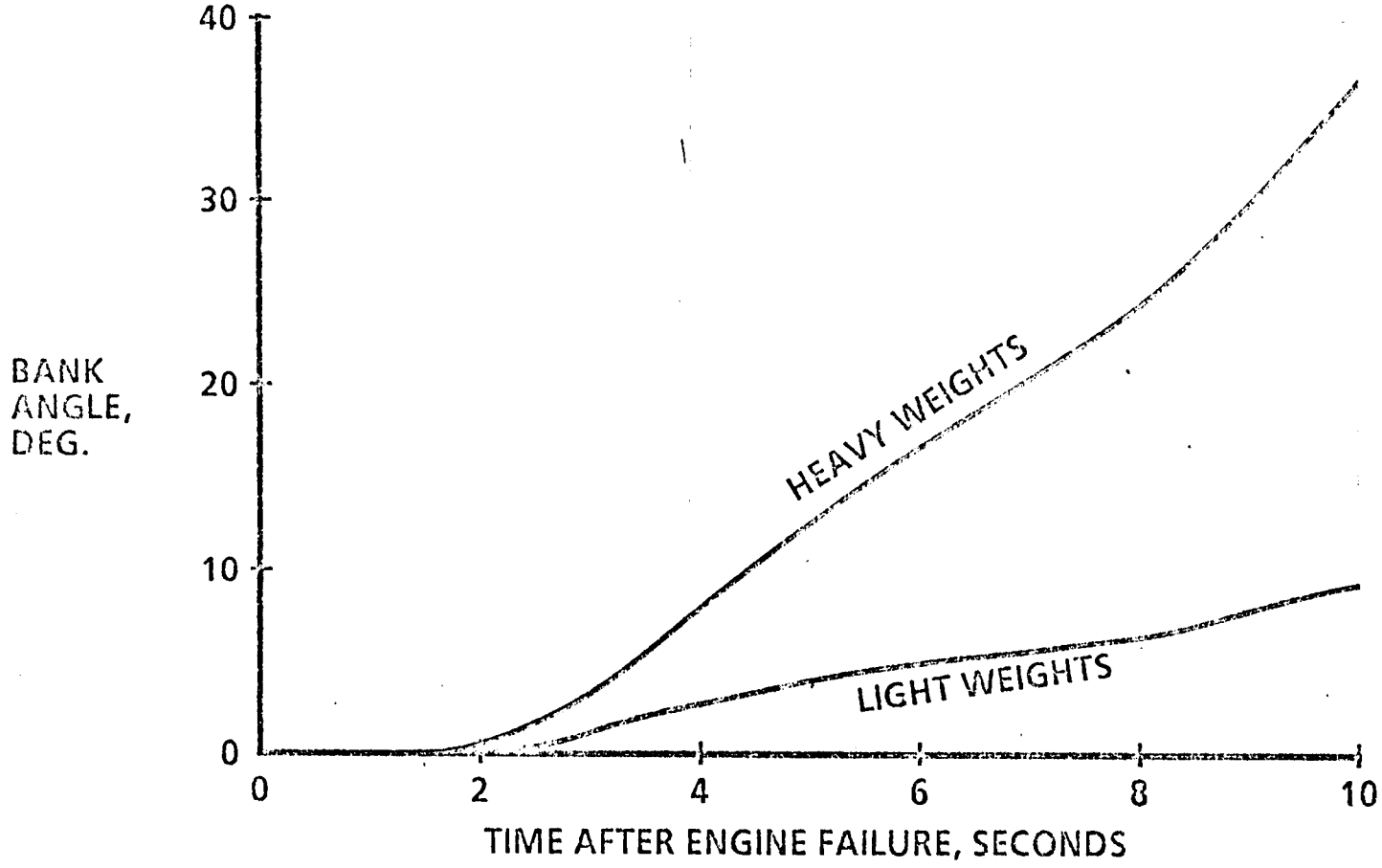


CONDITIONS:

- STANDARD DAY
- GROSS WEIGHT RANGE 120,000 LBS TO 300,000 LBS
- CONTROL WHEEL CENTERED

AIRCRAFT RESPONSE TO AN ENGINE FAILURE - CRUISE FLIGHT CONDITIONS

NO PILOT CORRECTIVE ACTION



C/KC-135 ENROUTE DESCENT SPEEDS

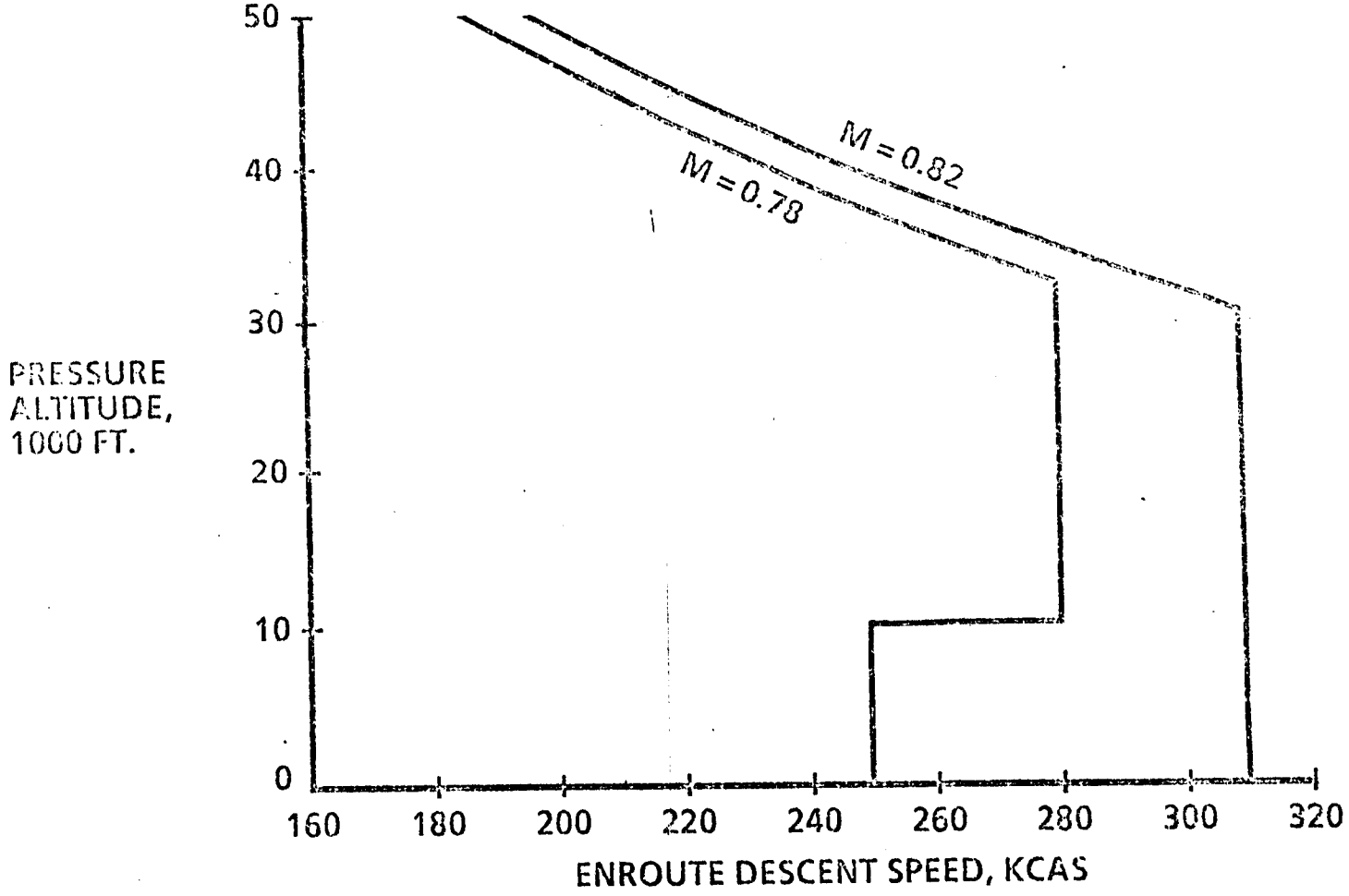
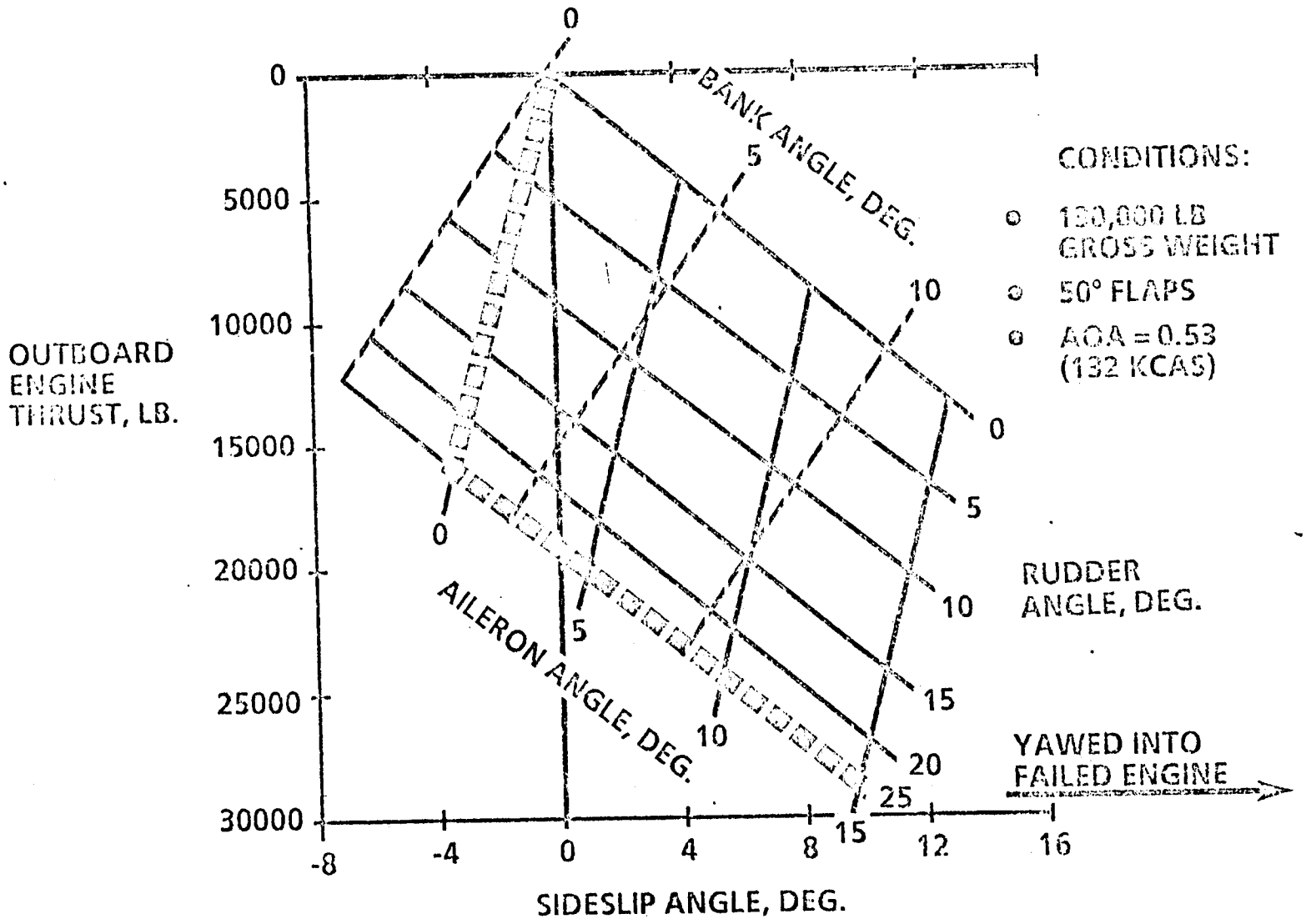
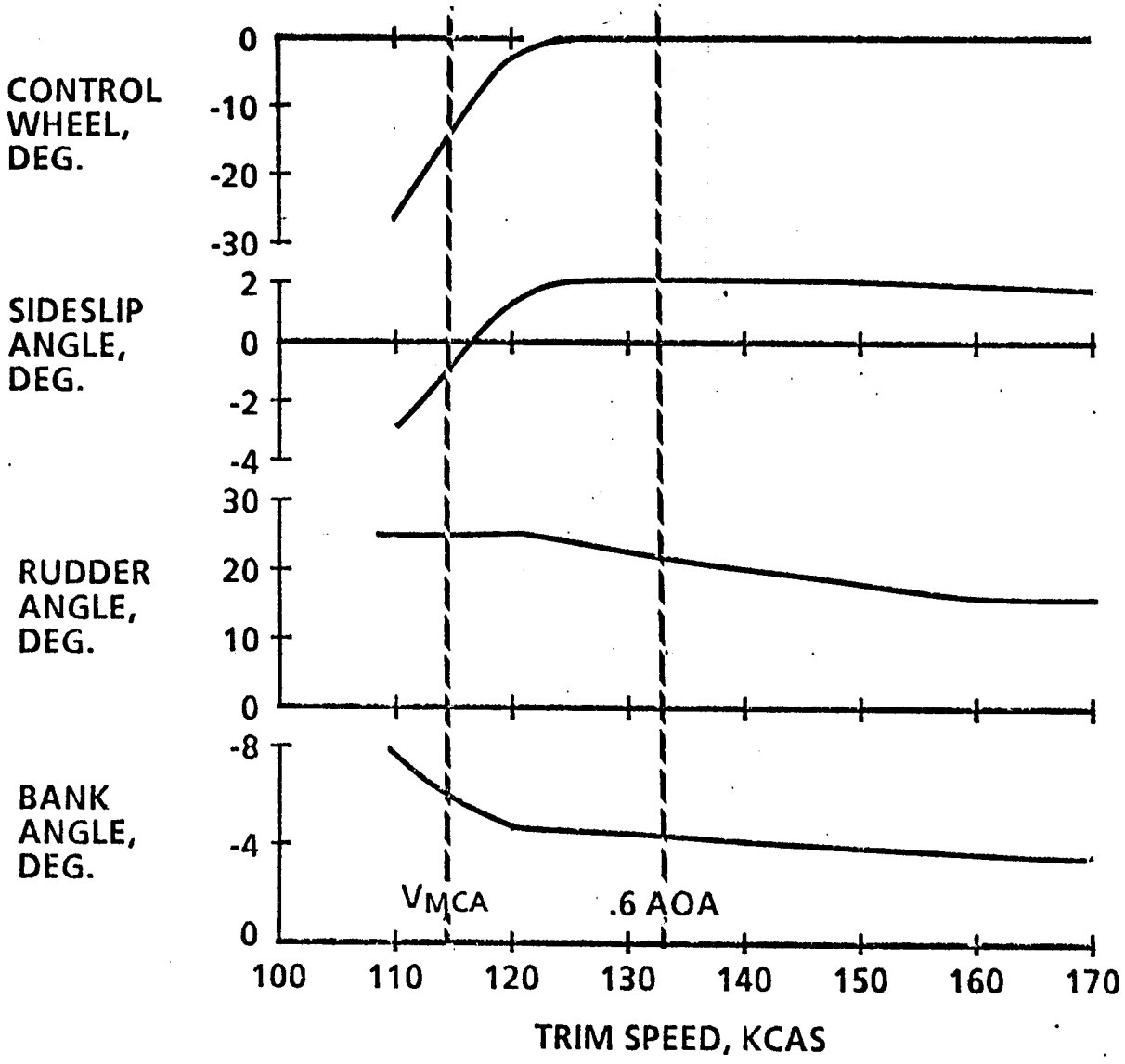


FIGURE 71

TYPICAL C/KC-135 ASYMMETRIC TRIM CHARACTERISTICS



EFFECT OF SPEED ON GO-AROUND TRIM CONDITIONS - C-135B

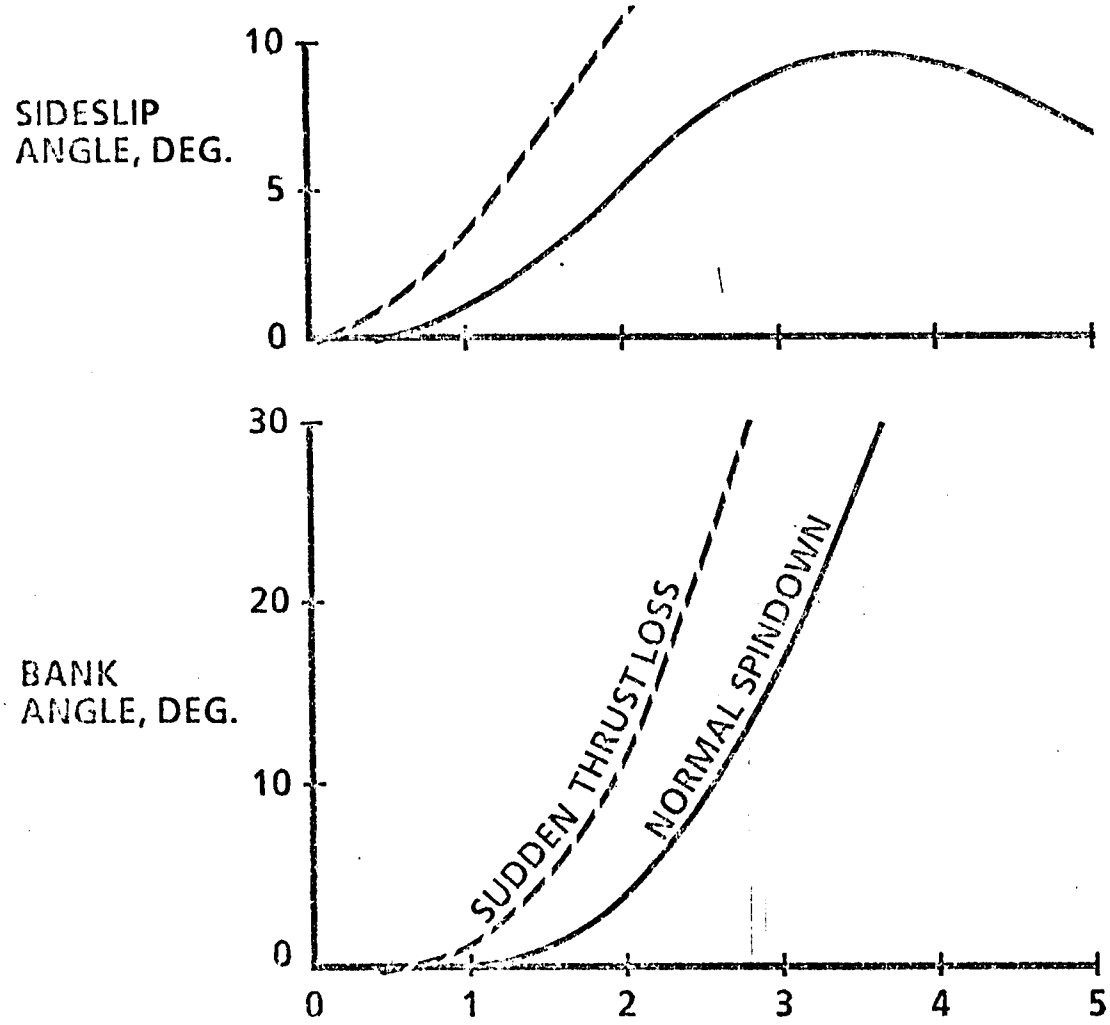


CONDITIONS:

- GROSS WEIGHT 150,000 LBS.
- SEA LEVEL, 59° F
- 50° FLAPS
- EPR = 1.829

C-135B RESPONSE TO AN ENGINE FAILURE DURING A GO-AROUND

V_{MCA} CRITICAL CONDITION - NO PILOT CONTROL INPUTS APPLIED

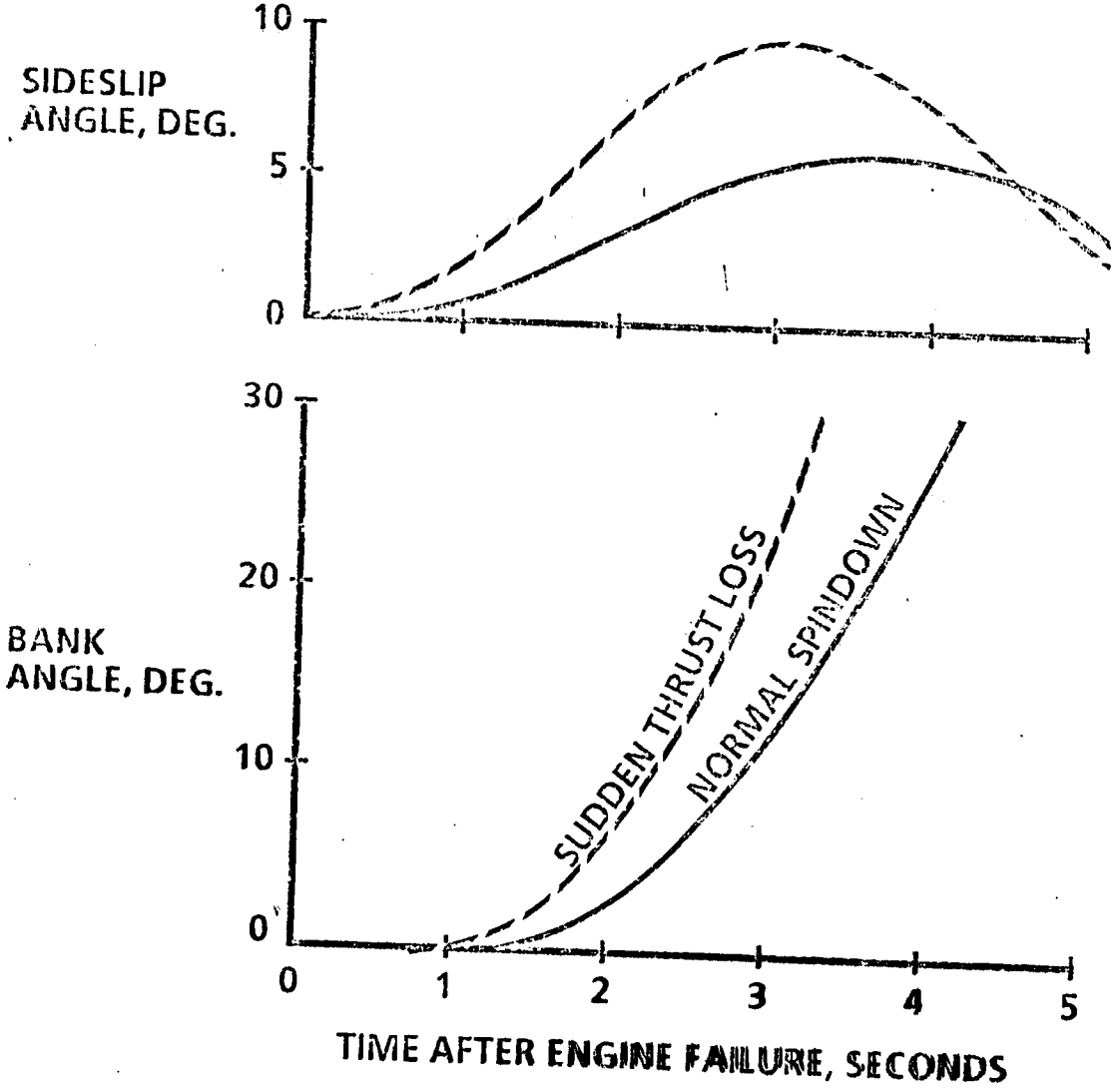


CONDITIONS:

- GROSS WEIGHT 120,000 LBS.
- FLAPS 50°
- GEAR DOWN
- PRESSURE ALTITUDE 200 FT.
- TEMPERATURE 59° F
- SPEED 118.6 KCAS
- GO-AROUND EPR = 1.83
- OUTBOARD ENGINE FAILURE

C-135B RESPONSE TO AN ENGINE FAILURE DURING A GO-AROUND

MINIMUM RATE OF CLIMB CONDITION - NO PILOT CONTROL INPUTS APPLIED



CONDITIONS:

- GROSS WEIGHT 200,000 LBS.
- FLAPS 50°
- GEAR DOWN
- PRESSURE ALTITUDE 3000 FT.
- TEMPERATURE 90° F
- SPEED 141 KCAS (THRESHOLD SPEED MINUS 10 KNOTS)
- GO-AROUND EPR = 1.47
- OUTBOARD ENGINE FAILURE

FIGURE 75