AIRCRAFT FLIGHT PROCEDURES PROGRAM: DATA BASE DEVELOPMENT

BY: LARRY A. RONK
TIMOTHY A. GATES
WILLIAM S. WILKINSON

MARCH 1981

PREPARED UNDER:
CONTRACT NO. 68-01-6151
TASK ORDER 038

FOR THE
OFFICE OF NOISE ABATEMENT AND CONTROL
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

N-96-01
II-A-196

AIRCRAFT FLIGHT PROCEDURES PROGRAM: DATA BASE DEVELOPMENT

By:

Larry A. Ronk
Timothy A. Gates
William S. Wilkinson

March 1981

Prepared Under:

Contract No. 68-01-6151
Task Order 038

For the

Office of Noise Abatement and Control
U.S. Environmental Protection Agency
Washington, D.C. 20460

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA 550/9-82-330	2.	3. Recipient's Accession No.

4. Title and Subtitle
Aircraft Flight Procedures Program:
Data Base Development

5. Report Date March 1981

6.

7. Author(s)
L. A. Ronk, T. A. Gates, and W. S. Wilkinson

8. Performing Organization Rept. No. ORI TR 1799

9. Performing Organization Name and Address
ORI, Inc.
1400 Spring Street
Silver Spring, MD 20910

10. Project/Task/Work Unit No. Task Order 38

11. Contract(C) or Grant(G) No.
(C) EPA 68-01-6151
(G)

12. Sponsoring Organization Name and Address
Office of Noise Abatement and Control
U.S. Environmental Protection Agency
Washington, D.C. 20460

13. Type of Report & Period Covered Final

14.

15. Supplementary Notes A description of the aircraft flight procedures "User's Manual" is presented in a separate report ORI TR 1992 This report, as well as a computer tape of the programs and data bases are available from NTIS.

16. Abstract (Limit: 200 words)

The purpose of this study was to identify and collect performance and operational data and information required to construct flight paths and performance schedules for selected commercial aircarrier aircraft types powered by low-by-pass ratio and high-by-pass ratio turbofan engines. The performance and operational data and information can be used to determine the flight paths and performance schedules for aircraft operating in accordance with specified flight procedures, and over a range of airport temperatures and airport pressure altitudes.

In addition, this study effort also included an evaluation of available flight procedures computer programs developed by various organizations such as aircraft manufacturers, consultants, and the Federal government (NASA, FAA, etc.) The purpose of evaluating these programs was to identify existing analytical and computer programming work which can be used in developing a modified computer program model to generate aircraft flight path and performance schedule data which was compatible with the input data requirements of the FAA's INM and the USAF's NOISEMAP.

17. Document Analysis a. Descriptors

Flight Procedures Computer Model
Flight Path
Flight Profile
Performance Schedules
Commercial Aircarrier Aircraft
Integrated Noise Model (INM)
NOISEMAP

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement:	19. Security Class (This Report)	21. No. of Pages
Release Unlimited	Unclassified	
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

TABLE OF CONTENTS

		Page
	LIST OF FIGURES	iii
	LIST OF TABLES	iv
	SYMBOLS AND ABBREVIATIONS	viii
I.	INTRODUCTION	1-1
	BACKGROUND	1-1
	PURPOSE OF STUDY	1-2
	REPORT OVERVIEW	1-3
	Section II; Section III; Section IV; Appendix A; Appendix B; Appendix C	
II.	PERFORMANCE AND OPERATIONAL DATA AND INFORMATION REQUIREMENTS	2-1
	TAKEOFF PROCEDURES	2-1
	APPROACH AND LANDING PROCEDURES	2-3
	OTHER PERFORMANCE AND OPERATIONAL DATA REQUIREMENTS	2-4
III.	DEVELOPMENT OF PERFORMANCE AND FLIGHT OPERATIONS DATA BASE	3-1
	AIRCRAFT AND ENGINE TYPES SELECTED	3-1
	AIRCRAFT PERFORMANCE AND FLIGHT OPERATIONS DATA	3-3
	Data Sources and Collection Procedures; Aircraft Performance Equations; Takeoff Operations; Approach and Landing Operations; Other Performance and Operational Data Requirements	

TABLE OF CONTENTS (cont.)

		Page
IV.	EVALUATION OF AVAILABLE FLIGHT PROCEDURE COMPUTER PROGRAM MODELS	4-1
	FLIGHT PROCEDURE MODELS	4-1
	FLIGHT PROCEDURES COMPUTER PROGRAM LISTINGS	4-2
	REFERENCES	R-1
	APPENDIX A: TAKEOFF FLIGHT PROCEDURES	A-1
	APPENDIX B: AIRCRAFT PERFORMANCE AND OPERATIONAL DATA AND INFORMATION	B-1
	APPENDIX C: ENGINE PERFORMANCE AND OPERATIONAL DATA AND INFORMATION	C-1

LIST OF FIGURES

Figures		Page
3.1	Forces Acting on the Aircraft During Climb	3-4
3.2	Coordinate System Used to Define Aircraft Flight Path and Flight Track From 35 Feet HAA to 400 Feet HAA . . .	3-9
3.3	Graphical Representation of the Procedure Used to Approximate Distance to Point of Life-Off	3-11
3.4	Relationships Derived from Aircraft Performance Equations	3-16

LIST OF TABLES

Tables		Page
3.1	Aircraft/Engine Identification and Selection	3-2
3.2	Wing Area (S_W) for Six Generic Aircraft Types (From References 5,21 and 26)	3-6
3.3	Engine Thrust Lapse as a Function of Temperature or Change in Pressure Altitude (From References 4 and 5)	3-12
B.1.1	All-Engine Horizontal DFBR to 35 Feet (D35) HAA for Reference Atmospheric Conditions (Sea-Level, 77°F); 2E-LBPR-NB	B-4
B.1.2	All-Engine D35 Temperature-Altitude Ratios (TMALT-35); 2E-LBPR-NB	B-5
B.1.3	All-Engine Horizontal Distance from 35 Feet HAA to 400 Feet (D400) HAA for Reference Atmospheric Conditions (Sea-Level, 77°F); 2E-LBPR-NB	B-6
B.1.4	All-Engine D400 Temperature-Altitude Ratios (TMALT-400); 2E-LBPR-NB	B-7
B.1.5	Equivalent Air Speeds for Takeoff and Approach and Landing Operations (V35, V_2, 1.3 Vs); 2E-LBPR-NB	B-8
B.1.6	Aircraft Lift and Drag Coefficients (C_L, C_D); 2E-LBPR-NB	B-9
B.1.7	Flap Retraction Speed Schedule and Times; 2E-LBPR-NB . . .	B-10
B.2.1	All-Engine Horizontal DFBR to 35 Feet (D35) HAA for Reference Atmospheric Conditions (Sea-Level, 77°F); 3E-LBPR-NB	B-11
B.2.2	All-Engine D35 Temperature-Altitude Ratios (TMALT-35); 3E-LBPR-NB	B-12

LIST OF TABLES (Cont.)

Page

Tables		Page
B.2.3	All-Engine Horizontal Distance From 35 Feet HAA to 400 Feet (D400) HAA for Reference Atmospheric Conditions (Sea-Level, $77^{\circ}F$); 3E-LBPR-NB	B-13
B.2.4	All-Engine D400 Temperature-Altitude Ratios (TMALT-400); 3E-LBPR-NB	B-14
B.2.5	Equivalent Air Speeds for Takeoff and Approach and Landing Operations (V35, V_2, 1.3 Vs); 3E-LBPR-NB	B-15
B.2.6	Aircraft Lift and Drag Coefficients (C_L, C_D); 3E-LBPR-NB .	B-17
B.2.7	Flap Retraction Speed Schedule and Times; 3E-LBPR-NB . . .	B-18
B.3.1	All-Engine Horizontal DFBR to 35 Feet (D35) HAA for Reference Atmospheric Conditions (Sea-Level, $77^{\circ}F$); 4E-LBPR-NB	B-19
B.3.2	All-Engine D35 Temperature-Altitude Ratios (TMALT-35); 4E-LBPR-NB	B-20
B.3.3	All-Engine Horizontal Distance from 35 Feet HAA to 400 Feet (D400) HAA for Reference Atmospheric Conditions (Sea-Level, $77^{\circ}F$); 4E-LBPR-NB	B-21
B.3.4	All-Engine D400 Temperature-Altitude Ratios (TMALT-400); 4E-LBPR-NB)	B-22
B.3.5	Equivalent Air Speeds for Takeoff and Approach and Landing Operations (V35, V_2, 1.3 Vs); 4E-LBPR-NB	B-23
B.3.6	Aircraft and Drag Coefficients (C_L, C_D); 4E-LBPR-NB . . .	B-25
B.3.7	Flap Retraction Speed Schedule and Times; 4E-LBPR-NB . . .	B-26
B.4.1	All-Engine Horizontal DFBR to 35 Feet (D35) HAA for Reference Atmospheric Conditions (Sea-Level, $77^{\circ}F$); 4E-HBPR-WB	B-27
B.4.2	All-Engine D35 Temperature-Altitude Ratios (TMALT-35); 4E-HBPR-WB	B-28
B.4.3	All-Engine Horizontal Distance from 35 Feet HAA to 400 Feet (D400) HAA for Reference Atmospheric Conditions (Sea-Level, $77^{\circ}F$); 4E-HBPR-WB	B-29
B.4.4	All-Engine D400 Temperature-Altitude Ratios (TMALT-400); 4E-HBPR-WB	B-30
B.4.5	Equivalent Air Speeds for Takeoff and Approach and Landing Operations (V35, V_2, 1.3 Vs); 4E-HBPR-WB	B-31
B.4.6	Aircraft Lift and Drag Coefficients (C_L, C_D); 4E-HBPR-WB	B-32
B.4.7	Flap Retraction Speed Schedule and Times; 4E-HBPR-WB . . .	B-33

LIST OF TABLES (Cont.)

Tables		Page
B.5.1	All-Engine Horizontal DFBR to 35 Feet (D35) HAA; 2E-HBPR-WB	B-34
B.5.2	All-Engine Horizontal DFBR to 400 Feet (D400) HAA for Initial Climb Speed at V_2 + 10 KEAS; 2E-HBPR-WB	B-37
B.5.3	All-Engine Horizontal DFBR to 400 Feet (D400) HAA for Initial Climb Speed at V_2 + 20 KEAS; 2E-HBPR-WB	B-40
B.5.4	All-Engine Horizontal DFBR to 400 Feet (D400) HAA for Initial Climb at V_2 + 30 KEAS; 2E-HBPR-WB	B-43
B.5.5	Equivalent Air Speeds for Takeoff and Approach and Landing Operations (V35, V_2, 1.3 Vs); 2E-HBPR-WB	B-46
B.5.6	Aircraft Lift and Drag Coefficients (C_L, C_D); 2E-HBPR-WB .	B-47
B.5.7	Flap/Slat Retraction Speed Schedule and Times; 2E-HBPR-WB.	B-48
B.6.1	All-Engine Horizontal DFBR to 35 Feet (D35) HAA; 3E-HBPR-WB	B-49
B.6.2	All-Engine Horizontal DFBR to 400 Feet (D400) HAA for Initial Climb Speed at V_2 + 10 KEAS; 3E-HBPR-WB	B-52
B.6.3	All-Engine Horizontal DFBR to 400 Feet (D400) HAA for Initial Climb Speed at V_2 + 20 KEAS: 3E-HBPR-WB	B-55
B.6.4	All-Engine Horizontal DFBR to 400 Feet (D400) HAA for Initial Climb Speed at V_2 + 30 KEAS; 3E-HBPR-WB	B-58
B.6.5	Equivalent Air Speeds for Takeoff and Approach and Landing Operations (V35, V_2, 1.3 Vs); 3E-HBPR-WB	B-61
B.6.6	Aircraft Lift and Drag Coefficients (C_L, C_D); 3E-HBPR-WB .	B-62
B.6.7	Flap/Slat Retraction Speed Schedule and Times; 3E-HBPR-WB.	B-63
C.1.1	Total Net Takeoff Thrust (TOT) Per Engine, Pounds (lbs); 2E-LBPR-NB	C-4
C.1.2	Maximum (Normal) Climb Thrust (MCT) EPR Setting Per Engine; 2E-LBPR-NB	C-7
C.1.3	Referred Net Thrust (Fn/δ) Per Engine, Pounds (lbs); 2E-LBPR-NB	C-8
C.2.1	Total Net Takeoff Thrust (TOT) Per Engine, Pounds (lbs); 3E-LBPR-NB	C-9
C.2.2	Maximum (Normal) Climb Thrust (MCT) EPR Setting Per Engine; 3E-LBPR-NB	C-12
C.2.3	Referred Net Thrust (Fn/δ) Per Engine, Pounds (lbs); 3E-LBPR-NB	C-13
C.3.1	Total Net Takeoff Thrust (TOT) Per Engine, Pounds (lbs); 4E-LBPR-NB	C-15

LIST OF TABLES (Cont.)

Tables		Page
C.3.2	Maximum (Normal) Climb Thrust (MCT) EPR Setting Per Engine; 4E-LBPR-NB	C-16
C.3.3	Referred Net Thrust (Fn/δ) Per Engine, Pounds (lbs); 4E-LBPR-NB	C-17
C.4.1	Total Net Takeoff Thrust (TOT) Per Engine; Pounds (lbs); 4E-HBPR-WB	C-18
C.4.2	Maximum (Normal) Climb Thrust (MCT) EPR Setting Per Engine; 4E-HBPR-WB	C-20
C.4.3	Referred Net Thrust (Fn/δ) Per Engine, Pounds (lbs); 4E-HBPR-WB	C-21
C.4.4	Referred Low Pressure Fan Speed ($N1/\sqrt{\Theta T2}$), RPM; 4E-HBPR	C-22
C.5.1	Total Net Takeoff Thrust (TOT) Per Engine, Pounds (lbs); 2E-HBPR-WB	C-23
C.5.2	Maximum (Normal) Climb Thrust (MCT) EPR Setting Per Engine; 2E-HBPR-WB	C-26
C.5.3	Referred Net Thrust (Fn/δ) Per Engine, Pounds (lbs); 2E-HBPR-WB	C-27
C.5.4	Referred Low Pressure Fan Speed ($N1/\sqrt{\Theta T2}$), RPM; 2E-HBPR-WB.	C-28
C.6.1	Total Net Takeoff Thrust (TOT) Per Engine, Pounds (lbs); 3E-HBPR-WB	C-29
C.6.2	Maximum (Normal) Climb Thrust (MCT) Low Pressure Fan Speed (N1) Setting Per Engine, RPM; 3E-HBPR-WB	C-31
C.6.3	Referred Net Thrust (Fn/δ) Per Engine, Pounds (lbs); 3E-HBPR-WB	C-32

SYMBOLS AND ABBREVIATIONS

Symbol/ Abbreviation	Units	Description
AC	-	Advisory circular issued by the FAA
ALPA	-	Airline Pilots Association
CTB	pounds	Cutback thrust
CDC	-	Control Data Corporation
C/B	pounds	Cutback or reduction in thrust
C_D	-	Aerodynamic drag coefficient
C_L	-	Aerodynamic lift coefficient
D	pounds	Aircraft drag
DCA	-	Washington National Airport identification symbol
DFBR	feet	Distance from brake release
DLOF'	feet	Distance to point of lift-off
D/L	-	Aircraft drag-to-lift ratio
$\overline{D/L}$	-	Average aircraft drag-to-lift ratio

Symbol/ Abbreviation	Units	Description
D35	feet	Horizontal distance from brake release to a point where the aircraft is 35 feet above the airport
D400	feet	Horizontal distance from brake release to a point where the aircraft is 400 feet above the airport
E	-	Aircraft engine
EAS	knots, ft/sec	Equivalent air speed
EPA	-	Environmental Protection Agency
EPR	-	Engine-Pressure-Ratio
^oF	deg	Atmospheric temperature in degrees fahrenheit
FAA	-	Federal Aviation Administration
FAR	-	Federal Aviation Regulation
F_n	pounds	Net thrust
$\overline{F}_n$	pounds	Average total net thrust
fpm	ft/min.	Aircraft rate-of-climb
$f(\Delta y)$	-	Function used to estimate D400 distances for the 2-engine and 3-engine high-by-pass ratio turbofan aircraft
g	ft/sec/sec	Acceleration of gravity
HAA	feet	Height above airport
HBPR	-	High-by-pass ratio
IBM	-	International Business Machines Corporation
INM	-	Integrated Noise Model computer program
K	feet	Flight path distance between 35 feet HAA and 400 feet HAA
KEAS	knots	Equivalent air speed

Symbol/ Abbreviation	Units	Description
L	pounds	Aircraft lift
LBPR	-	Low-by-pass ratio
MACH	-	Mach number
MCT	pounds	Maximum climb thrust
NASA	-	National Aeronautics and Space Administration
NCT	pounds	Normal climb thrust
NWA	-	Northwest Airlines
N1	rpm	Low pressure fan rotational speed
N1THETA	percent	Percent of the reference low pressure rotational speed (in rpm) at aircraft pressure altitude
$(N1THETA)_o$	percent	Percent of the reference low pressure fan rotational speed (in rpm) at airport pressure altitude
NOISEMAP	-	NOISEMAP computer program
OATPL	^oF	Outside air temperature at the aircraft's position
RPM	rpm	Engine rotational speed
S_w	sq. feet	Reference wing area
TM	^oF	Airport temperature
TOT	pounds	Total net takeoff thrust per engine
TWLOF	-	Thrust-to-weight ratio at point of lift-off
TMALT-35	-	Temperature-altitude ratio data used to compute equivalent brake release gross weight at 35 feet HAA
TMALT-400	-	Temperature-altitude ratio data used to compute equivalent brake release gross weight at 400 feet HAA
USAF	-	United States Air Force

Symbol/ Abbreviation	Units	Description
$\dot{V}$	ft/sec/sec	Aircraft acceleration
Ve	ft/sec	Equivalent air speed
V_T	ft/sec	True air speed
V_{LOF}	knots	Equivalent air speed at lift-off
Vs	knots	Equivalent air speed at stall
VZF	knots	Equivalent air speed at zero flap setting
V35	knots	Equivalent air speed at 35 feet HAA
W	pounds	Aircraft weight
X	-	Axial coordinate in the lateral direction
Y	-	Axial coordinate in the direction of the runway
Z	-	Axial coordinate in the vertical direction
α_B	degrees	Aircraft body angle of attack
γ	degrees	Aircraft flight path angle
γ'	degrees	Aircraft flight path angle from 35 feet HAA to 400 feet HAA
ΔALT	KFt.	Change in pressure altitude
ΔTOT1	pounds	Reduction in pounds of thrust per degree change in temperature (^oF), per engine
ΔY	feet	Incremental change in flight track distance
ΔZ	feet	Incremental change in vertical direction or altitude
δ	-	Ratio of ambient pressure to sea level reference pressure of 33.73 inches of mercury
δ_F	degrees	Aircraft flap position or setting

Symbol/ Abbreviation	Units	Description
ΘT_2	-	Ratio of the total temperature at the fan stage face to sea level reference temperature of $77^{o}F$
ρ	$\frac{lbs\text{-}sec^2}{ft^4}$	Ambient air density
ρ_0	$\frac{lbs\text{-}sec^2}{ft^4}$	Air density at sea level

I. INTRODUCTION

BACKGROUND

Computer program models are routinely used to predict community noise exposure produced by aircraft flight operations. Among the most important input data common to all aircraft noise exposure models are descriptions of the flight path and performance schedules of the aircraft operating in the vicinity of the airport. Flight path is defined as the set of points which describe the position of the aircraft in the three dimensional space and performance schedules are the values of the thrust (or another appropriate measure of propulsion), velocity, and flap settings of the aircraft along the flight path. An accurate description of that input is necessary to determine the position of the aircraft relative to the noise receiver locations and to specify its characteristics that relate to noise generation.

Flight path with performance schedule information is generally an input data requirement which must be supplied by the computer program user. The flight path can be defined in terms of flight track and altitude profile, and performance schedule in terms of flight track and thrust and velocity profiles. The flight track is the projection of the aircraft's flight path onto the ground plane. The altitude profile defines the aircraft's height above the airport horizontal reference plane as a function of distance along the flight track from an airport reference point. The reference point is generally located on the runway and is the position of brake release for departures and the runway threshold for arrivals. The thrust and velocity profiles define the aircraft thrust and velocity as a function of distance along the flight track from the same airport reference point. The aircraft flight tracks at a particular airport are determined primarily by local air traffic pattern requirements and, on the average, do not vary significantly as a function of aircraft type. However, for a particular aircraft type operating in accordance with a specified flight procedure, the resulting altitude, thrust, and velocity profiles will depend on the aircraft's performance and operational characteristics, and on a number of airport-specific parameters, such as ambient temperature and pressure altitude.

PURPOSE OF STUDY

The purpose of this study was to identify and collect performance and operational data and information required to construct flight paths and performance schedules for selected commercial aircarrier aircraft types powered by low-by-pass ratio and high-by-pass ratio turbofan engines. The performance and operational data and information can be used to determine the flight paths and performance schedules for aircraft operating in accordance with specified flight procedures, and over a range of airport temperatures and airport pressure altitudes.

In addition, this study effort also included an evaluation of available flight procedures computer programs developed by various organizations such as aircraft manufacturers, consultants, and the Federal government (NASA, FAA, etc.). The purpose of evaluating these programs was to identify existing analytical and computer programming work which can be used in developing a modified computer program model to generate aircraft flight path and performance schedule data which are compatible with the input data requirements of the FAA's INM and the USAF's NOISEMAP.

REPORT OVERVIEW

The results of this study are presented in Sections II, III, and IV and in Appendices A, B, and C.

Section II

In this section, the aircraft and engine performance and operational data and information required to construct flight paths and performance schedules are identified. These data and information are identified with respect to two types of aircraft flight operations: (1) takeoff and (2) approach and landing. Performance and operational data specifically related to aircraft engines are also identified.

Section III

This section describes the aircraft types selected for this study. A brief description of the required aircraft and engine performance and operational data and information identified in Section II is also presented in this section. Along with these descriptions, the sources and procedures used to obtain the required data and information are also presented.

Section IV

This section discusses the findings of the evaluation of available flight procedures computer program models. In addition, an assessment is made of the potential use of these models and their computer program coding for generating aircraft flight path and performance schedule data compatible with all of the input requirements of the FAA's INM and the USAF's NOISEMAP computer programs.

Appendix A

This appendix presents a brief description of the takeoff procedures which are currently used or capable of being used in routine departures. These procedures were used as a basis for identifying the performance and operational data and information required to describe takeoff flight paths and performance schedules.

Appendix B

This appendix presents tabulated listings of the required aircraft performance and operational data and information described in Section III.

These data and information are provided for each aircraft type considered in this study.

Appendix C

This appendix presents tabulated listings of the required aircraft engine performance and operational data and information described in Section III. These data and information are provided for each aircraft engine type considered in this study.

II. PERFORMANCE AND OPERATIONAL DATA AND INFORMATION REQUIREMENTS

TAKEOFF PROCEDURES

Aircraft takeoff procedures can be divided into three general operations.[1] These operations are:

- Ground-roll and initial climb
- Thrust reduction
- Normal climb

The aircraft flight path and performance schedule associated with each of these three general operations will vary depending upon the specific flight procedure employed, the aircraft's aerodynamic performance characteristics, and the performance and operational characteristics of aircraft's engines.

Six takeoff flight procedures have been used as a basis for identifying the aircraft performance and operational data and information required to describe takeoff operations. These takeoff flight procedures are:

- FAA AC 91-39
- FAA AC 91-53

- ALPA/NWA Maximum Thrust Reduction
- ALPA/NWA Minimum Thrust Reduction
- DCA
- FAR 36

A brief description of each of these takeoff flight procedures is presented in Appendix A. Based on a review of these six takeoff procedures, nine unique takeoff operations were identified. These takeoff operations are:

- Acceleration from brake release to point of lift-off with constant flap and thrust settings*; landing gear extended
- Acceleration from point of lift-off to 35 feet height above airport (HAA) with constant flap and thrust settings; landing gear extended
- Acceleration from 35 feet HAA to 400 feet HAA with constant flap and thrust settings; initiate landing gear retraction
- Climb at constant equivalent air speed (EAS), and constant flap and thrust settings; landing gear retracted
- Acceleration with changing flap setting, and with a constant thrust setting; landing gear retracted
- Acceleration with constant flap and thrust settings; landing gear retracted
- Acceleration with constant flap setting and with changing thrust setting; landing gear retracted
- Climb at constant EAS and constant flap setting, and with changing thrust setting; landing gear retracted

*Takeoff thrust from brake release to point of lift-off is not actually constant since the final thrust is not reached until some time after the throttle is set. The throttle position for takeoff thrust is set statically at the point of brake release, or at a specified ground-roll speed, depending on the aircraft/engine type.

- Climb at constant EAS with changing flap setting, and with constant thrust setting; landing gear retracted.

From the above list of takeoff operations, the aircraft performance and operational data and information required to construct takeoff flight paths and performance schedules were identified. These data and information are:

- All-engine distance from brake release (DFBR), EAS, and net thrust at the point of lift-off
- All-engine DFBR, EAS, and net thrust at 35 feet HAA
- All-engine DFBR, EAS, and net thrust at 400 feet HAA
- Engine thrust values over the full range of takeoff flight conditions and thrust requirements
- Aircraft lift and drag coefficients as a function of takeoff flap settings
- Flap retraction speed schedule and retraction times.

APPROACH AND LANDING PROCEDURES

In general, there is less variability in aircraft approach and landing procedures as compared with the takeoff procedures. Typically, the approach and landing operation begins at the point where the aircraft initiates its descent to a final glideslope intercept altitude with the flaps set at "maneuver" position. The aircraft maintains level flight at the intercept altitude until the final glideslope is intercepted. Prior to intercepting the final glideslope, flaps are extended to the "approach" position. Descent along the final glideslope is initiated at the point of intersection with the intercept altitude. As the aircraft descends, flaps are extended to the full "landing" position, the landing gear are extended, and the aircraft continues along the fixed glideslope until point of touchdown.

Based on the description of the general approach and landing procedure, four unique operations were identified. These approach and landing operations are:

- Descend at constant EAS, and constant flap and thrust settings; landing gear retracted or extended
- Descend at constant EAS or deceleration with constant flap setting and with changing thrust setting; landing gear retracted or extended
- Level flight at constant EAS, and constant flap and thrust settings; landing gear retracted or extended
- Level flight deceleration with constant flap setting and with changing thrust setting; landing gear retracted or extended

From the four approach and landing operations listed above, the aircraft performance and operational data and information required to construct approach and landing flight paths and performance schedules were identified. These data and information are:

- EAS as a function approach and landing flap settings and landing gear position
- Engine thrust values over the full range of approach and landing conditions and thrust requirements
- Aircraft lift and drag coefficients as a function of approach and landing flap settings and landing gear position.

OTHER PERFORMANCE AND OPERATIONAL DATA REQUIREMENTS

Other performance and operational data and information useful in defining the aircraft's flight path include:

- Referred (or corrected) net thrust (Fn/δ) as a function of engine-pressure-ratio (EPR) and air speed
- Referred (or corrected) low pressure fan speed ($N1/\sqrt{\theta T_2}$) as a function EPR and air speed
- Referred (or corrected) net thrust as a function of low pressure fan speed and air speed.

III. DEVELOPMENT OF PERFORMANCE AND FLIGHT OPERATIONS DATA BASE

AIRCRAFT AND ENGINE TYPES SELECTED

The aircraft types selected for this study are representative of all types of in-service commercial aircarrier aircraft powered by low-by-pass ratio (LBPR) and high-by-pass ratio (HBPR) turbofan engines. The current fleet of "narrow body" aircraft types are powered by LBPR engines and the "wide body" aircraft types are powered by HBPR engines. The aircraft considered in this study consist of the following six generic classes:

- 2-Engine LBPR-Narrow Body (2E-LBPR-NB)
- 3-Engine LBPR-Narrow Body (3E-LBPR-NB)
- 4-Engine LBPR-Narrow Body (4E-LBPR-NB)
- 2-Engine HBPR-Wide Body (2E-HBPR-WB)
- 3-Engine HBPR-Wide Body (3E-HBPR-WB)
- 4-Engine HBPR-Wide Body (4E-HBPR-WB)

Table 3.1 presents a listing of specific aircraft types which are representative of the above generic classes and identifies the aircraft selected to represent each generic class. The engines used to power the selected aircraft are also presented on Table 3.1.

TABLE 3.1

AIRCRAFT/ENGINE IDENTIFICATION AND SELECTION

Generic Aircraft Class	Representative Aircraft Types	Aircraft Selected To Represent Generic Class	Engine Used To Power Selected Aircraft
2-Engine LBPR-Narrow Body	737/DC-9	737-200 ADV.	JT8D-15
3-Engine LBPR-Narrow Body	727	727-200 ADV.	JT8D-15
4-Engine LBPR-Narrow Body	707/DC-8	707-300 B	JT3D-3B/C
2-Engine HBPR-Wide Body	A300	*	JT9D-20
3-Engine HBPR-Wide Body	DC-10/L-1011	DC-10-10	CF6-6D
4-Engine HBPR-Wide Body	747	747-200	JT9D-7

*A pseudo aircraft has been used to represent the generic class of 2-engine HBPR-wide body aircraft types. Aircraft performance and operational data and information for the pseudo aircraft were based on actual data and information for the DC-10-40. The pseudo aircraft is powered by two (2) JT9D-20 engines.

AIRCRAFT PERFORMANCE AND FLIGHT OPERATIONS DATA

Data Sources and Collection Procedures

The major portion of the aircraft performance and operational data and information has been obtained from aircraft manufacturers. These data and information were extracted from published government reports or obtained through direct communication with manufacturer personnel. Some data and information were obtained from aircraft operators (airlines) or estimated using fundamental aircraft and engine performance relationships. Sea-level pressure altitude and 77°F have been selected as the reference atmospheric conditions.

Aircraft Performance Equations

When calculations were required to determine performance and operational data, the following aircraft performance equations were used:

$$\bar{F}_n \cos \alpha_B = D + \frac{W}{g} \dot{V} + W \sin \gamma \qquad (3\text{-}1)$$

$$L + \bar{F}_n \sin \alpha_B = W \cos \gamma \qquad (3\text{-}2)$$

where:

- $\bar{F}_n$ = Average total net thrust
- W = Aircraft weight
- g = Acceleration of gravity
- D = Aircraft drag
- L = Aircraft lift
- $\dot{V}$ = Aircraft acceleration
- γ = Climb angle, degrees
- α_B = Body angle-of-attack, degrees

Equations 3-1 and 3-2 describe the forces acting on the aircraft in a direction along and normal to the flight path axis, respectively. A diagram displaying the various forces acting on the aircraft during climb is shown on Figure 3.1 In deriving equations 3-1 and 3-2, two assumptions were made: (1) the net thrust can be considered to act along the aircraft body axis, i.e., the angle

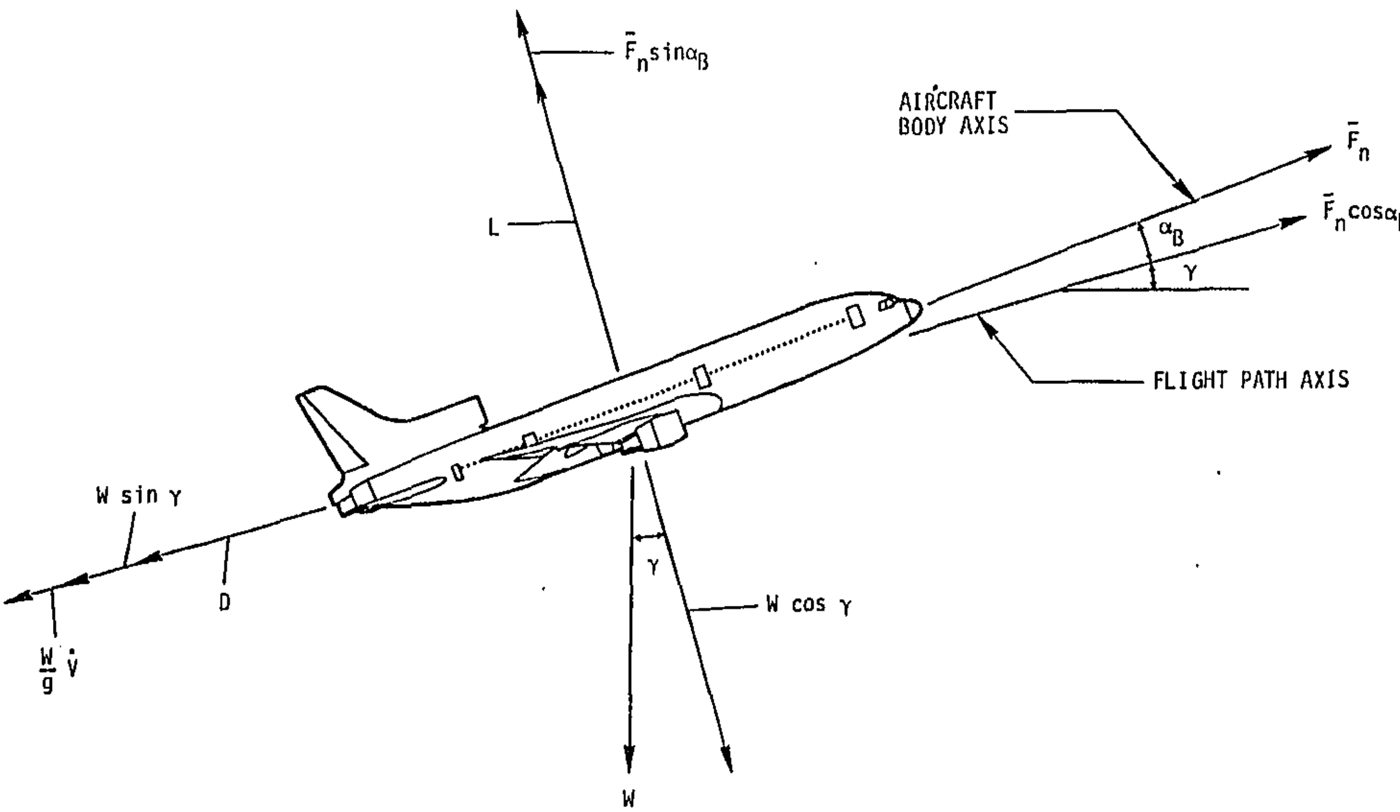

FIGURE 3.1 FORCES ACTING ON THE AIRCRAFT DURING CLIMB

between the thrust vector and aircraft body axis is equal to 0, and (2) the centrifugal force component, resulting from a change in flight path angle, is small compared to the other forces normal to the flight path axis. For calculations performed using equations 3-1 and 3-2, both of the above assumptions have been shown to be reasonable.

The aircraft lift and drag forces are defined by the following equations:

$$D = \frac{1}{2} \rho V_T^2 S_w C_D = \frac{1}{2} \rho_o V_e^2 S_w C_D \qquad (3\text{-}3)$$

$$L = \frac{1}{2} \rho V_T^2 S_w C_L = \frac{1}{2} \rho_o V_e^2 S_w C_L \qquad (3\text{-}4)$$

where:

ρ ambient air density

ρ_o = air density at sea level

V_e = equivalent air speed of the aircraft

V_T = true air speed of the aircraft

S_w = aircraft wing area

C_D = aircraft drag coefficient

C_L = aircraft lift coefficient

The aircraft wing area (S_w) for each of the six generic aircraft types considered in this study are presented on Table 3.2.

<u>Takeoff Operations</u>

The aircraft and engine performance and operational data and information required to construct takeoff flight paths and performance schedules have been identified in Section II. The following presents a brief description of these data and information.

TABLE 3.2

WING AREA (S_w) FOR SIX GENERIC AIRCRAFT TYPES (From References 5, 21 and 26)

Aircraft Type	Wing Area, Sq. Ft.
2E-LBPR-NB	980
3E-LBPR-NB	1560
4E-LBPR-NB	2892
2E-HBPR-WB	2798
3E-HBPR-WB	3550
4E-HBPR-WB	5500

All-Engine DFBR To 35 Feet HAA (D35). The all-engine DFBR to 35 feet HAA is the horizontal distance from brake release to a point where the aircraft is 35 feet above the airport (D35). The data presented in this report were obtained directly from publications prepared by the aircraft manufacturers.[4,5] Over the range of takeoff flap settings, D35 distances can be determined for the entire operational range of brake release gross weight (BRGW) for each aircraft type considered.

For the 2-engine, 3-engine, and 4-engine LBPR aircraft, and for the 4-engine HBPR aircraft, D35 values are presented as a function of takeoff flap setting and BRGW for reference atmospheric conditions only (sea-level, 77°F). Horizontal distance to 35 feet HAA for nonreference conditions are computed using the following procedure: (1) determine the appropriate temperature-altitude ratio (TMALT-35), (2) multiply the actual BRGW by the TMALT-35 value to determine an equivalent BRGW, (3) using the D35 reference table, compute the D35 value for the equivalent BRGW. The D35 value determined by this procedure is the actual distance to 35 feet HAA for the nonreference conditions.

The D35 values for the 2-engine and 3-engine HBPR aircraft are determined directly from D35 tables. The D35 data are presented as a function of airport pressure altitude, airport temperature, BRGW, and takeoff flap setting.

All Engine DFBR To 400 Feet HAA (D400). The all-engine DFBR to 400 feet HAA is the horizontal distance to a point where the aircraft is 400 feet above the airport (D400). The data presented in this report were obtained directly, or estimated, from publications prepared by the aircraft manufacturers.[4,5] Over the range of takeoff flap settings, D400 distances can be determined for the entire operational range of BRGW for each aircraft type considered.

Data required to determine D400 for the 2-engine, 3-engine, and 4-engine LBPR aircraft, and for the 4-engine HBPR aircraft are presented as a function of takeoff flap setting, BRGW, and takeoff climb speed for reference atmospheric conditions only (sea-level, 77°F). For these aircraft types, the data presented in the reference D400 tables represent the horizontal distance from 35 feet HAA to 400 feet HAA. The distance from 35 feet HAA to 400 feet HAA for nonreference conditions is determined by using the same procedure as used to determine the D35 values. Temperature-altitutde ratio data (TMALT-400) required to compute D400 values are presented as a function of airport pressure altitude, airport temperature, and takeoff climb speed.

For the 2-engine and 3-engine HBPR aircraft, the distance to 400 feet HAA can be determined directly from the D400 tables. The D400 data are presented as a function of airport pressure altitude, airport temperature, takeoff flap setting, BRGW, and takeoff climb speed. The D400 distances for takeoff climb speed of V_2* + 10 were obtained from reference 5. For climb speeds of $V_2 + 20$ and $V_2 + 30$, the D400 data were estimated using an equation derived from equations 3-1 and 3-2:

$$\left(\frac{\overline{F}_n}{W}\frac{K}{\Delta Z} - \frac{\overline{D}}{L}\frac{\Delta Y}{\Delta Z} - 1\right) 2g\Delta Z - \left[(V2)^2 - (V1)^2\right] = f(\Delta Y) = 0 \qquad (3\text{-}5)$$

where: ΔZ = change in aircraft altitude (≈365 feet)

ΔY = D400 - D35 (change in horizontal distance from 35 feet HAA to 400 feet HAA), feet

$K = \left[(\Delta Z)^2 + (\Delta Y)^2\right]^{1/2}$, feet

V2 = aircraft speed at 400 feet HAA ($V_2 + 20$ or $V_2 + 30$), feet/sec

V1 = aircraft speed at 35 feet HAA (V35), feet/sec

$\frac{\overline{D}}{L}$ = average drag-to-lift ratio from 35 feet HAA to 400 feet HAA

The coordinate system used to define the aircraft flight path and flight track from 35 feet HAA to 400 feet HAA is presented in Figure 3.2.

---

*V_2 is the engine-out takeoff safety speed.

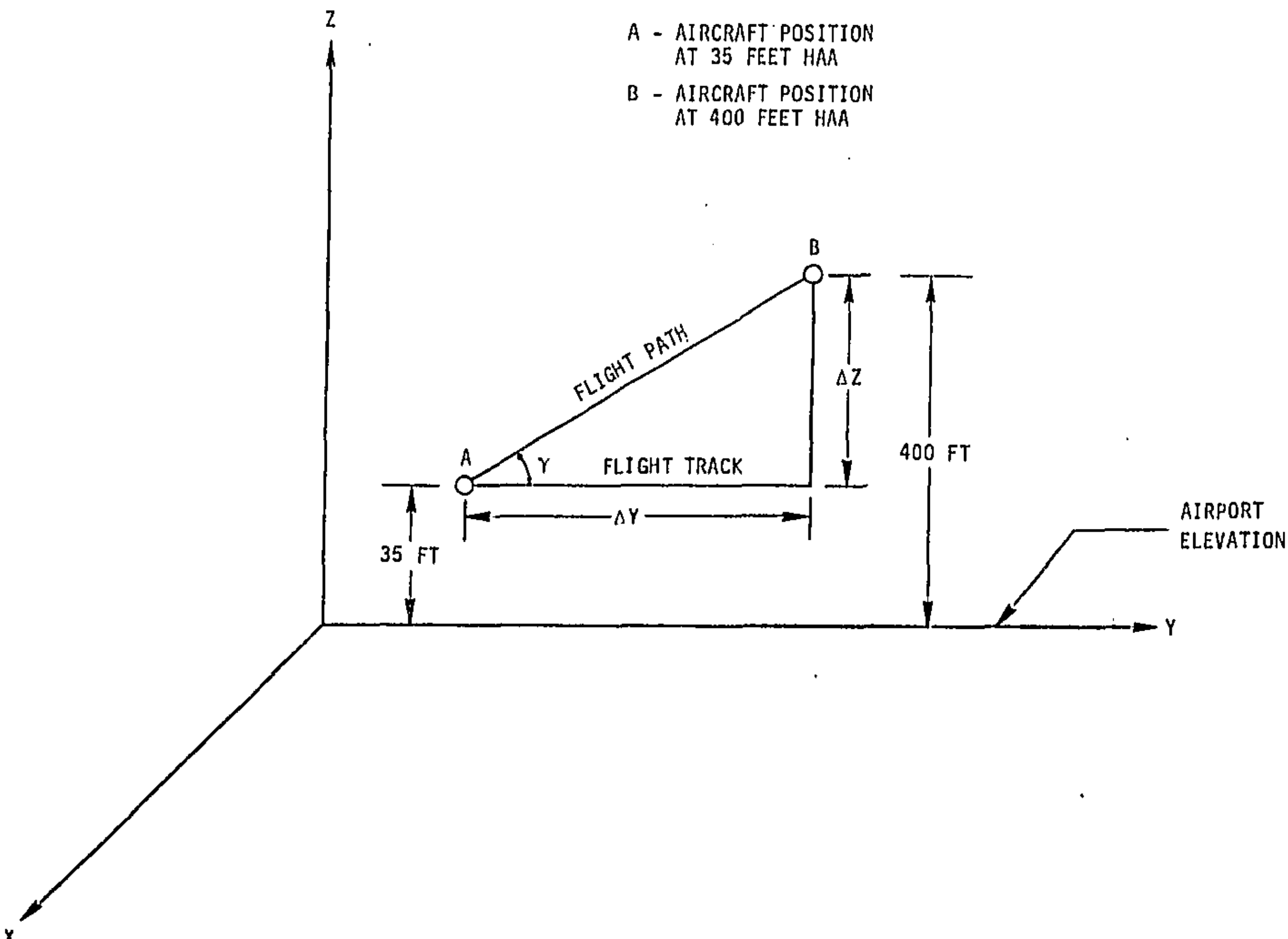

FIGURE 3.2 COORDINATE SYSTEM USED TO DEFINE AIRCRAFT FLIGHT PATH AND FLIGHT TRACK FROM 35 FEET HAA TO 400 FEET HAA

The average drag-to-lift ratio was determined by taking the arithmetic mean of the D/L for the landing gear extended and the D/L for the landing gear retracted. The use of the average drag-to-lift appears to be reasonable since the times required to go from 35 feet HAA to 400 feet HAA for a range of representative takeoff weights are not significantly different from an actual landing gear retraction time.[2]

In deriving equation 3-5, the aircraft body angle-of-attack, α_B, has been assumed to be small, i.e., $\alpha_B = 0$. This small angle assumption is commonly used in deriving the aircraft performance equations of motion,[6,7] and should provide reasonable estimates of the horizontal distance from 35 feet HAA and 400 feet HAA since the change in aircraft altitude (ΔZ) is small. However, for changes in aircraft altitude greater than 365 feet, α_B should not be set equal to zero in the aircraft performance equations.

<u>All-Engine DFBR At The Point of Lift-Off</u>. The all-engine DFBR at the point of lift-off is the horizontal distance from brake release to a point where the aircraft lifts off the runway surface and becomes airborne. These data are not presented in this report in tabulated form. However, estimates of the distance to the point of lift-off (DLOF) can be estimated from the D35 and D400 data tables presented for each aircraft type considered. Figure 3.3 presents a graphical representation of the procedure which can be used to approximate DLOF. From Figure 3.3, it can be seen that the approximate distance to the point of lift-off (DLOF') is given by:

$$DLOF' = D35 - \frac{35}{\tan \gamma'} \qquad (3\text{-}6)$$

where γ' is the climb angle from 35 feet HAA to 400 feet HAA.

<u>All-Engine EAS At 35 Feet HAA</u>. The all-engine EAS at 35 feet HAA (V35) will vary as a function of the aircraft's BRGW and takeoff flap setting. Federal Aviation Regulations[8] require that turbine powered transport category aircraft reach the takeoff safety speed, V_2, before 35 feet HAA. This requirement applys to aircraft operations with one-engine inoperative. Therefore, the speeds at 35 feet HAA with all-engine operation are somewhat higher than the V_2 engine-out safety speed.[2]

A - BRAKE RELEASE
B - ACTUAL LIFT-OFF POINT
B'- ESTIMATED LIFT-OFF POINT
C - 35 FEET HAA
D - 400 FEET HAA

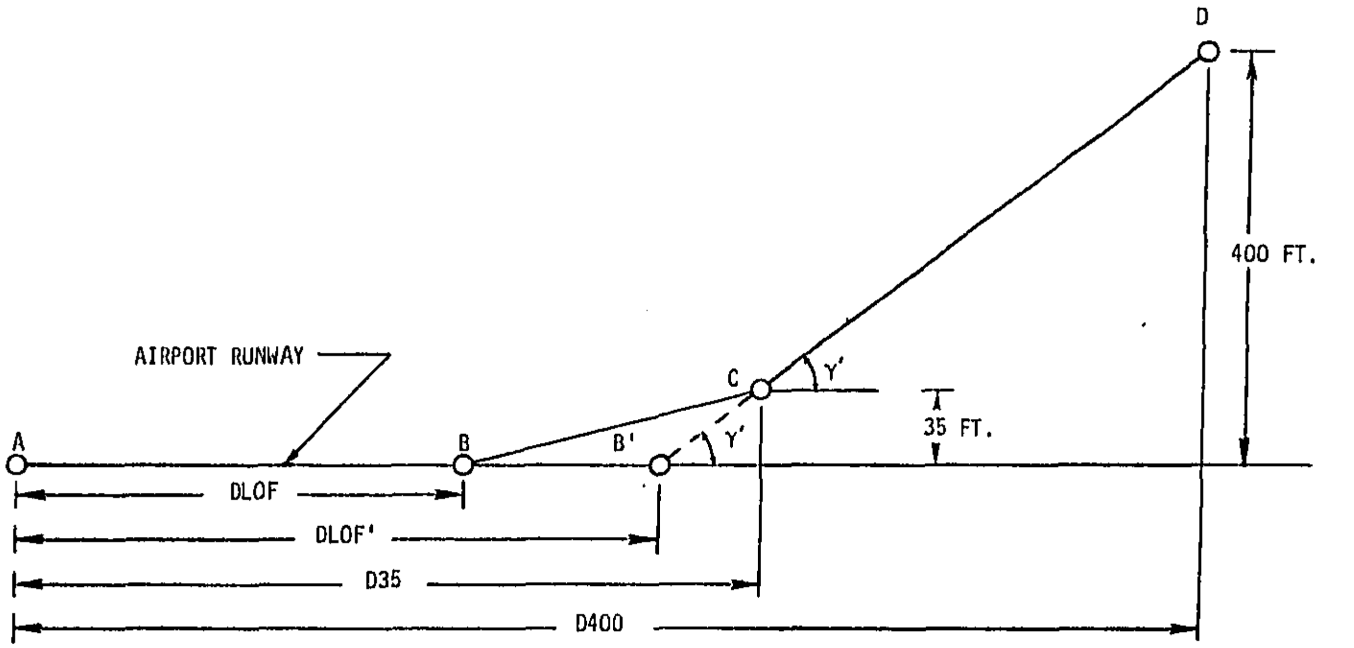

FIGURE 3.3 GRAPHICAL REPRESENTATION OF THE PROCEDURE USED TO APPROXIMATE DISTANCE TO POINT OF LIFT-OFF

The V35 speeds presented in this report were estimated using equation 3-5. In determining the V35 speed, it was assumed that: (1) the average drag-to-lift ratio determined by taking the arithmetic mean of the D/L for landing gear extended and the D/L for the landing gear retracted is representative over the flight path between 35 feet HAA and 400 feet HAA, and (2) the aircraft body angle-of-attack can be approximated as 0.

Using equation 3-5, V35 speeds were determined for each aircraft type considered in this study. For each takeoff flap setting and BRGW, V35 speeds were computed for two takeoff climb speeds.* The arithmetic mean of these V35 values are presented in the V35 tables as a function of aircraft BRGW and takeoff flap setting.

Comparisons of the estimated time from 35 feet HAA to 400 feet HAA with the estimated time from 35 feet HAA to the landing gear up position** show that for some cases the V35 may be over estimated. However, the differences between the actual and estimated V35 for all aircraft types considered in this study are within approximately 2 KEAS.

All-Engine EAS at 400 Feet HAA. By the time the aircraft has reached 400 feet HAA, it is assumed that the landing gear have been completely retracted and the initial all-engine climb speed has been reached. Over the range of representative aircraft takeoff weights, this assumption is supported by climbout profile data presented in publications prepared by the aircraft manufacturers.[5,9,10,11,12,13] Therefore, the all-engine EAS at 400 feet HAA will be the same as the selected all-engine climbout speeds. Depending on the takeoff procedure used, the all-engine climbout speeds generally vary over a range of from V_2 + 10 to V_2 + 30, where V_2 is the engine-out takeoff safety speed. The V_2 speeds are presented in this report as a function of takeoff flap setting and takeoff BRGW. The V_2 speeds were obtained directly from publications prepared by the aircraft manufacturers[4] or through direct communication with manufacturer personnel.[14]

---

*The takeoff climb speeds used to determine V35 speeds were V_2 + 10 (except for the 2E-LBPR-NB aircraft where V_2 + 15 was used) and V_2 + 30.

**The estimated times from 35 feet HAA to the landing gear up position were determined from an empirical relationship derived for the Lockheed L-1011 Tristar aircraft.

All-Engine EAS At The Point of Lift-Off. The all-engine EAS at the point of lift-off (V_{LOF}) will vary as a function of the aircraft's thrust-to-weight ratio (TWLOF) at lift-off.[2] Over a representative range of TWLOF values for all-engine takeoff operations (0.16 to 0.36), V_{LOF} can be approximated by the following relationship:

$$V_{LOF} = V_2 \left[1.0748 - (0.3360 \cdot \text{TWLOF}) \right] \qquad (3\text{-}7)$$

where V_2 is the engine-out takeoff safety speed in KEAS. Equation 3-7 was derived from relationships specifying the all-engine V_{LOF} and the engine-out V_2 speed as functions of the aircraft stalling speed (Vs).[3] A comparison of the V_{LOF} speed computed using equation 3-7 with the all-engine V_{LOF} speed obtained from flight test data shows that equation 3-7 is accurate to within approximately 0.1 KEAS.[2]

Equation 3-7 is considered applicable for determining V_{LOF} speeds for the selected aircraft types shown on Table 3.1 since the approximate thrust-to-weight ratios*, over a range of representative takeoff weights and all-engine takeoff thrust, are comparable with those used to derive this equation.

All-Engine Takeoff Thrust. All-engine takeoff thrust (TOT) is a function of pressure altitude, ambient temperature, and the aircraft's true air speed. The all-engine thrust data presented in this report were obtained directly from publications prepared by the aircraft manufacturers[4] or through direct communication with manufacturer personnel.[14] These data are presented as a function of airport pressure altitude, airport temperature, and aircraft true air speed.

The TOT tables presented in this report can be used to compute thrust over the range from sea-level pressure altitude to 6000 feet above sea-level for the 2E-LBPR-NB, 3E-LBPR-NB, 4E-LBPR-NB, and 4E-HBPR-WB aircraft types and up to 8000 feet above sea-level for the 2E-HBPR-WB and 3E-HBPR-WB aircraft types. At pressure altitudes higher than these, a function describing the reduction in thrust as a direct function of ambient temperature, or pressure altitude change is required. Table 3.3 presents these thrust lapse functions for the engines used with the aircraft types considered in this study.

*Determined at 35 feet HAA.

TABLE 3.3

Engine Thrust Lapse as a Function of Temperature or Change in Pressure Altitude (From References 4 and 5)

Aircraft Type	Δ TOT1 = $a_0 + a_1$ TM		NITHETA = $(NITHETA)_0[a_0 + a_1 (\Delta ALT)]$	
	a_0	a_1	a_0	a_1
2E-LBPR-NB	41.50	0.10	-	-
3E-LBPR-NB	41.50	0.10	-	-
4E-LBPR-NB	47.11	0.10	-	-
4E-HBPR-WB	120.00	0.00	-	-
2E-HBPR-WB	-	-	100.08×10^{-2}	1.29×10^{-2}
3E-HBPR-WB	-	-	99.78×10^{-2}	1.39×10^{-2}

Notes:

Δ TOT1 = reduction in pounds of thrust per degree change in temperature (°F), per engine

TM = airport temperature (°F)

NITHETA = percent of the reference low pressure fan speed (in RPM) at aircraft pressure altitude

$(NITHETA)_0$ = percent of the reference low pressure fan speed (in RPM) at airport pressure altitude

Δ ALT = change in pressure altitude, KFt.

Reference RPM for 2E-HBPR-WB = 3600

Reference RPM for 3E-HBPR-WB = 3433

Maximum Thrust For Normal Climb. The maximum approved thrust for normal climb is a function of pressure altitude and outside air temperature at the aircraft's position (OATPL). The maximum climb thrust is generally specified in terms of engine-pressure-ratio (EPR) or in terms of the fan speed (N1). The maximum climb thrust data presented in this report were obtained through personal communications with aircraft manufacturer personnel.[14,15,16]

Aircraft Lift and Drag Coefficients. For low speed flight operations, aircraft lift and drag coefficients are specified as functions of flap setting (δ_F) and body (or wing) angle-of-attack. The landing gear position will also affect the drag coefficients but has little affect on the lift coefficients. For a given flap setting, lift coefficients (C_L) presented in this report are specified as linear functions of aircraft body angle-of-attack. The drag coefficients (C_D) for a given flap setting are specified as a function of $(C_L)^2$ since this nonlinear relationship provided the highest correlation between the two variables. Also, this parabolic relationship is generally used to describe the variation in C_D with C_L.[5,6,19]

For all aircraft types considered in this study, the relationships describing C_L as a function of flap setting and angle-of-attack, and C_D as a function of flap setting and $(C_L)^2$, were derived from data supplied by the aircraft manufacturers.[4,14,15,16,17,18,20,21] The C_D and C_L data were obtained directly from C_L versus angle-of-attack graphs and drag polar plots, or by calculations using equations 3-1, 3-2, 3-3, and 3-4. Required performance and operational data identified in these equations were obtained from publications prepared by the aircraft manufacturers.[4,5] Figure 3.4 presents examples of the relationships derived from the data computed using equations 3-1, 3-2, 3-3, and 3-4.

Flap Retraction Speed Schedule and Retraction Times. The flap retraction speed schedule specifies the minimum EAS at which flap retraction from takeoff ground-roll flap positions (and other intermediate flap positions) may be initiated to lower flap positions. The flap retraction speed schedules presented in this study cover the range of flap settings from maximum takeoff to zero flap position. The flap retraction time is the time required to retract flaps from a given position to lower flap positions.

The flap retraction speed schedules and flap retraction times presented in this report were supplied by the aircraft manufacturers.[14,21]

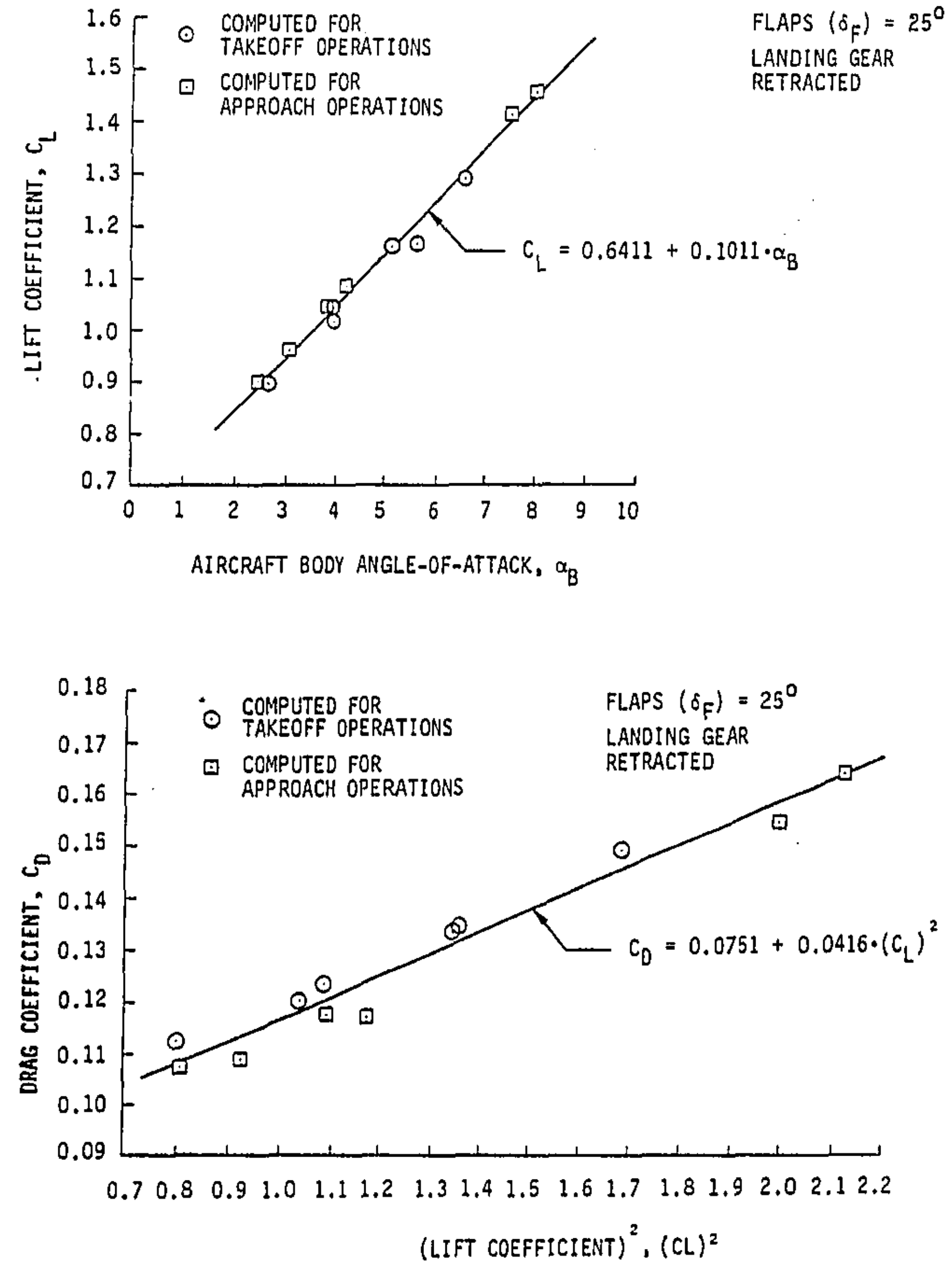

FIGURE 3.4 RELATIONSHIPS DERIVED FROM AIRCRAFT PERFORMANCE EQUATIONS

Approach and Landing Operations

The aircraft performance and operational data and information required to construct approach and landing flight paths and performance schedules have been identified in Section II. The following presents a brief description of these data and information.

Approach and Landing EAS. The EAS for approach and landing operations is a function of aircraft weight, flap setting, and for some aircraft types, landing gear position. Approach and landing operations at a given aircraft weight and flap setting can be performed at several EAS values. The range of EAS values for approach and landing is specified as 1.3 times the certified stall speeds (Vs, KEAS) plus x, where x is equal to 10, 20, or 30 knots. Approach and landing speeds presented in this report are 1.3 Vs speeds given as a function of aircraft weight, flap setting, and landing gear position. These data were obtained from publications prepared by the aircraft manufacturers.[4,5]

Other Performance and Operational Data Requirements

Referred Net Thrust (Fn/δ). Referred net thrust is the actual net thrust (Fn) that an engine would develop at sea-level pressure altitude under identical operating conditions (i.e., the ratio of the ambient to sea-level pressure (δ) = 1). The referred net thrust data presented in this report are specified as a function of EPR and MACH number or as a function of $N1/\sqrt{\Theta T_2}$ and MACH number. These data are applicable over the full range of takeoff, and approach and landing flight conditions and thrust requirements. The referred net thrust data presented in this report were obtained from publications prepared by the aircraft manufacturers.[4,5]

Referred Low Pressure Fan Speed ($N1/\sqrt{\Theta T_2}$). Referred low pressure fan speed is the actual fan rotor speed (N1) that an engine would develop at standard ambient temperature under identical operating conditions (i.e., the ratio of the total temperature at the fan stage face to standard temperature (ΘT_2) = 1). The referred low pressure fan speed data presented in this report are specified for the 2E-HBPR-WB, 3E-HBPR-WB, and 4E-HBPR-WB aircraft types only. These data are applicable over a wide range of takeoff, and approach and landing flight conditions and thrust requirements. The referred low speed fan speed data presented in this report were obtained from publications prepared by the aircraft manufacturers.[4,5]

IV. EVALUATION OF AVAILABLE FLIGHT PROCEDURE COMPUTER PROGRAM MODELS

FLIGHT PROCEDURE MODELS

A number of aircraft flight procedure computer models have been developed by aircraft manufacturers, consultants, and the Federal government.[3,4,5,7,22,23] All but one of the flight procedure models considered in this study were developed specifically for evaluating noise exposure resulting from aircraft flight operations. The one exception was a model developed by the Federal Aviation Administration (FAA) to examine aircraft fuel consumption under a wide variety of operational conditions and air traffic control procedures.[23] However, the output from model does provide a description of the aircraft's vertical flight profile (i.e., altitude versus distance from the airport) for takeoff, and approach and landing operations.

The available documentation describing the structure of the computer models considered in this study, and the algorithms used with these models to generate flight path and performance schedules were evaluated. From this evaluation, it was concluded that none of the available models considered generate aircraft flight path and performance schedule data which are compatible with all of the input data requirements of the FAA's INM and the USAF's NOISEMAP computer programs.

In general, the structure of these models and the models' algorithms are not compatible with the performance and operational data and information requirements described in Section II of this report. In addition, most of the available models evaluated use "simplified" relationships to describe the aircraft's performance and operational characteristics. Therefore, the analytical expressions incorporated in these available flight procedures computer models will require some modifications before they can be used to generate input data required by the FAA's INM and the USAF's NOISEMAP computer programs.

FLIGHT PROCEDURES COMPUTER PROGRAM LISTINGS

Computer program listings have been obtained for all but one of the flight procedures models considered in this study. However, the program user guide for this model provides an adequate description of the structure of the main program and all of the subroutines, and the input data format and requirements.[7] The program listings for the other models were obtained from published reports[3,4] or through personal communications with the program users.[24,25] All of these computer programs are written in a FORTRAN IV coding language. However, only one program was written for operation on an IBM computer system.[3] The other programs were written for operation on a CDC series 6000 computer system. Because of the system incompatibility between the EPA's computer system* and the CDC system, it is likely that little, if any, of the existing programming work can be used to generate all of the input data requirements of the INM and the NOISEMAP computer programs without extensive source code modifications.

*The EPA's computer system consists of the following central processing units: IBM 370/168, IBM 3032, and UNIVAC 1100/44.

REFERENCES

1. Sperry, W. C., "Effectiveness of Aircraft Takeoff Procedures for Noise Abatement," Noise Control Engineering, Vol. 12, (No. 3), May-June 1979.

2. Shapiro, N., et al, "Commercial Aircraft Noise Definition, L-1011 Tristar-Volume I, Final Report", Federal Aviation Administration Report No. FAA-EQ-73-6, I, September 1974.

3. Shapiro, N. et al, "Commercial Aircraft Noise Definition, L-1011 Tristar-Volume V, Computer Programmer's Manual," Federal Aviation Administration Report No. FAA-EQ-73-6, V, September 1974.

4. Bhatia, K., et al, "Boeing Airplane/Noise Performance Computer Programs; Programmer's Manual," Federal Aviation Administration Report No. FAA-EQ-73-7, 7, December 1973.

5. Goodman, J. S., et al, "Aircraft Noise Definition, Phase I, Analysis of Existing Data for the DC-8, DC-9, and DC-10 Aircraft," Federal Aviation Administration Report No. FAA-EQ-75-3, August 1973.

6. Perkins, C. D. and Hage, R. E., Airplane Performance Stability and Control, John Wiley and Sons, New York, 1958.

7. Galloway, W. J., et al, "Data Base for Predicting Civil Aircraft: Flight Profile Prediction," Bolt Beranek and Newman Report 2746R, March 1976.

8. "Airworthiness Standards: Transport Category Airplanes," Federal Aviation Regulation Part 25, Federal Register, 43, 2302 (16 January 1978).

9. Shapiro, N. et al, "Commercial Aircraft Noise Definition, L-1011 Tristar-Volume II-L-1011-1 Data," Federal Aviation Administration Report No. FAA-EQ-73-6, II, September 1974.

10. Williams, B. G. and Yates, R., "Aircraft Noise Definition, Individual Aircraft Technical Data, Model 707," Federal Aviation Administration Report No. FAA-EQ-73-7, 2, December 1973.

11. Williams, B. G. and Yates, R., "Aircraft Noise Definition, Individual Aircraft Technical Data, Model 727," Federal Aviation Administration Report No. FAA-EQ-73-7, 3, December 1973.

12. Williams, B. G. and Yates, R., "Aircraft Noise Definition, Individual Aircraft Technical Data, Model 737," Federal Aviation Administration Report No. FAA-EQ-73-7, 4, December 1973.

13. Williams, B. G. and Yates, R., "Aircraft Noise Definition, Individual Aircraft Technical Data, Model 747," Federal Aviation Administration Report No. FAA-EQ-73-7, 5, December 1973.

14. McPike, A. L., McDonnel Douglas Corporation, personal communication with W. C. Sperry, Reference No. C1-25-5164, (DC-10-10, DC-10-40) 27 October 1975.

15. Schelp, D. A., Boeing Commercial Airplane Company, personal communication with L. A. Ronk, Reference No. B-8286-00-030 (B747-100/200), 12 August 1975.

16. Schelp, D. A., Boeing Commercial Airplane Company, personal communications with F. Mintz, Reference No. B-8286-00-022 (B707-300B, B727-200, B737-200), 10 March 1975.

17. Schelp, D. A., Boeing Commercial Airplane Company, personal communications with L. A. Ronk, Reference No. AERO-B8102-DS-L80-017, (B737-200), 28 August 1980.

18. Francis, J. A., McDonnell Douglas Corporation, personal communications with W. C. Sperry, Reference No. C1-25-3260 (DC-10-40), 15 September 1980.

19. Collins, B. P., "Estimation of Fuel Consumption of Commercial Jet Aircraft from Path Profile Data," MP-80W00007, Metrek Division, MITRE Corporation, May 1980.

20. Schelp, D. A., Boeing Commercial Airplane Company, personal communications with L. A. Ronk, Reference No. B8286-00-043, 7 January 1976.

21. Hall, F., Boeing Commercial Airplane Company, personal communications with F. Mintz, 15 March 1975.

22. Padula, S. L., "Prediction of Noise Constrained Optimum Takeoff Procedures," presented at the AIAA 6th Aeroacoustics Conference, Hartford, CT, June 4-6, 1980.

23. Winer, D. E., and Hoch, C. J., "Energy Conservation in Terminal Airspace Through Fuel Consumption Modeling," presented at the 1980 International Air Transportation Meeting, Cincinnati, Ohio, May 20-22, 1980.

24. Padula, S. L., NASA Langley Research Center, personal communication with L. A. Ronk, 23 August 1980.

25. Winer, D. E., Office of Environmental and Energy, Federal Aviation Administration, personal communication with L. A. Ronk, 22 August 1980.

26. "A300 Aircraft Noise Definition Manual," Airbus Industrie, Airbus Support Division, May 1980.

APPENDIX A

TAKEOFF FLIGHT PROCEDURES

APPENDIX A
TAKEOFF FLIGHT PROCEDURES

This appendix presents a brief description of six takeoff procedures which are currently used or capable of being used in routine departures. Each procedure consists of three flight path segments which are identified by their principal operational activities. These segments are:

- Ground-roll and initial climb
- Thrust reduction
- Normal climb

Each of these three segments may be comprised of several sections in which the aircraft performs various operational activities such as landing gear retraction, flap retraction, acceleration, and thrust adjustment. The location at which these activities are initiated and the sequence of their occurrence will depend on the specific flight procedure employed.

FAA Advisory Circular (AC) 91-39

The AC 91-39 procedure was recommended by the FAA for commercial jet departure profiles on January 18, 1974. This procedures specifies a reduction in engine power from takeoff thrust to normal climb thrust at 1500 feet height above airport (HAA) with subsequent climb and acceleration at 3000 feet HAA with changes in deck angle and flap retraction. The AC 91-39 procedure is outdated and has been replaced by AC 91-53.

AC 91-39 Takeoff Procedure

A. First Segment (ground roll and initial climb)

A.1 Brake release; takeoff ground roll with takeoff thrust (TOT); rotate and climb to 35 feet height above airport (HAA); and accelerate to V35* KEAS

A.2 Retract gear; climb to 400 feet HAA; and accelerate to V_2 + 10 KEAS

A.3 Climb to 1500 feet HAA with thrust = TOT, Speed = V_2 + 10** KEAS, flaps = takeoff, and gear = retracted

B. Second Segment (thrust cutback)

B.1 At 1500 Ft HAA, maintain speed, reduce thrust to maximum climb thrust (MCT) and perform partial flap retraction if speed permits

B.2 Climb to 3000 feet HAA with thrust = MCT, Speed = V_2 + 10** KEAS, flaps = takeoff or partial retraction if speed permits, and gear = retracted

---

*V35 is the all engines operating speed at 35 feet HAA

**Indicates speed acceleration beyond V_2 + 10 KEAS if pitch attitude is limited or to enable a lesser flap setting during second segment, or if required for practical of safety reasons.

C. Third Segment (normal climb)

C.1 At 3000 feet HAA, maintain MCT, retract flaps per flap retraction schedule, and accelerate to 250 KEAS with 500 to 1000 fpm rate-of-climb.

C.2 Climb and accelerate to 250 KEAS with thrust = MCT, speed = V_2 + 10** KEAS, flaps = retract, and gear = retracted

C.3 When a speed of 250 KEAS and flap retraction are achieved, maintain MCT and initiate normal climb schedule

C.4 Climb to 10,000 feet HAA with thrust = MCT, speed = 250 KEAS, flaps = retracted, and gear = retracted.

FAA Advisory Circular (AC) 91-53

The AC 91-53 procedure supersedes the earlier AC 91-39 procedure. The AC 91-53 procedures specifies a reduction from takeoff thrust after clean-up has been performed. The extent of the thrust reduction will depend upon the aircraft type. This procedure allows for thrust reduction at intermediate flap setting for aircraft with slow flap retraction times, and for thrust reduction below 1000 feet HAA.

FAA AC 91-53 Takeoff Procedure

A. First Segment (ground roll and initial climb)

A.1 Brake release; takeoff ground roll with takeoff thrust (TOT); rotate and climb to 35 feet height above airport (HAA); and accelerate to V35 KEAS

A.2 Retract gear; climb to 400 feet HAA; and accelerate to an airspeed of V_2 + 10 to 20 KEAS

A.3 Climb to 1000 feet HAA with thrust = TOT, speed = V_2 + 10 to 20 KEAS, flaps = takeoff, and gear = retracted

B. Second Segment (thrust cutback)

B.1 At 1000 feet HAA*, lower nose and accelerate to zero flap speed (VZF), retract flaps per schedule and maintain TOT

B.2 When a speed of VZF and flap retraction are achieved, reduce thrust consistent with the following: (1) airplanes with high bypass ratio engines should be reduced to normal climb thrust (NCT); (2) airplanes with low bypass ratio engines should be reduced below NCT but not lower than the following

---

*Airplanes not using wing flaps for takeoff should reduce thrust before attaining 1000 feet HAA but not before 500 feet HAA.

positive climb gradients if one engine should become inoperative: two-engine aircraft = 1.2 percent, three-engine aircraft = 1.5 percent, and four-engine aircraft = 1.7 percent, and (3) airplanes with slow flap retraction rates should be reduced at an intermediate flap setting.

B.3 Climb to 3000 feet HAA with reduced thrust, speed = not greater than VZF + 10 KEAS, flaps = retracted, and gear = retracted

C. Third Segment (normal climb)

C.1 At 3000 feet HAA, gradually increase thrust to NCT,** if required, and accelerate to 250 KEAS

C.2 When a speed of 250 KEAS and NCT are achieved, initiate normal climb schedule

C.3 Climb to 10,000 feet HAA with thrust = NCT, speed = 250 KEAS, flaps = retracted, and gear = retracted

---

**Reapplication of power can be delayed if that event would occur over a noise sensitive area.

Airline Pilots Association/Northwest Airlines;
Large Cutback After Cleanup (ALPA/NWA Max. C/B)

This procedure is routinely used by NWA and, except for minor differences, is identical to the procedure recommended by ALPA. The procedure specifies a reduction from takeoff thrust to a cutback thrust that equals the one engine-out certification requirement for thrust after clean-up is performed. Acceleration and clean-up are initiated at 1000 feet HAA.

ALPA/NWA Max. C/B Takeoff Procedure

A. First Segment (roll and initial climb)

- A.1 Brake release; takeoff roll with takeoff thrust (TOT); rotate and climb to 35 feet HAA; and accelerate to V35 KEAS
- A.2 Retract gear; climb to 400 feet HAA, and accelerate to an airspeed of V_2+10 KEAS
- A.3 Climb to 1000 feet HAA with thrust = TOT, speed = V_2+10 KEAS (greater if required), flaps = takeoff, and gear = retracted.

B. Second Segment (thrust cutback)

- B.1 At 1000 feet HAA lower nose and accelerate to zero flaps speed (VZF), retract flaps per schedule, maintain TOT and a pitch attitude within one half the initial climb value plus 0 to 3 degrees and a rate-of-climb not less than 500 fpm.
- B.2 Climb and accelerate to VZF with thrust = TOT speed = V_2+10 to VZF KEAS, flaps = retract, and gear = retracted.

B.3 When a speed of VZF and flap retraction are attained, reduce the thrust to the greater cutback thrust (CBT) that will give a rate-of-climb of 1000 fpm or the following positive climb gradients if one engine should become inoperative: two-engine aircraft = 1.2 percent, three-engine aircraft = 1.5 percent, and four-engine aircraft = 1.7 percent.

B.4 Climb to 4000 feet HAA with thrust = CBT, speed = VZF KEAS, flaps = retracted, and gear = retracted.

C. Third Segment (normal climb)

C.1 At 4000 feet HAA, gradually increase thrust to maximum climb thrust (MCT) and accelerate to 250 KEAS with 500 to 1000 fpm rate-of-climb.

C.2 Climb and accelerate to 250 KEAS with thrust = CBT to MCT, speed = VZF to 250 KEAS, flaps = retracted, and gear = retracted.

C.3 When a speed of 250 KEAS and a thrust of MCT are achieved initiate normal climb schedule.

C.4 Climb to 10,000 feet HAA with thrust = MCT, speed = 250 KEAS, flaps = retracted, and gear = retracted.

Airline Pilots Association/Northwest Airlines;
Small Cutback After Cleanup (ALPA/NWA Min. C/B)

This procedure is similar to ALPA/NWA Max. C/B except that the takeoff thrust is reduced to a cutback thrust equal to the maximum climb thrust after cleanup is performed.

ALPA/NWA Min. C/B Takeoff Procedure

A. First Segment (roll and initial climb)

A.1 Brake release; takeoff roll with takeoff thrust (TOT); Rotate and climb to 35 feet HAA and accelerate to V35 KEAS.

A.2 Retract gear; climb to 400 feet HAA; and accelerate to V_2+10 KEAS.

A.3 Climb to 1000 feet HAA with thrust = TOT, speed = V_2+10 KEAS (greater if required), flaps = takeoff, and gear = retracted.

B. Second Segment (thrust cutback)

B.1 At 1000 feet HAA, lower nose and accelerate to zero flap speed (VZF), retract flaps per schedule, maintain TOT and a pitch attitude within one half the initial climb value plus 0 to 3 degrees, and a rate-of-climb not less than 500 fpm.

B.2 Climb and accelerate to VZF with thrust = TOT, speed = V_2+10 to VZF KEAS, flaps = retract, and gear = retracted.

B.3 When a speed of VZF and flap retraction are achieved, reduce thrust to maximum climb thrust (MCT).

B.4 Climb to 4000 feet HAA with thrust = MCT, speed = VZF KEAS, flaps = retracted, and gear = retracted.

C. Third Segment (normal climb)

C.1 At 4000 feet HAA, maintain MCT and accelerate to 250 KEAS with 500 to 1000 fpm rate-of-climb.

C.2 Climb and accelerate to 250 KEAS with thrust = MCT, speed = VZF to 250 KEAS, flaps = retracted, and gear = retracted.

C.3 When a speed of 250 KEAS is achieved, maintain MCT and initiate normal climb schedule.

C.4 Climb to 10,000 feet HAA with thrust = MCT, speed = 250 KEAS, flaps = retracted, and gear = retracted.

Washington National Airport (DCA)

The DCA procedure is a specific procedure used as a noise abatement measure at Washington National Airport. This procedure specifies a reduction from takeoff thrust to a cutback thrust that gives approximately a 500 feet per minute rate-of-climb before cleanup.

DCA Takeoff Procedure

A. First Segment (roll and initial climb)

A.1 Brake release; takeoff roll with takeoff thrust (TOT); rotate and climb to 35 feet HAA; and accelerate to V35 KEAS.

A.2 Retract gear; climb to 400 feet HAA and accelerate to V_2+10 KEAS.

A.3 Climb to 1500 feet HAA with thrust = TOT, speed = V_2+10 KEAS (or greater if required), flaps = takeoff, and gear = retracted.

B. Second Segment (thrust cutback)

B.1 At 1500 feet HAA, maintain speed and reduce the thrust to a cutback thrust (CBT) computed for hot day conditions at max. gross takeoff weight to give approximately 500 fpm rate-of-climb.

B.2 Climb to not less than the HAA required to reach ten nautical miles distance from brake release (DFBR) with thrust = CBT, speed = V_2+10 KEAS, flaps = takeoff, and gear = retracted.

C. Third Segment (normal climb)

C.1 At ten nautical miles DFBR, maintain speed and gradually increase thrust to achieve maximum climb thrust (MCT) at not less than 4000 feet HAA.

C.2 Climb to the HAA required to achieve MCT with thrust = CBT to MCT, speed = V_2+10, flaps = takeoff, and gear = retracted.

C.3 At the HAA required to achieve MCT, retract flaps per schedule and accelerate to 250 KEAS with 500 to 1000 fpm rate-of-climb.

C.4 Climb and accelerate to 250 KEAS with thrust = MCT, speed = V_2+10 to 250 KEAS, flaps = retract, and gear = retracted.

C.5 When a speed of 250 KEAS and flap retraction are achieved, maintain MCT and initiate normal climb schedule.

C.6 Climb to 10,000 feet HAA with thrust = MCT, speed = 250 KEAS, flaps = retracted, and gear = retracted.

FAR 36

The FAR 36 procedure is not generally used in routine airport operations. This procedure specifies a reduction from takeoff thrust (before cleanup) to a cutback thrust that is equal to the thrust required for a one engine out level flight or for a four percent climb gradient, whichever is greater.

FAR 36 Takeoff Procedure

A. First Segment (roll and initial climb)

A.1 Brake release; takeoff roll with takeoff thrust (TOT); rotate and climb to 35 feet HAA and accelerate to V35.

A.2 Retract gear; climb to 400 feet HAA; and accelerate to V_2+10 KEAS.

A.3 Climb to 1000 feet HAA with thrust = TOT, speed = V_2+10 KEAS (greater if required), flaps = takeoff, and gear = retracted.

B. Second Segment (thrust cutback)

B.1 At 1000 feet HAA, maintain speed and reduce thrust to the cutback thrust (CBT) which will give level flight with one engine inoperative or a 4 percent climb gradient, whichever thrust is greater.

B.2 Climb to 3000 feet HAA with thrust = CBT, speed = V_2+10 KEAS, flaps = takeoff, and gear = retracted.

C. Third Segment (normal climb)

C.1 At 3000 feet HAA, maintain speed and gradually increase thrust to achieve maximum climb thrust (MCT) at not less than 4000 feet HAA.

C.2 Climb to the HAA required to achieve MCT with thrust = CBT to MCT, speed = V_2+10 KEAS, flaps = takeoff, and gear = retracted.

C.3 At the HAA required to achieve MCT, retract flaps per schedule and accelerate to 250 KEAS with 500 to 1000 fpm rate-of-climb.

C.4 Climb and accelerate to 250 KEAS with thrust = MCT, speed = V_2+10 to 250 KEAS, flaps = retract, and gear = retracted.

C.5 Climb to 10,000 feet HAA with thrust = MCT, speed = 250 KEAS, flaps = retracted, and gear = retracted.

APPENDIX B

AIRCRAFT PERFORMANCE AND OPERATIONAL DATA AND INFORMATION

APPENDIX B

AIRCRAFT PERFORMANCE AND OPERATIONAL
DATA AND INFORMATION

This appendix presents tabulated listings of the aircraft performance and operational data and information required to construct takeoff, and approach and landing flight paths and performance schedules for selected commercial aircarrier aircraft types powered by low-by-pass ratio (LBPR) and high-by-pass ratio (HBPR) turbofan engines. Data and information are provided for the following six generic aircraft types:

- 2-Engine LBPR-Narrow Body (2E-LBPR-NB)
- 3-Engine LBPR-Narrow Body (3E-LBPR-NB)
- 4-Engine LBPR-Narrow Body (4E-LBPR-NB)
- 2-Engine HBPR-Wide Body (2E-HBPR-WB)
- 3-Engine HBPR-Wide Body (3E-HBPR-WB)
- 4-Engine HBPR-Wide Body (4E-HBPR-WB)

Data and information presented in this appendix include:

- All-engine horizontal distance from brake release (DFBR) to 35 feet (D35) height above airport (HAA) for reference atmospheric conditions (sea-level, 77°F)*

*Data presented for the 2E-HBPR-WB and the 3E-HBPR-WB aircraft types are given for a range of pressure altitudes and ambient temperatures.

- All-engine D35 temperature-altitude ratios (TMALT-35) to determine equivalent brake release gross weight (BRGW) for nonreference atmospheric conditions (for 2E-LBPR-NB, 3E-LBPR-NB, 4E-LBPR-NB, and 4E-HBPR-WB aircraft types only).
- All-engine horizontal distance from 35 feet HAA to 400 feet (D400) HAA for reference atmospheric conditions (sea-level, 77^oF)*
- All-engine D400 temperature-altitude ratios (TMALT-400) to determine equivalent BRGW for nonreference atmospheric conditions (for 2E-LBPR-NB, 3E-LBPR-NB, 4E-LBPR-NB, and 4E-HBPR-WB aircraft types only).
- All-engine equivalent air speed (EAS) at 35 feet HAA (V35)
- One-engine out takeoff safety EAS (V_2).
- Aircraft lift and drag coefficients (C_L and C_D) as a function of flap setting (δ_F) and landing gear position
- Flap retraction speed schedule and times
- EAS for approach and landing operations (1.3 Vs)

---

*Data presented for the 2E-HBPR-WB and the 3E-HBPR-WB aircraft types are the horizontal DFBR to 400 ft HAA. These data are given for a range of pressure altitudes and ambient temperatures.

TABLE B.1.1

ALL-ENGINE HORIZONTAL DFBR TO 35 FEET (D35) HAA FOR REFERENCE ATMOSPHERIC CONDITIONS (SEA-LEVEL, 77°F); 2E-LBPR-NB

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs						
	70	80	90	100	110	120	125
1	2607	3269	4061	5004	6082	7310	8980
2	2443	3055	3789	4657	5646	6770	7350
5	2347	2931	3631	4453	5388	6447	7000
10	2179	2718	3358	4139	5044	6083	6258*
15	2069	2577	3180	3928	4789	5781	5944*
25	2007	2501	3091	3813	4643	5598	5761*

* These values have been obtained by extrapolation.

TABLE B.1.2

ALL-ENGINE D35 TEMPERATURE-ALTITUDE
RATIOS (TMALT-35); 2E-LBPR-NB

Airport Pressure Altitude, Feet	Temperature, Degrees, °F							
	30	45.5	48	53	66	74	84	100
0	0.957	0.972	0.974	0.978	0.990	0.998	1.006	1.056
1000	0.981	0.986	0.991	1.004	1.016	1.024	1.042	1.093
2000	0.988	1.022	1.028	1.032	1.042	1.058	1.078	1.130
3000	1.019	1.059	1.065	1.069	1.081	1.096	1.117	1.176
4000	1.060	1.097	1.103	1.108	1.120	1.136	1.158	1.214
5000	1.098	1.137	1.142	1.147	1.161	1.176	1.198	1.257
6000	1.138	1.177	1.183	1.189	1.202	1.217	1.239	1.305

TABLE B.1.3

ALL-ENGINE HORIZONTAL DISTANCE FROM 35 FEET HAA TO 400 FEET (D400) HAA FOR REFERENCE ATMOSPHERIC CONDITIONS (SEA-LEVEL, 77°F); 2E-LBPR-NB

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs					
	70	80	90	100	110	120
TAKEOFF CLIMB SPEED - V_2 + 15						
1	1261	1573	1906	2269	2676	3131
2	1281	1603	1950	2330	2760	3242
5	1292	1617	1969	2358	2798	3291
10	1337	1680	2060	2481	2964	3514
15	1358	1711	2104	2542	3094	3629
25	1405	1780	2202	2680	3243	3898
TAKEOFF CLIMB SPEED - V_2 + 20						
1	1448	1813	2207	2639	3123	3665
2	1464	1841	2248	2697	3205	3775
5	1474	1851	2264	2721	3238	3820
10	1516	1913	2354	2846	3412	4057
15	1536	1941	2396	2906	3497	4175
25	1584	2014	2501	3056	3708	4470
TAKEOFF CLIMB SPEED - V_2 + 30						
1	1842	2317	2836	3408	4052	4773
2	1851	2336	2869	3459	4127	4877
5	1857	2345	2880	3477	4154	4918
10	1897	2404	2972	3612	4347	5189
15	1912	2428	3010	3670	4434	5313
25	1967	2512	3132	3847	4686	5669

TABLE B.1.4

ALL-ENGINE D400 TEMPERATURE-ALTITUDE RATIOS
(TMALT-400); 2E-LBPR-NB

Airport Pressure Altitude, Feet	Temperature, Degrees, °F							
	30	45.5	48	53	66	74	84	100
TAKEOFF CLIMB SPEED - V_2 + 15								
0	0.998	0.998	0.998	0.999	0.999	1.000	1.000	1.073
1000	0.993	0.994	0.999	1.016	1.017	1.017	1.036	1.113
2000	0.992	1.031	1.038	1.038	1.040	1.054	1.076	1.154
3000	1.029	1.073	1.078	1.078	1.078	1.093	1.119	1.198
4000	1.038	1.111	1.118	1.119	1.121	1.136	1.162	1.252
5000	1.105	1.153	1.162	1.163	1.164	1.180	1.207	1.307
6000	1.155	1.198	1.207	1.208	1.211	1.227	1.254	1.369
TAKEOFF CLIMB SPEED - V_2 + 20								
0	0.996	0.997	0.998	0.998	0.998	0.999	1.000	1.068
1000	0.993	0.993	0.999	1.016	1.017	1.018	1.038	1.108
2000	0.991	1.030	1.038	1.038	1.039	1.051	1.076	1.149
3000	1.031	1.068	1.077	1.078	1.079	1.092	1.117	1.197
4000	1.064	1.109	1.118	1.118	1.121	1.133	1.159	1.246
5000	1.106	1.150	1.159	1.159	1.162	1.176	1.206	1.303
6000	1.153	1.196	1.204	1.205	1.208	1.221	1.252	1.364
TAKEOFF CLIMB SPEED - V_2 + 30								
0	0.993	0.995	0.996	0.997	0.998	0.999	1.001	1.072
1000	0.990	0.993	1.000	1.014	1.016	1.018	1.038	1.113
2000	0.899	1.031	1.038	1.039	1.040	1.053	1.080	1.156
3000	1.031	1.070	1.078	1.079	1.081	1.094	1.122	1.202
4000	1.059	1.109	1.119	1.121	1.123	1.138	1.166	1.255
5000	1.104	1.152	1.163	1.164	1.168	1.182	1.212	1.310
6000	1.156	1.200	1.208	1.211	1.216	1.230	1.263	1.372

TABLE B.1.5

EQUIVALENT AIR SPEEDS FOR TAKEOFF AND APPROACH AND LANDING OPERATIONS (V35, V_2, 1.3 Vs); 2E-LBPR-NB

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs					
	70	80	90	100	110	120
TAKEOFF SPEED AT 35 FEET HEIGHT ABOVE AIRPORT, V35, KEAS						
1	131.49	138.78	146.07	153.09	160.12	167.14
2	127.04	134.01	140.97	147.72	154.47	161.31
5	124.24	131.14	138.03	144.63	151.23	157.82
10	120.09	126.19	132.28	139.10	145.92	152.73
15	120.02	125.49	130.97	136.43	141.91	147.38
25	120.37	125.25	130.13	135.01	139.89	144.77
TAKEOFF SAFETY SPEED, V_2, KEAS						
1	119.2	127.6	135.2	142.5	149.8	157.2
2	115.1	123.2	130.7	137.8	144.9	152.0
5	112.5	120.6	127.8	134.8	141.7	148.6
10	108.5	115.2	122.3	129.3	136.3	143.5
15	108.5	111.8	118.9	125.6	132.4	139.2*
25	108.5	109.7	116.2	122.9	129.5	136.1*
APPROACH SPEED, 1.3 Vs, KEAS						
15	103.3		128.6		143.8	
25	111.0		125.8		140.5	
25 E	111.0		125.8		140.5	
30 E	108.0		122.8		138.0	
40 E	105.3		119.7		134.3	

*These values have been obtained by extrapolation.

Note: Landing gear retracted except for flap setting designated with an E.

TABLE B.1.6

AIRCRAFT LIFT AND DRAG COEFFICIENTS (C_L, C_D); 2E-LBPR-NB

LIFT COEFFICIENT AS A FUNCTION OF AIRCRAFT BODY ANGLE OF ATTACK

Flap Setting, δ_F Degrees	Landing Gear Position	$C_L = a_0 + a_1 \cdot \alpha_B$	
		a_0	a_1
0	Up	0.0743	0.0782
1	Up	0.1086	0.0921
2	Up	0.1394	0.0936
5	Up	0.2269	0.0962
10	Up	0.3229	0.0938
15	Up	0.4489	0.1045
25	Up	0.5597	0.1042
25	Down	0.5941	0.1084
30	Down	0.7860	0.1092
40	Down	1.1095	0.1024

DRAG COEFFICIENT AS A FUNCTION OF LIFT COEFFICIENT

Flap Setting, δ_F Degrees	Landing Gear Position	$C_D = a_0 + a_1 \cdot (C_L)^2$	
		a_0	a_1
0	Up	0.0197	0.0491
1	Up	0.0275	0.0405
2	Up	0.0297	0.0423
5	Up	0.0335	0.0408
10	Up	0.0435	0.0411
15	Up	0.0523	0.0360
25	Up	0.0575	0.0413
25	Down	0.0764	0.0410
30	Down	0.0919	0.0419
40	Down	0.1397	0.0411

TABLE B.1.7

FLAP RETRACTION SPEED SCHEDULE AND TIMES; 2E-LBPR-NB

T/O Roll Flap Position, δ_F Deg.	Selected Flap Position, δ_F Deg.	Minimum Initiation Speed For Selected Flap Pos., KEAS
		All Aircraft Weights
25	15	V2 + 15
	5	150
	1	170
	0	190
10 or 15	5	V2 + 15
	1	170
	0	190
2 or 5	1	V2 + 15
	0	190
1	0	190
Minimum Zero Flap Speed		210

Initial Flap Setting, δ_F Deg.	Selected Flap Setting, δ_F Deg.	Flap Retraction Time Sec.
25	15	1.2
15	10	1.9
10	5	5.1
5	2	5.1
2	1	11.2
1	0	5.3

TABLE B.2.1

ALL-ENGINE HORIZONTAL DFBR TO 35 FEET (D35) HAA FOR REFERENCE ATMOSPHERIC CONDITIONS (SEA-LEVEL, 77°F); 3E-LBPR-NB

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs										
	110	130	140	150	160	170	180	190	200	210	230
5	2902	4051	4693	5385	6132	6936	7804	8775	9824	10964	13551
15	2584	3595	4156	4758	5404	6098	6842	7669	8559	9521	11689
20	2456	3420	3956	4532	5150	5815	6529	7324	8181	9109	11209
25	2340	3263	3776	4327	4921	5559	6246	7010	7837	8734	10769

TABLE B.2.2

ALL-ENGINE D35 TEMPERATURE-ALTITUDE RATIOS (TMALT-35); 3E-LBPR-NB

Airport Pressure Altitude, Feet	Temperature, Degrees, °F								
	30	46	48	53	66	74	84	94	100
0	.9592	.9733	.9750	.9794	.9906	.9974	1.0060	1.0373	1.0572
1000	.9736	.9882	.9915	1.0040	1.0164	1.0236	1.0431	1.0758	1.0964
2000	.9886	1.0250	1.0299	1.0343	1.0460	1.0617	1.0819	1.1158	1.1374
4000	1.0680	1.1039	1.1086	1.1135	1.1261	1.1430	1.1647	1.2013	1.2245
6000	1.1510	1.1898	1.1948	1.2000	1.2135	1.2317	1.2553	1.2470	1.3220

TABLE B.2.3

ALL-ENGINE HORIZONTAL DISTANCE FROM 35 FEET HAA TO 400 FEET (D400) HAA FOR REFERENCE ATMOSPHERIC CONDITIONS (SEA-LEVEL, 77°F); 3E-LBPR-NB

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs						
	110	130	150	170	190	210	230
TAKEOFF CLIMB SPEED - $V_2 + 10$							
5	1753	2094	2564	3172	3931	4857	5969
15	1763	2122	2617	3263	4076	5086	6324
20	1810	2207	2754	3478	4410	5605	7127
25	1856	2294	2909	3730	4821	6270	8238
TAKEOFF CLIMB SPEED - $V_2 + 20$							
5	2200	2711	3384	4238	5294	6584	8142
15	2196	2722	3416	4310	5426	6812	8521
20	2247	2818	3578	4566	5832	7458	9540
25	2298	2915	3754	4861	6325	8269	10915
TAKEOFF CLIMB SPEED - $V_2 + 30$							
5	2686	3375	4262	5369	6734	8399	10414
15	2669	3373	4283	5435	6867	8647	10848
20	2728	3485	4475	5746	7373	9457	12139
25	2785	3599	4682	6093	7962	10440	13815

TABLE B.2.4

ALL-ENGINE D400 TEMPERATURE-ALTITUDE RATIOS
(TMALT-400); 3E-LBPR-NB

Airport Pressure Altitude, Feet	Temperature, Degrees, °F								
	30	46	48	53	66	74	84	94	100
TAKEOFF CLIMB SPEED - V_2 + 10									
0	0.9955	0.9970	0.9972	0.9977	0.9989	0.9997	1.0005	1.0436	1.0714
1000	0.9941	0.9958	0.9989	1.0155	1.0174	1.0189	1.0385	1.0835	1.1125
2000	0.9939	1.0345	1.0398	1.0404	1.0420	1.0579	1.0784	1.1254	1.1556
4000	1.0791	1.1167	1.1216	1.1223	1.1241	1.1413	1.1634	1.2142	1.2470
6000	1.1642	1.2054	1.2108	1.2118	1.2145	1.2335	1.2573	1.3150	1.3504
TAKEOFF CLIMB SPEED - V_2 + 20									
0	0.9907	0.9938	0.9942	0.9952	0.9978	0.9994	1.0012	1.0448	1.0728
1000	0.9906	0.9939	0.9972	1.0150	1.0175	1.0199	1.0402	1.0857	1.1149
2000	0.9920	1.0336	1.0390	1.0403	1.0435	1.0601	1.0812	1.1286	1.1589
4000	1.0790	1.1179	1.1229	1.1243	1.1280	1.1460	1.1687	1.2203	1.2533
6000	1.1663	1.2089	1.2145	1.2164	1.2216	1.2414	1.2663	1.3230	1.3608
TAKEOFF CLIMB SPEED - V_2 + 30									
0	0.9863	0.9909	0.9914	0.9929	0.9967	0.9991	1.0018	1.0463	1.0747
1000	0.9873	0.9920	0.9956	1.0145	1.0178	1.0210	1.0421	1.0884	1.1178
2000	.9902	1.0331	1.0387	1.0405	1.0451	1.0623	1.0845	1.1325	1.1629
4000	1.0795	1.1198	1.1250	1.1270	1.1323	1.1511	1.1750	1.2274	1.2607
6000	1.1694	1.2133	1.2190	1.2217	1.2288	1.2493	1.2761	1.3350	1.3720

TABLE B.2.5

EQUIVALENT AIR SPEEDS FOR TAKEOFF AND APPROACH AND LANDING OPERATIONS (V35, V_2, 1.3 Vs); 3E-LBPR-NB

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs					
	120	140	160	180	200	210
TAKEOFF SPEED AT 35 FEET HEIGHT ABOVE AIRPORT, V35, KEAS						
5	138.11	149.21	160.30	169.44	178.57	183.14
15	130.07	140.55	151.03	159.68	168.33	172.66
20	126.46	137.19	147.91	157.10	166.29	170.88
25	122.74	132.80	142.84	151.43	160.02	164.31
TAKEOFF SAFETY SPEED, V_2, KEAS						
5	134.8	144.5	153.6	162.2	170.8	174.9
15	127.4	136.6	145.1	153.2	161.4	165.3
20	123.2	132.4	140.9	149.0	157.2	161.3*
25	120.0	128.6	136.7	144.3	151.9	155.7*

* These values have been obtained by extrapolation.

TABLE.B.2.5
(continued)

APPROACH SPEED, 1.3 Vs, KEAS

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs						
	100	110	120	130	140	150	160
15	116.3	121.9	127.7	133.5	139.2	144.5	149.8
25	108.7	114.1	119.4	124.6	129.8	134.8	139.7
25 E	108.7	114.1	119.4	124.6	129.8	134.8	139.7
30 E	106.7	111.9	117.2	122.5	127.6	132.7	137.6
40 E	102.9	107.8	113.2	118.9	124.5	130.2	135.9

Note: Landing gear retracted except for flap settings designated with an E.

TABLE B.2.6

AIRCRAFT LIFT AND DRAG COEFFICIENTS (C_L, C_D); 3E-LBPR-NB

LIFT COEFFICIENT AS A FUNCTION OF AIRCRAFT BODY ANGLE OF ATTACK

Flap Setting, δ_F Degrees	Landing Gear Position	$C_L = a_0 + a_1 \cdot \alpha_B$	
		a_0	a_1
0	Up	0.1776	0.0690
2	Up	0.2005	0.0759
5	Up	0.1621	0.0924
15	Up	0.3566	0.0955
20	Up	0.4859	0.0952
25	Up	0.6411	0.1011
25	Down	0.6574	0.1002
30	Down	0.8339	0.0990
40	Down	1.1251	0.0929

DRAG COEFFICIENT AS A FUNCTION OF LIFT COEFFICIENT

Flap Setting, δ_F Degrees	Landing Gear Position	$C_D = a_0 + a_1 \cdot (C_L)^2$	
		a_0	a_1
0	Up	0.0187	0.0490
2	Up	0.0328	0.0589
5	Up	0.0448	0.0455
15	Up	0.0523	0.0418
20	Up	0.0676	0.0409
25	Up	0.0751	0.0416
25	Down	0.0888	0.0441
30	Down	0.1155	0.0411
40	Down	0.1822	0.0371

TABLE B.2.7

FLAP RETRACTION SPEED SCHEDULE AND TIMES; 3E-LBPR-NB

T/O Roll Flap Position, δ_F	Selected Flap Position, δ_F	Minimum Initiation Speed For Selected Flap Pos., KEAS			
		Aircraft Gross Weight, KLB.			
Deg.	Deg.	120.0 TO 154.5	154.5+ TO 176.0	176.0+ TO 191.0	191.0+ TO 210.0
25	15	V2 + 10	V2 + 10	V2 + 10	V2 + 10
	5	150	160	170	180
	2	160	170	180	190
	0	190	200	210	225
20	15	V2 + 10	V2 + 10	V2 + 10	V2 + 10
	5	150	160	170	180
	2	160	170	180	190
	0	190	200	210	225
15	5	V2 + 10	V2 + 10	V2 + 10	V2 + 10
	2	160	170	180	190
	0	190	200	210	225
5	2	V2 + 30	V2 + 30	V2 + 30	V2 + 30
	0	190	200	210	225
Minimum Zero Flap Speed		200	210	220	235

Initial Flap Setting, δ_F Deg.	Selected Flap Setting, δ_F Deg.	Flap Retraction Time Sec.
25	20	1.8
20	15	1.7
15	5	3.7
5	2	8.7
2	0	7.1

TABLE B.3.1

ALL-ENGINE HORIZONTAL DFBR TO 35 FEET (D_{35}) HAA FOR
REFERENCE ATMOSPHERIC CONDITIONS (SEA-LEVEL, 77°F); 4E-LBPR-NB

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs							
	180	248	250	270	290	310	330	350
14	5000	5000	5080	6006	7028	8146	9383	10784

TABLE B.3.2

ALL-ENGINE D35 TEMPERATURE-ALTITUDE RATIOS (TMALT-35); 4E-LBPR-NB

Airport Pressure Altitude, Feet	Temperature, Degrees, °F					
	30	37	48	59	84	100
0	0.9635	0.9690	0.9778	0.9862	1.0052	1.0602
1000	0.9743	0.9810	1.0029	1.0222	1.0413	1.0984
2000	0.9852	0.9982	1.0290	1.0604	1.0798	1.1385
4000	1.0596	1.0770	1.1080	1.1409	1.1618	1.2244
6000	1.1431	1.1620	1.1940	1.2314	1.2535	1.3212

TABLE B.3.3

ALL-ENGINE HORIZONTAL DISTANCE FROM 35 FEET HAA TO 400 FEET (D400) HAA FOR REFERENCE ATMOSPHERIC CONDITIONS (SEA-LEVEL, 77°F); 4E-LBPR-NB

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs								
	190	210	230	250	270	290	310	330	350
TAKEOFF CLIMB SPEED - V_2 + 10									
14	1899	2272	2654	3047	3455	3901	4402	4968	5618
TAKEOFF CLIMB SPEED - V_2 + 20									
14	2456	2951	3470	4019	4606	5251	5982	6812	7768
TAKEOFF CLIMB SPEED - V_2 + 30									
14	3057	3680	4343	5055	5827	6680	7651	8753	10024

TABLE B.3.4

ALL-ENGINE D400 TEMPERATURE-ALTITUDE RATIOS
(TMALT-400); 4E-LBPR-NB

Airport Pressure Altitude, Feet	Temperature, Degrees, °F						
	30	37	45	48	59	84	100
TAKEOFF CLIMB SPEED - V_2 + 10							
0	0.9990	0.990	0.9990	0.9990	0.9989	1.0004	1.0698
1000	0.9918	1.0010	1.0130	1.0161	1.0349	1.0359	1.1077
2000	0.9843	0.9970	1.0240	1.0350	1.0737	1.0741	1.1481
4000	1.0609	1.0780	1.1037	1.1120	1.1546	1.1577	1.2349
6000	1.1475	1.1670	1.1931	1.2030	1.2466	1.2485	1.3330
TAKEOFF CLIMB SPEED - V_2 + 20							
0	0.9938	0.9940	0.9950	0.9958	0.9972	1.0010	1.0703
1000	0.9883	0.9970	1.0080	1.0141	1.0339	1.0378	1.1095
2000	0.9827	0.9959	1.0230	1.0330	1.0374	1.0773	1.1512
4000	1.0613	1.0780	1.1052	1.1130	1.1567	1.1640	1.2413
6000	1.1504	1.1710	1.1974	1.2080	1.2516	1.2584	1.3431
TAKEOFF CLIMB SPEED - V_2 + 30							
0	0.9893	0.9910	0.9930	0.9930	0.9957	1.0017	1.0712
1000	0.9853	0.9950	1.0070	1.0125	1.0332	1.0396	1.1116
2000	0.9812	0.9950	1.0230	1.0340	1.0735	1.0804	1.1547
4000	1.0619	1.0800	1.1070	1.1170	1.1593	1.1701	1.2480
6000	1.1537	1.1730	1.2020	1.2130	1.2573	1.2681	1.3536

TABLE B.3.5

EQUIVALENT AIR SPEEDS FOR TAKEOFF AND APPROACH AND LANDING OPERATIONS (V35, V_2, 1.3 Vs); 4E-LBPR-NB

TAKEOFF SPEED AT 35 FEET HEIGHT ABOVE AIRPORT, V35, KEAS

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs							
	190	210	230	250	270	290	310	330
14	134.11	139.69	145.28	150.86	156.44	162.03	167.61	173.20

TAKEOFF SAFETY SPEED, V_2, KEAS

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs								
	190	210	230	250	270	290	310	330	340
14	130.0	136.1	141.9	147.4	152.9	158.1	163.2	168.1	170.6

TABLE B.3.5
(continued)

APPROACH SPEED, 1.3 Vs KEAS

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs					
	160	180	200	220	240	260
25	113.4	120.7	127.6	134.3	140.7	147.0
25E	113.4	120.7	127.6	134.3	140.7	147.0
40E	111.3	118.2	124.7	130.9	136.8	142.6
50E	110.2	117.0	123.2	129.2	134.9	140.4

*These values have been obtained by extrapolation.

Note: Landing gear retracted except for flap settings designated with an E.

TABLE B.3.6

AIRCRAFT LIFT AND DRAG COEFFICIENTS (C_L, C_D); 4E-LBPR-NB

LIFT COEFFICIENT AS A FUNCTION OF AIRCRAFT BODY ANGLE OF ATTACK

Flap Setting, δ_F Degrees	Landing Gear Position	$C_L = a_0 + a_1 \cdot \alpha_B$	
		a_0	a_1
0	Up	0.0664	0.0786
14	Up	0.2282	0.0925
25	Up	0.4948	0.0862
25	Down	0.4146	0.0871
40	Down	0.6731	0.0838
50	Down	0.7707	0.0855

DRAG COEFFICIENT AS A FUNCTION OF LIFT COEFFICIENT

Flap Setting, δ_F Degrees	Landing Gear Position	$C_D = a_0 + a_1 \cdot (C_L)^2$	
		a_0	a_1
0	Up	0.0101	0.0425
14	Up	0.0303	0.0489
25	Up	0.0449	0.0527
25	Down	0.0534	0.0537
40	Down	0.0843	0.0513
50	Down	0.1057	0.0521

TABLE B.3.7

FLAP RETRACTION SPEED SCHEDULE AND TIMES; 4E-LBPR-NB

T/O Roll Flap Position, δ_F, Deg.	Selected Flap Position, δ_F Deg.	Minimum Initiation Speed For Selected Flap Pos., KEAS
		All Aircraft Weights
14	0	V2 + 30
Minimum Zero Flap Speed		V2 + 50

Initial Flap Setting, δ_F Deg.	Selected Flap Setting, δ_F Deg.	Flap Retraction Time Sec.
14	0	15.6

TABLE B.4.1

ALL-ENGINE HORIZONTAL DFBR TO 35 FEET (D35) HAA FOR REFERENCE ATMOSPHERIC CONDITIONS (SEA-LEVEL, $77^{o}F$); 4E-HBPR-WB

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs										
	500	550	600	625	650	675	700	725	750	775	800
10	4060	4843	5774	6293	6877	7513	8206	8964	9751	10612	11500
20	3820	4446	5299	5774	6307	6894	7531	8225	8967	9766	10600

TABLE B.4.2

ALL-ENGINE D35 TEMPERATURE-ALTITUDE RATIOS (TMALT-35); 4E-HBPR-WB

Airport Pressure Altitude, Feet	Temperature, Degrees, °F								
	30	45	59	66	73	80	87	94	100
0	0.9630	0.9751	0.9860	0.9913	0.9969	1.0023	1.0186	1.0362	1.0523
2000	1.0184	1.0308	1.0421	1.0479	1.0537	1.0707	1.0885	1.1073	1.1246
4000	1.0779	1.0911	1.1033	1.1099	1.1274	1.1454	1.1646	1.1850	1.2039
6000	1.1434	1.1567	1.1697	1.1878	1.2065	1.2261	1.2463	1.2650	1.2825

TABLE B.4.3

ALL-ENGINE HORIZONTAL DISTANCE FROM 35 FEET HAA TO 400 FEET (D400) HAA FOR REFERENCE ATMOSPHERIC CONDITIONS (SEA-LEVEL, 77°F); 4E-HBPR-WB

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs											
	500	550	575	600	625	650	675	700	725	750	775	800
TAKEOFF CLIMB SPEED - V_2 + 10												
10	2687*	3307	3617	3931	4255	4572	4901	5244	5608	6001	6414	6827*
20	2689*	3349	3679	4020	4373	4723	5096	5488	5909	6367	6865	7363*
TAKEOFF CLIMB SPEED V_2 + 20												
10	3397*	4209	4615	5034	5471	5911	6373	6860	7382	7947	8547	9147*
20	3392*	4252	4682	5127	5607	6093	6605	7157	7760	8403	9112	9821*
TAKEOFF CLIMB SPEED V_2 + 30												
10	4148*	5160	5666	6194	6748	7314	7914	8551	9230	9974	10764	11554*
20	4138*	5212	5749	6315	6915	7539	8202	8919	9696	10549	11479	12409*

*These values were obtained by extrapolation.

TABLE B.4.4

ALL-ENGINE D400 TEMPERATURE-ALTITUDE RATIOS
(TMALT-400); 4E-HBPR-WB

Airport Pressure Altitude, Feet	Temperature, Degrees, °F								
	30	45	59	66	73	80	87	94	100
TAKEOFF CLIMB SPEED - V_2 + 10									
0	0.9987	0.9990	0.9992	0.9997	0.9999	1.0001	1.0218	1.0456	1.0677
2000	1.0508	1.0514	1.0521	1.0527	1.0533	1.0756	1.0993	1.1245	1.1485
4000	1.1095	1.1099	1.1106	1.1121	1.1346	1.1584	1.1834	1.2109	1.2364
6000	1.1721	1.1731	1.1754	1.1982	1.2222	1.2477	1.2742	1.3040	1.3280
TAKEOFF CLIMB SPEED - V_2 + 20									
0	0.9931	0.9951	0.9970	0.9985	0.9994	1.0004	1.0218	1.0453	1.0669
2000	1.0457	1.0485	1.0514	1.0531	1.0547	1.0768	1.1001	1.1247	1.1480
4000	1.1065	1.1092	1.1121	1.1144	1.1370	1.1606	1.1854	1.2122	1.2369
6000	1.1707	1.1746	1.1797	1.2024	1.2264	1.2516	1.2776	1.3090	1.3330
TAKEOFF CLIMB SPEED- V_2 + 30									
0	0.9884	0.9919	0.9952	0.9974	0.9991	1.0007	1.0222	1.0455	1.0668
2000	1.0420	1.0466	1.0513	1.0538	1.0562	1.0783	1.1014	1.1258	1.1486
4000	1.1049	1.1094	1.1142	1.1173	1.1400	1.1636	1.1883	1.2148	1.2389
6000	1.1708	1.1771	1.1844	1.2071	1.2311	1.2560	1.2816	1.3120	1.3360

TABLE B.4.5

EQUIVALENT AIR SPEEDS FOR TAKEOFF AND APPROACH AND LANDING OPERATIONS (V35, V_2, 1.3 Vs); 4E-HBPR-WB

Flap Setting, δ_F Degrees	Aircraft Weight, Klbs				
	500	575	650	725	800
TAKEOFF SPEED AT 35 FEET HEIGHT ABOVE AIRPORT, V35, KEAS					
10	138.89	151.12	163.35	175.58	187.81
20	132.70	144.43	156.15	167.87	179.60
TAKEOFF SAFETY SPEED, V_2, KEAS					
10	137.9	149.5	160.6	171.6	182.2
20	131.6	142.9	153.7	164.5	174.9

APPROACH SPEED, 1.3 Vs, KEAS

	450	500	550	600	650
20	134.3	142.7	150.9	158.9	166.8
20 E	135.1	143.5	151.8	159.8	167.8
25 E	130.8	138.8	146.5	154.0	161.3
30 E	125.6	132.7	139.5	146.8	155.0

Note: Landing gear retracted except for flap settings designated with an E.

TABLE B.4.6

AIRCRAFT LIFT AND DRAG COEFFICIENTS (C_L, C_D); 4E-HBPR-WB

LIFT COEFFICIENT AS A FUNCTION OF AIRCRAFT BODY ANGLE OR ATTACK

Flap Setting, δ_F Degrees	Landing Gear Position	$C_L = a_0 + a_1 \cdot \alpha_B$	
		a_0	a_1
0	Up	0.2037	0.0628
1	Up	0.1748	0.0685
5	Up	0.1069	0.0864
10	Up	0.2414	0.0849
20	Up	0.4459	0.0921
20	Down	0.4719	0.0921
25	Down	0.6547	0.0856
30	Down	0.8334	0.0971

DRAG COEFFICIENT AS A FUNCTION OF LIFT COEFFICIENT

Flap Setting, δ_F Degrees	Landing Gear Position	$C_D = a_0 + a_1 \cdot (C_L)^2$	
		a_0	a_1
0	Up	0.0152	0.0617
1	Up	0.0208	0.0472
5	Up	0.0328	0.0442
10	Up	0.0254	0.0611
20	Up	0.0344	0.0554
20	Down	0.0539	0.0542
25	Down	0.0610	0.0549
30	Down	0.0918	0.0546

TABLE B.4.7

FLAP RETRACTION SPEED SCHEDULE AND TIMES; 4E-HBPR-WB

T/O Roll Flap Position, δ_F Deg.	Selected Flap Position, δ_F Deg.	Minimum Initiation Speed For Selected Flap Pos., KEAS
		All Aircraft Weights
20	10	V2 + 20
	5	V2 + 40
	1	V2 + 60
	0	V2 + 80
10	5	V2 + 40
	1	V2 + 60
	0	V2 + 80
Minimum Flap Speed		V2 + 80

Initial Flap Setting, δ_F Deg.	Selected Flap Setting, δ_F Deg.	Flap Retraction Time Sec.
20	10	6.1
10	5	4.7
5	1	30.6
1	0	10.0

TABLE B.5.1

ALL-ENGINE HORIZONTAL DFBR TO 35 FEET (D35) HAA;
2E-HBPR-WB

AIRPORT PRESSURE ALTITUDE SEA LEVEL

Airport Temperature, Degrees °F	Aircraft Weight, Klbs							
	203.8	233.1	262.4	291.8	321.1	350.5	379.8	394.5
TAKEOFF FLAP SETTING - 5 DEGREES, δ_F								
40	3431	4429	5000	6000	7318	8750	10500	11180
60	3637	4643	5200	6133	7453	9028	10780	11530
77	3775	4714	5333	6267	7657	9167	10990	11879
85	3912	4929	5400	6467	7792	9444	11270	12228
95	4118	5000	5600	6667	8131	9931	11830	12578
TAKEOFF FLAP SETTING - 15 DEGREES, δ_F								
40	3294	4286	4667	5667	6911	8403	10080	10831
60	3431	4429	4867	5800	7047	8542	10220	11040
77	3500	4500	5000	6000	7250	8750	10500	11250
85	3706	4643	5200	6200	7453	8958	10780	11460
95	3775	4857	5400	6400	7792	9444	11200	12158
TAKEOFF FLAP SETTING - 25 DEGREES, δ_F								
40	3020	4000	4600	5400	6708	8264	9870	10761
60	3157	4143	4667	5533	6911	8472	10080	10971
77	3363	4286	4867	5733	7114	8681	10360	11180
85	3500	4429	5000	5933	7318	8958	10570	11530
95	3637	4643	5267	6333	7724	9514	11410	12439

TABLE B.5.1
(continued)

AIRPORT PRESSURE ALTITUDE 3000 FT

Airport Temperature, Degrees °F	Aircraft Weight, Klbs							
	203.8	233.1	262.4	291.8	321.1	350.5	379.8	394.5
TAKEOFF FLAP SETTING - 5 DEGREES, δ_F								
40	4250	5250	6321	7500	8860	10858	13000	14000
60	4322	5321	6392	7640	9070	11071	13212	14210
77	4538	5534	6676	7850	9349	11355	13495	14700
85	4682	5747	6889	8131	9698	11852	14130	15400
95	5042	6030	7457	8762	10465	12774	15190	16520
TAKEOFF FLAP SETTING - 15 DEGREES, δ_F								
40	4034	4966	5966	7079	8512	10361	12364	13090
60	4178	5037	6108	7290	8721	10645	12647	13510
77	4250	5250	6250	7500	9000	11000	13000	14000
85	5114	5392	6534	7780	9349	11426	13636	14770
95	5331	5676	6960	8271	9837	12206	14625	15890
TAKEOFF FLAP SETTING - 25 DEGREES, δ_F								
40	3890	4753	5824	7009	8372	10290	12364	13300
60	3962	4895	6037	7220	8651	10574	12717	13650
77	4106	5037	6179	7430	8860	10929	13071	14210
85	4250	5321	6463	7710	9279	11568	13848	15190
95	4466	5605	6818	8131	9837	12277	14908	16310

TABLE B.5.1
(continued)

AIRPORT PRESSURE ALTITUDE 6000 FT

Airport Temperature, Degrees °F	Aircraft Weight, Klbs							
	203.8	233.1	262.4	291.8	321.1	350.5	379.8	394.5
TAKEOFF FLAP SETTING - 5 DEGREES, δ_F								
40	4479	5860	7360	8900	10758	13045	15694	17362
60	4750	5930	7430	9110	10969	13397	16046	17717
77	5021	6279	7850	9600	11672	14314	17313	19212
85	5157	6488	8061	9951	12094	14878	18087	20065
95	5429	6907	8622	10511	12797	15795	19284	21488
TAKEOFF FLAP SETTING - 15 DEGREES, δ_F								
40	4343	5581	6939	8479	10336	12622	15202	17006
60	4479	5721	7150	8830	10617	12833	15483	17290
77	4750	6000	7500	9250	11250	13750	16750	18500
85	4954	6279	7921	9670	11742	14385	17172	19425
95	5089	6628	8131	10091	12305	15231	18791	21062
TAKEOFF FLAP SETTING - 25 DEGREES, δ_F								
40	4139	5372	6659	8339	10195	12692	15342	17148
60	4343	5512	6939	8619	10547	12904	15624	17504
77	4546	5930	7430	9180	11180	13821	16891	18972
85	4750	6140	7710	9530	11672	14526	17946	20279
95	5021	6419	8061	10021	12305	15513	19424	21844

TABLE B.5.2
ALL-ENGINE HORIZONTAL DFBR TO 400 FEET (D400)
HAA FOR INITIAL CLIMB SPEED AT V_2 + 10 KEAS; 2E-HBPR-WB

AIRPORT PRESSURE ALTITUDE SEA LEVEL

Airport Temperature, Degrees °F	Aircraft Weight, Klbs							
	198.3	225.6	252.9	280.2	307.5	334.9	362.2	375.9
TAKEOFF FLAP SETTING - 5 DEGREES, δ_F								
40	5000	6200	7500	9000	10800	12600	15000	16000
60	5300	6500	7800	9200	11000	13000	15400	16500
77	5500	6600	8000	9400	11300	13200	15700	17000
85	5700	6900	8100	9700	11500	13600	16100	17500
95	6000	7000	8400	10000	12000	14300	16900	18000
TAKEOFF FLAP SETTING - 15 DEGREES, δ_F								
40	4800	6000	7000	8500	10200	12100	14400	15500
60	5000	6200	7300	8700	10400	12300	14600	15800
77	5100	6300	7500	9000	10700	12600	15000	16100
85	5400	6500	7800	9300	11000	12900	15400	16400
95	5500	6800	8100	9600	11500	13600	16000	17400
TAKEOFF FLAP SETTING - 25 DEGREES, δ_F								
40	4400	5600	6900	8100	9900	11900	14100	15400
60	4600	5800	7000	8300	10200	12200	14400	15700
77	4900	6000	7300	8600	10500	12500	14800	16000
85	5100	6200	7500	8900	10800	12900	15100	16500
95	5300	6500	7900	9500	11400	13700	16300	17800

TABLE B.5.2
(continued)

AIRPORT PRESSURE ALTITUDE 3000 FT

Airport Temperature, Degrees °F	Aircraft Weight, Klbs							
	198.3	225.6	252.9	280.2	307.5	334.9	362.2	375.9
TAKEOFF FLAP SETTING - 5 DEGREES, δ_F								
40	5900	7400	8900	10700	12700	15300	18400	20000
60	6000	7500	9000	10900	13000	15600	18700	20300
77	6300	7800	9400	11200	13400	16000	19100	21000
85	6500	8100	9700	11600	13900	16700	20000	22000
95	7000	8500	10500	12500	15000	18000	21500	23600
TAKEOFF FLAP SETTING - 15 DEGREES, δ_F								
40	5600	7000	8400	10100	12200	14600	17500	18700
60	5800	7100	8600	10400	12500	15000	17900	19300
77	5900	7400	8800	10700	12900	15500	18400	20000
85	7100	7600	9200	11100	13400	16100	19300	21100
95	7400	8000	9800	11800	14100	17200	20700	22700
TAKEOFF FLAP SETTING - 25 DEGREES, δ_F								
40	5400	6700	8200	10000	12000	14500	17500	19000
60	5500	6900	8500	10300	12400	14900	18000	19500
77	5700	7100	8700	10600	12700	15400	18500	20300
85	5900	7500	9100	11000	13300	16300	19600	21700
95	6200	7900	9600	11600	14100	17300	21100	23300

TABLE B.5.2
(continued)

AIRPORT PRESSURE ALTITUDE 6000 FT

Airport Temperature, Degrees °F	Aircraft Weight, Klbs							
	198.3	225.6	252.9	280.2	307.5	334.9	362.2	375.9
TAKEOFF FLAP SETTING - 5 DEGREES, δ_F								
40	6600	8400	10500	12700	15300	18500	22300	24400
60	7000	8500	10600	13000	15600	19000	22800	24900
77	7400	9000	11200	13700	16600	20300	24600	27000
85	7600	9300	11500	14200	17200	21100	25700	28200
95	8000	9900	12300	15000	18200	22400	27400	30200
TAKEOFF FLAP SETTING - 15 DEGREES, δ_F								
40	6400	8000	9900	12100	14700	17900	21600	23900
60	6600	8200	10200	12600	15100	18200	22000	24300
77	7000	8600	10700	13200	16000	19500	23800	26000
85	7300	9000	11300	13800	16700	20400	24400	27300
95	7500	9500	11600	14400	17500	21600	26700	29600
TAKEOFF FLAP SETTING - 25 DEGREES, δ_F								
40	6100	7700	9500	11900	14500	18000	21800	24100
60	6400	7900	9900	12300	15000	18300	22200	24600
77	6700	8500	10600	13100	15900	19600	24000	26600
85	7000	8800	11000	13600	16600	20600	25500	28500
95	7400	9200	11500	14300	17500	22000	27600	30700

TABLE B.5.3
ALL-ENGINE HORIZONTAL DFBR TO 400 FEET (D400) HAA FOR INITIAL CLIMB SPEED AT V_2 + 20 KEAS; 2E-HBPR-WB

AIRPORT PRESSURE ALTITUDE SEA LEVEL

Airport Temperature, Degrees °F	Aircraft Weight, Klbs							
	198.3	225.6	252.9	280.2	307.5	334.9	362.2	375.9
TAKEOFF FLAP SETTING - 5 DEGREES, δ_F								
40	5461	7009	8079	9974	11807	14112	16918	17927
60	5789	7348	8403	10195	12026	14560	17369	18487
77	6007	7461	8618	10417	12354	14784	17707	19047
85	6225	7800	8726	10749	12573	15232	18158	19607
95	6553	7913	9049	11082	13119	16016	19060	20167
TAKEOFF FLAP SETTING - 15 DEGREES, δ_F								
40	5272	6776	7600	9452	11240	13644	16379	17546
60	5492	7002	7926	9674	11460	13870	16606	17885
77	5602	7115	8143	10008	11791	14208	17061	18225
85	5932	7341	8469	10342	12122	14546	17516	18565
95	6041	7680	8794	10675	12673	15336	18198	19697
TAKEOFF FLAP SETTING - 25 DEGREES, δ_F								
40	4850	6365	7576	9096	11291	14014	17020	18813
60	5070	6593	7686	9321	11633	14368	17382	19180
77	5401	6820	8015	9658	11975	14721	17865	19546
85	5621	7047	8235	9995	12317	15192	18227	20157
95	5842	7388	8674	10669	13001	16134	19676	21745

TABLE B.5.3
(continued)

AIRPORT PRESSURE ALTITUDE 3000 FT

Airport Temperature, Degrees °F	Aircraft Weight, Klbs							
	198.3	225.6	252.9	280.2	307.5	334.9	362.2	375.9
TAKEOFF FLAP SETTING - 5 DEGREES, δ_F								
40	6444	8366	9587	11858	13885	17136	20753	22409
60	6553	8479	9695	12080	14213	17472	21091	22745
77	6881	8818	10126	12412	14650	17920	21542	23529
85	7099	9157	10449	12855	15197	18704	22557	24649
95	7646	9609	11311	13853	16399	20160	24249	26442
TAKEOFF FLAP SETTING - 15 DEGREES, δ_F								
40	6151	7905	9210	11231	13444	16463	19904	21168
60	6371	8018	9337	11564	13774	16914	20359	21848
77	6481	8357	9554	11898	14215	17478	20928	22640
85	7799	8583	9988	12343	14766	18155	21952	23885
95	8129	9035	10640	13121	15537	19395	23544	25696
TAKEOFF FLAP SETTING - 25 DEGREES, δ_F								
40	5952	7615	9003	11230	13686	17076	21124	23211
60	6063	7843	9332	11567	14142	17547	21727	23822
77	6283	8070	9552	11904	14484	18136	22331	24799
85	6503	8525	9991	12353	15168	19196	23659	26509
95	6834	8979	10540	13027	16081	20374	25469	28464

TABLE B.5.3
(continued)

AIRPORT PRESSURE ALTITUDE 6000 FT

Airport Temperature, Degrees °F	Aircraft Weight, Klbs							
	198.3	225.6	252.9	280.2	307.5	334.9	362.2	375.9
TAKEOFF FLAP SETTING - 5 DEGREES, δ_F								
40	7208	9496	11311	14074	16727	20720	25151	27338
60	7645	9609	11419	14406	17055	21280	25715	27898
77	8082	10174	12065	15182	18148	22736	27745	30251
85	8300	10513	12388	15736	18804	23632	28986	31595
95	8738	11191	13250	16623	19897	25088	30903	33836
TAKEOFF FLAP SETTING - 15 DEGREES, δ_F								
40	7030	9035	10748	13455	16198	20185	24568	27055
60	7250	9261	11074	14011	16639	20523	25023	27508
77	7689	9713	11617	14678	17631	21989	27070	29432
85	8019	10165	12268	15345	18402	23004	27752	30904
95	8238	10729	12594	16012	19284	24357	30368	33507
TAKEOFF FLAP SETTING - 25 DEGREES, δ_F								
40	6724	8753	10430	13364	16537	21199	26314	29441
60	7054	8980	10869	13814	17108	21552	26797	30052
77	7385	9662	11638	14712	18134	23083	28970	32495
85	7716	10003	12077	15274	18932	24261	30781	34816
95	8157	10458	12626	16060	19959	25909	33316	37504

TABLE B.5.4

ALL-ENGINE HORIZONTAL DFBR TO 400 FEET (D400) HAA FOR
INITIAL CLIMB SPEED AT V_2 + 30 KEAS; 2E-HBPR-WB

AIRPORT PRESSURE ALTITUDE SEA LEVEL

Airport Temperature, Degrees °F	Aircraft Weight, Klbs							
	198.3	225.6	252.9	280.2	307.2	334.9	362.2	375.9
TAKEOFF FLAP SETTING - 5 DEGREES, δ_F								
40	5953	7647	8867	11005	13033	15622	18781	19942
60	6310	8017	9222	11249	13274	16118	19281	20565
77	6548	8140	9458	11494	13636	16366	19657	21188
85	8786	8510	9576	11861	13877	16862	20158	21811
95	7143	8633	9931	12228	14481	17730	21159	22434
TAKEOFF FLAP SETTING - 15 DEGREES, δ_F								
40	5769	7412	8379	10475	12478	15198	18311	19687
60	6010	7659	8739	10721	12723	15449	18565	20068
77	6130	7783	8978	11091	13090	15826	19074	20449
85	6491	8030	9337	11461	13457	16203	19583	20830
95	6611	8401	9696	11830	14069	17082	20346	22100
TAKEOFF FLAP SETTING - 25 DEGREES, δ_F								
40	5337	7014	8411	10149	12634	15736	19206	21299
60	5579	7265	8533	10400	13017	16132	19614	21714
77	5943	7515	8899	10776	13400	16529	20159	22129
85	6186	7765	9143	11152	13783	17058	20568	22821
95	6428	8141	9630	11904	14549	18116	22202	24619

TABLE B.5.4
(continued)

AIRPORT PRESSURE ALTITUDE 3000 FT

Airport Temperature, Degrees °F	Aircraft Weight, Klbs							
	198.3	225.6	252.9	280.2	307.5	334.9	362.2	375.9
TAKEOFF FLAP SETTING - 5 DEGREES, δ_F								
40	7024	9127	10522	13084	15325	18970	23038	24927
60	7143	9250	10640	13328	15687	19342	23413	25301
77	7500	9620	11113	13695	16170	19838	23914	26173
85	7738	9900	11468	14184	16773	20706	25041	27419
95	8333	10483	12413	15285	18101	22318	26919	29413
TAKEOFF FLAP SETTING - 15 DEGREES, δ_F								
40	6731	8648	10055	12447	14925	18338	22253	23751
60	6972	8771	10295	12816	15292	18840	22761	24513
77	7092	9142	10534	13186	15781	19468	23397	25402
85	8534	9389	11013	13679	16393	20222	24541	26799
95	8895	9883	11731	14542	17249	21603	26322	28831
TAKEOFF FLAP SETTING - 25 DEGREES, δ_F								
40	6549	8392	9996	12530	15315	19175	23837	26278
60	6670	8642	10362	12906	15825	19704	24518	26970
77	6913	8893	10606	13282	16208	20364	25199	28076
85	7156	9394	11094	13783	16974	21555	26697	30012
95	7519	9895	11703	14535	17995	22878	28740	32225

TABLE B.5.4
(continued)

AIRPORT PRESSURE ALTITUDE 6000 FT

Airport Temperature, Degrees °F	Aircraft Weight, Klbs							
	198.3	225.6	252.9	280.2	307.5	334.9	362.2	375.9
TAKEOFF FLAP SETTING - 5 DEGREES, δ_F								
40	7858	10360	12413	15529	18463	22937	27920	30411
60	8334	10483	12532	15896	18825	23557	28546	31035
77	8810	11100	13241	16752	20032	25169	30800	33652
85	9048	11470	13596	17363	20756	26161	32177	35148
95	9524	12210	14541	18342	21963	27773	34306	37640
TAKEOFF FLAP SETTING - 15 DEGREES, δ_F								
40	7693	9883	11851	14911	17984	22483	27466	30356
60	7933	10130	12210	15528	18473	22860	27975	30864
77	8414	10624	12809	16267	19574	24493	30264	33023
85	8775	11118	13527	17006	20430	25623	31027	34674
95	9015	11736	13886	17746	21409	27131	33952	37595
TAKEOFF FLAP SETTING - 25 DEGREES, δ_F								
40	7398	9644	11581	14911	18504	23801	29693	33331
60	7762	9895	12069	15413	19142	24198	30238	34023
77	8126	10646	12922	16415	20291	25917	32690	36789
85	8490	11022	13410	17042	21184	27239	34733	39417
95	8975	11523	14019	17919	22333	29091	37594	42459

TABLE B.5.5

EQUIVALENT AIR SPEEDS FOR TAKEOFF AND APPROACH AND LANDING OPERATIONS (V35, V_2, 1.3 Vs); 2E-HBPR-WB

TAKEOFF SPEED AT 35 FEET HEIGHT ABOVE AIRPORT, V35, KEAS

Flap Setting, δ_F Degrees	Aircraft Weight Klbs								
	200.0	220.0	240.0	260.0	280.0	300.0	320.0	340.0	360.0
5	127.2	131.7	136.2	140.6	145.1	149.6	154.1	158.6	163.0
15	124.0	128.3	132.6	136.9	141.2	145.5	149.8	154.1	158.4
25	122.6	126.5	130.4	134.3	138.3	142.2	146.1	150.0	153.9

TAKEOFF SAFETY SPEED, V_2, KEAS

Flap Setting, δ_F Degrees	Aircraft Weight Klbs								
	200.0	220.0	240.0	260.0	280.0	300.0	320.0	340.0	360.0
5	130.1	134.1	138.2	142.2	146.3	150.4	154.5	158.6	162.6
15	123.8	127.7	131.6	135.6	139.5	143.4	147.3	151.2	155.1
25	117.8	121.6	125.4	129.2	133.0	136.8	140.6	144.4	148.1

APPROACH SPEED, 1.3 Vs, KEAS

Flap Setting, δ_F Degrees	Aircraft Weight Klbs							
	190.0	210.0	230.0	250.0	270.0	290.0	310.0	330.0
35	109.2	113.2	117.1	121.1	125.0	129.0	132.9	136.9
50	104.7	108.6	112.5	116.5	120.4	124.4	128.3	132.3

TABLE B.5.6

AIRCRAFT LIFT AND DRAG COEFFICIENTS (C_L, C_D); 2E-HBPR-WB

LIFT COEFFICIENT AS A FUNCTION OF AIRCRAFT BODY ANGLE OF ATTACK

Flap Setting, δ_F Degrees	Landing Gear Position	Slat Position	$C_L = a_0 + a_1 \cdot \alpha_B$	
			a_0	a_1
0	Up	Retracted	0.1511	0.0575
0	Up	Extended	0.0217	0.0758
5	Up	Extended	0.0917	0.0772
15	Up	Extended	0.2511	0.0783
25	Up	Extended	0.4011	0.0780
35	Up	Extended	0.5113	0.0831
50	Up	Extended	0.6620	0.0780
35	Down	Extended	0.5113	0.0831
50	Down	Extended	0.6620	0.0780

DRAG COEFFICIENT AS A FUNCTION OF LIFT COEFFICIENT

Flap Setting, δ_F Degrees	Landing Gear Position	Slat Position	$C_D = a_0 + a_1 \cdot (C_L)^2$	
			a_0	a_1
0	Up	Retracted	0.0140	0.0590
0	Up	Extended	0.0217	0.0591
5	Up	Extended	0.0237	0.0582
15	Up	Extended	0.0312	0.0547
25	Up	Extended	0.0453	0.0533
35	Up	Extended	0.0751	0.0521
50	Up	Extended	0.1294	0.0514
35	Down	Extended	0.0917	0.0521
50	Down	Extended	0.1419	0.0514

TABLE B.5.7

FLAP/SLAT RETRACTION SPEED SCHEDULE AND TIMES; 2E-HBPR-WB

FLAP/SLAT RETRACTION SPEED SCHEDULE, KEAS		
INITIAL FLAPS/SLATS	SELECT FLAPS/SLATS	FLAP RETRACTION INITIATION SPEED
Takeoff	0^{o}/ Extended	V_2 + Takeoff Flap Setting
0^{o}/Extended	0^{o}/ Retracted	(Flap Retraction Speed) + (Takeoff Weight/10,000), or final segment climb speed, whichever is lower
Minimum Zero Flaps/Slats		118 + (Takeoff Weight/3,400), or 260, whichever is lower

Initial Flap/Slap Setting, δ_F Deg.	Selected Flap/Slap Setting, δ_F Deg.	Flap/Slat Retraction Time Sec.
25/Extended	20/Extended	2.1
20/Extended	15/Extended	2.0
15/Extended	10/Extended	2.2
10/Extended	5/Extended	2.1
5/Extended	0/Extended	2.2
0/Extended	0/ Retracted	12.0

TABLE B.6.1
ALL-ENGINE HORIZONTAL DFBR TO 35 FEET (D35) HAA;
3E-HBPR-WB

AIRPORT PRESSURE ALTITUDE SEA LEVEL

Airport Temperature, Degrees °F	Aircraft, Weight, Klbs					
	260	300	340	380	420	440
TAKEOFF FLAP SETTING - 0 DEGREES, δ_F						
40	3100	3933	5000	6126	7552	8418
60	3238	4066	5267	6321	7746	8677
77	3376	4133	5400	6517	8004	8807
85	3445	4266	5533	6582	8133	8937
95	3514	4400	5667	6778	8456	9325
TAKEOFF FLAP SETTING - 10 DEGREES, δ_F						
40	2893	3600	4600	5539	6777	7511
60	3031	3733	4733	5735	7035	7770
77	3100	3800	4800	5800	7100	7900
85	3169	3933	4933	5930	7229	8094
95	3307	4000	5200	6321	7810	8612
TAKEOFF FLAP SETTING - 20 DEGREES, δ_F						
40	2617	3334	4267	5214	6454	7123
60	2755	3534	4467	5474	6712	7447
77	2893	3667	4667	5670	6906	7706
85	3031	3734	4800	5800	7100	7900
95	3169	3800	5000	6126	7487	8418

TABLE B.6.1
(continued)

AIRPORT PRESSURE ALTITUDE 3000 FT

Airport Temperature, Degrees °F	Aircraft, Weight, Klbs					
	260	300	340	380	420	440
TAKEOFF FLAP SETTING - 0 DEGREES, δ_F						
40	3912	5114	6438	7850	9808	10911
60	4117	5319	6706	8177	10135	11240
77	4186	5455	6840	8308	10331	11503
85	4323	5591	7041	8504	10893	11897
95	4666	5728	7511	9158	11639	13081
TAKEOFF FLAP SETTING - 10 DEGREES, δ_F						
40	3363	4227	5365	6542	8238	9071
60	3431	4432	5566	6869	8369	9203
77	3500	4500	5700	7000	8500	9400
85	3637	4636	5901	7262	8958	9992
95	3912	5114	6438	7981	10069	11241
TAKEOFF FLAP SETTING - 20 DEGREES, δ_F						
40	3088	4091	5097	6215	7323	8809
60	3226	4228	5298	6542	8173	9006
77	3363	4364	5432	6738	8369	9203
85	3500	4569	5767	7261	8761	9860
95	3843	5046	6304	7785	9807	11044

TABLE B.6.1
(continued)

AIRPORT PRESSURE ALTITUDE 6000 FT

Airport Temperature, Degrees °F	Aircraft, Weight, Klbs					
	260	300	340	380	420	440
TAKEOFF FLAP SETTING - 0 DEGREES, δ_F						
40	4403	6078	7631	9263	11455	12479
60	4674	6352	8096	9727	11913	12929
77	5013	6693	8361	10322	12764	13894
85	5148	6898	8759	10918	13484	14988
95	5487	7444	9356	11844	14728	15146
TAKEOFF FLAP SETTING - 10 DEGREES, δ_F						
40	3861	5122	6304	7940	9687	10614
60	4065	5395	6702	8271	10080	11064
77	4200	5600	7100	8800	10800	11900
85	4403	5805	7498	9263	11455	12736
95	4742	6488	8294	10322	12960	14473
TAKEOFF FLAP SETTING - 20 DEGREES, δ_F						
40	3658	4781	5972	7477	9032	10034
60	3794	5122	6238	7780	9491	10485
77	3929	5327	6636	8469	10407	11578
85	4132	5600	7300	9064	11258	12479
95	4471	6147	8030	10255	13156	14858

TABLE B.6.2

ALL-ENGINE HORIZONTAL DFBR TO 400 FEET (D400) HAA FOR INITIAL CLIMB SPEED AT V_2 + 10 KEAS; 3E-HBPR-WB

AIRPORT PRESSURE ALTITUDE SEA LEVEL

Airport Temperature, Degrees °F	Aircraft Weight, Klbs					
	260	300	340	380	420	440
TAKEOFF FLAP SETTING - 0 DEGREES, δ_F						
40	4500	5900	7500	9400	11700	13000
60	4700	6100	7900	9700	12000	13400
77	4900	6200	8100	10000	12400	13600
85	5000	6400	8300	10100	12600	13800
95	5100	6600	8500	10400	13100	14400
TAKEOFF FLAP SETTING - 10 DEGREES, δ_F						
40	4200	5400	6900	8500	10500	11600
60	4400	5600	7100	8800	10900	12000
77	4500	5700	7200	8900	11000	12200
85	4600	5900	7400	9100	11200	12500
95	4800	6000	7800	9700	12100	13300
TAKEOFF FLAP SETTING - 20 DEGREES, δ_F						
40	3800	5000	6400	8000	10000	11000
60	4000	5300	6700	8400	10400	11500
77	4200	5500	7000	8700	10700	11900
85	4400	5600	7200	8900	11000	12200
95	4600	5700	7500	9400	11600	13000

TABLE B.6.2
(continued)

AIRPORT PRESSURE ALTITUDE 3000 FT

Airport Temperature, Degrees ^{o}F	Aircraft Weight, Klbs					
	260	300	340	380	420	440
TAKEOFF FLAP SETTING - 0 DEGREES, δ_F						
40	5700	7500	9600	12000	15000	16600
60	6000	7800	10000	12500	15500	17100
77	6100	8000	10200	12700	15800	17500
85	6300	8200	10500	13000	16300	18100
95	6800	8400	11200	14000	17800	19900
TAKEOFF FLAP SETTING - 10 DEGREES, δ_F						
40	4900	6200	8000	10000	12600	13800
60	5000	6500	8300	10500	12800	14000
77	5100	6600	8500	10700	13000	14300
85	5300	6800	8800	11100	13700	15200
95	5700	7500	9600	12200	15400	17100
TAKEOFF FLAP SETTING - 20 DEGREES, δ_F						
40	4500	6000	7600	9500	12000	13400
60	4700	6200	7900	10000	12500	13700
77	4900	6400	8100	10300	12800	14000
85	5100	6700	8600	11100	13400	15000
95	5600	7400	9400	11900	15000	16800

TABLE B.6.2
(continued)

AIRPORT PRESSURE ALTITUDE 6000 FT

Airport Temperature, Degrees °F	Aircraft Weight, Klbs					
	260	300	340	380	420	440
TAKEOFF FLAP SETTING - 0 DEGREES, δ_F						
40	6500	8900	11500	14000	17500	19400
60	6900	9300	12200	14700	18200	20100
77	7400	9800	12600	15600	19500	21600
85	7600	10100	13200	16500	20600	23300
95	8100	10900	14100	17900	22500	25400
TAKEOFF FLAP SETTING - 10 DEGREES, δ_F						
40	5700	7500	9500	12000	14800	16500
60	6000	7900	10100	12500	15400	17200
77	6200	8200	10700	13300	16500	18500
85	6500	8500	11300	14000	17500	19800
95	7000	9500	12500	15600	19800	22500
TAKEOFF FLAP SETTING - 20 DEGREES, δ_F						
40	5400	7000	9000	11300	13800	15600
60	5600	7500	9400	11800	14500	16300
77	5800	7800	10000	12800	15900	18000
85	6100	8200	11000	13700	17200	19400
95	6600	9000	12100	15500	20100	23100

TABLE B.6.3

ALL-ENGINE HORIZONTAL DFBR TO 400 FEET (D400) HAA FOR INITIAL CLIMB SPEED AT V_2 + 20 KEAS; 3E-HBPR-WB

AIRPORT PRESSURE ALTITUDE SEA LEVEL

Airport Temperature, Degrees °F	Aircraft Weight, Klbs					
	260	300	340	380	420	440
TAKEOFF FLAP SETTING - 0 DEGREES, δ_F						
40	4978	6531	8275	10400	12960	14421
60	5199	5752	8716	10732	13292	14865
77	5420	6863	8937	11064	13735	15087
85	5531	7084	9158	11175	13957	15309
95	5641	7306	9378	11507	14510	15974
TAKEOFF FLAP SETTING - 10 DEGREES, δ_F						
40	4626	5965	7634	9425	11645	12891
60	4846	6186	7855	9758	11755	13336
77	4956	6296	7966	9869	12199	13558
85	5066	6517	8187	10091	12421	13891
95	5286	6627	8630	10756	13419	14780
TAKEOFF FLAP SETTING - 20 DEGREES, δ_F						
40	4226	5517	7137	8951	11246	12409
60	4449	5848	7471	9348	11696	12973
77	4671	6069	7806	9734	12033	13424
85	4893	6179	8029	9958	12370	13762
95	5116	6290	8364	10517	13045	14665

TABLE B.6.3
(continued)

AIRPORT PRESSURE ALTITUDE 3000 FT

Airport Temperature, Degrees °F	Aircraft Weight, Klbs					
	260	300	340	380	420	440
	TAKEOFF FLAP SETTING - 0 DEGREES, δ_F					
40	6303	8302	10592	13277	16615	18415
60	6636	8634	11033	13830	17169	18969
77	6747	8855	11254	14051	17501	19413
85	6968	9076	11585	14383	18055	20079
95	7521	9298	12357	15489	19716	22075
	TAKEOFF FLAP SETTING - 10 DEGREES, δ_F					
40	5397	6848	8851	11089	13973	15665
60	5507	7180	9183	11643	14195	15559
77	5617	7290	9404	11865	14417	15892
85	5837	7511	9736	12309	15193	16892
95	6278	8284	10621	13528	17079	19004
	TAKEOFF FLAP SETTING - 20 DEGREES, δ_F					
40	5005	6621	8475	10629	13495	15116
60	5228	6841	8810	11188	14058	15455
77	5450	7062	9033	11524	14395	15793
85	5672	7393	9591	12419	15070	16921
95	6229	8165	10483	13314	16869	18952

TABLE B.6.3
(continued)

AIRPORT PRESSURE ALTITUDE 6000 FT

Airport Temperature, Degrees °F	Aircraft Weight, Klbs					
	260	300	340	380	420	440
TAKEOFF FLAP SETTING - 0 DEGREES, δ_F						
40	7190	9852	12688	15490	19384	21521
60	7632	10295	13461	16264	20159	22298
77	8185	10848	13902	17260	21599	23962
85	8406	11180	14564	18256	22817	25848
95	8959	12066	15567	19805	24922	28178
TAKEOFF FLAP SETTING - 10 DEGREES, δ_F						
40	6277	8598	10510	13306	16414	18336
60	6608	8726	11174	13861	17079	19114
77	6828	9057	11838	14748	18299	20559
85	7158	9388	12502	15524	19408	22004
95	7709	10493	13829	17298	21959	25004
TAKEOFF FLAP SETTING - 20 DEGREES, δ_F						
40	6005	7724	10036	12643	15519	17598
60	6228	8276	10482	13202	16307	18387
77	6450	8607	11151	14321	17881	20305
85	6784	9048	12266	15328	19343	21884
95	7340	9931	13493	17342	22604	26058

TABLE B.6.4

ALL-ENGINE HORIZONTAL DFBR TO 400 FEET (D400) HAA FOR INITIAL CLIMB SPEED AT V_2 + 30 KEAS; 3E-HBPR-WB

AIRPORT PRESSURE ALTITUDE SEA LEVEL

Airport Temperature, Degrees °F	Aircraft Weight, Klbs					
	260	300	340	380	420	440
TAKEOFF FLAP SETTING - 0 DEGREES, δ_F						
40	5472	7317	9114	11471	14291	15930
60	5715	7443	9600	11837	14657	16420
77	5958	7565	9843	12203	15146	16665
85	6080	7809	10086	12325	15390	16910
95	6201	8053	10329	12565	16001	17645
TAKEOFF FLAP SETTING - 10 DEGREES, δ_F						
40	5083	6570	8424	10408	12879	14259
60	5325	6813	8668	10776	13369	14751
77	5446	6935	8790	10898	13492	14997
85	5567	7178	9034	11143	13737	15336
95	5809	7300	9522	11878	14841	16349
TAKEOFF FLAP SETTING - 20 DEGREES, δ_F						
40	4745	6164	7929	9978	12594	13923
60	4994	6533	8300	10477	13098	14556
77	5244	6780	8672	10851	13476	15062
85	5494	6903	8920	11100	13854	15442
95	5743	7027	9291	11724	14609	16454

TABLE B.6.4
(continued)

AIRPORT PRESSURE ALTITUDE 3000 FT

Airport Temperature, Degrees °F	Aircraft Weight, Klbs					
	260	300	340	380	420	440
TAKEOFF FLAP SETTING - 0 DEGREES, δ_F						
40	6931	9151	11666	14644	18322	20341
60	7295	9517	12152	15254	18933	20954
77	7417	9761	12395	15498	19299	21444
85	7660	10005	12760	15864	19910	22179
95	8268	10249	13610	17084	21742	24385
TAKEOFF FLAP SETTING - 10 DEGREES, δ_F						
40	5930	7543	9767	12245	15454	16963
60	6051	7908	10133	12857	15700	17209
77	6172	8030	10377	13102	15945	17578
85	6414	8273	10743	13592	16804	18684
95	6898	9125	11720	14939	18889	21020
TAKEOFF FLAP SETTING - 20 DEGREES, δ_F						
40	5619	7396	9416	11849	15113	16961
60	5868	7642	9787	12473	15743	17340
77	6118	7889	10035	12847	16121	17720
85	6368	8259	10654	13845	16877	18986
95	6992	9122	11646	14843	18892	21264

TABLE B.6.4
(continued)

AIRPORT PRESSURE ALTITUDE 6000 FT

Airport Temperature, Degrees °F	Aircraft Weight, Klbs					
	260	300	340	380	420	440
TAKEOFF FLAP SETTING - 0 DEGREES, δ_F						
40	7904	10860	13974	17084	21375	23772
60	8390	11348	14825	17939	22230	24630
77	8998	11958	15311	19037	23818	26468
85	9241	12324	16040	20135	25162	28551
95	9849	13300	17134	21844	27482	31124
TAKEOFF FLAP SETTING - 10 DEGREES, δ_F						
40	6898	9125	11598	14694	18153	20283
60	7261	9612	12330	15306	18889	21143
77	7503	9977	13063	16286	20238	22741
85	7866	10342	13796	17143	21465	24339
95	8471	11559	15261	19102	24286	27658
TAKEOFF FLAP SETTING - 20 DEGREES, δ_F						
40	6743	8629	11150	14094	17380	19745
60	6992	9245	11646	14718	18262	20631
77	7242	9615	12389	15965	20025	22783
85	7617	10108	13628	17088	21662	24555
95	8241	11094	14991	19333	25315	29238

TABLE B.6.5

EQUIVALENT AIR SPEEDS FOR TAKEOFF AND APPROACH AND LANDING OPERATIONS (V35, V_2, 1.3 Vs); 3E-HBPR-WB

TAKEOFF SPEED AT 35 FEET HEIGHT ABOVE AIRPORT, V35, KEAS

Flap Setting, δ_F Degrees	Weight (Klbs)					
	260	300	340	380	420	440
0	145.0	153.5	161.4	168.1	174.9	179.9
10	132.0	139.2	147.8	153.4	159.2	163.2
20	129.7	135.4	143.2	149.0	156.4	160.3

TAKEOFF SAFETY SPEED, V_2, KEAS

Flap Setting, δ_F Degrees	Weight (Klbs)					
	260	300	340	380	400	440
0	143.0	153.5	163.0	171.5	175.5	184.0
10	128.0	137.5	146.5	154.0	157.5	165.0
20	121.0	130.0	138.0	145.0	148.5	157.3*

*This value has been obtained by extrapolation

APPROACH SPEED, 1.3 Vs, KEAS

Flap Setting, δ_F Degrees	Weight (Klbs)					
	240	260	280	300	340	380
35	114.6	119.0	123.5	128.0	136.3	143.0
50	111.0	115.8	120.0	124.1	131.8	138.0

TABLE B.6.6

AIRCRAFT LIFT AND DRAG COEFFICIENTS (C_L, C_D); 3E-HBPR-WB

LIFT COEFFICIENT AS A FUNCTION OF AIRCRAFT BODY ANGLE OF ATTACK

Flap Setting, δ_F Degrees	Landing Gear Position	Slat Position	$C_L = a_0 + a_1 \cdot \alpha_B$	
			a_0	a_1
0	Up	Retracted	0.1542	0.0638
0	Up	Extended	0.0638	0.0786
5	Up	Extended	0.1495	0.0775
10	Up	Extended	0.2248	0.0795
20	Up	Extended	0.3762	0.0826
35	Up	Extended	0.7656	0.0471
50	Up	Extended	0.8991	0.0448
35	Down	Extended	0.7656	0.0471
50	Down	Extended	0.8991	0.0448

DRAG COEFFICIENT AS A FUNCTION OF LIFT COEFFICIENT

Flap Setting, δ_F Degrees	Landing Gear Position	Slat Position	$C_D = a_0 + a_1 \cdot (C_L)^2$	
			a_0	a_1
0	Up	Retracted	0.0141	0.0637
0	Up	Extended	0.0208	0.0641
5	Up	Extended	0.0225	0.0630
10	Up	Extended	0.0247	0.0630
20	Up	Extended	0.0347	0.0624
35	Up	Extended	0.0687	0.0498
50	Up	Extended	0.1349	0.0491
35	Down	Extended	0.0805	0.0498
50	Down	Extended	0.1425	0.0491

TABLE B.6.7

FLAP/SLAT RETRACTION SPEED SCHEDULE AND TIMES; 3E-HBPR-WB

FLAP/SLAT RETRACTION SCHEDULE, KEAS		
INITIAL FLAP/SLATS	SELECT FLAPS/SLATS	FLAP RETRACTION INITIATION SPEED
Takeoff	0^o/Extended	V_2 + Takeoff Flap Setting (TFS)*
0^o/Extended	0^o/Retracted	V_2 + 35 + TFS
Minimum Zero Flaps/Slats		V_2 + 90 or 240, whichever is lower

*Takeoff Flaps 10^o or less use TFS = 10

Initial Flap/Slap Setting, δ_F Deg.	Selected Flap/Slap Setting, δ_F Deg.	Flap/Slat Retraction Time Sec.
20/Extended	15/Extended	2.0
15/Extended	10/Extended	2.2
10/Extended	5/Extended	2.1
5/Extended	0/Extended	2.2
0/Extended	0/Retracted	10.3

APPENDIX C

ENGINE PERFORMANCE AND OPERATIONAL DATA AND INFORMATION

APPENDIX C

ENGINE PERFORMANCE AND OPERATIONAL DATA AND INFORMATION

This appendix presents tabulated listings of aircraft engine performance and operational data and information required to construct takeoff, and approach and landing flight paths and performance schedules for selected commercial aircarrier aircraft types powered by low-by-pass ratio (LBPR) and high-by-pass ratio (HBPR) turbofan engines. Data and information are presented for engines which power the following six generic aircraft types:

- 2-Engine LBPR-Narrow Body (2E-LBPR-NB)
- 3-Engine LBPR-Narrow Body (3E-LBPR-NB)
- 4-Engine LBPR-Narrow Body (4E-LBPR-NB)
- 2-Engine HBPR-Wide Body (2E-HBPR-WB)
- 3-Engine HBPR-Wide Body (3E-HBPR-WB)
- 4-Engine HBPR-Wide Body (4E-HBPR-WB)

Data and information presented in this appendix include:

- Total net takeoff thrust (TOT) as a function of pressure altitude, true air speed and ambient temperature, per engine

- Maximum (normal) climb thrust (MCT) engine-pressure-ratio (EPR) setting or low pressure fan speed (N1) setting as a function of pressure altitude and ambient temperature, per engine
- Referred net thrust (Fn/δ) as a function of EPR and MACH number, per engine (for all aircraft types except the 3E-HBPR-WB)
- Referred low pressure fan speed ($N1/\sqrt{\theta T_2}$) as a function of EPR and MACH number, per engine (for the 2E-HBPR-WB and 4E-HBPR-WB aircraft types only)
- Referred net thrust (Fn/δ) as a function of referred low pressure fan speed and MACH number, per engine (for the 3E-HBPR-WB aircraft only).

TABLE C.1.1
TOTAL NET TAKEOFF THRUST (TOT) PER ENGINE, Pounds (lbs);
2E-LBPR-NB

Airport Temperature, Degrees °F	Aircraft Speed, VT, KTAS			
	100	150	200	250
AIRPORT PRESSURE ALTITUDE - SEA LEVEL				
0	13892	13481	13166	12983
59	13931	13501	13134	12877
84	13934	13512	13127	12847
100	13056	12584	12139	11797
122	11795	11316	10855	10475
AIRPORT PRESSURE ALTITUDE - 1000 FT				
0	13984	13596	13297	13135
45	14012	13610	13286	13057
53	13711	13304	12960	12725
74	13708	13303	12947	12691
84	13444	13037	12666	12397
100	12598	12142	11713	11383
122	11410	10920	10474	10108

TABLE C.1.1
(CONTINUED)

Airport Temperature, Degrees °F	Aircraft Speed, VT, KTAS			
	100	150	200	250
AIRPORT PRESSURE ALTITUDE - 2000 FT				
0	14058	13686	13406	13271
29	14060	13682	13377	13205
40	13715	13331	13014	12816
48	13420	13031	12706	12490
66	13426	13038	12702	12467
84	12969	12577	12219	11960
100	12153	11714	11300	10982
122	11008	10536	10106	9753
AIRPORT PRESSURE ALTITUDE - 3000 FT				
0	14092	13737	13482	13365
10	14098	13742	13478	13351
20	13833	13472	13191	13047
40	13226	12856	12551	12359
48	12942	12567	12254	12045
66	12948	12573	12250	12023
84	12508	12129	11785	11534
93	12056	11649	11272	10986
122	10617	10162	9748	9407

TABLE C.1.1
(CONTINUED)

Airport Temperature, Degrees °F	Aircraft Speed, VT, KTAS			
	100	150	200	250
AIRPORT PRESSURE ALTITUDE - 4000 FT				
0	13802	13464	13225	13110
20	13337	12990	12720	12580
40	12753	12396	12174	11918
48	12479	12118	11816	11615
66	12485	12124	11812	11594
84	12061	11696	11364	11123
100	11303	10794	10510	10215
122	10239	9800	9400	9073
AIRPORT PRESSURE ALTITUDE - 6000 FT				
0	12882	12509	12286	12180
20	12391	12068	11818	11689
40	11849	11518	11245	11074
48	11595	11260	10980	10793
66	11600	11265	10976	10773
84	11206	10868	10560	10336
100	10503	10124	9768	9494
122	9516	9109	8739	8434

TABLE C.1.2
MAXIMUM (NORMAL) CLIMB THRUST (MCT) EPR SETTING PER ENGINE;
2E-LBPR-NB

Pressure Altitude, Feet	Temperature, Degrees ^{O}F, (OATPL)											
	-4.00	14.00	32	41	59	68	77	86	95	104	113	122
0	2.07	2.07	2.07	2.03	1.93	1.88	1.84	1.79	1.75	1.72	1.68	1.64
1000	2.13	2.13	2.08	2.03	1.93	1.88	1.84	1.79	1.75	1.72	1.68	1.64
2000	2.19	2.18	2.08	2.03	1.93	1.88	1.84	1.79	1.75	1.72	1.68	1.64
3000	2.23	2.17	2.08	2.02	1.92	1.88	1.83	1.79	1.75	1.71	1.67	1.63
4000	2.23	2.17	2.08	2.02	1.92	1.87	1.83	1.79	1.75	1.71	1.67	1.63
5000	2.23	2.17	2.08	2.02	1.92	1.87	1.83	1.79	1.75	1.71	1.67	1.63
10000	2.22	2.16	2.07	2.01	1.91	1.86	1.82	1.78	1.74	1.70	1.66	1.62
20000	2.21	2.15	2.05	2.00	1.90	1.85	1.81	1.76	1.72	1.69	1.65	1.61
30000	2.19	2.13	2.04	1.98	1.88	1.83	1.79	1.75	1.71	1.67	1.63	1.59

TABLE C.1.3
REFERRED NET THRUST (Fn/δ) PER ENGINE, Pounds (lbs);
2E-LBPR-NB

Engine Pressure Ratio, EPR	MACH Number					
	0.0	0.1	0.2.	0.3	0.4	0.5
1.05	1166*	--	--	--	--	1449*
1.10	2035	1752*	1679*	1710*	1853*	2048
1.15	2904	2527	2378	2368	2463	2647
1.20	3774	3302	3077	3026	3073	3246
1.25	4574	4069	3776	3648	3683	3844
1.30	5349	4764	4433	4313	4286	4433
1.35	6110	5458	5070	4916	4881	5018
1.40	6795	6141	5707	5512	5476	5602
1.45	7479	6782	6331	6120	6071	6188
1.50	8156	7423	6945	6723	6663	6776
1.55	8805	8061	7558	7325	7254	7365
1.60	9455	8667	8163	7928	7846	7953
1.65	10095	9273	8744	8486	8411	8523
1.70	10686	9878	9326	9039	8967	9091
1.75	11278	10447	9907	9591	9522	9659
1.80	11870	11000	10447	10139	10076	10225
1.85	12424	11556	10979	10674	10616	10787
1.90	12967	12105	11511	11209	11157	11348
1.95	13511	12628	12042	11743	11697	11910
2.00	14053	13152	12563	12274	12239	12469
2.05	14588	13675	13083	12800	12783	13028
2.10	15123	14198	13604	13326	13326	13587
2.15	15658	14719	14124	13853	13870	14148
2.20	16193*	15240	14642	14377	14415	14716
2.25	--	15760	15161	14901	14962	15284
2.30	--	16281*	15679	15424	15508	15852
2.35	--	--	16197*	15948	16055*	16420*
2.40	--	--	--	16471*	--	--

*These values have been obtained by extrapolation.

TABLE C.2.1

TOTAL NET TAKEOFF THRUST (TOT) PER ENGINE; Pounds (lbs); 3E-LBPR-NB

Airport Temperature, Degrees °F	Aircraft Speed, VT, KTAS			
	100	150	200	250
AIRPORT PRESSURE ALTITUDE - SEA LEVEL				
0	13950	13530	13190	12980
48	13980	13550	13170	12900
84	13980	13570	13160	12860
100	13100	12630	12170	11820
AIRPORT PRESSURE ALTITUDE - 1000 FT				
0	14010	13610	13290	13100
46	14040	13630	13270	13020
53	13750	13340	12970	12710
74	13740	13340	12960	12690
84	13490	13080	12690	12400
100	12630	12180	11740	11400

TABLE C.2.1
(CONTINUED)

Airport Temperature, Degrees °F	Aircraft Speed, VT, KTAS			
	100	150	200	250
AIRPORT PRESSURE ALTITUDE - 2000 FT				
30	14040	13670	13360	13200
48	13440	13050	12700	12470
66	13450	13050	12700	12450
84	13010	12610	12230	11960
100	12180	11740	12320	10990
AIRPORT PRESSURE ALTITUDE - 4000 FT				
0	13760	13420	13140	13000
48	12490	12120	12800	11570
66	12490	12130	12800	11550
84	12080	11720	12370	11110
100	11310	10910	10520	10200

TABLE C.2.1
(CONTINUED)

Airport Temperature, Degrees °F	Aircraft Speed, VT, KTAS			
	100	150	200	250
AIRPORT PRESSURE ALTITUDE - 6000 FT				
0	12770	12450	12200	12070
48	11590	11240	10950	10740
66	11590	11250	10950	10720
84	11210	10870	10550	10300
100	10490	10130	9750	9470

TABLE C.2.2

MAXIMUM (NORMAL) CLIMB THRUST (MCT) EPR SETTING PER ENGINE; 3E-LBPR-NB

Pressure Altitude, Feet	Temperature, Degrees °F, (OATPL)											
	-4.00	14.00	32	41	59	68	77	86	95	104	113	122
0	2.07	2.07	2.07	2.03	1.93	1.88	1.84	1.79	1.75	1.72	1.68	1.64
1000	2.13	2.13	2.08	2.03	1.93	1.88	1.84	1.79	1.75	1.72	1.68	1.64
2000	2.19	2.18	2.08	2.03	1.93	1.88	1.84	1.79	1.75	1.72	1.68	1.64
3000	2.23	2.17	2.08	2.02	1.92	1.88	1.83	1.79	1.75	1.71	1.67	1.63
4000	2.23	2.17	2.08	2.02	1.92	1.87	1.83	1.79	1.75	1.71	1.67	1.63
5000	2.23	2.17	2.08	2.02	1.92	1.87	1.83	1.79	1.75	1.71	1.67	1.63
10000	2.22	2.16	2.07	2.01	1.91	1.86	1.82	1.78	1.74	1.70	1.66	1.62
20000	2.21	2.15	2.05	2.00	1.90	1.85	1.81	1.76	1.72	1.69	1.65	1.61
30000	2.19	2.13	2.04	1.98	1.88	1.83	1.79	1.75	1.71	1.67	1.63	1.59

TABLE C.2.3
REFERRED NET THRUST (Fn/δ) PER ENGINE, Pounds (lbs);
3E-LBPR-NB

Engine Pressure Ratio, EPR	MACH Number					
	0.0	0.1	0.2	0.3	0.4	0.5
1.00	--	--	--	--	--	--
1.05	1257*	--	--	--	--	1413*
1.10	2083	1699*	1651*	1674*	1815*	2012
1.15	2909	2584	2350	2327	2432	2611
1.20	3736	3469	3049	2980	3049	3210
1.25	4523	4248	3748	3634	3667	3808
1.30	5292	4870	4410	4267	4269	4393
1.35	6055	5491	5051	4873	4854	4971
1.40	6745	6115	5692	5479	5439	5549
1.45	7434	6756	6331	6084	6024	6129
1.50	8116	7397	6968	6687	6615	6718
1.55	8761	8036	7605	7289	7207	7306
1.60	9406	8639	8211	7892	7799	7894
1.65	10048	9241	8767	8453	8363	8463
1.70	10651	9843	9322	9006	8912	9028
1.75	11253	10413	9878	9558	9462	9593
1.80	11855	10972	10417	10106	10011	10156
1.85	12413	11531	10952	10638	10551	10711
1.90	12957	12083	11487	11170	11092	11267
1.95	13500	12604	12021	11702	11632	11822
2.00	14042	13125	12542	12229	12172	12382
2.05	14563	13646	13063	12750	12710	12944
2.10	15083	14165	13583	13271	13247	13506

TABLE C.2.3
(CONTINUED)

Engine Pressure Ratio, EPR	MACH Number (cont.)					
	0.0	0.1	0.2	0.3	0.4	0.5
2.15	15604	14680	14104	13792	13785	14067
2.20	16125*	15196	14622	14316	14326	14629
2.25	--	15711	15140	14842	14870	15191
2.30	--	16226*	15658	15368	15413	15753
2.35	--	--	16176*	15895	15957	16315*
2.40	--	--	--	16422*	16501*	--

*These values have been obtained by extrapolation

TABLE C.3.1

TOTAL NET TAKEOFF THRUST (TOT) PER ENGINE, Pounds (lbs);
4E-LBPR-NB

Airport Temperature, Degrees °F	Aircraft Speed, VT, KTAS					
	0	100	150	200	250	300
AIRPORT PRESSURE ALTITUDE - SEA LEVEL						
-6.5	17210	15340	14470	13690	12900	12360
59	17310	15630	14850	14130	13450	12850
84	17330	15700	14910	14230	13570	12960
120	14880	13200	12500	11880	11320	10840
AIRPORT PRESSURE ALTITUDE - 2000 FT						
-6.5	17210	15620	14880	14230	13600	13280
33	17290	15830	15160	14600	13990	13460
59	16060	14560	13810	13170	12490	11910
84	16080	14620	13940	13260	12620	12020
120	13770	12360	11680	11070	10510	10050
AIRPORT PRESSURE ALTITUDE - 4000 FT						
20	16650	15100	14420	13870	13340	12990
40	15820	14380	13720	13150	12570	12080
59	15050	13530	12840	12260	11630	11080
84	15070	13620	12920	12300	11720	11160
120	12910	11500	10900	10340	9810	9320
AIRPORT PRESSURE ALTITUDE - 6000 FT						
20	15290	13990	13320	12790	12350	12050
40	14630	13340	12670	12140	11640	11250
59	13850	12510	11900	11360	10770	10260
84	13870	12590	11960	11410	10850	10330
120	11840	10650	10090	9560	9060	8630

TABLE C.3.2
MAXIMUM (NORMAL) CLIMB THRUST (MCT) EPR SETTING PER ENGINE;
4E-LBPR-NB

Pressure Altitude, Feet	Temperature, Degrees °F, (OATPL)										
	-4.0	14.0	32	41	59	68	77	86	95	104	113
0	1.79	1.79	1.79	1.74	1.67	1.63	1.60	1.56	1.53	1.49	1.46
1000	1.86	1.86	1.78	1.74	1.67	1.63	1.60	1.56	1.53	1.49	1.46
2000	1.90	1.86	1.78	1.74	1.67	1.63	1.60	1.56	1.53	1.49	1.46
3000	1.94	1.86	1.78	1.74	1.67	1.63	1.60	1.56	1.53	1.44	1.46
4000	1.94	1.86	1.78	1.74	1.67	1.63	1.60	1.56	1.53	1.44	1.46
5000	1.94	1.86	1.78	1.74	1.67	1.63	1.60	1.56	1.53	1.44	1.46
20000	1.94	1.86	1.78	1.74	1.67	1.63	1.60	1.56	–	–	–
25000	1.94	1.86	1.79	1.76	1.71	1.67	1.64	1.60	–		
30000	1.93	1.87	1.81	1.77	1.70	1.66	1.63	1.59	–		

TABLE C.3.3

REFERRED NET THRUST (Fn/δ) PER ENGINE, Pounds (lbs);
4E-LBPR-NB

Engine Pressure Ratio, EPR	MACH Number				
	0.0	0.1	0.2	0.3	0.4
1.00	-	-	1120*	1207*	1386*
1.05	1968*	1951*	2120	2108	2263
1.10	3491	3190	3120	3009	3140
1.15	5014	4429	4122	3910	4018
1.20	6386	5619	5143	4833	4919
1.25	7590	6708	6145	5759	5820
1.30	8688	7750	7055	6661	6661
1.35	9729	8704	7965	7554	7487
1.40	10698	9630	8842	8400	8288
1.45	11642	10500	9719	9200	9045
1.50	12504	11333	10519	10000	9803
1.55	13317	12148	11282	10730	10525
1.60	14119	12889	12041	11460	11234
1.65	14859	13630	12726	12172	11943
1.70	15600	14338	13411	12834	12590
1.75	16341	15014	14089	13497	13231
1.80	17082*	15689	14726	14150	13872
1.85	-	16364*	15363	14775	14526
1.90	-	-	16000	15400	15184
1.95	-	-	16637*	16025*	15842
2.00	-	-	-	-	16500*

*These values have been obtained by extrapolation.

TABLE C.4.1

TOTAL NET TAKEOFF THRUST (TOT) PER ENGINE, Pounds (lbs); 4E-HBPR-WB

Airport Temperature, Degrees °F	Aircraft Speed, VT, KTAS			
	100	150	200	250
AIRPORT PRESSURE ALTITUDE - SEA LEVEL				
-6.5	36741	34039	31787	29887
59	37455	35006	32094	31043
77	37538	35124	33036	31192
80	37552	35143	33057	31216
90	36359	34017	31954	30089
100	35036	32778	30740	28862
AIRPORT PRESSURE ALTITUTDE - 2000 FT				
-6.5	34969	32440	30352	28638
52	35611	33297	31330	29622
70	35691	33410	31457	29758
73	35704	33428	31477	29779
83	34604	32382	30447	28729
93	33458	31301	29389	27651
103	32209	30132	28244	29498

TABLE C.4.1

(Continued)

Airport Temperature, Degrees °F	Aircraft Speed, VT, KTAS			
	100	150	200	250
AIRPORT PRESSURE ALTITUDE - 4000 FT				
-6.5	33198	30844	28910	27356
45	33769	31596	29763	28193
66	33859	31719	29902	28337
76	32879	30778	28970	27387
86	31859	29810	28019	26417
96	30760	28775	27006	25388
100	29583	27673	25927	24306
AIRPORT PRESSURE ALTITUDE - 6000 FT				
-6.5	31439	29253	27476	26052
38	31942	29908	28212	26770
59	32026	30023	28341	26904
69	31161	29185	27499	26043
79	30230	28293	26619	25146
89	29281	27396	25739	24247
100	28230	26409	24773	23269

TABLE C.4.2

MAXIMUM (NORMAL CLIMB THRUST (MCT) EPR SETTING PER ENGINE;
4E-HBPR-WB

Pressure Altitude, Feet	Temperature, Degrees ^{0}F, (OATPL)						
	-5	13	31	49	67	85	103
0	1.28	1.28	1.28	1.28	1.28	1.29	1.24
1000	1.29	1.29	1.29	1.29	1.29	1.29	1.24
2000	1.30	1.30	1.30	1.30	1.30	1.28	1.23
5000	1.33	1.33	1.33	1.33	1.33	1.27	1.22
9000	1.37	1.37	1.37	1.37	1.32	1.26	1.21
10000	1.33	1.33	1.33	1.33	1.31	1.24	1.18
19000	1.43	1.43	1.43	1.39	1.31	--	--
20000	1.44	1.44	1.44	1.39	1.31	--	--
24000	1.47	1.47	1.45	1.39	1.31	--	--
25000	1.47	1.47	1.45	1.39	1.31	--	--
29000	1.49	1.49	1.44	1.38	1.30	--	--
30000	1.50	1.50	1.45	1.39	1.31	--	--

TABLE C.4.3

REFERRED NET THRUST (Fn/δ) PER ENGINE, Pounds (lbs);
4E-HBPR-WB

Engine Pressure Ratio EPR	MACH Number			
	0.1	0.2	0.3	0.4
1.00	1742	3361	5406	7231
1.05	7371	7953	9280	10982
1.10	13000	12545	13154	14475
1.15	18000	16894	16889	17864
1.20	22320	20960	20414	20909
1.25	26291	24596	23688	23778
1.30	29927	27875	26722	26488
1.35	33213	30889	29500	28927
1.40	36269	33667	31976	31217
1.45	39012	36120	34317	33391
1.50	41755*	38411	36297	35321
1.55	--	40280	38233	37156
1.60	--	42077*	39900	38812
1.65	--	--	41567	40316
1.70	--	--	43234*	41820
1.75	--	--	--	43324*

*These values have been obtained by extrapolation.

TABLE C.4.4

REFERRED LOW PRESSURE FAN SPEED ($N1/\sqrt{\theta T_2}$); RPM;

4E-HBPR-WB

Engine Pressure Ratio EPR	MACH Number			
	0.1	0.2	0.3	0.4
1.00	1264*	1548*	1848*	2074
1.05	1703	1897	2119	2331
1.10	2142	2246	2390	2551
1.15	2458	2525	2624	2748
1.20	2673	2739	2810	2904
1.25	2841	2896	2958	3032
1.30	2980	3023	3080	3140
1.35	3099	3132	3182	3230
1.40	3206	3228	3268	3311
1.45	3298	3310	3347	3385
1.50	3390*	3386	3410	3450
1.55	--	3446	3471	3511
1.60	--	3506*	3524	3564
1.65	--	--	3576	3609
1.70	--	--	3628*	3655
1.75	--	--	--	3701*

*These values have been obtained by extrapolation

TABLE C.5.1

TOTAL NET TAKEOFF THRUST (TOT) PER ENGINE, Pounds (lbs); 2E-HBPR-WB

Airport Temperature, Degrees ^{o}F	Aircraft Speed, VT, KTAS				
	0	100	150	200	250
AIRPORT PRESSURE ALTITUDE - SEA LEVEL					
20	43352	37146	35284	34136	33711
40	43352	37294	35407	34191	33751
60	43352	37383	35495	34225	33795
80	43352	37471	35565	34253	33834
100	40856	35332	33581	32453	32165
AIRPORT PRESSURE ALTITUDE - 2000 FT					
20	41283	35273	33478	32429	31988
40	41283	35422	33589	32486	32032
60	41283	35511	33668	32523	32077
80	40837	35290	33474	32238	31817
100	37988	32852	31224	30175	29907

TABLE C.5.1

(Continued)

Airport Temperature, Degrees °F	Aircraft Speed, VT, KTAS				
	0	100	150	200	250
AIRPORT PRESSURE ALTITUDE - 4000 FT					
20	39126	33278	31490	30662	30231
40	39126	33430	31662	30718	30274
60	39126	33520	31728	30752	30319
80	37934	32781	31094	29946	29555
100	35287	30516	29004	28030	27781
AIRPORT PRESSURE ALTITUDE - 6000 FT					
20	37025	31354	29726	28950	28531
40	37025	31506	29804	29904	28573
60	37025	31598	29860	29036	28617
80	35197	30416	28851	27786	27423
100	32742	28315	26912	26008	25777

TABLE C.5.1

(Continued)

Airport Temperature, Degrees °F	Aircraft Speed, VT, KTAS				
	0	100	150	200	250
AIRPORT PRESSURE ALTITUDE - 8000 FT					
20	34935	29467	27923	27259	26854
40	34935	29618	27988	27311	26896
60	34050	29104	27521	26727	26345
80	32624	28192	26742	25821	25418
100	30348	26245	24944	24106	23892

TABLE C.5.2

MAXIMUM (NORMAL) CLIMB THRUST (MCT) EPR SETTING PER ENGINE;
2E-HBPR-WB

Pressure Altitude, Feet	Temperature, Degrees °F, (OATPL)						
	-5	13	31	49	67	85	103
0	1.30	1.30	1.30	1.30	1.30	1.30	1.26
1000	1.31	1.31	1.31	1.31	1.31	1.30	1.26
2000	1.32	1.32	1.32	1.32	1.32	1.30	1.26
5000	1.34	1.34	1.34	1.34	1.34	1.30	1.26
9000	1.38	1.38	1.38	1.38	1.34	1.30	1.26
10000	1.35	1.35	1.35	1.35	1.32	1.29	1.24
12000	1.37	1.37	1.37	1.37	1.32	1.29	1.24
15000	1.40	1.40	1.40	1.39	1.32	1.29	1.24
20000	1.45	1.45	1.45	1.39	1.32	1.29	1.24
25000	1.49	1.49	1.46	1.39	1.32	1.29	1.24
30000	1.53	1.52	1.46	1.39	1.32	1.29	1.24

TABLE C.5.3

REFERRED NET THRUST (Fn/δ) PER ENGINE, Pounds (lbs);
2E-HBPR-WB

Engine Pressure Ratio, EPR	MACH Number					
	0.0	0.1	0.2	0.3	0.4	0.5
1.00	1400	1000	2200	3700	5600	7900
1.05	7800	6600	7000	8100	9600	11600
1.10	14200	12300	11800	12400	13400	15200
1.15	20000	17300	16100	16300	17200	18800
1.20	24600	21600	20300	20000	20700	22200
1.25	29200	25800	24000	23400	23900	25100
1.30	33400	29500	27500	26500	26800	27600
1.35	37000	33000	30700	29600	29400	29900
1.40	40600	36400	33700	32200	31900	32100
1.45	43800	39400	36400	34600	34000	34100
1.50	46800	42000	38000	36700	36000	36000
1.55	49700*	44500*	39500*	38700*	37900*	37800*

*These values have been obtained by extrapolation.

TABLE C.5.4

REFERRED LOW PRESSURE FAN SPEED ($N1/\sqrt{\theta T_2}$), RPM;
2E-HBPR-WB

Engine Pressure Ratio, EPR	MACH Number					
	0.0	0.1	0.2	0.3	0.4	0.5
1.00	--	--	1170	1566	1908	2304
1.05	1530	1584	1764	1998	2250	2502
1.10	2034	2052	2178	2358	2538	2725
1.15	2394	2412	2493	2610	2754	2898
1.20	2628	2646	2718	2808	2916	3024
1.25	2826	2826	2880	2952	3042	3132
1.30	2970	2988	3020	3078	3159	3215
1.35	3096	3114	3132	3186	3231	3294
1.40	3204	3204	3240	3276	3312	3348
1.45	3312	3312	3321	3348	3375	3402
1.50	3402	3402	3402	3420	3438	3456
1.55	3492*	3492*	3483*	3492*	3492	3510
1.60	--	--	--	--	3546	3564

*These values have been obtained by extrapolation.

TABLE C.6.1

TOTAL NET TAKEOFF THRUST (TOT) PER ENGINE, Pounds (lbs);

3E-HBPR-WB

Airport Temperature, Degrees °F	Aircraft Speed, VT, KTAS				
	0	100	150	200	250
AIRPORT PRESSURE ALTITUDE - SEA LEVEL					
20	36156	30732	28773	27158	25848
40	38116	32752	30760	29077	27747
60	40124	34736	32700	30935	29608
80	42164	36741	34613	32781	31458
100	41654	36352	34254	32472	31148
AIRPORT PRESSURE ALTITUDE - 2000 FT					
20	34620	30235	28369	26798	25553
40	36454	32128	30211	28586	27321
60	38445	33899	31924	30234	28974
80	40247	35768	33705	31952	30696
100	38730	34426	32443	30767	29525

TABLE C.6.1

(Continued)

Airport Temperature, Degrees °F	Aircraft Speed, VT, KTAS				
	0	100	150	200	250
AIRPORT PRESSURE ALTITUDE - 4000 FT					
20	33090	29473	27687	26178	24999
40	34743	31245	29393	27842	26644
60	36681	33059	31144	29527	28331
80	37650	34027	32083	30493	29379
100	35977	32560	30687	29112	27950
AIRPORT PRESSURE ALTITUDE - 6000 FT					
20	31501	28718	26993	25553	24438
40	33136	30368	28580	27099	25965
60	34771	31939	30122	28680	27648
80	34935	32094	30271	28822	27822
100	33382	30212	28985	27507	26420
AIRPORT PRESSURE ALTITUDE - 8000 FT					
20	29956	27748	26093	24725	23674
40	31471	29391	27696	26367	25376
60	33200	30841	29120	27847	26973
80	32380	30299	28590	27274	26383
100	30941	28991	27333	25975	24986

TABLE C.6.2

MAXIMUM (NORMAL) CLIMB THRUST (MCT)
LOW PRESSURE FAN SPEED (N1) SETTING PER ENGINE, RPM;
3E-HBPR-WB

Pressure Altitude, Feet	Temperature, Degrees °F, (OATPL)					
	0	20	40	60	80	100
0	3083	3145	3206	3275	3330	3344
5000	3176	3244	3306	3375	3436	3344
10000	3234	3303	3364	3436	3447	3344
15000	3282	3351	3416	3488	3447	3344
20000	3337	3406	3474	3526	3447	3344
25000	3402	3467	3539	3526	3447	3344
30000	3474	3543	3577	3526	3447	3344

TABLE C.6.3

REFERRED NET THRUST (Fn/δ) PER ENGINE, Pounds (lbs);

3E-HBPR-WB

Referred Low Pressure Fan Speed, ($N1/\sqrt{\Theta T_2}$) RPM	MACH Number					
	0.0	0.1	0.2	0.3	0.4	0.5
2060	11000	9500	8100	6900	5900	4900
2231	13300	11500	9900	8600	7500	6500
2403	16000	13900	11900	10400	9300	8300
2575	19000	16300	14200	12600	11400	10500
2746	21900	19000	16900	15200	14000	13000
2918	25400	22300	20000	18200	16900	15900
3090	29400	26000	23500	21700	20200	19200
3261	34000	30400	27600	25600	24000	22900
3433	38900	35100	32300	30000	28300	27200
3605	44000	40100	36900	34400	32600	31600
3776	49800	45000	41300	39100	37700	36900