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(6) Supersonic Transport Development Program, Phase ~~III~~ 3 Proposal.
BOEING MODEL 2707.

AIRFRAME/ENGINE TECHNICAL AGREEMENT (PRATT AND WHITNEY) (U) (8)

(14) D6A10199-1

September 6, 1966

(10) W. J. Bakken

PREPARED BY W J Bakken APPROVED BY [signature]

APPROVED BY R. S. Neuhart APPROVED BY [signature]

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1. INTRODUCTION

In compliance with section I paragraph IX of the Phase III Request for Proposal this document is the technical portion of the Airframe/Engine Agreement. The document is part B of the Airframe/Engine Agreement D6A10184-1 and the approval signatures on part A separately bound are also equally applicable to this part.

1.1 SCOPE

This agreement establishes the interface requirements including the performance, design, fabrication and testing for the Boeing Model B-2707 (P&WA) Supersonic Transport airplane and for the Pratt and Whitney Aircraft JTF17A-21B turbofan engine.

This agreement covers the certification and production phases (Phase IV and Phase V) of the SST Program in addition to the prototype construction and 100 hours flight test (Phase III). Therefore, the requirements as set forth herein, are intended to be applicable to production JTF17A-21B engines and production Model B-2707 (P&WA) airplane. While the requirements are also generally applicable to the prototype engines and airplanes except as specifically stated to the contrary herein, it is anticipated that some deviations may be required for prototype engines and airplanes. Accordingly, both P&WA and Boeing shall immediately notify the other whenever, in the course of design or development it becomes apparent that the prototype engine or airplane will not meet the requirements specified herein.

1.2 PURPOSE

The purpose of this agreement is to define the responsibilities of P&WA and Boeing for the physical and functional interface requirements for the Boeing Model B-2707 (P&WA) airplane and the P&WA JTF17A-21B turbofan engine.

2. APPLICABLE DOCUMENTS

2.1 GOVERNMENT

The following documents, of the issue date shown, form a part of this agreement to the extent specified herein.

2.1.1 AND 10050 — Air Force-Navy Aeronautical Design Standard "Bosses, Standard Dimensions for Gasket Seal Straight Thread", dated July 18, 1956.

2.1.2 MIL-E-005607C — Military Specification "Engine, Gas Turbine, Preparation for Storage and Shipment of, Process for", dated March 25, 1963.

2.1.3 MIL-S-8879 — Military Specification "Screw Threads, Standard Aeronautical", dated September 21, 1960.

2.1.4 FAR 33 — Federal Aviation Regulations "Airworthiness Standards. Aircraft Engines", dated February 1, 1965.

2.1.5 FAR 1 — Federal Aviation Regulations "Definitions and Abbreviations", dated May 15, 1962.

2.1.6 British Civil Airworthiness Requirements — Section C, dated March 1, 1957.

2.1.7 Air Force Specification Bulletin 526 — "Contaminants, Cabin Air, Maximum Allowable Concentration of", dated February 3, 1961.

2.1.8 FAR 21 — Federal Aviation Regulations Certification Procedures: Products and Parts, dated November 14, 1965.

2.1.9 FAR 25 — Federal Aviation Regulations Airworthiness Standards: Transport Category Airplanes and Tentative Airworthiness Standards for Supersonic Transports.

2.1.10 TT-S-735 Federal Specification Standard Test Fluids: Hydrocarbon.

2.1.11 MIL-E-5007A — Military Specification "Engine Aircraft, Turbojet, and Turbofan, General Specification for", dated 7/21/51.

2.1.12 MIL-E-5007C — Military Specification "Engine Aircraft, Turbojet, and Turbofan, General Specification for", dated 12/31/65.

2.1.13 FAR AC 33-1 — Federal Aviation Agency Advisory Circular: Turbine Engine Foreign Object Ingestion and Rotor Blade Containment Type Certification Procedures, dated 6/24/65.

2.1.14 MIL-E-5272C — Environmental Testing, Aeronautical and Associated Equipment, General Specification for, dated 4/13/59, including Amendment 1, dated 1/20/60.

2.2 NONGOVERNMENT

The following documents of the issue date shown, form a part of this agreement to the extent specified herein. One copy of each document listed below and marked with an asterisk is to be furnished to Pratt & Whitney with each copy of this agreement.

2.2.1 AS518 — SAE Aerospace Standard "Drive-Accessory, 3.000 Pilot Diameter, Q.A.D.", issued 12/15/63.

2.2.2 AS520 — SAE Aerospace Standard "Drive-Accessory, 6.500 Pilot Diameter, Q.A.D.", issued 12/15/63.

2.2.3 AS522 — SAE Aerospace Standard "Flange-Accessory, 3.000 Pilot Diameter, Q.A.D.", issued 12/15/63.

2.2.4 PWA 522 — P&WA Specification, Fuel Commercial Aircraft Turbine Engine, dated 11/5/65.

2.2.5 PWA 521-B Type II Pratt & Whitney Aircraft Specification Lubricant, Aircraft Turbine Engine, dated 6/25/63.

2.2.6 SAE Document AIR 876 "Procedures for Jet Noise Prediction", dated 7/10/65.

2.2.7 SAE Document ARP 865 "Definitions and Procedures for Computing the Perceived Noise Level of Aircraft Noise", dated 10/15/64.

2.2.8 SAE Document ARP 866 "Standard Values of Atmospheric Absorption as a Function of Temperature and Humidity for use in Evaluating Aircraft Flyover Noise", dated 8/31/64.

2.2.9 Delete

2.2.10 Delete

*2.2.11 Boeing Standard BAC F22AC "Flange, Coupling" Specification Control Drawing.

2.2.12 Boeing Document D6A10112-1 — Propulsion Subsystem Specification — P&WA, dated 9/6/66.

2.2.13 P&WA Engine Model Specification 2710, dated 8/8/66.

2.2.14 P&WA Engine Installation Drawing No. 2129601 (Production). P&WA Engine Installation Drawing No. 2130301 (FTS).

2.2.15 P&WA 533 — P&WA Specification, Fuel, Aircraft Turbine Engine, dated 11/10/64.

3. DESIGN REQUIREMENTS

3.1 GENERAL REQUIREMENTS FOR DESIGN

3.1.1 Engine Specification Requirements

3.1.1.1 Engine Model Specification
An engine model specification, defining engine performance and design in compliance with the requirements of this Engine/Airframe Technical Agreement shall be prepared by Pratt & Whitney Aircraft (P&WA) for use in airplane performance determination. The Boeing approved Engine Model Specification, Ref. 2.2.13, shall be a portion of this Engine/Airframe Technical Agreement to the extent specified herein.

3.1.1.2 Engine Installation Drawing
An engine installation drawing, Ref. 2.2.14, defining the installation envelope, overall dimensions, support details, engine control locations and motion, accessory locations, drains, installation, details, instrumentation provisions, and all other coordinated engine-airframe installation requirements, shall be a part of the Engine Model Specification to the extent specified herein.

3.1.1.2.1 Supporting Data
Pratt & Whitney Aircraft shall furnish a list of essential engine accessories and engine capabilities and provisions for installation of aircraft accessories.

Pratt & Whitney Aircraft shall furnish system diagrams of the electrical, fuel, lubrication, and other systems such as thrust reverser actuation, secondary air system, etc.

3.1.1.3 Card Deck Programs
A card deck program shall be provided capable of running on a mutually agreed upon high-speed computer. This program will define estimated engine performance, representing maximum fuel flow, minimum thrust and average values for all other items, and will be consistent with the guaranteed engine performance and shall be used to calculate data used in guaranteed airplane performance. Idle thrust may be average. The program will be based on a cycle match calculation rather than a program which uses a multiplicity of tables to generate performance data. The program shall be capable of generating data at any power setting from idle to takeoff at any altitude, Mach number, or ambient temperature within the engine operating envelope. The program shall be capable of making corrections for horsepower extraction, inlet recovery, and airbleed.

The card deck program will be used as the prime data source. Performance curves provided in Ref. 2.2.13, shall be in agreement with the card deck program and maintained up-to-date.

3.1.1.4 Analytical Model for Engine-Inlet Dynamic Studies
Pratt & Whitney Aircraft shall submit an analytical representation of the engine and its control systems suitable for use in inlet-engine dynamic simulation studies at Boeing. The simulation shall be valid over the operating performance envelope of the engine as specified in Fig. 1.

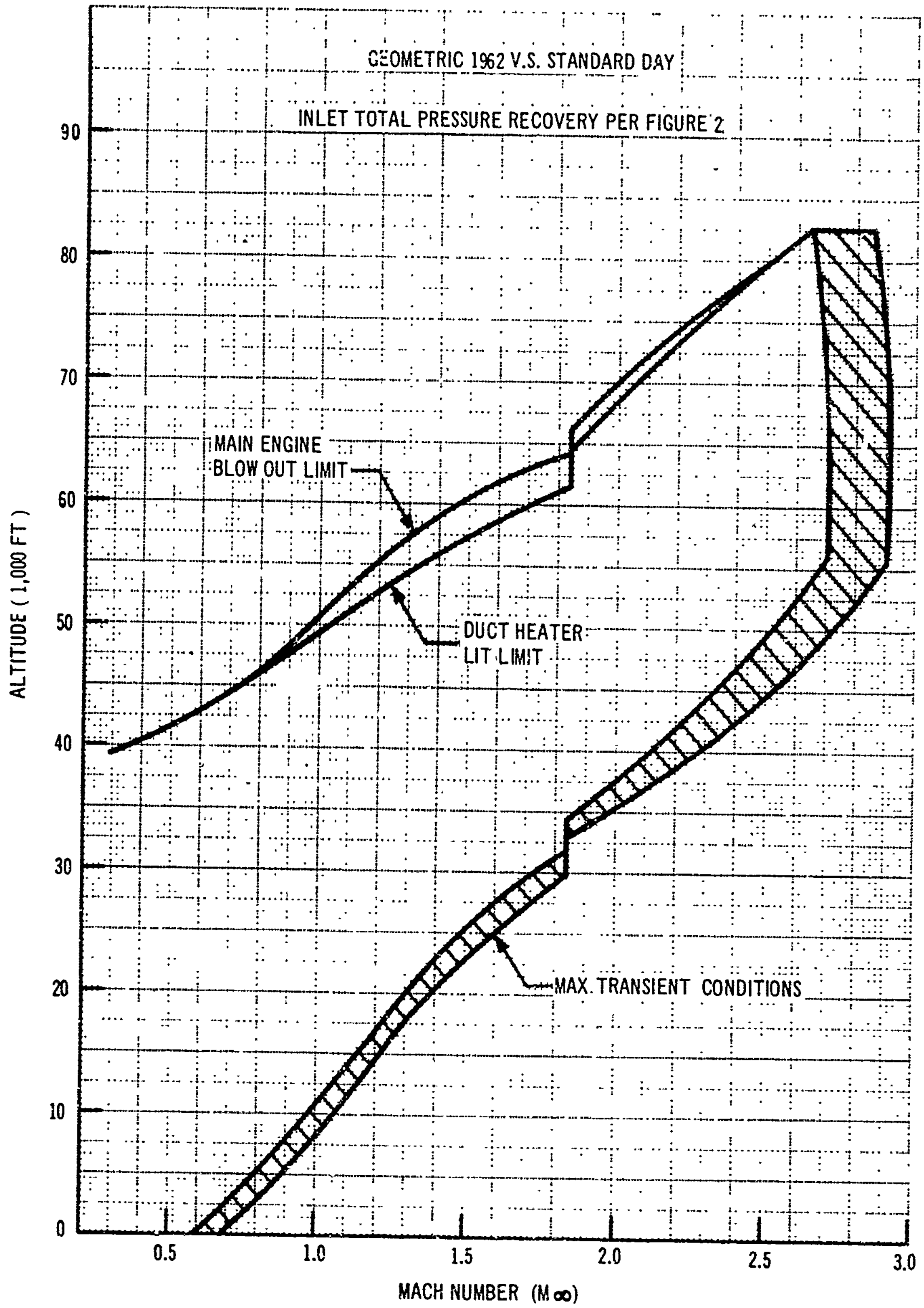


Figure 1. Engine Operating Limits

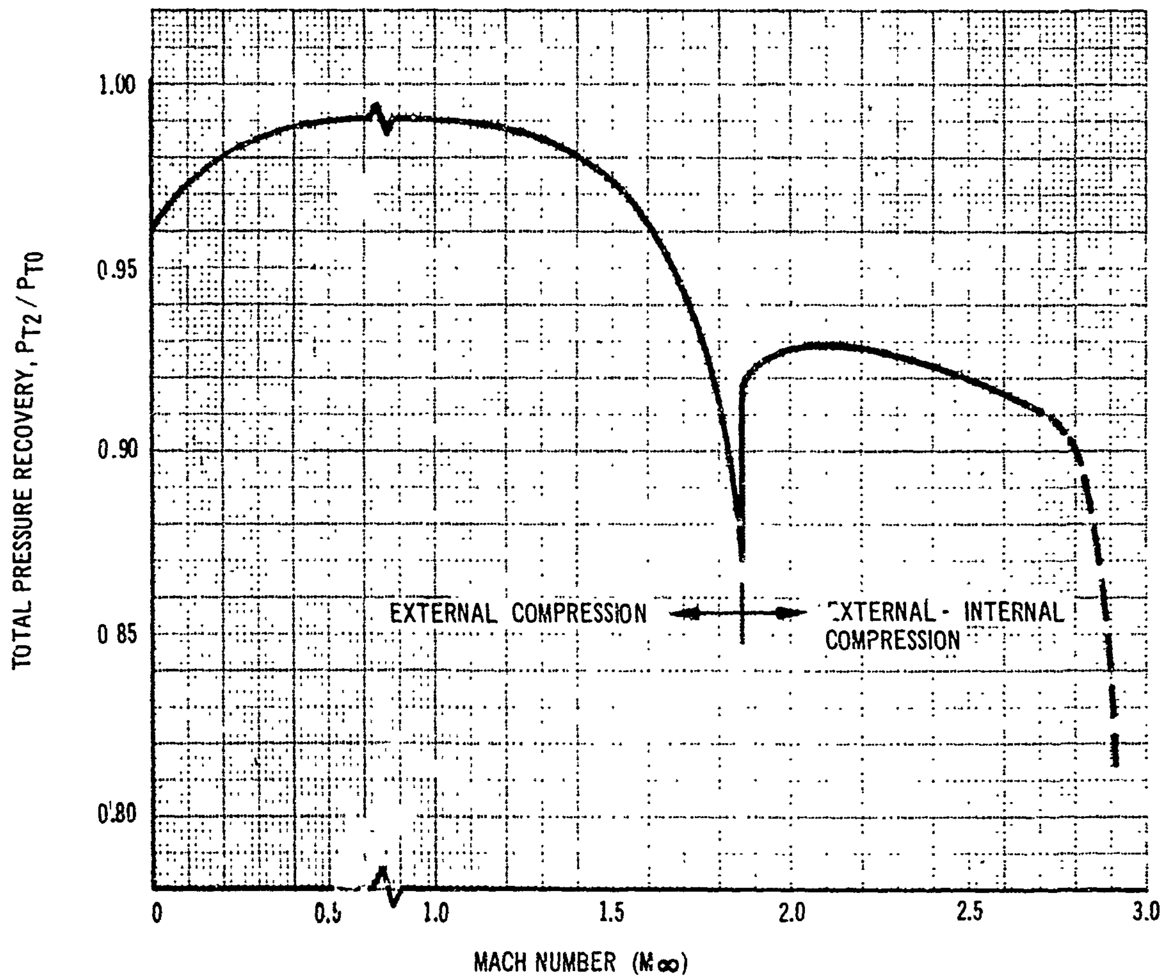


Figure 2. Inlet Total Pressure Recovery

The simulation shall allow determination of the effects of normal engine transients on inlet and inlet control operation. These transients include:

a. Throttle movements including "full burst" and "chop."

b. Augmentor "lightoff" and "shutdown."

c. Inflight engine "shutdown" and "restart," including windmill brake operation.

Also, the engine simulation shall be used to determine the transient effects of abnormal engine operation on inlet and control operation. These transients include:

d. Compressor stall (with and without distorted flow).

e. Main burner blowout.

f. Augmentor blowout.

g. Possible engine failure conditions (i.e., nozzle failure) insofar as practical.

Boeing will submit to P&WA an inlet dynamic simulation throughout the range of inlet started operation including inlet distortion profiles, ram recovery and air flow. Pratt & Whitney Aircraft will use this data in a test program to provide data for simulating compressor stall with distorted flow.

Simulation programs developed during Phase II-C will be updated by both P&WA and Boeing during Phase III as inlet and engine development programs provide additional data.

3.1.2 Performance

The estimated engine performance, representing maximum fuel flow and minimum thrust and with all other values being average for all operating conditions, shall be specified in the Engine Model Specification. This performance shall be consistent with the guaranteed performance points shown in Table I. All production engines shall be capable of demonstrating the guaranteed engine performance.

For the Phase III Flight Test Program, prototype FTS engine performance is shown in Table I.

3.1.3 Environment

3.1.3.1 Ambient Temperature Conditions

The complete engine shall perform satisfactorily under ambient temperature defined by Figs. 3 and 4.

Table I. Performance Guarantees

Power Setting	Pressure Alt (ft)	Ambient Temp	Mach No.	Ram Recovery	Min Net (1) Thrust (lb)(6)(8)	Max SFC (2)(8)	Airflow lb/sec (3)	HP Extraction	Bleed lb/sec
Maximum augmented	0	Std	0.0	0.96	56,740	1.83	660	450	0
Minimum nonaugmented	0	Std	0.0	0.96	35,490	0.75	660	450	0
Maximum augmented	0	Std +40°F	0.0	0.96	49,860	1.90	608	450	0
Maximum nonaugmented	0	Std +40°F	0.0	0.96	31,180	0.76	608	450	0
Maximum augmented	45,000	Std	1.2	0.986	19,630	1.90	248	450	0
Maximum augmented	45,000	Std +10°C	1.2	0.986	18,140	1.96	237	450	0
Partial augmented	65,000	Std	2.7	0.910	15,000	1.54	341	150	0
Partial augmented	65,000	Std +10°C	2.61	0.914	15,000	1.63	311	450	0
Partial nonaugmented	36,150	Std	0.85	0.99	5,000	1.06	236	450	0
Partial nonaugmented	15,000	Std	0.50	0.988	5,000	1.09	327	450	0
Maximum reverse	0	Std	0.0	0.96	14,080	---	---	550	2.1
Idle	0	Std	0.0	0.97	(7)	(4)	---	300	2.1
Idle	50,000	Std	1.2	0.986	-2,060	(5)	---	500	1.85

((1), (2), (3), -- For the Phase III FTS engines)

(1) Net thrust at maximum augmented and maximum nonaugmented shall not be less than 97% of the production engine ratings. For special demonstrations requiring full thrust rating, the production maximum duct heat rating shall be available for a 30-min period.

(2) SFC's for all thrust values shown shall not be more than 105% of the production SFC at the same thrust values.

(3) Airflow and airflow variations for all power settings and flight conditions shall be the same as the production engine guarantees.

(4) Maximum fuel flow = 4,050 lb/hr.

(5) Maximum fuel flow = 1,670 lb/hr.

(6) Thrust is along exhaust nozzle centerline.

(7) See Par. 3.2.18.

(8) 6% Corrected secondary airflow @ S. L.
2% Corrected secondary airflow @ Altitude

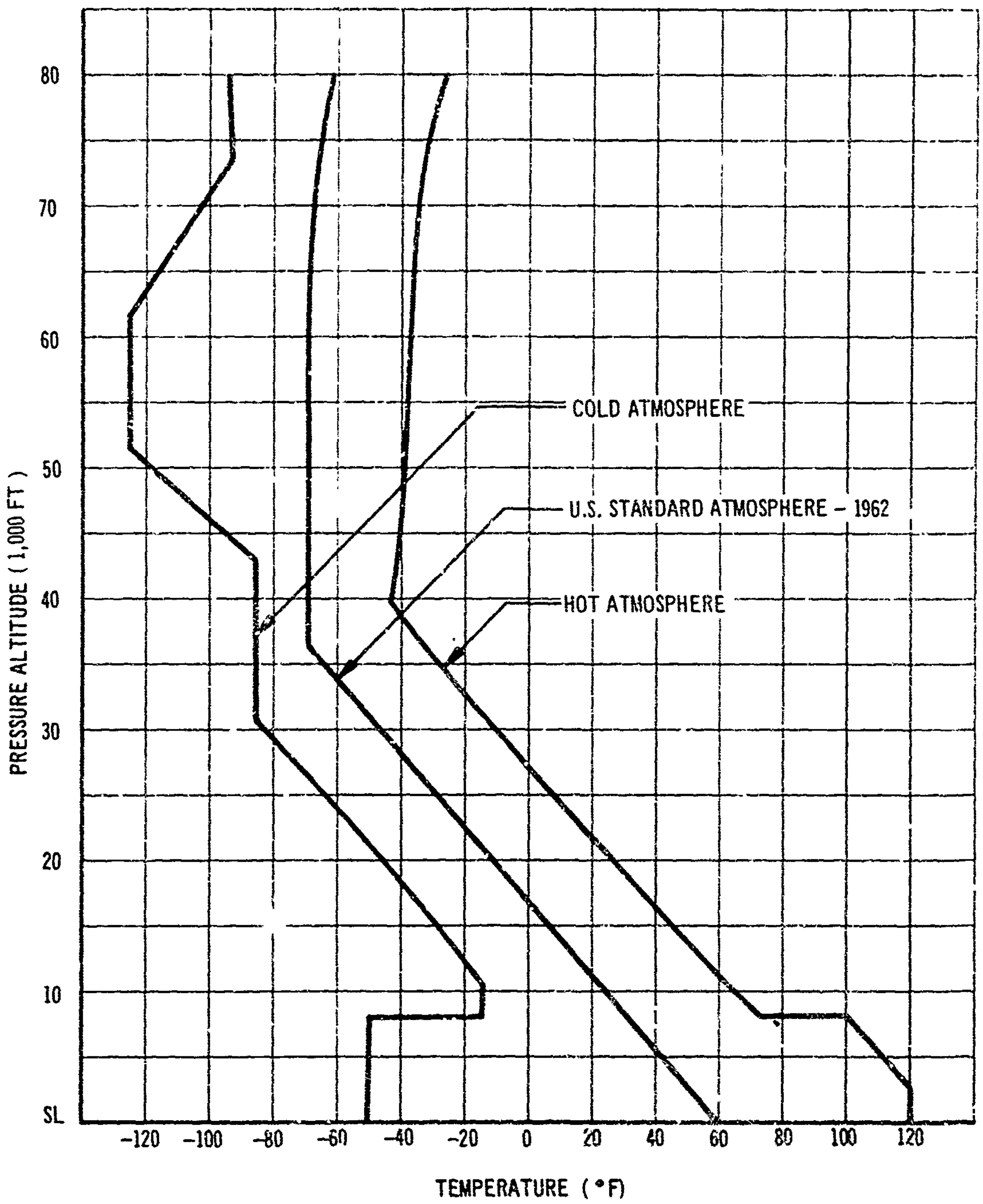


Figure 3. Flight Ambient Temperature Envelope

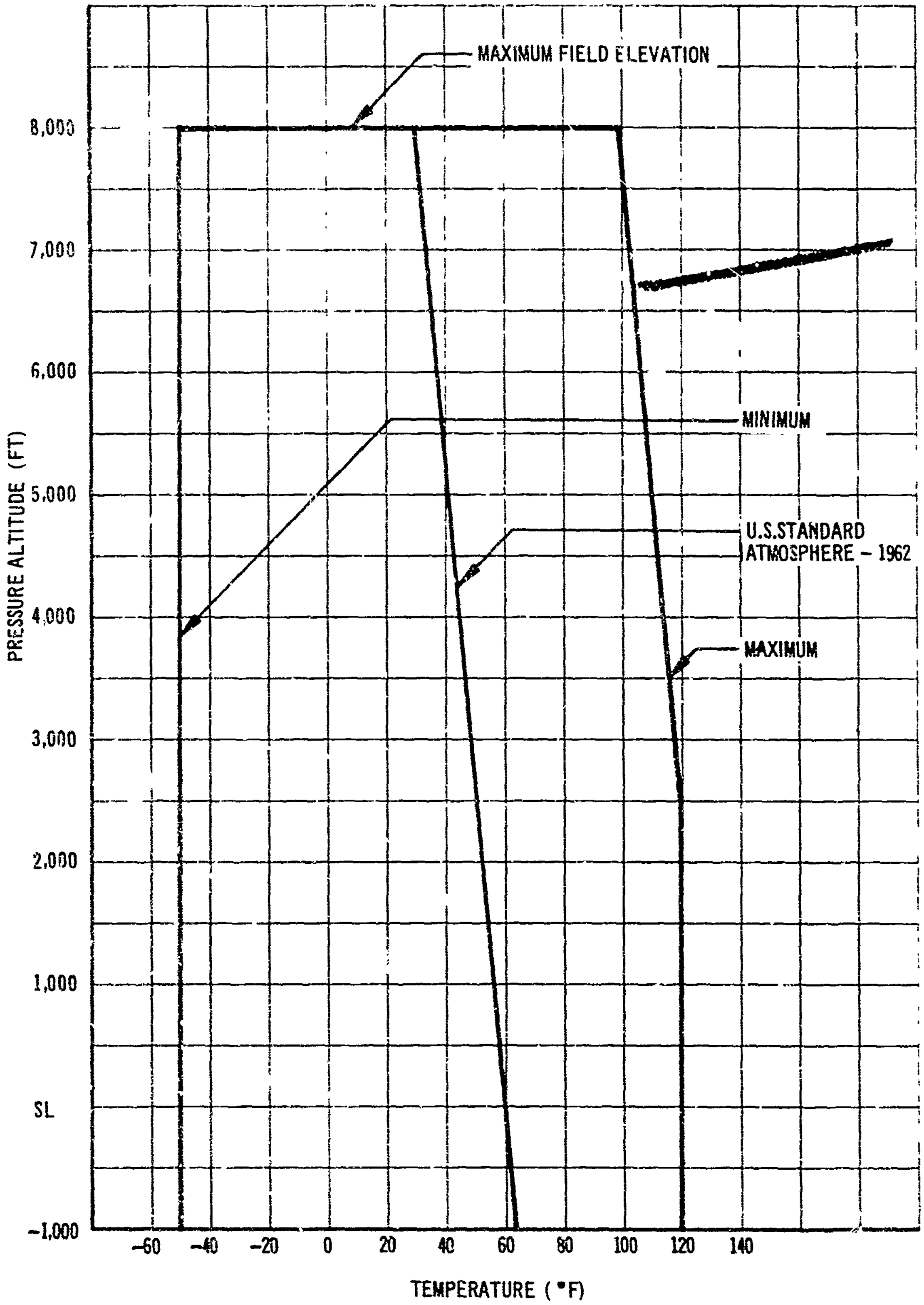


Figure 4. Ground Ambient Temperature Envelope

3.1.3.1.1 Design Inlet Temperatures
Maximum air stagnation temperature will be 500°F with an overshoot to a stagnation temperature of 590°F based on a variable ratio of specific heats for air. The stagnation temperature will not exceed 500°F for more than one minute.

3.1.3.1.2 Operating Envelope
The engine and engine systems shall function satisfactorily within the operating envelope as defined in Fig. 1.

3.1.3.1.3 Usage
The intended usage of the engine is for powering a supersonic transport aircraft.

3.1.3.1.4 Engine Nacelle Temperature
The engine and components shall perform satisfactorily during normal operation with that portion of the engine forward of the firewall surrounded by stagnant air at a maximum average temperature of 650°F. Components located at the forward half of the nacelle accessory compartment will not be exposed to more than 600°F.

3.1.4 Fuel
The engine shall function satisfactorily throughout its complete operating range for any steady state operating conditions when using only those fuels, specified in Ref. 2.2.4, with a flash point above 110°F with fuel temperature and time limits as shown in Figs. 5 and 7. When using fuel per Ref. 2.2.15, the fuel temperature and time limits are shown in Figs. 5 and 6.

3.1.5 Lubrication
The engine shall function satisfactorily throughout its complete operating range for any steady-state and transient operating condition when lubricants conforming to and having any of the variations in characteristics permitted by Ref. 2.2.5 are being used.

3.1.6 Starting
The engine shall be capable of ground starting from -1,000 ft to +8,000 ft within the ambient temperature conditions as defined in Fig. 4, subject to the fuel and lubrication limitations and torque requirements noted herein.

3.1.7 Dry Weight of Complete Engine
The dry weight of the engine shall not exceed 10,640 lb. The weight of the FTS engine shall be within 105 percent not including special test instrumentation. The engine shall include the following components:

a. Fuel system including gas generator control, duct heater control, and fuel pumps.

b. Lubrication system including oil tank, filter (strainer), and fuel/oil cooler.

c. Engine ignition system without power source.

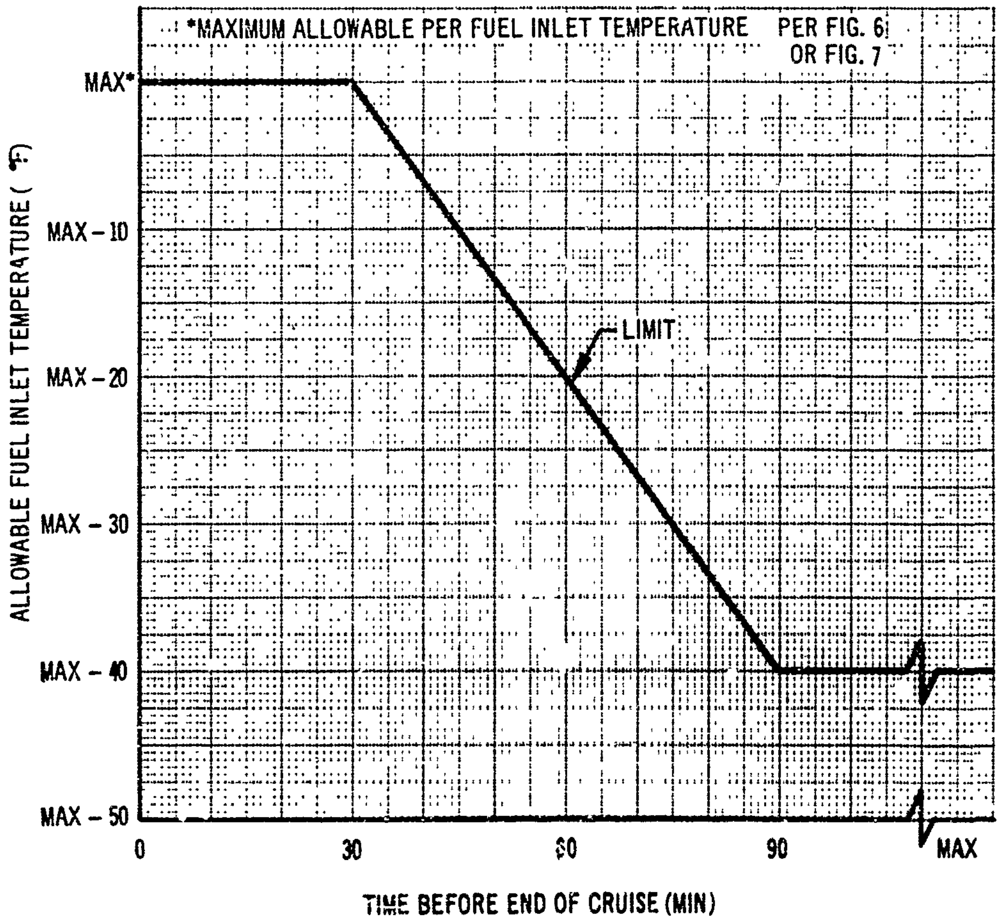


Figure 5. Allowable Time at Maximum Fuel Temperature

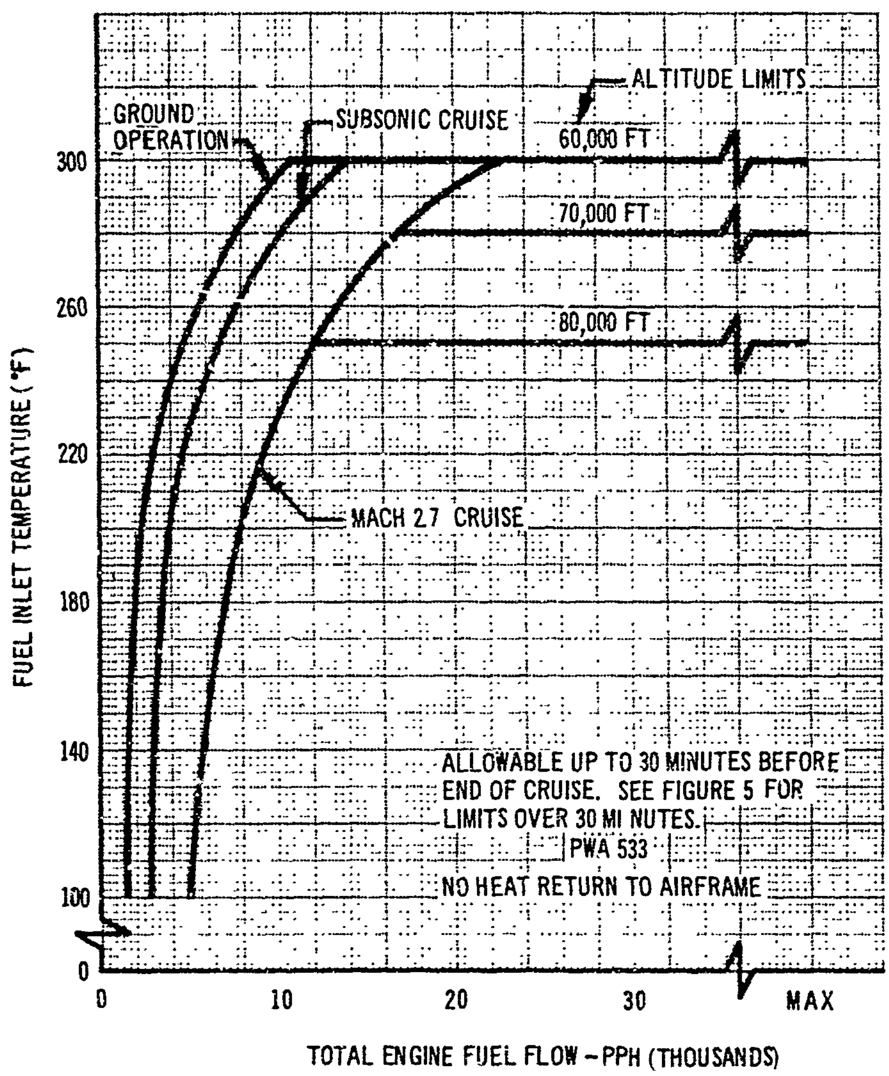


Figure 6. Fuel Inlet Temperature Limits (P&WA 533)

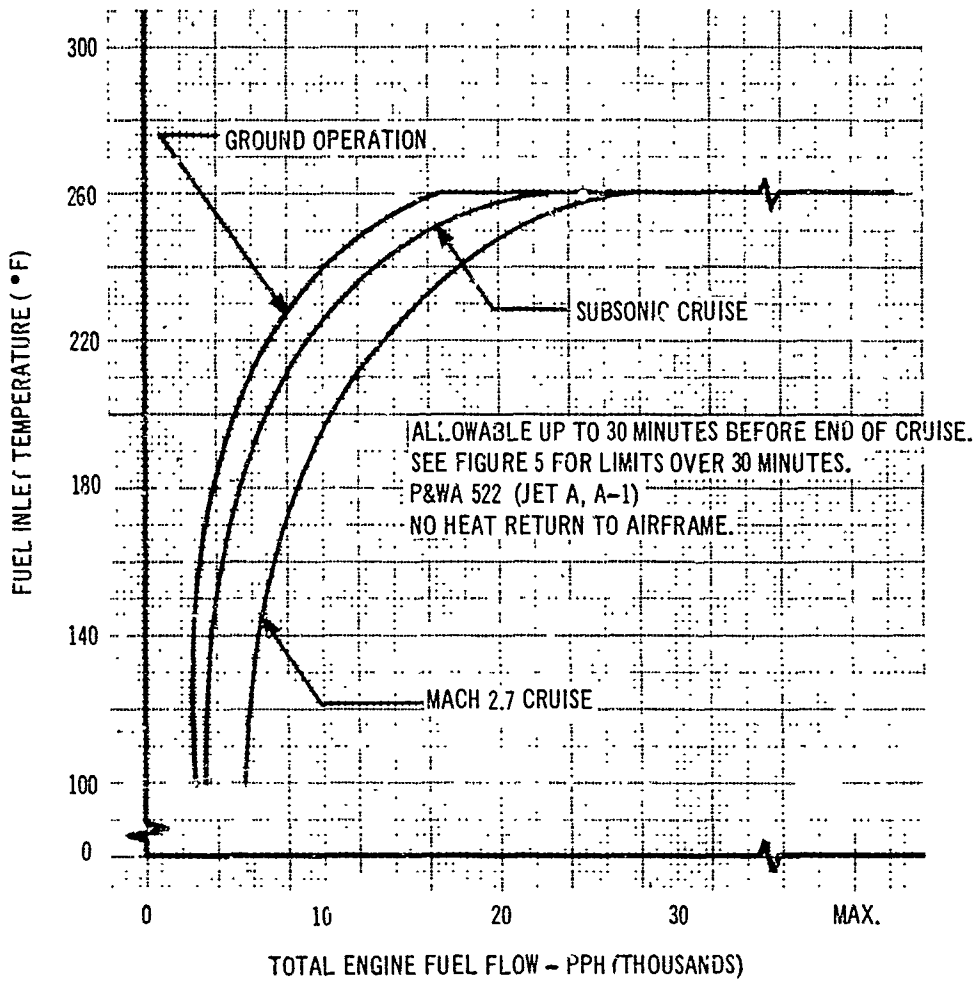


Figure 7. Fuel Inlet Temperature Limits (P&WA 522)

d. Variable area duct heater exhaust nozzle including control system.

e. Fuel inlet manifold.

f. Windmilling brake system (aerodynamic).

g. Reverser-suppressor, including control system.

h. Power takeoff provisions, including inlet hydraulic pump drive gearbox.

i. Gas generator exhaust gas temperature and pressure probes.

j. Provisions for power setting instrumentation.

k. Secondary air ducting including control system and bulkhead.

This weight (10,640 lb) does not include the weight allowance required for those brackets supplied with the engine that are to be utilized for the support of airframe equipment.

3.1.8 Useful Life
Engine parts and components shall be designed for a useful life including repair consistent with an airplane normal service life expectancy of at least 50,000 hr. Pratt and Whitney Aircraft shall undertake the design and development of improved components or parts and/or repair procedures for the components or parts, as shown to be required by airline service.

3.1.9 Time Between Overhaul (Deleted)

3.1.10 Flight Maneuvers

3.1.10.1 Attitude
The engine shall function satisfactorily under the flight attitudes defined in Fig. 8 under the following conditions:

a. Continuous operation for vertical accelerations of 0.5 to 2.0 g positive.

b. Operation for 60 sec when subjected to vertical accelerations for 0.1 to 0.5 g positive, and from 2.0 to 3.5 g positive.

c. Operation for 10 sec when subjected to vertical accelerations for 0.1 to 1.0 g negative.

d. Operation for 5 sec when subjected to 0 g condition (±0.1 g).

e. Operation for 15 sec when subjected to side accelerations from 0.5 to 1.7 g. (From either side).

f. Continuous operation when subjected to fore and aft accelerations from 0 to 0.5 g.

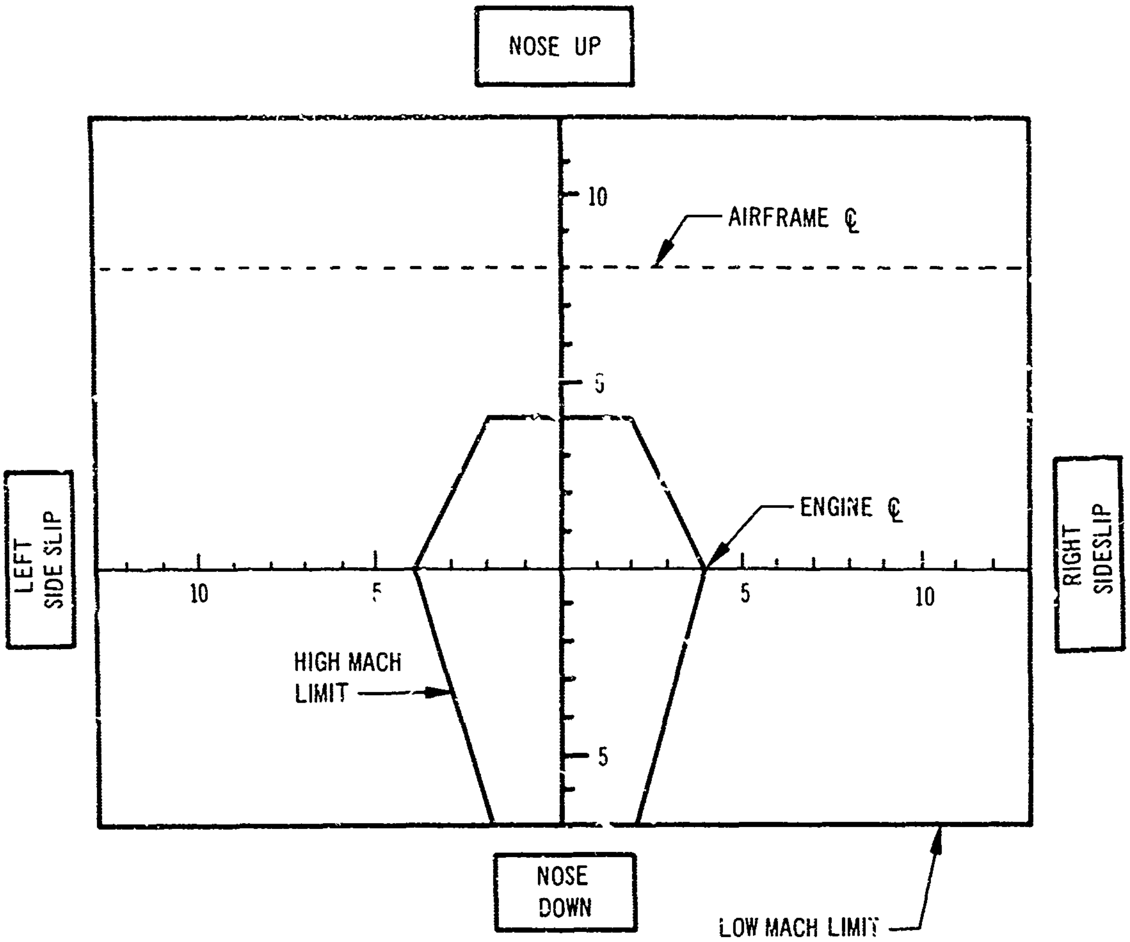


Figure 8. Engine Attitude Limits

g. Continuous operation when subjected to side accelerations from 0 to 0.5 g (from either side).

3.1.11 Connection Identification
Insofar as practical, the engine shall be permanently marked to indicate all airframe connections shown on the Installation Drawing for instrumentation, electrical, fuel, oil, and air connections.

3.1.12 External Flammable Fluid Lines
All external lines and fittings which convey flammable fluids shall be fireproof as defined in Ref. 2.1.5.

3.1.13 Containment
The engine shall be designed for rotor blade containment to meet the requirements of Par. 33.19 of Ref. 2.1.4 and shall be specified in the engine type certificate. Furthermore, the engine shall be designed to meet the engine requirements of Par. 25.903(d), Item 1 and 2 of Ref. 2.1.9 and shall be specified in the engine type certification.

3.1.14 Accessibility
Those parts of the engine requiring line [illegible] e, adjustment, checking, or replacement shall be made accessi[illegible]ardown of the engine or removal of major parts, component [illegible]ies.

3.1.15 Documentation
Pratt and Whitney Aircraft shall furnish to Boeing documentation of performance for both engine and the engine-furnished components, as an aid to Boeing in obtaining certification in accordance with the then-existing commercial Basic Agreement between P&WA and Boeing.

3.1.16 Design Changes
Pratt & Whitney Aircraft shall have the responsibility for developing detail design of the engine to reflect performance characteristics that are in accord with the general objectives and specific requirements of this agreement.

It shall be P&WA's responsibility to coordinate with the Boeing engineering design group whenever, in the course of P&WA's design activities, there is any indication that a particular design detail might be contrary to the requirements or intent of this agreement.

3.2 SPECIFIC REQUIREMENTS FOR DESIGN

3.2.1 Guaranteed Performance and Noise Control

3.2.1.1 Performance
In addition to the guaranteed calibration stand performance shown in the Engine Model Specification, the engine shall meet the flight performance points shown in Table I. Estimated performance for other flight conditions shall be included in the engine performance data deck.

3.2.1.2 Noise Control

3.2.1.2.1 Noise Levels
The noise levels generated by one engine shall not exceed the values in Table II at any point along a line parallel to and 300 ft from the axis of the engine. Measurements may be made either on the line or on an arc of 300 ft radius and corrected to the line by SAE procedures. The engine shall be in compliance with these values under the following conditions:

a. Static operation

b. P&WA bellmouth inlet

c. Production engine or accoustically similar engine

d. Standard day at sea level 59°F and 70 percent relative humidity

The prototype engines shall be considered to have met these requirements, if measured data corrected by analysis for differences between the prototype and production configuration fall within the limits of Table II.

Noise level measured as specified in Par. 3.2.1.2.1 shall not exceed the following values for the conditions stated in Table III.

Table II. Noise Level

	PNDB
Maximum augmented thrust	139
23,900 lb thrust	122
12,000 lb thrust	107*
*Exclusive of noise radiating from engine inlet.	

Pratt and Whitney Aircraft, during engine development, will have as an objective the limitation of discrete frequency noise components to a point where the sound pressure level (SPL) in any 1/3 octave band does not exceed the SPL of the random noise in that 1/3 octave band by more than 5 db.

Both P&WA and Boeing shall coordinate and keep each other informed throughout the engine development program of the status of their efforts in meeting the noise requirements.

3.2.1.2.2 Noise Prediction
Pratt & Whitney Aircraft may use Par. 2.2.6 in predicting the engine noise level. The use of this prediction system does not relieve P&WA from meeting the required noise level.

3.2.1.2.3 Engine Acoustical Environment
The engine shall be designed and constructed to function for 100 hr duration without failure in any of the engine components when operating at a noise level of 155 db.

3.2.2 Engine Bleed Air

3.2.2.1 Air-Conditioning
The engine shall provide bleed air for air-conditioning and pressurization of the passenger and crew compartments which satisfies the following requirements:

3.2.2.1.1 Quality of Bleed Air
Dirt or other foreign particle concentration in the bleed air after expansion to atmospheric pressure shall not exceed that of air at the engine inlet on a per unit volume basis.

3.2.2.1.2 Contamination
The air at the engine bleed ports shall not contain quantities of engine generated noxious, toxic or irritating substances above the maximum threshold limit values of the substances shown in Table III.

Table III. Bleed Air Contamination Limits

Substances	Parts Per Million
Carbon dioxide	5,000.0
Carbon monoxide	50.0
Carbon tetrachloride	50.0
Decaborane	0.05
Diborane	0.1
Pentaborane	0.01
Ethyl alcohol (ethanol)	1,000.0
Fluorine	0.1
Fuels, aviation	250.0
Hydrogen peroxide	1.0
Methyl alcohol (methanol)	200.0
Methyl bromide	20.0
Monochlorobromomethane	40.0
Nitrogen dioxide	5.0
Oil breakdown products (aldehydes, acrolein, etc.)	1.0
Unsym-dimethyl hydrazine	0.5

The air shall contain a total of not more than 5 mg/cubic meter of submicron particles.

3.2.2.1.3 Seals
Accessory seals, bearing seals, and oil lines shall be designed so that a single failure (except an engine bearing failure) cannot result in bleed air contamination. Pratt & Whitney Aircraft shall submit a failure analysis to Boeing to demonstrate how the design meets this requirement.

3.2.2.1.4 Quantity of Bleed Air
One bleed port as shown in Fig. 9, shall be provided to supply the bleed air for airplane usage other than anti-icing, defined in Table IV.

3.2.2.2 Inlet Anti-Icing
One bleed port as shown in Fig. 9 shall be provided to supply the bleed air for inlet anti-icing defined in Table IV.

3.2.3 Accessory Drive Power Takeoff

3.2.3.1 Accessory Drive Power Takeoff Provisions
The engine shall provide a drive pad to allow the attachment of a Boeing-furnished external shaft and a remotely located airframe accessory gear box. Accessories mounted on the gear box include the main hydraulic pumps, ac generator and speed control, coolant air fan, cabin air boost compressor and air turbine starter. The pad and power takeoff mating shaft connection serves as (a) a means to obtain power from the engine to drive the gear box and mounted accessories, and (b) a means to transmit power from the accessory gear box to the engine rotor for starting.

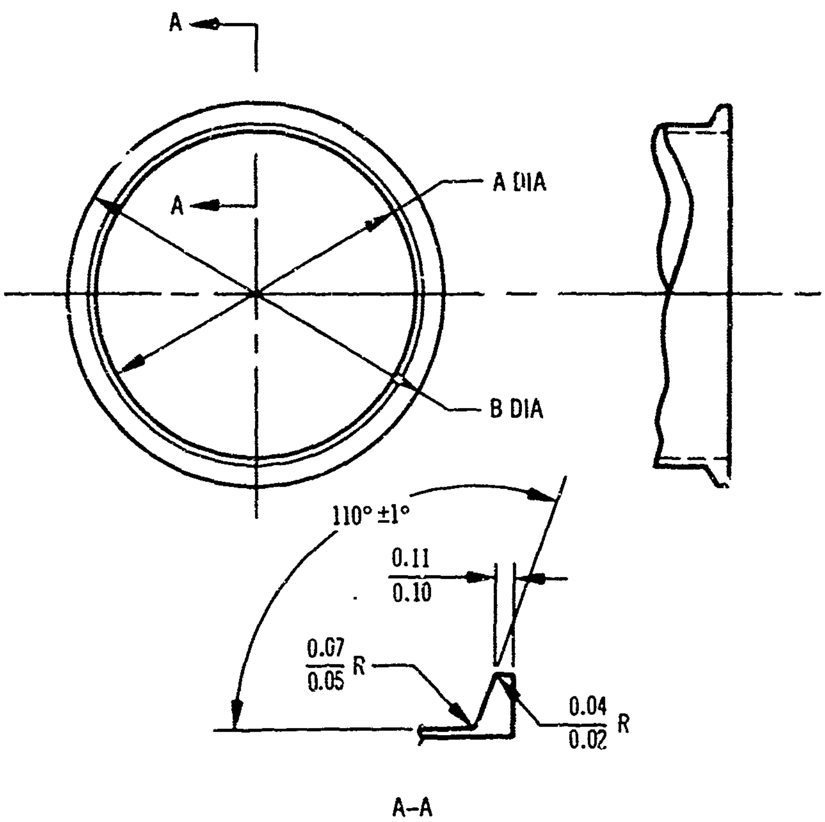
The drive pad, similar to Ref. 2.2.2 except for horsepower, shall be provided with mounting flange, location details, and direction of rotation as shown on the engine installation drawing.

3.2.3.1.1 Design Power Extraction
The drive pad shall be designed to transmit the power loads shown in Table V. The inlet hydraulic pump loads are not included in Table V; see Par. 3.2.6.1.

Cyclic load variations shall be ±10 hp at a frequency of 1 cycle per minute with the nominal continuous loads shown in Table V.

3.2.3.1.2 Engine Starting
The pad shall be designed to transmit the torque required for engine start.

3.2.3.1.3 Dynamic Loading
The drive pad shall be designed to withstand the impact load incurred when a static gearbox is connected to the pad with the engine windmilling at 1.6 percent rpm. The estimated gear box and accessories equivalent polar moment of inertia, at the PTO pad, is 40 lb-ft^2.



ENGINE BLEED PORT	DUCT O.D.	A DIA + 0.005 − 0.000	B DIA ±0.001
ENVIRONMENTAL CONTROL SYSTEM	6.00	6.03	6.69
INLET ANTI-ICE	3.50	3.53	4.19

Figure 9. Bleed Air Port Configuration

D6A:0199-1

Table IV. *Engine Bleed Air Flow Requirements*

Flight Condition	Mach Number	Altitude X 1,000 Feet	Ram Recovery	Bleed Air Requirements			Minimum Bleed Pressure Psia [1]	Maximum Bleed Temp °F
				Inlet Anti-icing Lb/Sec	Air Conditioning			
					Normal Lb/Sec	Maximum Lb/Sec*		
Ground & Climb	0 - 0.4	SL	0.98	3.0	2.1	5.30	50	1,100°F
	0.4 - 1.0	30	0.99	2.0	2.1	3.07	45	1,100°F
Climb	1.08	40	0.988		1.95	3.52	42	1,100°F
	1.35	50	0.982		1.80		40	1,100°F
	2.5	60	0.918		1.75	2.60	40	1,100°F
	2.5	70	0.918		1.65		40	1,100°F
	2.5	73	0.918		1.60	1.96	37.8	1,100°F
Descent	2.5	73	0.918		1.60	1.60	10	1,100°F
	2.5	70	0.918		1.65	1.65	10	1,100°F
	1.55	60	0.976		1.75	1.75	10	1,100°F
	1.15	50	0.987		1.80	1.80	10	1,100°F
	0.95	40	0.989	2.0	1.95	1.95	10	1,100°F
Descent & Hold	0.8 - 0.4	30	0.99	3.0	2.10	2.10	15	1,100°F
Ground	0.4 - 0	15-S.L.	0.98	3.0	2.10	2.10	20	1,100°F

* Reflects Requirement for Motoring ADS Plus Air-Condition

[1] Minimum Pressure Measured Downstream of the Engine Bleed Port

3.2.3.1.4 Power Takeoff Shaft Rotation
Shaft speed shall be 8,000 ±200 rpm with the engine rotor at 100 percent rated rpm. Direction of shaft rotation shall be clockwise when viewing the engine PTO pad.

3.2.3.1.5 Shear Section
Any shear section provided by P&WA shall be designed to shear at a torque of not less than 1,580 ft-lb.

3.2.3.1.6 Mounting Flange and PTO Shaft Loads
The gear box and accessories will be supported from the aircraft structure. However, the pad will be subjected to and shall be designed for an overhung moment of 1,000 in-lb incurred through angular and axial deflection of external shaft.

3.2.3.1.7 Lubrication
The pad and spline shall be lubricated by the engine lubrication system.

3.2.3.1.8 Windmilling Power
A windmilling engine at 1,160 rpm shall supply an estimated 65 hp at the PTO pad under the following conditions:

a. Sea level altitude

b. Standard day temperature

c. 200 kn equivalent air speed

d. 1.06 ground pressure ratio

Table V. Horsepower Extraction

Operation	Duration	Engine Speed		
		100% rpm	Ground Idle (54% rpm)	Flight Idle* (68% rpm)
Continuous		550 hp	265 hp	465 hp
Intermittent	4 min/hr	647 hp	442 hp	660 hp
	1 min/hr	1,035 hp	613 hp	832 hp
Maximum	10 sec/100 hr	1,090 hp	665 hp	885 hp

* Flight idle shall not exceed 7 min/hr average.

3.2.3.2 Mass Moment of Inertia of Rotating Parts
The effective mass moment of inertia of the low-pressure rotor about its axis is 30.0 slug-ft^2. The effective mass moment of inertia of the high pressure compressor-rotor about its axis is 21.5 slug-ft^2.

The effective mass moment of inertia of the engine masses to be driven through the accessory power takeoff during engine starting is 22.5 slug-ft^2 based on a pad-rotor gear ratio of 0.997:1.

3.2.4 Engine Mounting
Mounting provisions shall be provided to support the engine and inlet as defined in Fig. 10. Mounting point locations and allowable loads shall be shown on the Installation Drawing.

3.2.4.1 Design Load Factors
The engine mounting points shall be designed for ultimate load factors not less than the following for the propulsion pod. The engine supports shall withstand 2/3 of the ultimate design loads as shown in Table VI without permanent deformation. The engine shall be designed to operate satisfactorily under 2/3 of the vertical, side, and thrust loads of Table VI and a pitch and yaw rate of 1 rad/sec and 0.5 rad/sec respectively.

3.2.4.2 Supersonic Inlet Provisions
The engine compressor case shall provide 8 point support for an interchangeable supersonic inlet as defined on the Engine Installation Drawing.

3.2.4.2.1 Engine Inlet Flange Design Loads
The ultimate design loads for the engine forward flange are defined in Fig. 12. The flange shall withstand the specified loads without failure and 2/3 the specified loads without permanent deformation.

3.2.5 Ground Handling Attachments
Mounting provisions shall be provided on the engine for support of the engine on ground equipment or for attachment of hoisting equipment. These attach points shall be readily accessible without removal of any engine components. The location and dimensions shall be as shown on the Engine Installation Drawing.

The ground support attachments shall be designed for an ultimate load of at least 5 times the weight of the complete engine pod.

These support points shall be independent of the normal flight support points. They shall be usable with the flight support links installed.

3.2.6 Engine Aircraft Accessory Provisions

3.2.6.1 Inlet Hydraulic Pumps
Two drive pads in accordance with Ref. 2.2.1 shall be provided on the engine for mounting hydraulic pumps. The maximum drive speed shall be 5,000 rpm, (including the projected maximum engine growth). The minimum torque required is 1,100 in lb. The maximum continuous power to be delivered by both pads shall be a total of 35 hp. During flight conditions when the inlet is started

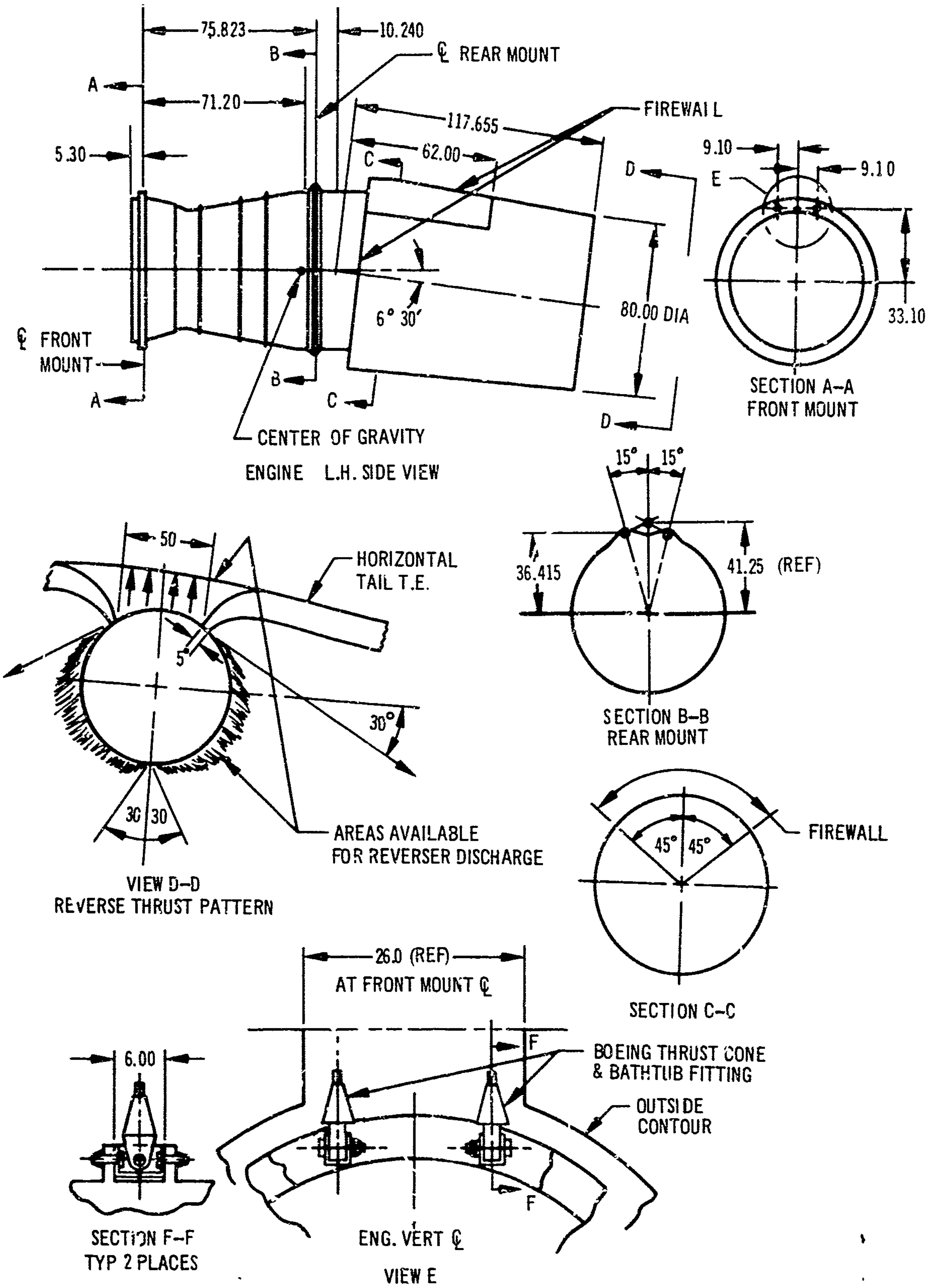


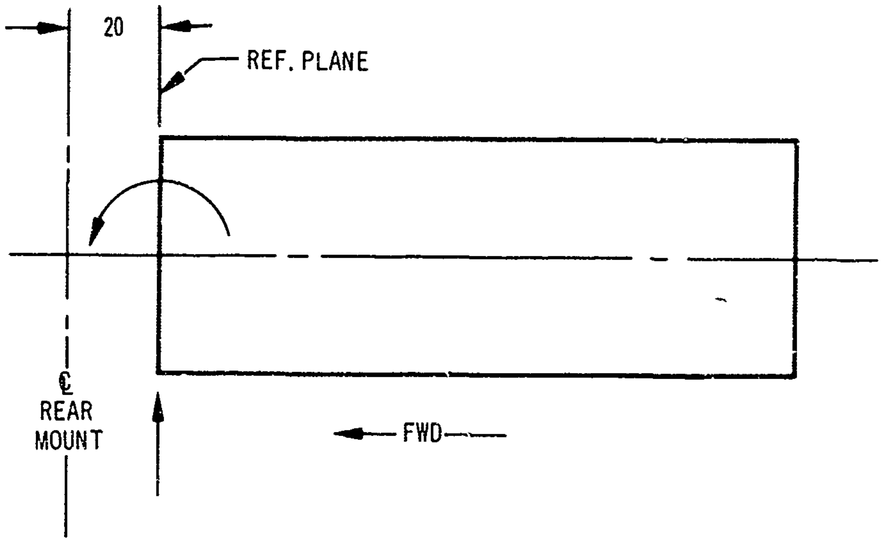
Figure 10. Engine Configuration

Table VI. Design Load Factors

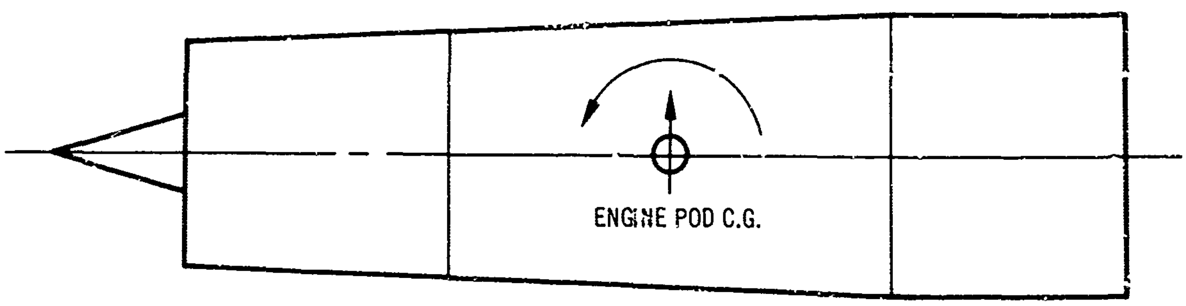
Condition	
1	6.0 V — Landing
2	-4.0 V — Landing
3	6.0 V + 1.5 T_M — Supersonic maneuver
4	-4.0 V + 1.5 T_M — Supersonic maneuver
5	3.0 T_M + 3.0 V
6	3.0 T_M
7	+2.5 S — Maneuver
8	-2.5 S — Maneuver
9	M_Y + 1.5 V + 1.5 T_M — Gyroscopic
10	-M_Y + 1.5 V + 1.5 T_M — Gyroscopic
11	M_P + 3.75 V + 1.5 T_M — Gyroscopic
12	-M_P + 3.75 V + 1.5 T_M — Gyroscopic
13	Aero (S) + 1.5 T_M — Supersonic maneuver
14	- Aero (S) + 1.5 T_M — Supersonic maneuver
15	1.5 T_M + Aero (T) — Transonic maneuver
16	1.5 T_M - Aero (T) — Transonic maneuver
17	9.0 D — Wheels-up landing
18	-6.0 D — Ditching
19	+3.0 T_R + 3.0 V
20	M_R — Engine-seizure

V = Wt of propulsion pod acting vertically
S = Wt of propulsion pod acting laterally
D = Wt of propulsion pod acting forward
T_M = Maximum engine thrust
T_R = Maximum engine reverse thrust (0.7 max. dry thrust)
M_Y = Gyroscopic yawing moment (due to airplane pitch rate of 2.25 rad/sec.)
M_P = Gyroscopic pitching moment (due to airplane yaw rate of 3.00 rad/sec.)
M_R = Roll moment due to engine seizure (see Par. 3.2.3.2 for magnitude)
Aero (S) = Loads due to external dynamic forces (supersonic) (see Fig. 17 for magnitude)
Aero (T) = Loads due to external aerodynamic forces (transonic)

NOTE: Weight of the propulsion pod is equal to the basic engine + 3,300 lb.

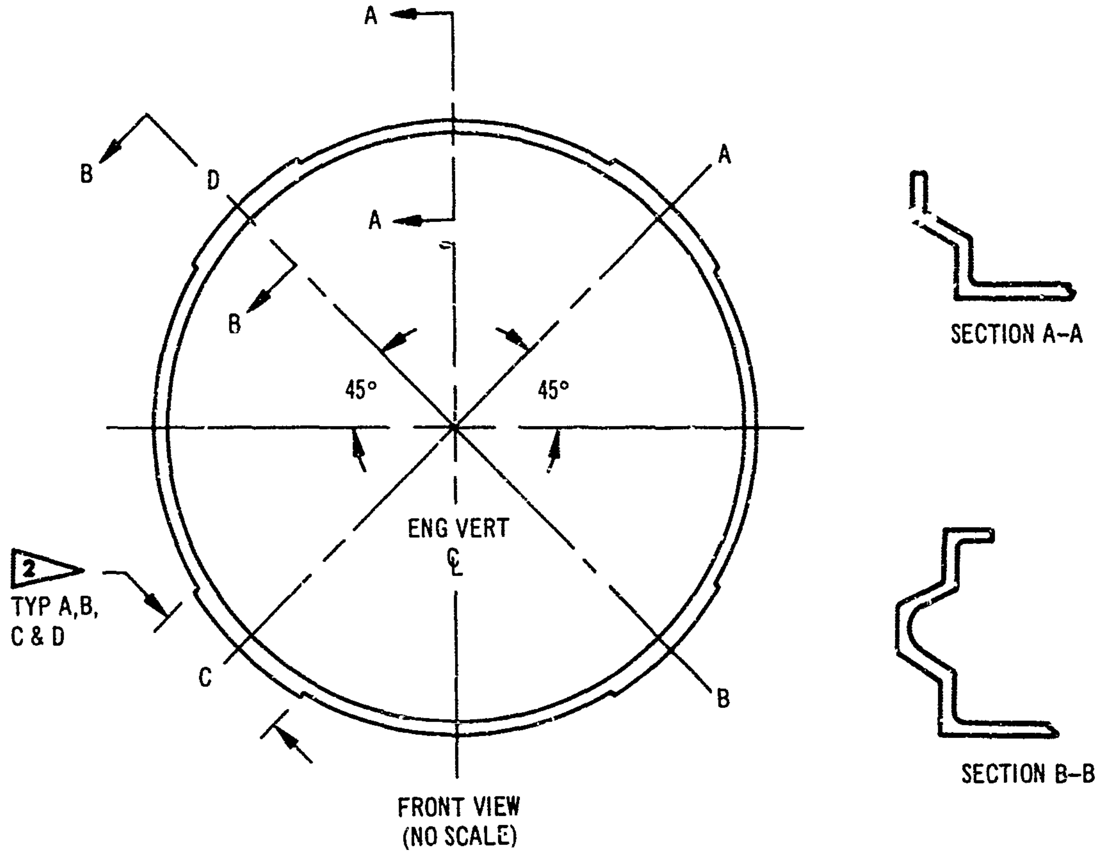


PART	LOAD DESCRIPTION	MAGNITUDE
EXH SYS	SHEAR DUE TO AERODYNAMIC SIDELOAD	5,700 LB
	BENDING DUE TO AERODYNAMIC SIDELOAD	300 IN KIP
	SHEAR DUE TO AERODYNAMIC VERT LOAD	3,800 LB
EXH SYS	BENDING DUE TO AERODYNAMIC VERT LOAD	200 IN KIP



RESULTANT LOAD ACTING AT ENGINE POD C.G.	MAGNITUDE (MAX)
AERODYNAMIC SIDELOAD ON ENTIRE POD	33,500 LB
MOMENT DUE TO AERO. SIDELOAD ON ENTIRE POD	3,390 IN KIP
AERODYNAMIC VERTICAL LOAD ON ENTIRE POD	22,300 LB
MOMENT DUE TO AERO. VERTICAL LOAD ON ENTIRE POD	2,260 IN KIP
ROLL MOMENT DUE TO ENGINE SEIZURE	820 IN KIP

Figure 11. Engine Mounting System Loading



SUPERSONIC INLET LOADS	MAGNITUDE
AXIAL THRUST DUE TO EXPULSION LOADS [1]	80,400 LB
SHEAR DUE TO AERODYNAMIC SIDELOAD	25,700 LB
BENDING DUE TO AERODYNAMIC SIDELOAD [1]	2,570 IN KIP
SHEAR DUE TO AERODYNAMIC VERT LOAD	17,100 LB
BENDING DUE TO AERODYNAMIC VERT LOAD [1]	1,715 IN KIP

[1] REACTED AT POINTS A,B,C & D ONLY

[2] LOAD CONCENTRATIONS AT NOTED POINTS MAY BE DISTRIBUTED OVER 2 BOLTS

Figure 12. Compressor Front Flange Loading

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the maximum power to be delivered by both pads shall be a total of 160 hp (80 at each pad). Pad locations are defined in Fig. 13. Drive data shall be shown on the Installation Drawing. The pump outline is shown in Fig. 14. The accessory power takeoff pad loads are given in Table V.

3.2.6.1.1 Pad Lubrication
The pad and spline shall be lubricated per Par. 3.2.10.2.

3.2.6.2 Rotor Speed
A drive pad shall be provided to mount the Boeing-furnished tachometer generator to provide N_2 RPM. An electrical pickup connection shall be provided to give N_1 rotor speed indication. These provisions shall be defined on the Engine Installation Drawing.

3.2.7 Engine Exhaust and Reverser
The engine shall be furnished with an exhaust system including forward thrust nozzle system and thrust reverser.

3.2.7.1 Variable Area Divergent Ejector Nozzle
The exhaust nozzle system shall include the required actuators and linkages.

The boattail angle at installed flight conditions shall be coordinated with Boeing.

3.2.7.2 Reverse Thrust
The engine shall be capable of satisfactory operation on a standard sea level day, with the reverser in either the forward thrust position, or full reverse position.

The net effective reverse thrust shall be in accordance with Table I. The reverse gas flow pattern shall be in accordance with Fig. 10. The thrust reverser operation shall be controlled by the basic engine power control system. The thrust reverser shall incorporate a position indicating transducer.

3.2.7.2.1 Reversing Time
The time required to change the engine power setting from maximum dry forward thrust to maximum reverse thrust is specified in Par. 3.2.19.5.

3.2.7.2.2 Reverser Safety Interlock
The reverser shall incorporate a safety interlock with the power control such that:

a. Power cannot be increased in the forward thrust lever regime, unless the reverser is in the forward thrust position.

b. Power cannot be increased in the reverse thrust lever regime, unless the reverser is in the full reverse position.

c. In the event that, at any power condition, the reverser should depart from the position dictated by the thrust lever position the engine power shall be reduced to idle.

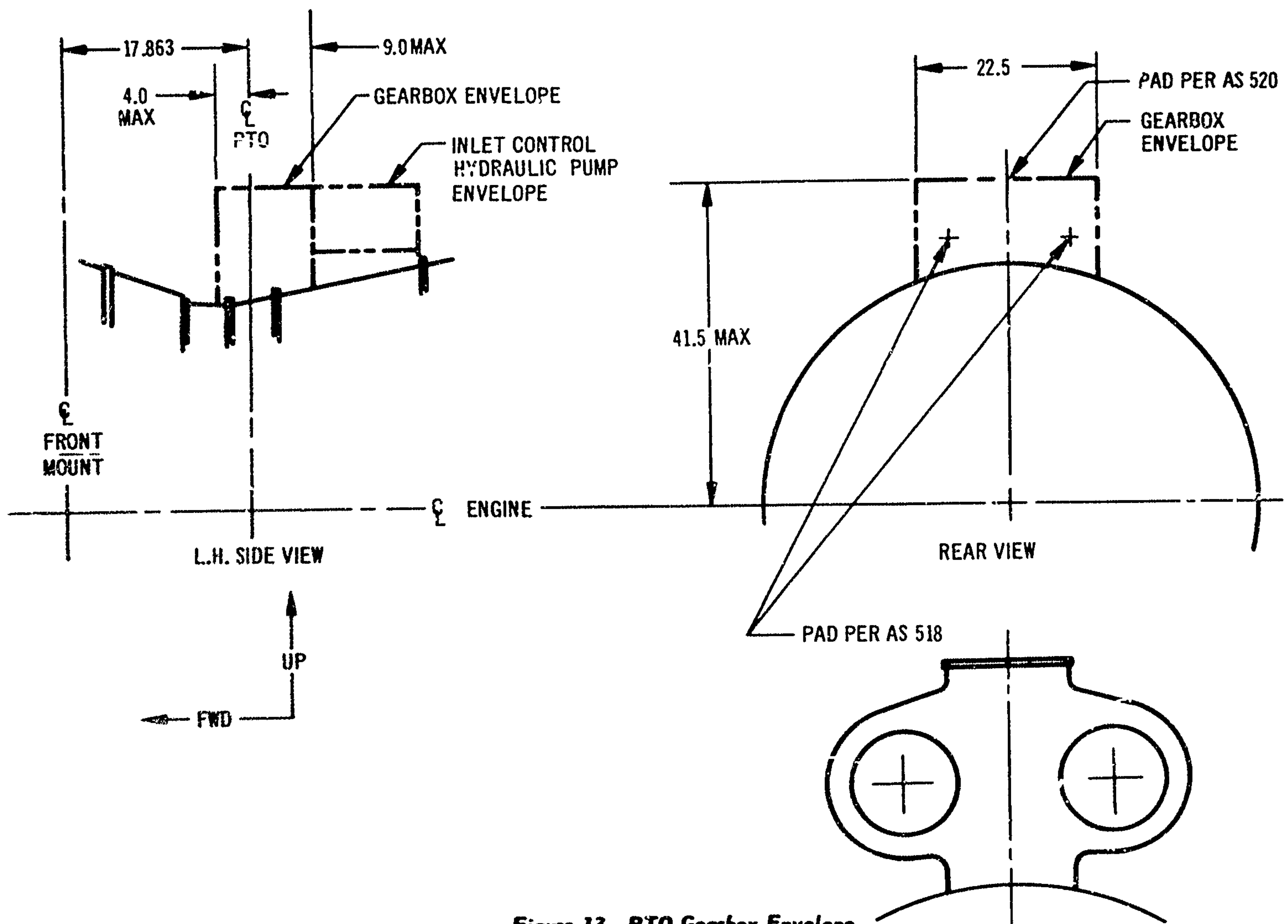

Figure 13. PTO Gearbox Envelope

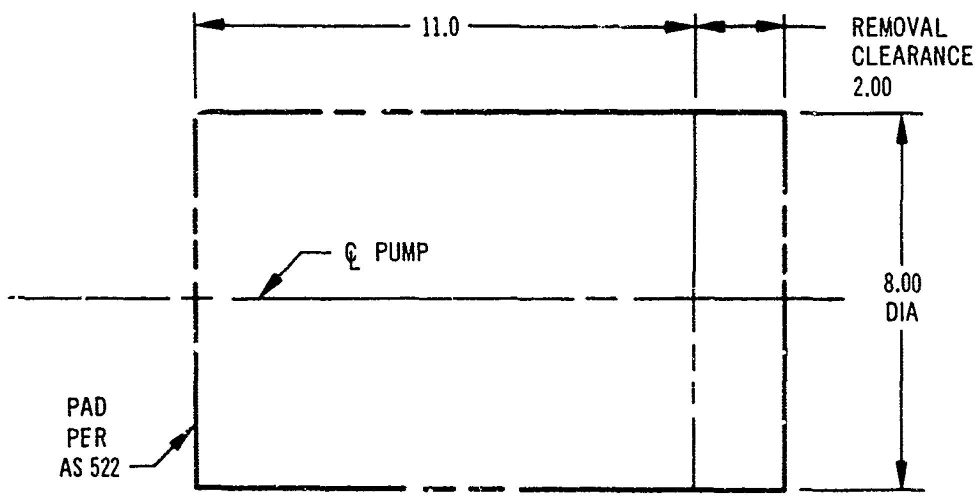

Figure 14. Inlet Control Hydraulic Pump Envelope

3.2.7.3 Measurement of Exhaust Gas Temperature
The engine shall be equipped with the thermocouple probes for measurement of turbine exhaust gas temperature. The thermocouples shall permit consistent measurement of average exhaust gas temperature.

3.2.7.4 Exhaust System Mounting Flange Loads
The ultimate aero design loads for the engine aft flange are defined in Fig. 11.

The flange shall withstand the specified loads without failure and 2/3 the specified loads without permanent deformation.

3.2.8 Engine Control Systems
The engine control systems shall include all control units required for proper and complete control of the engine.

3.2.8.1 Thrust Modulation
The relationship between engine thrust and thrust lever position shall be free of abrupt changes except as it is affected by augmentation and engine bleed. The variation of thrust versus power lever travel shall be per Fig. 15.

3.2.8.2 Starting Procedure
The normal starting procedure shall be simple and shall not require excessive pilot skills. With the power control in the idle position and energizing the ground start switch, movement of the fuel shut off control to the "run" position shall provide for ground and air starting and satisfactory acceleration to idle operating conditions.

3.2.8.3 Power Control
A single, separate control shall be provided on the engine to modulate thrust throughout the entire schedule defined by Fig. 15. The attachment for the airframe control system shall include a push-pull ratchet requiring 5 in. of linear motion.

The power control shall contain features that preclude any thrust lever creep in either the direction of increased or decreased engine rpm. Neither the control system nor throttle shall be self-energizing in any direction.

The power control system shall be provided with a rig pin, or equivalent to locate the engine components at the idle position and at a partial power position. In addition to the rigging stops, a protractor or scale and pointer shall be provided on the fuel control shaft to indicate the angle of movement and the major thrust settings.

The power control system shall incorporate provisions for rigging pins or other positive means of rigging engine furnished linkages.

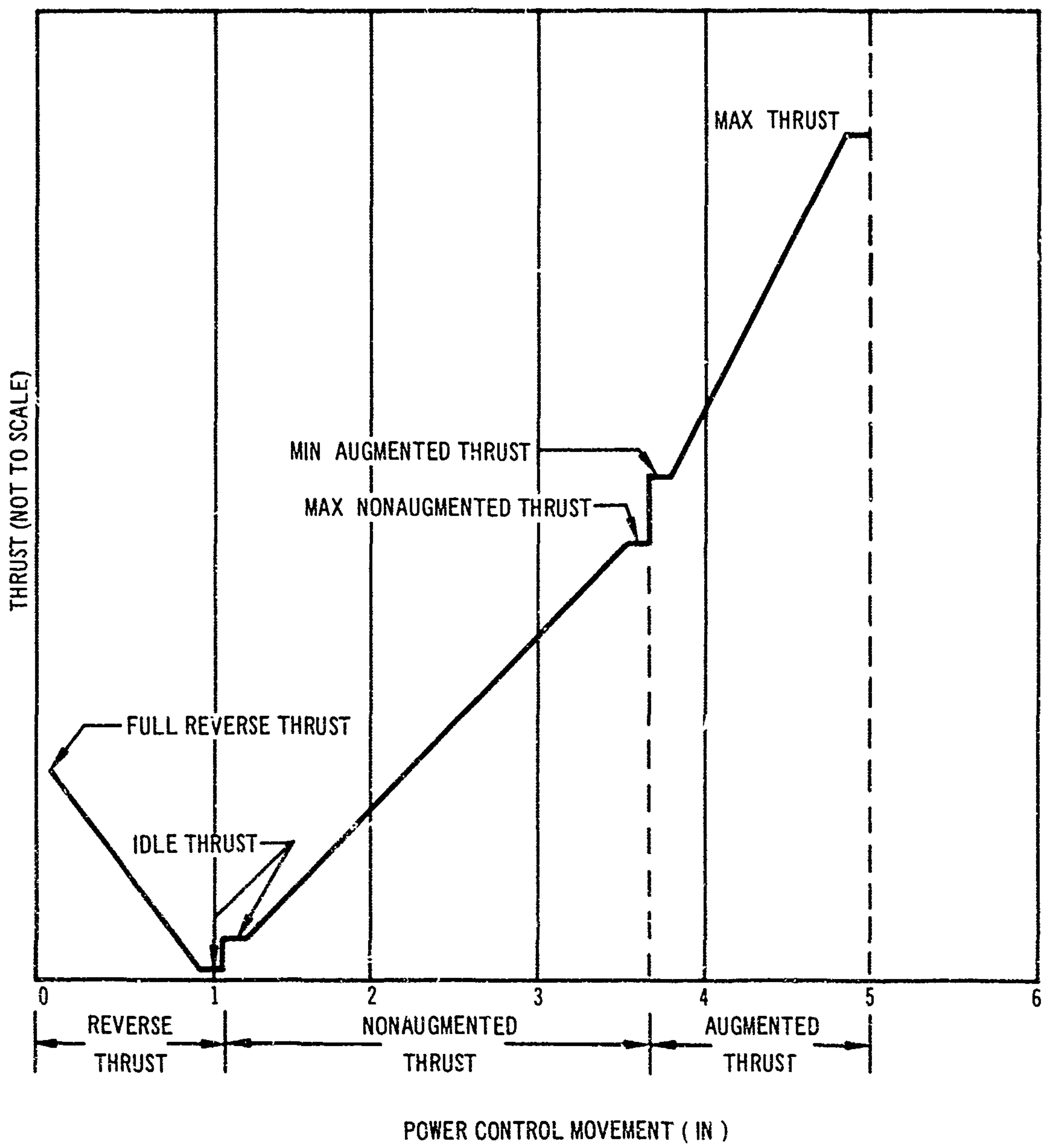

Figure 15. Power Control Schedule

3.2.8.3.1 Fuel Shutoff Lever

A single lever shall be provided to control the fuel shutoff, arm the windmill brake, and position secondary air valves as follows:

Mode	Arc of Travel
Pretravel —	0 - 20°
a. Shutdown — aerodynamic brake armed. actuator fuel shutoff.	20 - 35°
b. Run — fuel on flat.	35 - 55°
c. Secondary air — actuate secondary air valves	55 - 70°
Overtravel —	70 - 90°

The control shall incorporate provision for a rigging pin or other positive means for indexing the lever at the 10 and 80 deg positions. In addition to the rigging stops, a protractor or scale and pointer shall be provided to indicate the angle of movement and the major mode settings.

3.2.8.3.2 Engine Controls Maximum Operating Force

With the engine operating normally, the maximum force required to operate the engine power control throughout its range of travel shall not exceed 16 lb measured at the control's external attachment point. It shall not exceed 22 lb at any time throughout the service life of the control. The maximum torque required to operate the fuel shutoff lever throughout its range of travel shall not exceed 20 in lb measured at the control's external attachment point.

With the engine running, the values noted above shall apply throughout the engine starting and operating temperature range.

3.2.8.3.3 Engine Control System Design Loads

In the power control system, the engine power control shaft and the engine supplied linkage for the power control system shall neither bind nor take permanent deformation when an axial load of 1,000 lb is applied at the airframe attachment. The engine power control shaft and engine supplied linkage shall be designed to withstand 1.5 times the above load without failure. The fuel shutoff lever shall neither bind or take permanent deformation when a maximum torque of 500 in lb and a bending moment of 250 in lb is applied at the airframe attachment. The shaft shall be designed to carry 1.5 times the above loads without failure.

3.2.8.4 Control System Adjustments
External adjustments to the controls shall be limited to adjustments which can be made correctly with the engine assembled and with reference only to the operating characteristics of the engine. The external adjustments shall include at least the following:

a. Maximum engine fuel flow

b. Idle speed

c. Duct heater fuel flow

d. Cruise airflow

3.2.8.5 Exhaust Gas Temperature Trim
A remote engine fuel control adjustment is provided which permits adjustment of exhaust gas temperature within limits as required. A 200 volt electrical connector shall be provided on the engine for the control of EGT from the flight deck.

3.2.9 Engine Fuel System

3.2.9.1 Fuel System Pressure and Temperature
When the airframe fuel system shutoff valves are closed, the engine fuel system shall not be damaged by a sustained fuel pressure of 170 psig applied to the inlet connection with the engine shut down. The engine fuel shutoff valve can be in either the closed or open position.

3.2.9.2 Fuel Recirculation
The recirculation system shall be such that no fuel is returned to the airframe when engine fuel inlet temperatures are within the limits shown in Figs. 6 or 7.

3.2.9.3 Performance with Assistance from Airplane Boost Pump
The engine fuel system shall supply the required amount of fuel at the required pressures for satisfactory operation of the engine throughout its complete operating range (for cold starting limits, see Par. 3.2.17.4) with the following conditions at the fuel inlet connection on the engine:

a. Minimum fuel temperature of -50°F or 10°F above the fuel's freeze point whichever occurs first.

b. Fuel pressure — from true vapor pressure of the fuel plus 5 psi to 50 psig with a vapor liquid (V/L) ratio of zero.

3.2.9.4 Performance With No Assistance from Airplane Boost Pump
For emergency operation, the engine shall operate for the time periods and conditions listed below:

a. True vapor pressure of the fuel 0.25 psi maximum.

b. Fuel temperature of 140°F.

c. Ambient air temperature at standard day conditions.

Condition	Power	Altitude Feet	Mach No.	Time Hr	Fuel Pressure At Inlet Connection (psia)
1	Maximum Augmented	0-8,000	0 to 0.3	0.03	4.65 below ambient
2	Maximum Dry	0-15,000	0.45 at SL 0.60 at 15,000	0.03	3.75 below ambient
3	Part Power	36,150	0.8	4.00	1.3 below ambient
4	Idle	0-73,000	0 to 2.7	0.50	0.20 below ambient

The engine fuel system shall be capable of priming itself and starting within 5 min after a 10 sec fuel starvation when subjected to the following conditions:

a. Dry lift of 2 ft

b. 20,000 ft fuel tank altitude

c. 140°F fuel temperature

d. A fuel line volume of 14 U.S. gal maximum between the fuel pump inlet and the fuel pump supply.

e. Fuel per Par. 3.1.4 with a maximum of 0.25 psi tvp.

3.2.9.5 Ground Starting and Idle
The engine fuel system shall supply the required amount of fuel at the required pressure for satisfactory operation for ground starting and idle with 178°F fuel at the engine inlet connection at 0.20 psi below ambient pressure.

3.2.9.6 Fuel Filters
If a filter(s) is required, it (they) shall be a part of the engine, and shall be of sufficient capacity to permit a cumulative fuel flow equivalent to a minimum of 10 hr of engine operation at maximum fuel flow with fuel contamination as specified in Ref. 2.1.11 without being cleaned. Main flow filters shall be provided with an integral bypass for attaching instrumentation to determine when the filter is clogged or is bypassed.

A drain plug with locking provisions shall be installed to permit as complete drainage as possible of the filter case.

3.2.9.7 Fuel System Icing
The engine fuel system shall operate satisfactorily when supplied with 0°F fuel containing the amount of water equal to 80°F saturated fuel plus 0.75 cc of water per gal.

The detail parameters affecting fuel heating rates will be defined at a later date and will be used to determine the need for either a larger filter or a manually controlled fuel heater. If required, this item will be negotiated with P&WA.

3.2.9.8 Fuel Flowmeter
Provisions shall be made for installing a Boeing furnished fuel flowmeter(s) in an ice free section of the engine fuel system where the total engine fuel flow can be measured.

3.2.9.9 Fuel Temperature Sensors
Provisions shall also be made for installing Boeing furnished temperature sensors at the engine fuel inlet connection.

3.2.9.10 Fuel Resistance
The materials and designs used in the engine fuel system and components shall be satisfactory when tested with Ref. 2.2.4 test fluids.

3.2.9.11 Salt Water Resistance
The functioning of the engine fuel system shall not be adversely affected by the presence of salt water in the fuel to the extent specified in Ref. 2.1.11.

3.2.10 Engine Lubrication System

3.2.10.1 Lubricating System
The lubricating system shall use engine oil per Ref. 2.2.5 and shall adequately lubricate the engine throughout its operating range. The complete oil system shall be engine mounted, including oil reservoir and fuel oil coolers, and shall be furnished as component parts of the engine lubricating system. The fuel oil coolers shall be adequate to meet the complete and total engine oil cooling requirement throughout the operating range of the engine.

3.2.10.2 Drive Pad Lubrication
All drive pads, including spline surfaces, on the engine which are capable of transmitting more than 0.5 hp shall be pressure lubricated by the main engine lubrication system.

3.2.10.3 Oil Quantity
The oil reservoir shall contain usable oil sufficient for a minimum of 10 hr of engine operation at the maximum allowable consumption rate given in Par. 3.2.10.3.1. The reservoir shall provide a port per AND. 10050-28 for installation of a transmitter for a remote indicating oil quantity system. The reservoir shall be of fireproof construction.

3.2.10.3.1 Oil Consumption
The engine oil consumption shall not exceed 2.0 U.S. pints per hr. This maximum value applies to the engine thrust range from idle to maximum continuous thrust.

3.2.10.4 Oil Filling
The basic engine shall be furnished with a pressure fill system and gravity fill port, with a dipstick for checking oil level.

3.2.10.5 Oil Pressure
Provisions shall be made for installing a Boeing-furnished oil pressure transmitter and a Boeing-furnished low oil pressure warning switch.

3.2.10.6 Oil Temperature
Provisions shall be made for installing a Boeing-furnished oil temperature transmitter.

3.2.10.7 Oil Filter
The basic engine shall be furnished with a sufficient capacity oil filter incorporating an integral bypass with provisions for attaching instrumentation to determine when the filter is clogged or is bypassed.

3.2.11 Engine Drain System

3.2.11.1 Leakage and Drains
For normal operation, there shall be no liquid leakage from any part of the engine except at drains provided for this purpose. Provisions shall be made for automatically clearing the combustion areas of combustible fluids after each false start and for preventing excessive amounts of combustible fluids from entering the combustion areas after shutdown within the engine attitude envelope shown in Fig. 8. Provisions shall also be made for clearing all vent areas and other pockets or compartments where combustible fluids may collect during or subsequent to operation of the engine. The drain system shall be part of the basic engine.

3.2.11.2 Drain Tank
A drain tank shall be provided on the engine to collect leakage from engine accessory pad drains and to collect the fuel discharged from the fuel manifold and combustion chamber during start or shut-down. The tank shall have a minimum capacity for one normal shut-down and two false starts. Ports per AND 10050 shall be provided for both overflow and vent connections. The shape and location of the tank and size and location of the ports shall be coordinated with Boeing. The tank shall be of fireproof construction.

3.2.11.3 Drain Ejector
An ejector shall be incorporated into the engine to discharge the contents of the drain tank into the engine exhaust system. An ejector connection shall be provided on the engine for a cowl drain-line which will be coordinated after design details have been resolved. The engine breather shall be vented by P&WA.

3.2.12 Engine Electrical System

3.2.12.1 External Electrical Power
The external electrical power requirements shall not exceed:

a. Ignition (main)	7 amps maximum, 200 volts ac 400 Hz, single phase
b. Ignition (duct heater)	7 amps maximum, 200 volts ac 400 Hz, single phase
c. Fuel control trim motors	3 amps, 200 volts ac 400 Hz, single phase
d. Nozzle position indicator	3 amps, 200 volts ac 400 Hz, single phase
e. Switches	Rated at 250 ma/switch 200 volts, 400 Hz

3.2.12.2 Ignition System
The engine ignition system shall be defined on the installation drawing.

3.2.12.3 Ignition Proof
All external electrical components shall be explosion-proof to prevent ignition of any explosive mixture surrounding the component.

3.2.12.4 Connectors and Cable
With the engine stabilized at a temperature of -50°F, it shall be possible to connect or disconnect electrical connectors and to flex electrical conductors, as necessary for routine maintenance, without damage to these items.

3.2.12.5 Emergency Electrical Power
In the event of loss of external power while in operation, the engine shall be electrically self-sufficient. At all engine speeds from maximum nonaugmented to idle, the engine shall continue to operate safely. Supersonic inlet anti-icing and other systems not critical for operation, may be inoperative. Duct heater relight not required under this condition.

3.2.12.6 Electrical and Electronic Interference
No electrical or electronic components shall cause interference beyond the limits specified in Figs. 16 through 19. The components shall not be susceptible to interference generated by other electrical and electronic sources within the limits specified in Table VII.

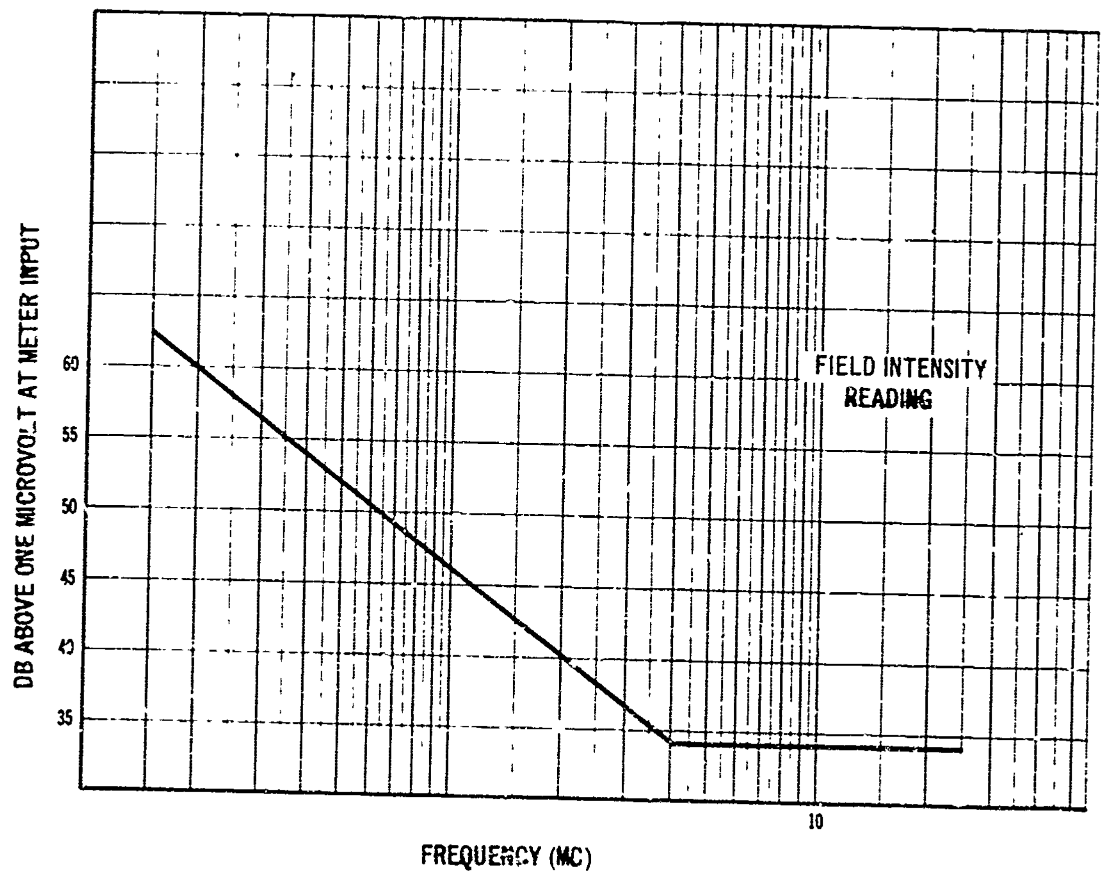

Figure 16. Narrow Band (CW) Conducted Interference Limits Using Stabilization Network

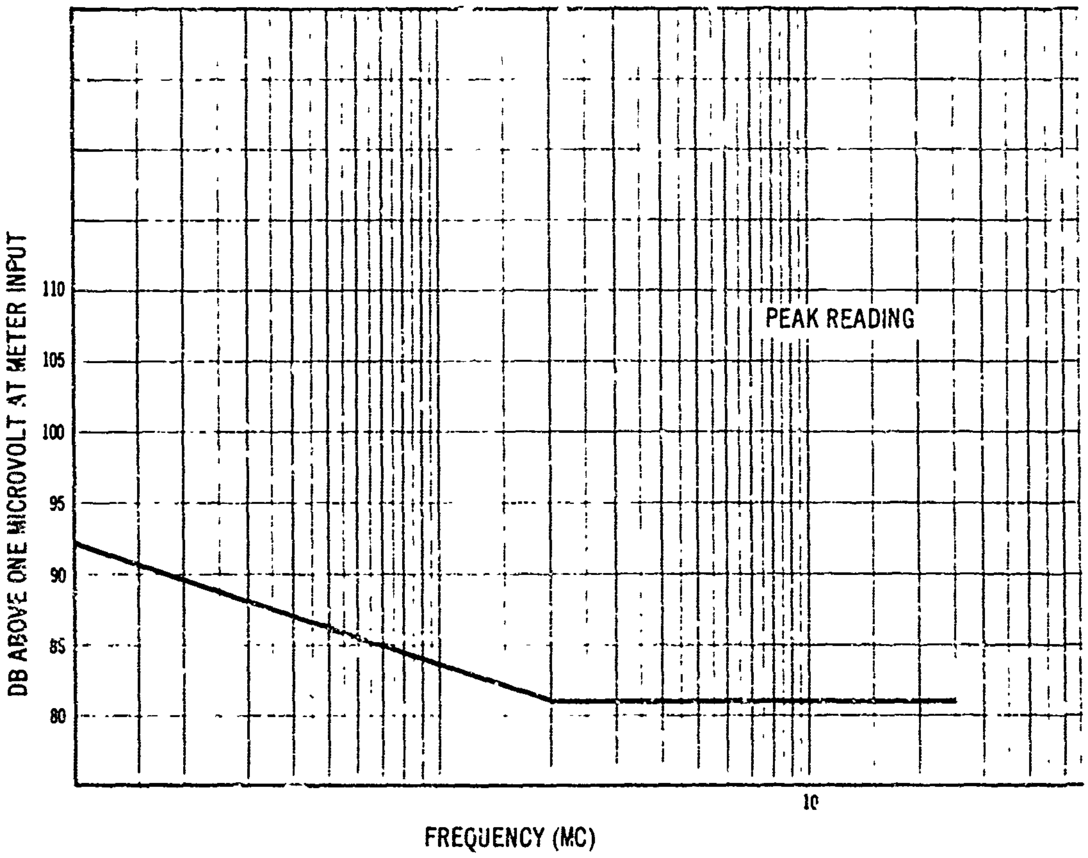

Figure 17. Broad Band and Pulsed (CW) Conducted Interference Limits Using Stabilization Network

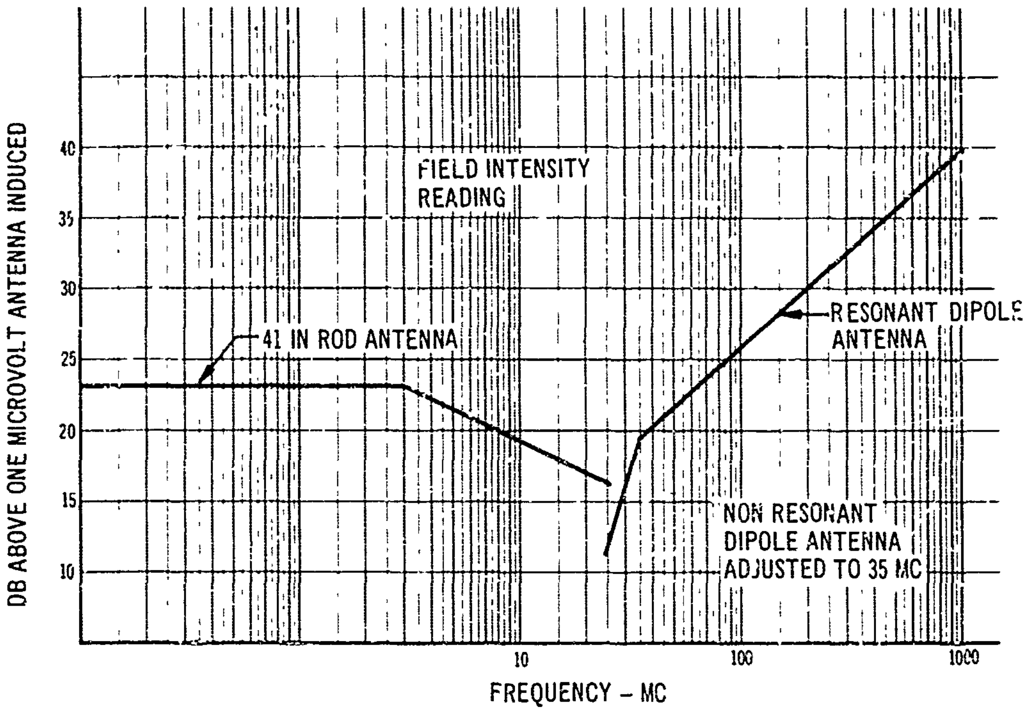

Figure 18. Narrow Band (CW) Radiated Interference Limits

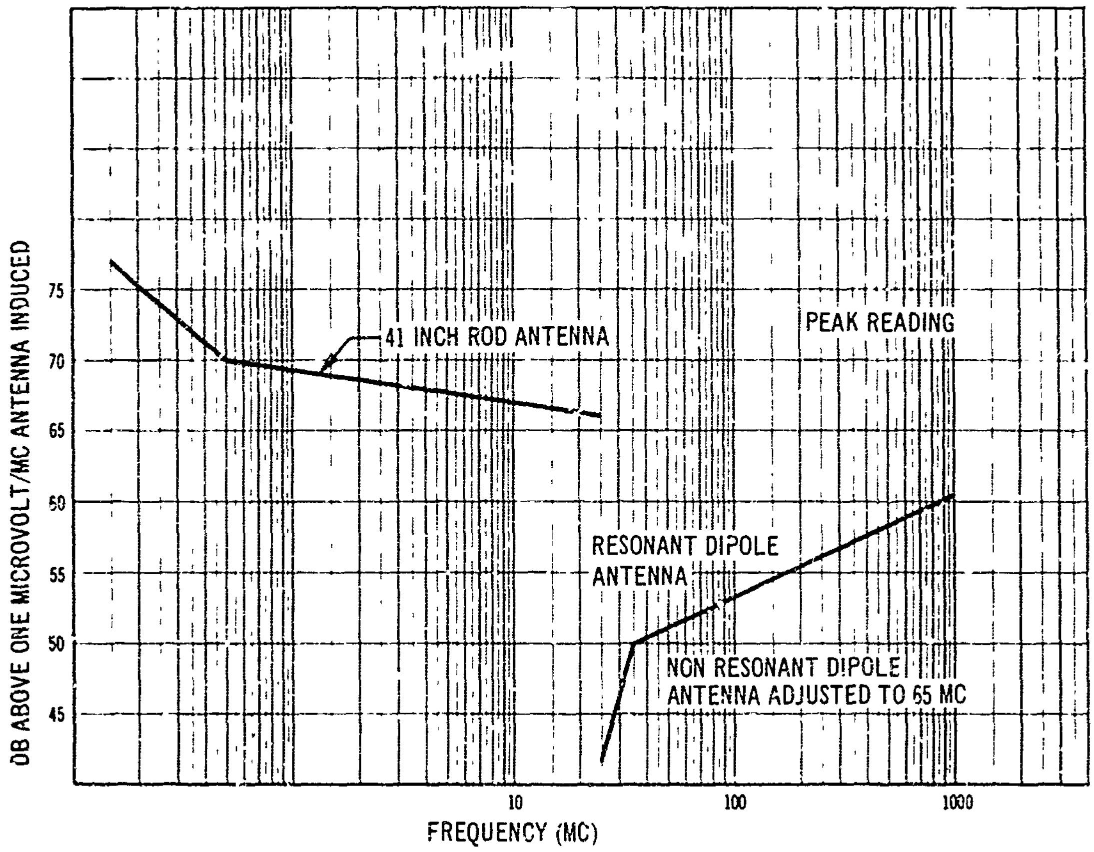

Figure 19. Broad Band and Pulsed (CW) Radiated Interference Limits

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Table VII. Electrical Interference Limits

Antenna	Frequency Range	Voltage (5)
Conducted interference	(rf) 0.15 to 1,000 MHz (1)	0.1 (3)
	(af) 50 to 15,000 Hz (2)	3.0
Radiated interference	(4) 41 in. rod 0.10 to 25 MHz	0.1 (3)
	35 MHz dipole 25 to 35 MHz	0.1 (3)
	tuned dipole 35 to 1,000 MHz	0.1 (3)

NOTES: (1) Applicable only to ungrounded line voltage power input points.

(2) Applicable only to ungrounded dc line voltage power input points.

(3) Modulated 30 percent at 400 to 1,000 cycles or any special form of modulation to which the equipment is vulnerable.

(4) Antenna placed 1 foot from electrical or electronic components.

(5) Value of open-circuit voltage from 50-ohm source impedance.

3.2.12.7 Short Duration Interference
The limits of Figs. 17 and 19 are intended to apply at all times to electrical or electronic items capable of generating broad band electro-magnetic interference. However, if P&WA considers a deviation is necessary or desirable, for relative short duration, infrequent, interference levels, (for example, once per flight) documented evidence shall be submitted to Boeing to support such a request. Documentation should be specific as to the time of occurrence and duration of deviations from the levels of Figs. 17 and 19 as well as their magnitude.

Boeing evaluation of the technical evidence submitted will not permit deviations over 20 db above the limits of Figs. 17 and 19 for short duration interference.

3.2.13 Engine Anti-Icing System
If any engine anti-icing system is required, it shall be the responsibility of P&WA.

3.2.14 Engine Nozzle Cooling
At the ambient conditions shown in Fig. 3, the engine shall be capable of continuous operation at partial augmentation and 30 minutes operation at maximum augmentation for the Mach numbers and altitudes shown on Fig. 1 without any convective cooling provided by Boeing.

Any secondary air system required for nozzle cooling shall be the responsibility of P&WA and shall be supplied as part of the basic engine assembly. The nozzle secondary airflow requirements are shown in Fig. 20. The maximum heat rejection shall be in accordance with Fig. 21 for the engine case and/or equipment.

3.2.14.1 Secondary Air Control Valve
A valve(s) shall be provided to control the flow of secondary air. A transmitter shall be provided to remotely indicate the position of the secondary air valve(s).

3.2.15 Engine Instrumentation
The following minimum instrumentation is required for airplane operation:

a. RPM Indicator (N_1 & N_2) Boeing

b. Exhaust gas temperature (see Par. 3.2.7.3) P&WA

c. Compressor inlet total pressure (see Par. 3.2.16.1) Boeing

d. Turbine exit total pressure (see Par. 3.2.16.2) P&WA

e. Nozzle area (see Par. 3.2.16.3) P&WA

f. Fuel temperature (see Par. 3.2.9.9) Boeing

g. Fuel flow (Turbine + D/H) (see Par. 3.2.9.8) Boeing

h. Pressure engine oil (see Par. 3.2.10.5) Boeing

i. Oil temperature (see Par. 3.2.10.6) Boeing

j. Thrust Reverser Position Switches (see Par. 3.2.7.2) P&WA

k. Pressure (Oil Filter Δ P) (see Par. 3.2.10.7) Boeing

l. Windmill brake position indicator switch (see Par. 3.2.20.1) P&WA

m. Low Oil Pressure Warning Switch (see Par. 3.2.10.5) Boeing

n. Secondary air valve position (see Par. 3.2.14.1) P&WA

o. Vibration (Comp. and Turbine) (see Par. 3.2.21.1) Boeing (2 places)

p. Oil quantity (see Par. 3.2.10.3) Boeing

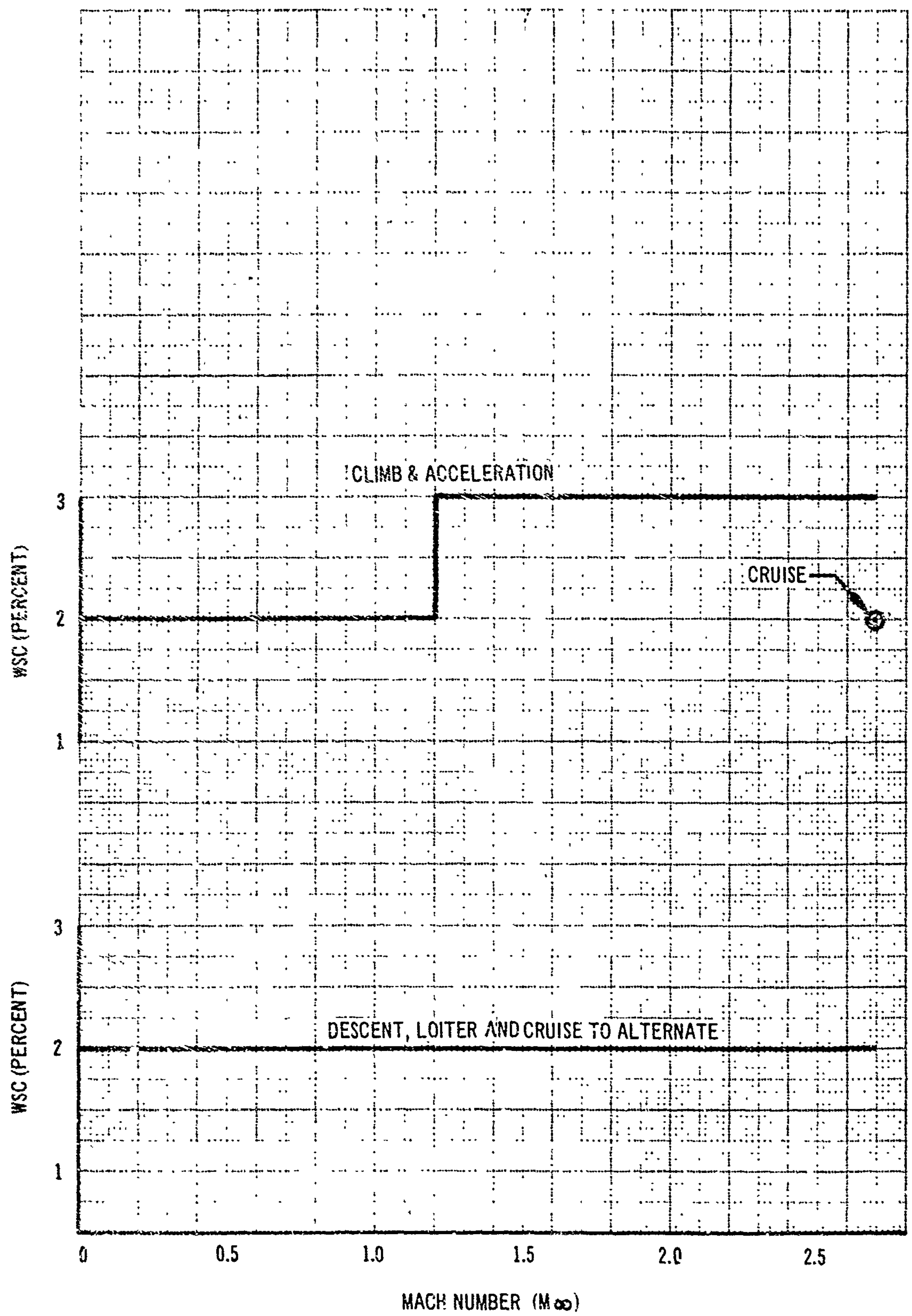

Figure 20. Nozzle Secondary Airflow Schedule

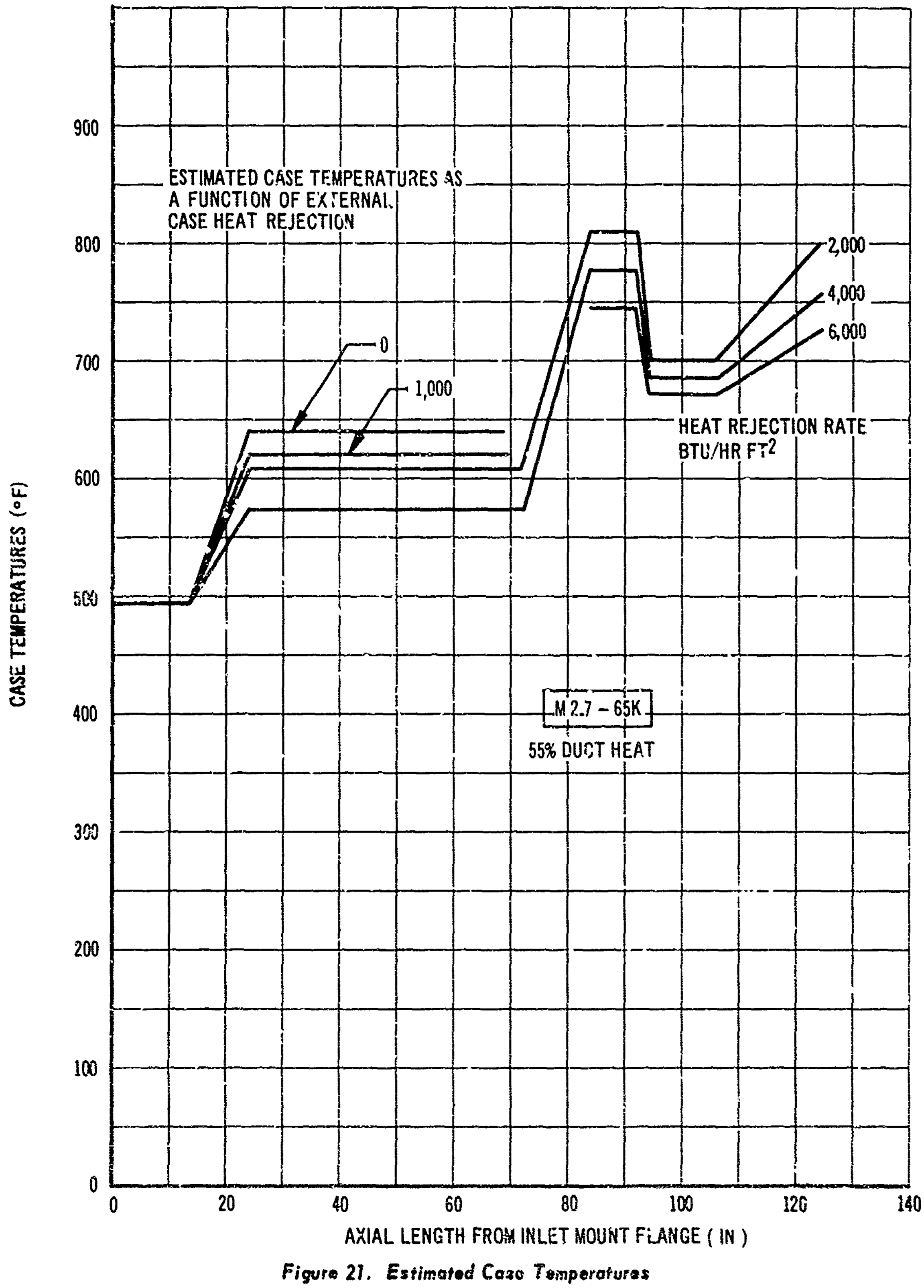

Figure 21. Estimated Case Temperatures

q. Load cell force indicator (see Par. 3.2.16.4) Boeing

If additional instrumentation is necessary to implement the AIDS subsystem, this instrumentation shall be negotiated with Boeing.

3.2.16 Engine Thrust Indication

Engine inlet total pressure, engine turbine exit total pressure and duct nozzle area (see Par. 3.2.16.3) shall be used to provide thrust indication.

3.2.16.1 Engine Inlet Total Pressure

Boeing shall provide a source for sensing engine inlet total pressure. The pressure source shall be accurate within ±0.5 percent.

3.2.16.2 Engine Turbine Exit Total Pressure

Pratt & Whitney Aircraft shall provide a source for sensing engine turbine exit total pressure. The pressure source shall be accurate within ±0.5 percent for maximum dry rated thrust and above.

3.2.16.3 Duct Heater Nozzle Area

Duct heater nozzle position indicator linear variable differential transformers (LVDT) shall be provided on the engine which will sense duct heater nozzle area within 3 percent (a development objective for accuracy shall be ±1 percent). Two signals are required. One LVDT will be used to indicate duct heater nozzle area and the other one will be used in the thrust indicating system per Par. 3.2.16.

3.2.16.4 Force Indicator

A Boeing-furnished load cell for measuring thrust will be installed in the airframe portion of the forward engine mount.

3.2.17 Engine Starting Requirements

3.2.17.1 Torque

The maximum and minimum starting torques and rpm shall be included in the engine model specification. The maximum starting torque at the PTO pad shall not exceed 980 ft lb.

3.2.17.2 Ground Starting

There shall be no limitation due to engine design that prevents establishing the starting time from 30 to 60 sec at standard sea level conditions.

3.2.17.2.1 Restarting Time

The maximum required time between ground starting attempts as determined by engine limitations shall be 30 sec.

3.2.17.3 Starting Envelope

The engine shall start consistently at any point within the engine operating envelope defined in Fig. 1.

3.2.17.4 Cold Starting

The engine shall start consistently in 60 sec immediately following 12 hr soaks at -50°F. The engine shall be serviced with oil per Ref. 2.2.5 and supplied at the fuel inlet port with fuel per Par. 3.1.4. No auxiliary heat or special appliances shall be required, provided the oil viscosity does not exceed 10,000 centistokes and fuel viscosity does not exceed 12 centistokes.

3.2.18 Idle

On the ground, under standard conditions, up to 6,000 ft altitude with the power lever in the idle position, the estimated thrust shall not exceed 2,100 lb per engine with a 265 hp load at the PTO pad, a total of 35 hp at the inlet hydraulic pump pads, in air bleed of 2.1 lb/sec, and 97 percent ram recovery at the inlet.

3.2.19 Engine Air Induction System

3.2.19.1 Stability

Under steady-state operating conditions without augmentation, thrust oscillation shall not exceed ±5 percent of the thrust available at that particular power lever position and flight condition, but in no event shall the thrust oscillation exceed ±1 percent of the maximum nonaugmented thrust available. During steady-state operation with any amount of augmentation up to maximum, the engine thrust oscillation shall not exceed ±1 percent of the maximum augmented thrust available at that condition. The engine shall continue to operate satisfactorily in the event of a single control mode failure of the inlet provided the resultant pressure transients and/or inlet distortions are within the limits specified in Par. 3.2.19.3.

Under steady-state operating conditions with stable inlet recovery and distortion and within the operating limits defined in Fig. 1, the airflow variations (ripple) for any one engine shall be aperiodic and limited to the values shown below. Under steady-state operating conditions, the rate of change of airflow shall not exceed 50 percent per second for airflow changes greater than ±0.5 percent.

Inlet Condition	Power Setting	Airflow Variation
Unstarted	Below max dry	±3% (Goal ±2%)
	Max dry and above	±3% (Goal ±2%)
Started	Below max dry	±2-1/2% (Goal ±1%)
	Max dry and above	[1] ±1% (Goal ±0.5%)

[1] FTS engines may be ±1.5%

The maximum engine to engine airflow variation span, considering all engines, shall not exceed ±3 percent for given operating conditions at maximum non-augmented and above engine conditions. Manual trim capability will be provided to match engine and inlet airflow at supersonic cruise within the limits shown on Fig. 22. The system shall be capable of setting airflow within ±0.5 percent.

3.2.19.2 Surge

The engine must be damage-free after a single or short duration surge that may occur due to inlet distortion, inlet unstarts, exhaust gas reingestion or control malfunction. Corrective action by the flight crew must be taken in accordance with engine and airplane operating instructions. The distortion limits and inlet pressure fluctuations which the engine shall accept without damage inflicting compressor surge are given in Par. 3.2.19.3

3.2.19.3 Engine Inlet Air Pressure Variation

In order to minimize the problem of inlet/engine compatibility, some levels of distortion overlap will be provided for the engine and inlet. The categories of distortion are defined as follows:

Distortion Levels	Flight Condition	Engine Effect
(1) Steady state - continuous operation	Subsonic cruise Supersonic cruise	No performance loss or decrease in engine life
(2) Time limited - normal transients	Aircraft acceleration and deceleration, maneuvers, power transients, gusts, etc.	No stall, surge or flameout. Some performance loss may result
(3) Emergency Transients (time limit - 10 sec)	Unstarts, restarts, inlet control failures, inlet buzz (excluding F.O.D.)	No mechanical damage

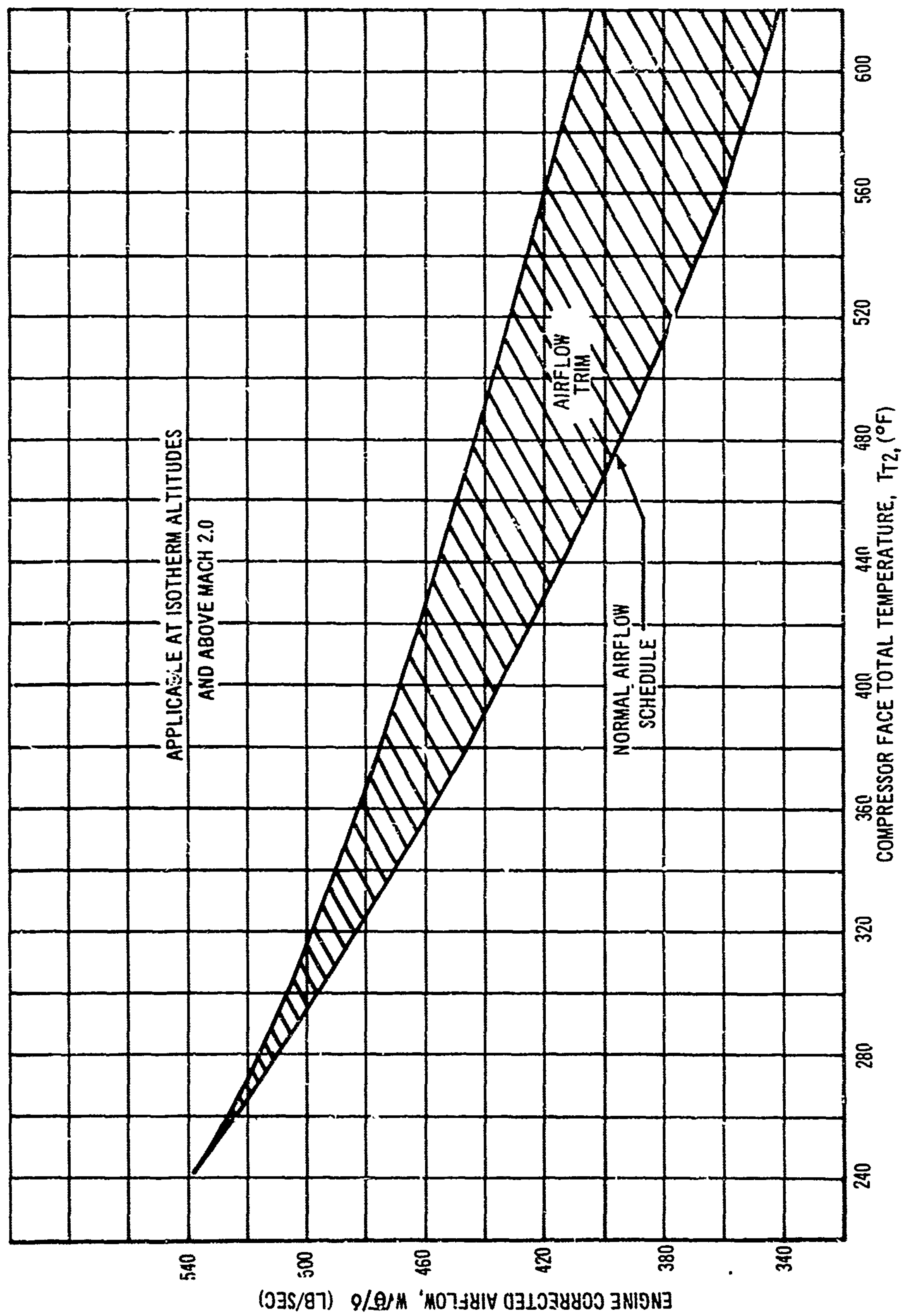

Figure 22. Airflow Trim Adjustment Limits

The allowable distortion levels for the inlet and engine are as follows:

Distortion Level	Inlet Allowable Distortion $\frac{P_{T2\,Max} - P_{T2\,Min}}{P_{T2\,Avg.}}$	Engine Allowable Distortion $\frac{P_{T2\,Max} - P_{T2\,Min}}{P_{T2\,Avg.}}$	Design Overlap
(1) Steady state	9%	13%	4% [1]
(2) Transients	20%	25%	5%
(3) Emergency	Any Level	Any Level	--

[1] This provides a 16% margin with respect to engine stall for normal cruise conditions

The above values of distortion are design objectives for the airplane. During Phase III development of the inlet and engine, a better definition of inlet distortion will be derived and specific distortion requirements for the inlet and engine will be established. The engine shall be capable of withstanding without mechanical damage instantaneous decrease in inlet total pressure of approximately 60 percent in 1/20 sec, followed by a return within 3 sec to a stabilized flow.

3.2.19.4 Engine Variations Affecting Inlet Performance

During starting and for engine speeds below idle, the instantaneous rate of change of engine airflow is not critical. During subsonic flight (M<1) at power settings above idle, the rate of change of engine airflow during acceleration, deceleration, augmentor lightoff and shutdown shall not exceed 70 percent per sec of the instantaneous airflow for airflow changes greater than ±5.0 percent. During supersonic flight (M>1), engine airflow changes, during engine acceleration, deceleration, augmentor lightoff at max dry power and above, shall be within the limits defined in Fig. 23. The engine case forward of the first rotor stage can be considered part of the subsonic diffuser section of the supersonic inlet. All vanes, struts, slots and doors located in this section shall be closely coordinated with Boeing in order to effect the optimum engine/inlet compatibility. The supersonic inlet shall continue to operate satisfactorily in the event of a single control mode failure within the engine.

3.2.19.5 Thrust Transients

The transient characteristics of the engine shall be compatible with all normal airline operating requirements. During the selection of all power lever positions, freedom from objectionable overspeed, overtemperature, combustion instability, combustion extinction and compressor instability shall be maintained. For rapid power lever movements (one second less), the time required to accomplish 95 percent of the thrust change safely shall not exceed the values specified below. The total time required to accomplish the specified

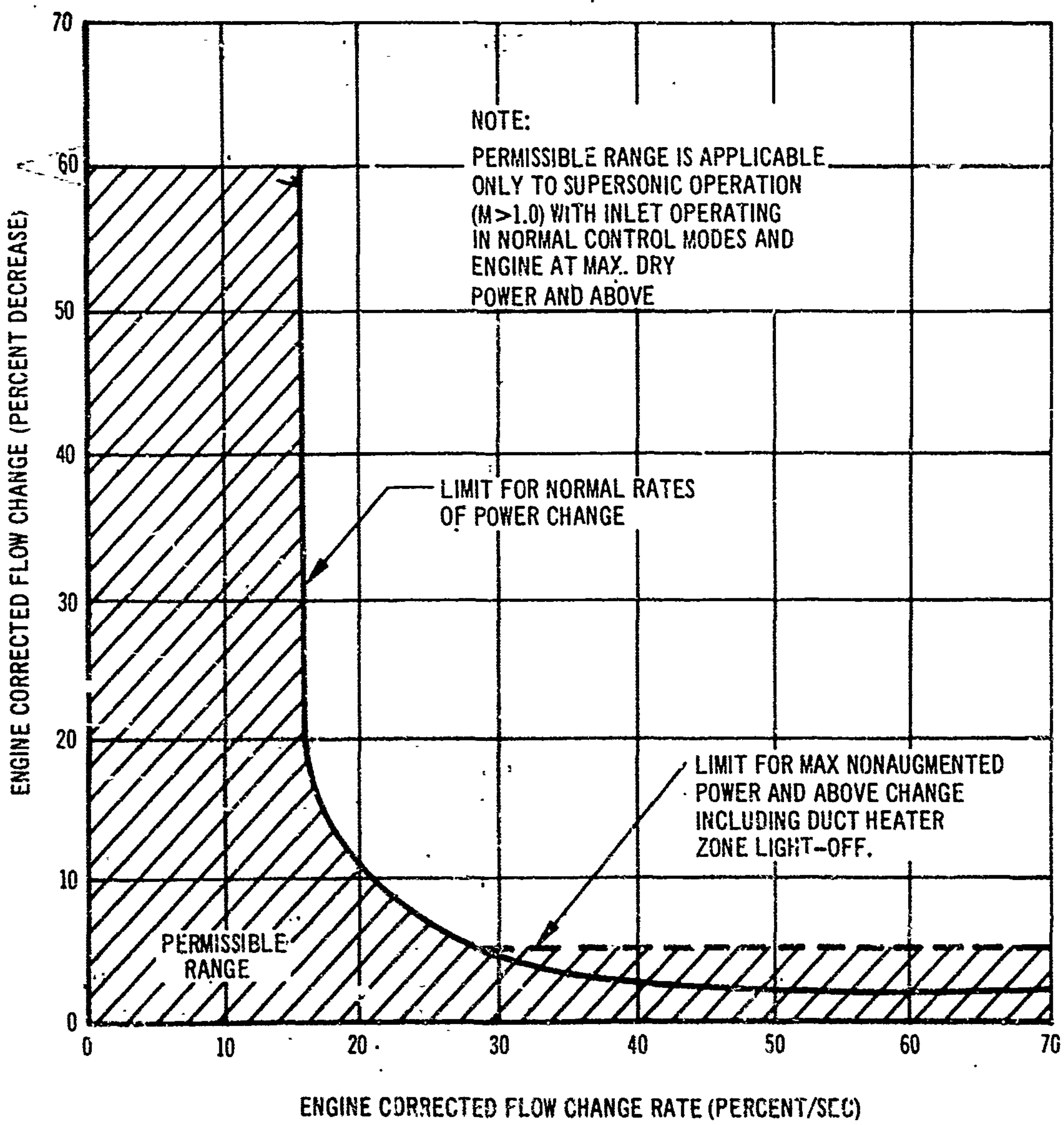

Figure 23. Permissible Range of Engine Flow Fluctuation

transients shall not exceed twice the time specified for 95 percent of the thrust change. The thrust transients shall be considered accomplished when the net jet thrust is maintained within ±2 percent of the final value. All transients specified are based on standard conditions, with loading of 500 hp on the accessory drives and 2.0 lb/sec compressor bleed flow and using the exhaust system as defined for the aircraft installation.

a. From ground idle condition to maximum dry, 8 sec from sea level to 6,000 ft, static conditions.

b. From idle to maximum thrust available, 8.5 sec from sea level to 6,000 ft, static conditions.

c. From maximum dry to maximum thrust available, 4 sec from sea level to 6,000 ft, static conditions.

d. From maximum thrust available to idle thrust, 6 sec from sea level to 6,000 ft, static conditions.

e. From maximum dry thrust to idle thrust, 5 sec from sea level to 6,000 ft, static conditions.

f. From maximum dry thrust to full reverse thrust, 6 sec from sea level to 6,000 ft, 50 to 150 kn.

3.2.20 Stopping

Normal stopping of the engine shall be accomplished by the use of the fuel shutoff lever with the power lever in the idle position. It shall be possible to shut off the fuel supply at any engine operating condition by the fuel shutoff lever without damage to the engine.

3.2.20.1 Windmilling

The engine shall be equipped with a windmill brake to reduce the engine high compressor rotor rpm to no more than 40 percent when the engine is shut-down at airplane curise conditions ($M_n = 2.7$, 60,000 ft altitude). The brake actuator shall be interlocked with the engine nozzle fuel shutoff to prevent actuation of the brake prior to shutting off nozzle fuel supply. The actuator shall be controlled through a remote electric switch. No damage to the engine shall result when the windmill brake is applied by the normal controls at any engine operating condition. In the event of actuator failure, the brake shall remain in the position occupied at the time of failure. A transducer shall be provided to remotely indicate the position of the engine brakes.

3.2.21 Engine Vibration

The engine shall be designed and constructed to function throughout its normal operating range of rotational speeds and engine powers without inducing excessive stress in any of the engine parts because of vibration. The engine unbalance at cruise rpm shall not be greater than to cause a maximum of 6 mils double amplitude displacement of engine cases as measured on the vendor's test stand. The location of vibration pickups shall be established by mutual agreement. The engine connection points for power and fuel shutoff attachment shall not exceed displacement of 10 mils double amplitude due to engine unbalance.

3.2.21.1 Vibration Sensor
Provisions shall be made for installing two Boeing-furnished vibration transducers.

3.2.22 Engine Foreign Object Ingestion Characteristics
The engine shall comply with the requirements of Ref. 2.1.13.

3.2.22.1 Hail Ingestion
A volly of hailstones of from 3/4 to 1-1/8 in. in diameter at a relative velocity of 375 kn.

3.2.22.2 **Ice Slab Ingestion**
Ingestion of an ice slab 1/2 in. thick by 8 in. square at a relative velocity of 100 kn. Ice density of 0.8.

3.2.22.3 Bird Ingestion
Ingestion of up to 6 lb of birds in 0.25 sec.

3.2.22.4 Rain Ingestion
The engine shall start and/or continue to operate satisfactorily during a severe rain storm, (6 in. of rain/hr, or 0.005 lb water/lb air) that may be encountered either on the ground or in subsonic flight.

3.2.22.5 Ice Balls
Ingestion of 20 ice balls of 2.0 in. in diameter at a relative velocity of 375 kn, during a 1 min interval.

3.2.23 Engine Fire Protection
The engine exhaust section shall be isolated from the accessory section with a circumferential firewall bulkhead. The upper quadrant of the exterior case of the exhaust section aft of the bulkhead shall provide the material functions of a firewall, except as interrupted by reverser doors, for engine-airframe isolation as shown in Fig. 10.

4. QUALIFICATION REQUIREMENTS

4.1 CERTIFICATION AND DEMONSTRATION REQUIREMENTS

4.1.1 General

Tests required to meet requirements of this agreement shall be conducted as specified herein and additionally as determined to be necessary by mutual agreement. Data from these tests shall be made available to both parties. Only those tests specifically designated as Phase III requirements shall be performed during Phase III of the SST Program.

Boeing and P&WA personnel shall be given all reasonable access to each other's facilities and test procedures used to determine conformance with this agreement and the Engine Model Specification.

In this agreement, performance definitions are as follows:

a. Guaranteed performance is the performance specified in the Engine Model Specification per Ref. 2.2.13.

b. Estimated performance is the performance calculated by the customer deck supplied by P&WA as a part of the Engine Model Specification per Par. 3.1.1.3.

c. Installed performance is the performance of the airframe/engine propulsion system including the airframe inlet and the exhaust nozzle.

4.1.2 FTS Substantiation Requirements (Phase III)

Pratt & Whitney shall compile a document describing in detail the Flight Test Status (FTS) substantiation requirements and transmit to Boeing for approval. In the event the FTS substantiation requirements are not acceptable to Boeing, P&WA and Boeing shall agree on a revised plan for submittal to the FAA.

The FAA will approve the FTS substantiation requirements established by P&WA and Boeing.

It shall be P&WA's responsibility to conduct tests to satisfy the FTS substantiation requirements. Boeing shall have the option to witness the tests. A summary of the FTS tests results shall be documented by P&WA and transmitted to Boeing prior to first flight of the prototype B-2707 airplane.

In support of the 100 Hour Flight Test Evaluation Program, an initial TBO of 100 hr has been established for the FTS engines. Based on previous supersonic flight test experience, it is anticipated that an initial effective TBO of 65 hr will be realized.

4.1.3 Type Certification Requirements (Phases IV and V)

It shall be P&WA's responsibility to conduct engine tests to satisfy the FAA Engine Type Certification requirements.

The FAA shall establish the Type Certification requirements. In establishing these requirements, consideration should be given to performing endurance testing under the simulated operational environment of the B-2707 aircraft. This simulated operational environment should include inlet temperature, pressure recovery and airflow distortion. In any event, these requirements should include sufficient testing at sustained severity levels to ensure that the engine is capable of safe operation in commercial supersonic aircraft.

Pratt & Whitney Aircraft recommendations to the FAA relative to Engine Type Certification requirements will be made available to Boeing.

If the Model B-2707 aircraft is required to have engines with British Air Registration Board (ARB) certification, P&WA will furnish Boeing the assistance to obtain such a certification in accordance with the then-existing Commercial Basic Agreement between the parties.

4.1.4 Guaranteed Performance Demonstration Requirements (Phases III, IV, and V)

Demonstration tests to show compliance with the Sea Level and Altitude performance guarantees of the engines specified in Pars. 3.1.2 and 3.2.1.1 will be performed in testing facilities having the capability of sea level static calibration and simulated subsonic and supersonic flight environment calibration at altitude. The installed performance of the engine will subsequently be demonstrated by flight test measurements in the Model B-2707 airplane. It is therefore implicit that Boeing and P&WA work together and mutually agree on the planning of, execution of, and analysis of the results from the ground laboratory, simulated altitude laboratory and airplane flight tests. The parties agree to work together to establish mutually acceptable procedures and criteria for accomplishing the objective set forth in the preceding sentence.

The primary responsibility for providing facilities, conducting the tests, and analyzing the data for the sea level static guaranteed performance demonstrations and simulated altitude guaranteed performance demonstrations shall be P&WA's .

The primary responsibility for providing facilities, conducting the tests, and analyzing the data for the installed engine performance demonstrations shall be The Boeing Company's.

4.2 ENGINE/AIRFRAME STATIC PERFORMANCE CALIBRATION REQUIREMENTS (PHASE III)

4.2.1 General

The test hardware and calibration testing required for the static demonstration of the specified engine performance are defined in the following paragraphs.

4.2.2 Test Hardware

4.2.2.1 Reference Bellmouth

Pratt & Whitney Aircraft shall provide a reference bellmouth inlet for static calibration of the engine. Pratt & Whitney Aircraft shall fabricate a minimum of two bellmouth inlets of identical design, one to be sent to Boeing for Boeing-conducted calibration testing and the other to be retained by the engine manufacturer.

4.2.2.2 Instrumentation
Boeing will require the support of Pratt & Whitney Aircraft to supply certain items of instrumentation and make provisions for others that are internal to the engine or require modification to the engine configuration. Pratt & Whitney Aircraft and Boeing shall coordinate these requirements early in the design phase. Pratt & Whitney Aircraft shall supply the mutually agreed upon instrumentation and instrumentation provisions on the ground and flight test engines. These engines shall be tested and the instrumentation calibrated in the P&WA's test facility prior to shipment to Boeing. The testing to be accomplished and basic instrumentation requirements shall be by mutual agreement.

4.2.2.3 Instrument Coordination
In order to promote the objective that the results of ground, simulated altitude and flight testing be consistent, it shall be a requirement that in so far as practical the instrumentation also be consistent for all test phases. Boeing and P&WA shall coordinate the instrumentation to be used for all performance demonstration tests, and mutually agree upon the instrumentation to be used for engine performance measurement.

As appropriate, the instrumentation to be used for Boeing flight test (and simulated altitude test) shall be subject to performance and endurance testing during normally scheduled P&WA development tests. Boeing shall make available and maintain such instrumentation for testing by P&WA.

4.2.3 Engine Ground Rig Performance Calibration Testing

4.2.3.1 General
Boeing will use the reference bellmouth inlet and a calibrated engine to calibrate Boeing's test facility. The static installed performance of the engine will be determined using both the reference bellmouth and Boeing production flight inlet during ground rig engine calibration. This will provide a comparison of the engine performance and incremental difference between reference bellmouth and production inlet.

4.2.3.2 Calibration
Pratt & Whitney Aircraft shall conduct performance calibrations of a (FTS) engine at sea level static and in a simulated altitude test facility using the reference bellmouth. Those calibrations shall include measurement of total inlet mass flow and determination of primary and secondary mass flows on one engine. The engine selected and schedule for these tests shall be mutually agreed to by the parties.

4.2.3.3 Calibration Requirements
Pratt & Whitney Aircraft shall compile a document describing in detail, for the sea level static and altitude performance calibrations in the simulated altitude facility, calibration procedures, instrumentation systems and accuracies, data reduction methods, and calculation procedures used in data analysis for transmittal to Boeing prior to the tests.

In addition to the above document, P&WA shall make available to Boeing such data reduction and data analyses computer decks as P&WA may develop for its own use. As additional information from test results becomes available or improved instrumentation and data analysis techniques are developed, these decks shall be updated.

4.2.4 Test Objectives
Pratt & Whitney Aircraft shall conduct tests during their normal development program to explore:

a. Overall engine operating envelope

b. Burner and augmentor operating envelopes

c. Airstart envelope

d. Acceleration and deceleration characteristics

e. Inlet total pressure and total temperature transients

4.3 GUARANTEED ENGINE PERFORMANCE DEMONSTRATION (PHASES III AND IV OR V)

4.3.1 General

4.3.1.1 Demonstration Requirements
Pratt & Whitney Aircraft shall compile a document describing in detail, for the sea level static guaranteed performance demonstration and for the altitude guaranteed performance demonstration in the simulated altitude facility, calibration procedures, instrumentation systems and accuracies, data reduction methods, and calculation procedures used in data analysis for transmittal to Boeing prior to guarantee demonstration. The data analysis computer decks specified in Par. 4.2.3.3 shall be used as applicable.

4.3.1.2 Demonstration Tests
The tests conducted to demonstrate guaranteed performance shall include the tests outlined below. Guarantee demonstration results will be documented in detail by P&WA and transmitted to Boeing.

4.3.1.2.1 Sea Level Tests
The sea level tests will be designed to demonstrate engine performance guarantees and operational characteristics by performing as a minimum, the tests listed below:

a. Steady state performance demonstration to verify the specified performance as given in Table I.

b. Thrust reverser operation.

c. Acceleration and deceleration capability.

d. Inlet distortion tolerance.

e. Augmentor operation.

4.3.1.2.2 Simulated Altitude Tests
The simulated altitude tests will be designed to demonstrate engine performance guarantees and operational characteristics by performing, as a minimum, the tests listed below:

a. Steady state performance demonstration of specified attitude performance guarantees as given in Table I.

b. Engine windmilling and windmill brake operation.

c. Inlet distortion tolerance.

4.3.1.3 Test Requirements
The engine performance guarantees shall be demonstrated within the test facility limitations using a typical FTS/Phase III/or production/Phase IV/ engine or aerodynamically similar engine. The measured engine performance will be corrected to a fuel having the minimum lower heating value of the fuel specified in the Engine Model Specification, Ref. Par. 2.2.13.

4.3.2 Basic Engine Performance

4.3.2.1 Sea Level Static Performance Demonstration (Calibration Stand)
The sea level static performance guarantees listed in Table I shall be demonstrated by P&WA using the reference bellmouth defined in Par. 4.2.2.1. This test shall be conducted in a suitable test facility. Thrust and fuel flow shall be measured using calibrated instrumentation covering a range of engine thrust settings from idle to maximum augmented power. Total inlet airflow shall be measured using a calibrated bellmouth. Tests may be conducted at other than stipulated ambient temperatures and pressures. Performance shall be corrected to specified Table I conditions.

4.3.2.2 Simulated Altitude Performance Demonstration
The demonstration of altitude performance guarantees defined in Table I shall be conducted by the P&WA in an altitude test facility.

Since the altitude facility is not capable of adequately simulating nozzle external flow or discharge static pressure, the measured thrust will be calculated as specified in the Engine Model Specification in accordance with Par. 4.3.1.1. These calculations will make use of full-scale static test data and nozzle model thrust coefficient test data.

The demonstration of any altitude performance points which exceed the capability of the laboratory will be calculated from test data obtained at test conditions which lie within the capability of the laboratory and corrected to specified Table I conditions.

4.4 INSTALLED PERFORMANCE CALIBRATION REQUIREMENTS (PHASE III)
Boeing shall conduct flight tests to demonstrate the installed performance and operation over the airplane flight and maneuver envelopes. The test program to demonstrate the airframe/engine performance will include as a minimum tests run, in so far as practical, at the conditions defined in Pars. 4.3.2.1 and 4.3.1.2.2. Additional tests to demonstrate airframe/engine performance, where required, will be mutually agreed upon by Boeing and P&WA. Boeing shall transmit to P&WA a summary of the flight test results.

Boeing in conjunction with P&WA shall compile a document describing in detail, for the installed performance demonstration on the Boeing test airplane, calibration procedures, instrumentation systems and accuracies, data reduction methods and calculation procedures used in data analysis prior to first flight of the Boeing test airplane.

The installed performance shall be demonstrated by flight test utilizing a FTS engine. It is recognized that the use of an engine previously calibrated in P&WA's Simulated Altitude Facility would be desirable and P&WA and Boeing shall mutually examine their respective schedules to determine the feasibility during Phase III. The flight tests shall be conducted with a production type flight inlet provided by The Boeing Company.

The flight tests shall be conducted at Boeing Flight Test facilities. All testing will be done in accordance with procedures agreed upon by P&WA and Boeing.

Thrust and fuel flow shall be measured using calibrated instrumentation covering a range of engine thrust settings from idle to maximum augmented power. The functional and thermodynamic performance of the propulsion system including inlet and exhaust nozzle shall be determined. Tests may be conducted at other than stipulated ambient temperatures and pressure altitudes. Performance data shall be corrected to specified Table I conditions.

4.5 NOISE DEMONSTRATION (PHASES AS INDICATED)

4.5.1 Static (Phases III and IV)
Pratt & Whitney Aircraft shall conduct a test on an outdoor test stand using an FTS or production engine or acoustically similar engine with the reference bellmouth inlet to demonstrate compliance with the guarantees of Par. 3.2.1.2.1. At least 6 test runs shall be made at each condition and the results averaged to show compliance.

Pratt & Whitney Aircraft shall submit a document showing test results. In addition, this document shall include a detail description of the acoustic measurement and analysis system. Boeing shall have the option of taking noise measurements parallel to the engine manufacturer's during the engine demonstration test.

Pratt & Whitney Aircraft shall provide noise level test data for an engine acoustically similar to the first flight engines. This data is to be provided within six months after delivery of the first flight engines.

4.5.2 Inflight (Phases III and IV)
A flight test shall be conducted by Boeing to demonstrate noise characteristics. The tests shall be conducted on the prototype Model B-2707 airplane using FTS engines and production type flight inlets. With the airplane operating at a mutually agreed to altitude, sound measurements shall be made on the ground under the flight paths. At least six test runs shall be made at each condition and the results averaged. Pratt & Whitney Aircraft shall have the option of taking noise measurements parallel to Boeing's during the flight test. The results of the test shall be documented by Boeing. The document shall include a detailed description of the measurement and analysis systems.

4.5.3 Sound Calculations (All Phases)
The perceived noise level calculations shall be made by use of the Noys table as defined in Ref. Par. 2.2.8. The discrete frequency peaks generated by the passage of fan, compressor or turbine blades shall be measured as the time average for 60 sec of the output of 1/24-octave band filter or a 50-cycle fixed band width filter tuned to the frequency being measured. The noise data shall be normalized to a standard sea level, 59°F and 70-percent RH day by standard SAE practices.

4.6 ENGINE AIRFLOW DEMONSTRATION (PHASE III)
The FTS engine airflow at engine operating conditions shown in Table I will be verified by test procedures mutually agreeable to the engine manufacturer and Boeing.

4.7 THRUST REVERSER DEMONSTRATION (PHASES III AND IV)

4.7.1 Static Reverser Performance Demonstration
Pratt & Whitney Aircraft shall conduct a test to demonstrate compliance with the guaranteed static reverse thrust performance specified in Ref. 2.2.13 in a suitable test stand. Reverse thrust shall be measured using calibrated instrumentation covering the range of reverse engine thrust settings from idle to maximum reverse. Performance shall be corrected to conditions specified in Ref. Par. 2.2.13. Demonstration results shall be documented in detail and transmitted to Boeing.

4.7.2 Installed Reverser Performance Demonstration
Boeing shall conduct tests to demonstrate installed thrust reverser performance and operation. Static reverser tests shall be conducted during Boeing's engine ground rig testing and high speed taxi and landing reverser tests shall be conducted during Boeing's flight test programs. Demonstration results shall be documented in detail and transmitted to P&WA.

4.8 VIBRATION DEMONSTRATION (PHASES AS INDICATED)

4.8.1 Pratt & Whitney Aircraft Vibration Tests
Pratt & Whitney Aircraft shall demonstrate vibration characteristics as specified in Par. 3.2.21 by conducting the following tests:

a. Phase III

Conduct back-to-back lineal vibration surveys throughout the normal engine operating (idle to maximum augmented thrust settings) on an experimental engine using (1) normal engine manufacturer production acceptance hardware

(2) Boeing prototype flight weight installation components to be provided by Boeing. The location of vibration pickups for demonstration shall be established by mutual agreement. Also the number, location and vibration limits of pickups to be used for prototype (FTS) engine acceptance runs shall be mutually determined from this demonstration test.

b. Phase IV
Conduct a lineal vibration survey throughout the normal engine operating range (idle to maximum augmented thrust setting) on a production engine using Boeing supplied production inlet and other installation components. The location of vibration pickups for the demonstration shall be established by mutual agreement. In the event that the results of this test using a production engine and production Boeing inlet do not meet the requirements of Par. 3.2.21 Boeing and P&WA will work together using their best efforts to determine the cause for the discrepancy and to establish the required corrective actions.

4.8.2 Boeing Vibration Tests
Boeing shall conduct the following tests:

a. Phase III
Conduct a vibration survey on the ground and inflight using a FTS engine and a prototype Model 2707 airplane to determine installation effects on engine and nacelle vibration levels.

b. Phase IV
Conduct a vibration survey on the ground and inflight using a production engine and a production flight test airplane to determine installation effects on engine and nacelle vibration levels.

4.8.3 Engine/Airframe Vibration Requirements
In recognition of the flight weight airframe components to be installed on the engine, Boeing will supply to P&WA preliminary configuration weight and cg location data to permit analytical evaluation early in the development period, Boeing and P&WA shall coordinate the interaction of engine and airframe hardware to establish the optimum engine installation that will satisfy the vibration requirements.

4.9 BLEED AIR QUALITY DEMONSTRATION (PHASE IV)
Pratt & Whitney Aircraft shall demonstrate compliance with the requirements of Pars. 3.2.2.1.1 and 3.2.2.1.2 by conducting the following tests on an experimental engine aerodynamically similar to production engine configurations.

4.9.1 Contaminant Quantity Test
With the engine operating at 70 percent and 90 percent sea level nonaugmented takeoff thrust the quantity of contaminant discharged from the compressor bleed shall be determined while introducing a given quantity of contaminant into the engine inlet over a period of time. The quantity of air bleed flow and other detail test procedures are to be established by mutual agreement.

The contaminant shall be coarse Arizona road dust AC Spark Plug Co. PN 154637 and shall be introduced in a manner to obtain substantially even distribution over the engine inlet area. The bleed air extracted from the port after expansion to atmospheric pressure shall not contain a greater concentration of engine ingested contaminants (pound of contaminant per cubic foot of air) then the concentration introduced within a test accuracy of ±25 percent.

4.9.2 Contaminant Quality Test
Samples of compressor bleed air shall be taken at temperatures within the ranges corresponding to the bleed air requirements of Table IV. At the same time the bleed air samples are taken, a sample of the air entering the compressor inlet shall be taken. All samples shall be properly identified. An analysis of the samples shall be made and if any of the contamination listed in Par. 3.2.2.1.2 has been contributed to the bleed air by operation of the engine, the concentration of contaminants shall be determined using mutually agreeable test methods.

This test shall be conducted on an engine incorporating lubrication system elements and seals which shall have been subjected to a minimum of 150 hr of operation.

Samples from the bleed air outlet shall be taken at temperature conditions obtained at nonaugmented takeoff power, 50 percent augmented takeoff power and idle. Additional, test power settings may be established by mutual agreement.

4.10 INLET DISTORTION TOLERANCE DEMONSTRATION (PHASE III)
Pratt & Whitney Aircraft and Boeing shall demonstrate engine and inlet distortion tolerances and limits specified in Par. 3.2.19.3 by conducting the following tests during the engine development program:

a. Conduct inlet distortion tolerance tests for sea level static and altitude conditions on an engine aerodynamically similar to a prototype engine configuration. The distortion patterns of the Boeing inlet are to be simulated for each particular flight Mach number and altitude simulated within the capability of the facility. Pressure profile surveys shall be taken at the compressor inlet over the operating range of the engine. The method of test and location of inlet pressure pickups for demonstration shall be established by mutual agreement. Demonstration results shall be documented in detail and transmitted to Boeing.

b. Conduct inlet distortion tolerance tests for altitude conditions on an engine aerodynamically similar to a prototype engine configuration with Boeing flight inlet. This demonstration shall be done in conjunction with the joint P&WA — Boeing Inlet/Engine AEDC test program. (Par. 5.2.1.3.) This joint program shall be used to demonstrate the specified inlet distortion levels of the inlet/engine combination.

5. COMPATIBILITY DEVELOPMENT PLAN (PHASE III)

5.1 GENERAL

Pratt & Whitney Aircraft and Boeing's tests required to develop, integrate, and flight test the propulsion system shall be conducted as specified herein and additionally as determined to be necessary by mutual agreement. Specified data from these tests shall be made available to P&WA or Boeing where required. The responsibility for providing facilities and for conducting or supporting the tests shall be accomplished as specified in the following paragraphs.

5.2 INLET/ENGINE COMPATIBILITY PLAN (PHASE III)

Boeing shall have prime responsibility for the development of the air induction and control system and for establishing inlet performance and distorting characteristics and to provide them to P&WA. Pratt & Whitney Aircraft shall have prime responsibility for the development of the engine and engine control system, for establishing the engine tolerances to inlet performance and distortion and defining requirements, and to provide them to Boeing. This includes distortion definition, measurement requirements and calculation procedures. The distortion information will include definition of the engine performance for distortion levels above the nominal no-performance loss levels. Pratt & Whitney Aircraft and Boeing shall have joint responsibility for the development of engine inlet dynamic compatibility.

5.2.1 Boeing Inlet/Engine Compatibility Tests

5.2.1.1 Model Test Program

Boeing shall conduct scale inlet m[illegible]ests to obtain high response rate distortion and pressure recovery dat[illegible] inlet design data. The type of instrumentation used to obtain this data wi[illegible] be determined by mutual agreement. Boeing shall provide P&WA with a summary of the test results. Distortion data from these model tests shall be used by P&WA to establish requirements for the tests of various distortion patterns for use in evaluating the engine tolerance to this distortion.

5.2.1.2 J-85 Engine Tests (AEDC)

Boeing shall conduct small engine/inlet tests (1/3 scale) at AEDC in mid-1967 for early inlet/engine compatibility verification. These tests will be used to define the performance of the inlet and the inlet controller and to investigate inlet/engine compatibility during steady state and transient operating conditions, including unstart-restart sequencing. This test will also be used to verify and update the mathematical simulation techniques of a short coupled inlet/engine system. Boeing shall provide P&WA with a summary of the test results.

5.2.1.3 Full Scale AEDC Tests

Boeing in conjunction with P&WA shall plan and conduct full scale inlet/engine compatibility tests at AEDC. These tests shall demonstrate the distortion levels of the inlet/engine combination, inlet performance, and inlet/engine dynamic compatibility.

The tests will be conducted in accordance with the Coordination Inlet/Engine Test Plan (Ref. D6A10007-2). Boeing and P&WA shall be responsible for jointly supporting the program as specified in the referenced test plan.

5.2.1.4 Full Scale Sea Level Static Tests
Boeing shall conduct engine/inlet ground tests to evaluate the compatibility under sea level static conditions (see Par. 5.4.1).

5.2.2 Pratt & Whitney Aircraft Inlet/Engine Compatibility Tests
It is necessary to integrate the engine and airframe inlet duct as early as possible to avoid the possibility of delays in the inlet/engine compatibility test program at AEDC and in the flight program. Thus, P&WA will initiate compatibility testing at his facility early in the engine development program on compressor component rigs and development engines.

5.2.2.1 Compressor Component Tests
Pratt & Whitney shall conduct the following tests.

a. Distortion Screen Tests
Pratt & Whitney Aircraft shall conduct distortion screen tests with a large scale compressor rig (fan and high compressor rotors) at flight Mach-altitude conditions. The distortion pattern for these tests will be established from the Boeing inlet model tests. Pratt & Whitney Aircraft shall evaluate the attenuating characteristics of the fan and high compressor to inlet distortion and provide Boeing with a summary of the test results.

b. Centerbody Venturi Tests
Combined steady-state and dynamic pressure distortion effects will be imposed on the compressor by P&WA. Pratt & Whitney Aircraft shall conduct distortion testing with a simulated inlet, which includes subsonic diffuser, throat and bleeds. These tests will impose the static pressure gradients produced by the fan on the simulated inlet and will permit an evaluation of the inlet performance and distortion as well as dynamic compatibility under more realistic operating conditions.

5.2.2.2 Engine Tests
Pratt & Whitney Aircraft will conduct engine tests to determine fan to high compressor interactions, coupling effects of the engine to the inlet, and engine-inlet dynamic compatibility using both distortion screens and simulated boiler plate inlet hardware.

This testing will include the determination of the effect of terminal shock location, distortion and turbulence on the engine, the effect of bypass and secondary air flow variations on the engine, and the effect of engine-generated disturbances on the terminal shock position. Boeing will assist in the test as required and receive the test results.

a. Screen Testing

Screen testing similar to testing done on the compressor rig (updating of distortion patterns will be done where applicable) will be done on full scale engines. This testing will permit evaluation of the fan to high compressor interactions and the high compressor distortion attenuating characteristics. This testing will include sea level static and flight Mach-altitude conditions.

b. Engine/Inlet Altitude Testing

Full scale engine testing with a simulated boiler plate inlet will be conducted early in the development program (prior to inlet/engine AEDC tests) at flight Mach-altitude conditions.

The boiler plate inlet will include bypass doors and several centerbody positions. Boeing will provide the centerbodies and inlet cowl with the bypass doors incorporated. Boeing will assist in the test as required and will receive the test results obtained.

c. Engine/Inlet Ground Testing

Engine/inlet sea level static conditions, including cross wind and choked inlet mode operation will be tested by P&WA using a boiler plate inlet supplied by Boeing. The inlet will be supplied with several centerbodies and incorporate takeoff doors in the cowl. Natural cross wind operation will be included in the testing. This test should be run as early in the program as hardware (engine and inlet) becomes available.

5.2.3 Inlet/Engine Dynamic Analysis

5.2.3.1 Mathematical Models

The mathematical models of both the inlet and engine will be updated based on data from the foregoing testing.

5.2.3.1.1 Engines

Pratt & Whitney Aircraft shall provide Boeing with updated engine mathematical model computer decks as required. The format and capability of the engine mathematical model must be mutually agreed to by P&WA and Boeing. Coordinated efforts between P&WA and Boeing shall be made to eliminate any detrimental inlet/engine interactions.

5.2.3.1.2 Inlet

Boeing shall provide P&WA with updated inlet mathematical model computer decks as required and in a format mutually agreed to.

5.2.3.2 Inlet/Engine Mathematical Model

Pratt & Whitney Aircraft and Boeing shall conduct analyses and simulation studies to evaluate the aerodynamic and control interactions between the inlet and engine.

Pratt & Whitney Aircraft and Boeing will work together on their mathematical model studies and analyses. The data will be used to predict the installed inlet/engine compatibility.

5.3 EXHAUST SYSTEM INTEGRATION TESTS (PHASE III)
Pratt & Whitney Aircraft shall have prime responsibility for the development of the exhaust system.

5.3.1 Thrust Reverser Development

5.3.1.1 Boeing Reverser Tests

5.3.1.1.1 Ingestion Tests (Model)
Boeing shall conduct aircraft model wind tunnel tests to determine the thrust reverser exhaust flow pattern requirements with respect to minimizing adverse reingestion and impingement effects. Boeing shall provide P&WA with a summary of the test results.

5.3.1.1.2 Reverser/Airplane Effectiveness Tests (Model)
Boeing shall conduct aircraft model wind tunnel tests to define the reverse thrust effectiveness. Boeing shall provide P&WA with a summary of the test results.

5.3.1.1.3 Definition of Airframe Reverser Requirements
Boeing shall define the airframe reverser exhaust external flow path requirements and the airframe control system requirements. Boeing shall provide P&WA with these requirements. These requirements will be coordinated between P&WA and Boeing to establish reverser compatibility.

5.3.1.1.4 Full-Scale Tests
Boeing shall conduct full-scale engine ground rig tests to evaluate installed effects on reverser performance and operation, reverser thrust response, and reingestion (see Par. 5.4.1).

5.3.1.2 Pratt & Whitney Aircraft Reverser Tests

5.3.1.2.1 Model Tests
Pratt & Whitney Aircraft shall conduct model tests to develop the reverser and reverser exit cover door design to meet the requirements of Par. 5.3.1.1.3.

5.3.1.2.2 Full-Scale Engine Tests
Pratt & Whitney Aircraft shall conduct full scale engine tests to evaluate the performance, operation and fail safe characteristics of the reverser. Pratt & Whitney Aircraft shall provide Boeing with a summary of the test results. Boeing shall have the option to witness the tests.

5.3.2 Nozzle Development

5.3.2.1 Boeing Model Tests

5.3.2.1.1 Wing/Pod Integration Tests
Boeing shall conduct model tests with the nozzle in the presence of a wing or wing-body to determine their effect on the nozzle installed performance and the pressure field around the nozzle. Boeing shall provide P&WA with a summary

of the test results. Pratt & Whitney Aircraft shall provide Boeing with current models or contours for their nozzle and pass on information on any revisions in the contours at the time they are incorporated.

5.3.2.2 Engine Manufacturer Tests

5.3.2.2.1 Model Tests
Pratt & Whitney Aircraft shall conduct isolated nozzle model test using the pressure field data from Par. 5.3.2.1.1 to determine nozzle performance and ejector pumping characteristics and to acquire data required for the design of the blow-in doors and trailing edge flaps. Pratt & Whitney Aircraft shall provide Boeing with a summary of the test results. Pratt & Whitney Aircraft and Boeing shall mutually determine the effects on nozzle performance and determine revisions required to achieve a mutually agreed to level of performance.

5.3.3 Noise Suppression Development

5.3.3.1 Boeing Tests

5.3.3.1.1 Model Tests
Boeing shall conduct scale model tests of exhaust nozzle suppressors under exhaust conditions identical to those proposed for the B-2707 engine. Evaluation of the noise characteristics of the suppressor nozzles shall be in terms of overall and octave band sound pressure levels as well as perceived noise level. Boeing shall provide P&WA with a summary of the test results. Pratt & Whitney Aircraft shall evaluate the noise suppressor nozzles in terms of their adaptability to the engine. The objective of these tests is to select promising designs for further analysis and full scale testing. Boeing will coordinate the testing with P&WA to avoid duplication with the P&WA testing described in Par. 5.3.3.2.1.

5.3.3.1.2 Full-Scale Tests
Boeing shall conduct full scale J-75 engine tests to evaluate promising jet noise suppressor obtained from model tests. The final nozzle configurations shall be suppressors obtained from model tests. The final nozzle configurations shall be tested on a J-75 engine. Test conditions on a J-75 will duplicate as closely as possible the conditions required on the B-2707 engine during takeoff and climbout maneuvers. Evaluation of the noise characteristics of the suppressor nozzles shall be in terms of overall and octave band sound pressure level as well as perceived noise level. Boeing shall provide P&WA with a summary of the test results.

The objective of these tests is to determine the jet noise suppression characteristics and performance losses for large scale exhaust nozzles.

5.3.3.2 Engine Manufacturer Tests

5.3.3.2.1 Model Tests
Pratt & Whitney Aircraft shall conduct small scale exhaust noise suppression tests of configurations which may be adaptable to the engine.

The objective of these tests is to select promising designs for further analysis and full scale testing. Pratt & Whitney Aircraft shall provide Boeing with a summary of the test results.

5.3.3.2.2 Full-Scale Testing
Pratt & Whitney Aircraft shall conduct full scale engine fan noise tests to determine noise generating and propagating characteristics. Pratt & Whitney Aircraft shall provide Boeing with a summary of the test results. Data shall be in the form of octave band and 50 cps octave band width SPL over a complete polar grid around the engine. Several thrusts from idle to full power shall be included.

Pratt & Whitney Aircraft shall conduct full-scale engine exhaust noise and performance tests to evaluate the final FTS engines and suppressor configuration. Pratt & Whitney Aircraft shall provide Boeing with a summary of the test results. Noise data shall be in the form of octave band SPL over a complete polar grid around the engine. Several thrusts from idle to full power shall be included.

Pratt & Whitney Aircraft shall conduct full-scale noise and performance tests on the engine to determine near and far field noise levels with an acoustically similar aircraft inlet supplied by Boeing installed. Pratt & Whitney Aircraft shall provide Boeing with a summary of the test results. Noise data shall be in the form of octave band and 50 cps band width SPL's over a complete polar grid around the engine. Several thrusts from idle to full power shall be included. Boeing shall have the option to witness the tests and take parallel noise measurements.

The objective of these tests and analysis is to obtain a noise suppression system compatible with the engine and airframe which results in noise levels at or better than FAA objectives during ground, takeoff and approach phases of the B-2707 operation.

5.4 ENGINE/AIRFRAME INSTALLATION TESTS (PHASE III)
The full-scale propulsion installation tests required to evaluate engine/airframe integration and compatibility and to evaluate the performance and operation of propulsion subsystems and components, are included herein.

5.4.1 Boeing Ground Rig Tests
Boeing shall conduct engine ground rig tests to evaluate the performance, operation and compatibility of all components of the propulsion installation including engine starting system, accessory power drive and airbleed system, engine and cowl cooling environment, fire detection and extinguishing system, engine instrumentation, engine controls, nacelle drainage, engine/nacelle fuel system, engine and airframe accessory vibration, and noise. Pratt & Whitney Aircraft shall supply Boeing with calibrated ground test engines and logistically support the test program as required.

5.4.2 Pratt & Whitney Aircraft Ground Tests
Pratt & Whitney Aircraft shall conduct engine ground tests to evaluate the performance, operation, and noise levels of the engine, including inlet/engine compatibility, thrust reverser performance and operation.

It is also desirable that P&WA conduct a test using Boeing-supplied, engine-driven airframe accessories to assist in determining compatibility of the engine and airframe components. A mutually agreeable plan will be developed during Phase III to accomplish this objective.

5.4.3 Pratt & Whitney Aircraft Appraisal of Production B-2707 Engine Installation
Pratt & Whitney Aircraft shall submit to Boeing a list of requirements for information and data considered necessary for evaluation and appraisal of the B-2707 engine installation. The appraisal will be made with respect to the production installation developed in Phase IV.

5.5 PHASE III FLIGHT TEST PROGRAM

5.5.1 General
The flight test demonstration of engine performance and operation, and the evaluation of the propulsion system, are included herein. Boeing shall conduct the flight tests. Pratt & Whitney Aircraft shall monitor and support these tests.

The following propulsion system flight tests will be accomplished during the Phase III flight test program:

5.5.2 Air Induction System Performance and Operation
Boeing shall conduct flight tests to demonstrate the air induction system performance and operation, and inlet/engine compatibility over the flight and maneuver envelopes of the airplane.

5.5.3 Engine Performance and Operation
Boeing shall conduct flight tests to demonstrate the installed engine performance and operation over the airplane flight and maneuver envelopes. Installed engine performance will be demonstrated as specified in Par. 4.4.

5.5.4 Evaluation of Propulsion Nacelle and System
Boeing shall conduct flight tests to demonstrate the engine and nacelle cowling structural integrity over the flight envelope of the airplane and the operation of the propulsion systems. These tests shall include: nacelle and engine cooling, engine oil system, accessory operation, fire extinguishing system, engine instruments, nacelle drainage, engine airplane fuel system, vibration surveys and automatic thrust control system.

5.5.5 Thrust Reverser Performance and Operation
Boeing shall conduct tests to determine reverse thrust effectiveness, reverser exhaust gas ingestion and impingement characteristics, and reverser operation under normal operational loads.

5.5.6 Noise Surveys
Boeing shall conduct ground, takeoff, and landing tests to demonstrate airport and community engine noise levels as specification in Par. 4.5.

6. PRODUCT ASSURANCE REQUIREMENTS

6.1 BASIC CONCEPTS AND DEFINITIONS

In the context used here, the term Product Assurance includes the subjects of Reliability, Safety, and Maintainability. The Product Assurance requirements contained herein are required to integrate the engine into the B-2707 system and provide assurance during design and test that adequate levels of reliability, safety, and maintainability are inherent in the final production design.

6.2 RESPONSIBILITIES

6.2.1 General

Boeing has overall responsibility and accountability for the reliability, safety, and maintainability of the B-2707 system. This responsibility includes system schedules, planning and reporting in addition to technical integration of the engine contractor produced equipment.

Pratt & Whitney Aircraft has responsibility and accountability for the reliability, safety, and maintainability characteristics of the engine and basic accessories and for the conduct of such tests or demonstrations as may be required to ensure that adequate levels of reliability, safety and maintainability are inherent in the final production design. This responsibility includes support to Boeing throughout the Phase III B-2707 Program to ensure achievement of overall system Product Assurance objectives as they relate to the engine/airplane interfaces. This support includes provision of the data specified herein required for Boeing to fulfill system management responsibilities.

6.2.2 Boeing Responsibilities

Boeing will assess the safety, reliability and maintainability of the B-2707 system and provide master schedules, planning, reporting, and integration for all Product Assurance elements. In fulfillment of these responsibilities, Boeing will provide to P&WA copies of the following items relative to reliability, safety, and maintainability.

a. Major program milestones.

b. Test and demonstration plans for flight test.

c. Operational and maintenance concepts to support the B-2707 system.

d. Time goals for performance of engine line maintenance tasks accomplished on the airplane.

e. The integrated System Safety Plan incorporating appropriate elements of the P&WA Engine Safety Plan.

f. Copies of engine malfunction and maintenance data assembled by Boeing personnel during Phase III.

In addition to the preceding, Boeing will:

g. Establish periodic meetings as may be required to ensure integration of the Product Assurance activities.

h. Develop, with P&WA, mutually compatible and acceptable data formats, flow processes, evaluation processes and reports as may be required.

Schedules for providing these items will be negotiated.

6.2.3 Pratt & Whitney Aircraft Responsibilities
Pratt & Whitney Aircraft will be responsible for complying with the reliability, safety, and maintainability requirements contained herein and will, in addition, provide technical representation to actively participate in the failure analysis team (see Par. 6.2.5).

6.2.4 Interface Elements
Sections 2.0 and 3.0 form the basis for identifying and defining mutually reacting malfunctions and malfunction effects.

6.2.5 Problem Analysis and Corrective Action
During the flight test, malfunctions and problems will undoubtedly occur requiring investigation, determination of responsibility, and identification of appropriate corrective action. The following will be accomplished in the event of failure or malfunction involving the engine/airframe interfaces:

a. A failure analysis team will be established consisting of Boeing and P&WA representatives.

b. Where on-the-spot cause determination and corrective action is mutually agreed upon, a report will be prepared and the necessary corrective action accomplished.

c. Malfunctioning components will be forwarded to the P&WA SST Spares store for disposition in accordance with the ancillary agreements. Parts or components requiring further investigation or analysis will be withdrawn from the store and later returned to the store in accordance with P&WA procedures. Analysis of the failed component will be accomplished by P&WA with Boeing participation, where requested by Boeing. A full report will be prepared and signed by both parties where an engine/airframe interface problem is indicated. Copies of all reports will be provided to Boeing.

d. For all joint investigations, in the event of disagreement, dissenting opinion shall be included on the failure analysis report.

6.3 RELIABILITY

6.3.1 General
This section contains the minimum elements to fulfill system reliability responsibility and provide effective engine/airframe interface. To the maximum possible extent, these requirements shall be fulfilled as part of the basic contract with the FAA and shall not require additional nor different effort.

6.3.2 Design Objectives

6.3.2.1 Numerical Objectives
When operated within the environments and performance limits specified in Sec. 3.0 of this document, the minimum frequency of malfunctions due to mechanical causes expressed as arithmetic mean values are shown in Table VIII.

Table VIII. Reliability Objectives

	Early Flight	$2X10^6$ Engine Flight Hr	$4.5X10^6$ Hr
Mean time between inflight shutdowns	10,000	21,000	29,100
Mean time between inability to sustain augmentation power*	70,000	127,000	178,000
Mean time between premature engine removals	2,500	4,000	5,000
*Inability to obtain selected augmented thrust, given the engine is running.			

Degree of attainment of these objectives shall be assessed in accordance with Par. 6.3.3.1.

6.3.2.2 Failure Requirements
Compliance with the failure requirements in Sec. 3.0 shall be demonstrated in accordance with Par. 6.3.3.2.

6.3.2.3 Malfunction Definitions
The P&WA Reliability Program Plan shall include specific definitions of malfunction. Definitions shall be related to one or more of the characteristics of Table VIII as well as to the appropriate portions of Sec. 3.0.

6.3.3 Quality Assurance Provisions

6.3.3.1 Numerical Demonstration
Achievement of parameters related to items (a) through (c) listed in Par. 6.3.2.1 shall be assessed as specified below. This requirement is not to be construed as requiring statistical reliability tests; however, it shall be construed to require statistical evaluation of data for this purpose.

a. A curve will be established for each parameter shown in Table VIII related to total commercial service engine hours.

b. Reliability time/cycle and failure data will be logged from in-plant tests and flight tests. This data will be analyzed on a periodic sliding basis to provide estimates of the following development reliability assessment parameters:

(1) Mean time between test stand engine shutdown

(2) Mean time between test stand augmentor failure

(3) Mean time between test stand engine removal

Numerical estimates of these test stand parameters will be provided in the P&WA Quarterly Reliability Reports when adequate sample sizes are accumulated.

c. Satisfactory progress at the end of Phase III shall be measured by a comparison of a best unbiased point estimate and a one sided 70 percent confidence interval.

6.3.3.2 Failure Requirements Demonstration
Evidence of compliance with the provisions of Par. 6.3.2.2 shall be provided as follows:

a. Each part of the P&WA furnished equipment shall be analyzed to determine the end result of failure and ensure that adequate protection exists. The analysis shall include at least the data shown in the sample Failure Mode and Effect Analysis format, Figs. 24 and 25 or equivalent. The analysis shall show conclusive evidence of compliance with the specified requirements.

b. These analyses will be supplemented, as required, by appropriate development test failure data.

c. Malfunctions occurring during the ground and flight test program producing results contrary to these requirements will require corrective action.

d. In addition, FMEA shall be conducted on engine failures induced by aircraft system malfunctions as coordinated between Boeing and P&WA.

6.3.4 Data Requirements

6.3.4.1 Reliability Program Plan
Pratt & Whitney Aircraft will submit to Boeing a copy of their Reliability Program Plan submitted to the FAA. After coordination with Boeing for overall program compatibility, the plan shall become the standard by which the P&WA Reliability Program will be conducted.

Revisions to the plan shall be provided to Boeing for information. If basic intent, direction, or Boeing interface is affected, the revision shall be coordinated with Boeing before submittal to the FAA.

JTF17 FAILURE MODE & EFFECT ANALYSIS							
ITEM	FUNCTION	FAILURE MODE	FAILURE EFFECT ON SUBSYSTEM	METHOD OF DETECTION	FAILURE EFFECT ON ENGINE	FAILURE EFFECT ON AIRCRAFT	CREW ACTION REQUIRED
ANALYZED BY:							

SAMPLE

Figure 24. Failure Mode and Effect Analysis (Sheet 1)

JTF17 FAILURE MODE & EFFECT ANALYSIS								
ITEM	FUNCTION	FAILURE MODE	HAZARD CLASSIFICATION				DESIGN PHILOSOPHY TO PRECLUDE FAILURE	DESIGN PHILOSOPHY TO REDUCE HAZARD
			I	II	III	IV		
ANALYZED BY:								

Figure 25. Failure Mode and Effect Analysis (Sheet 2)

6.3.4.2 Technical Data
Copies of the following data shall be furnished to Boeing as specified below:

a. Allocated reliability values and documented results of design reliability analyses and predictions kept up-to-date at intervals not to exceed six months. These data shall include details related to each component or part for each parameter specified in Par. 6.3.2.1 and shall include the pertinent data specified in Par. 6.5.4.3 AIDS, items (a) and (f). Sources and justification of reliability predictive data shall be included.

b. Comprehensive analyses of each possible engine failure mode, its effect and its criticality, kept up-to-date at intervals not to exceed six months. These analyses shall be prepared to fulfill the requirements of Pars. 6.3.2.2 and 6.3.3.2 and shall be provided to Boeing to show compliance with applicable portions of Sec. 3.0.

c. The critical ranking of failure modes, kept up-to-date at intervals not to exceed six months.

NOTE: It is preferable that these items be assembled into one package and submitted at the same time.

d. A detailed plan to achieve compliance with the provisions of Par. 6.3.3.1 shall be provided to Boeing. This shall include individual definitions of success and failure amplifying the provisions of Par. 6.3.2.3 and complying with Par. 6.5.4.3.a. A detailed set of relevant and nonrelevant failure classifications shall be included.

e. Summarized records of engine time/cycle failure and maintenance histories.

f. Failure and Analysis Summaries as generated bi-monthly.

Items e and f above shall be included in the status reports identified below.

6.3.4.3 Reliability Status Reporting
During Phase III, P&WA shall prepare and provide to Boeing, bi-monthly reports to provide a concise and accurate summary of Reliability Program status, technical status and significant problem areas. These may be included in or be derived from periodic reports submitted to the FAA. The report shall cover the following:

a. Program Status
Summarize status of each current task contained in the Reliability Program Plan. Reasons for any slides or schedule alteration shall be included, along with the program for recovery.

b. Technical Status
This part shall consist of reliability estimates for the overall system when available and each major segment or component thereof. Updated assessments shall be included semiannually. A summary of revised predictions and the impact of the change shall be included in this part of the report. The current

status of and results of significant tests or demonstrations for reliability purposes shall also be contained in this section.

c. Significant Reliability Problems
This part shall summarize significant reliability problems in the following format:

(1) Area of engine or accessories

(2) Brief statement of problem

(3) Proposed resolution

(4) Action agency

(5) Current status

(6) Reference correspondence or data

(7) Amplifying remarks

6.3.4.4 Final Reliability Report
The reliability portion of P&WA's final report required by the FAA shall be coordinated with Boeing prior to submittal for FAA approval and shall include a complete accounting of the accomplishments of the Phase III Reliability Program including:

a. Summary of results achieved by the contracted reliability program.

b. Status of equipment qualification program, including deviations accepted and their effect upon reliability.

c. Recommendations for continued maintenance of system reliability in the field.

d. Recommendations regarding additional reliability improvements.

Evidence of compliance with Pars. 6.3.2.1 and 6.3.2.2 shall be provided to Boeing.

6.4 SAFETY

6.4.1 General
This section defines the minimum System Safety program inteface responsibilities of Boeing and P&WA necessary to provide effective working relationships and to assure total airplane System Safety consideration during development and test. To the maximum possible extent, the activity implied in these responsibilities will be performed as a part of each contractor's basic contract with the FAA and shall not require additional effort.

Since the airframe contractor is responsible for the overall safety of the prototype airplanes during Phase III of the program, and further, is required to establish and maintain an Integrated System Safety Plan, it follows that The Boeing Company will establish the Safety analysis techniques used to evaluate the integrated airplane. Within this framework, the responsibilities of each contractor are defined as follows:

6.4.2 Boeing Responsibilities
Boeing will prepare an Integrated System Safety Plan (ISSP) upon receipt of the P&WA Engine Safety Plan. The ISSP will provide for coordination of the Safety Programs and will include the following:

a. Guidance to the engine contractor for the support of the System Fault Tree Analysis.

b. Schedules for submittal of safety analyses.

c. Method of integrating engine safety analyses into the B-2707 system fault tree.

d. Provisions for Engine/Airframe contractor safety program coordination meetings.

6.4.3 Pratt & Whitney Aircraft Responsibilities

a. Provide the Engine Safety Plan to Boeing at the time of the Phase III Proposal submittal. Subsequent Safety Plan revisions will be provided to Boeing at the time of their accomplishment.

b. Development and provide to Boeing, Engine Safety Analyses for all undesired events that have a serious threat to the operation of the B-2707. These undesired events shall include but not be limited to the following:

(1) Uncontained engine fire

(2) Turbine disc failure

(3) Compressor disc failure

(4) Loss of scheduled thrust

(5) Engine seizure

(6) Bleed air contamination

6.5 MAINTAINABILITY

6.5.1 General
This section contains the minimum elements to fulfill system maintainability responsibility and provide effective engine/airframe interface. To the maximum possible extent, these objectives shall be fulfilled as part of the basic contract with the FAA and shall not require additional or different effort.

6.5.2 Maintainability Requirements
When operated within the environments and performance limits specified in Sec. 3.0 of this document, the engine maintainability objectives are the arithmetic mean values shown in Table IX.

Table IX. Maintainability Goals

	Early* Flight	$2X10^6$ Engine Flight Hr	$4.5X10^6$ Engine Flight Hr
MMH/EH (Maintenance (1) manhours per 1,000 engine hours)			▷1
Mean maintenance task time (minutes)	▷1	▷1	▷1
TBO (Time before over-haul)	600	2,500	in excess of 5,000 hr

*Maintainability objective for certificated engines.

(1) Maintenance manhours including servicing, inspection and line replaceable unit (LRU) replacement per 1,000 engine hours of operation on the airplane excluding access and remove and replace of the complete engine.

▷1 Values to be inserted six months after start of Phase III

6.5.3 Validation
Pratt & Whitney Aircraft shall submit the following information as a part of its maintainability program to establish and verify quantitative requirements and provide for continued evaluation of P&WA's proposed design. Preliminary data will be submitted with the plan and updated at intervals not to exceed six months. The maintainability data shall be made excluding limitations of the airframe installation and shall consist of at least the following items:

a. For each line replaceable unit (LRU) installed on the engine and including the total engine as an LRU.

(1) Identification of the LRU.

(2) A list of scheduled and unscheduled maintenance servicing tasks required to keep the LRU in operable condition while installed on the aircraft.

(3) A list of tools, ground support equipment, and facilities required for the above tasks.

(4) The quantity and skill level of personnel to accomplish each discrete maintenance task listed above (a.2.).

(5) The elapsed clock time in minutes to accomplish each maintenance task listed above (a.2.), independent of that time required for access to the unit.

(6) Frequency of each maintenance action. (Failures per 1,000 engine hours or cycles as appropriate, and engine hours between scheduled actions.)

(7) Features incorporated in the design that will minimize maintenance, reduce servicing time, and facilitate maintenance.

(8) Identify inspection and servicing points which require quick access.

b. For each LRU, remove from the aircraft: *

(1) The recommended repair level to be established (minor repair or overhaul).

(2) A list of maintenance tasks required to restore the unit to operating condition.

(3) A preliminary list of tools, equipment, and facilities required to accomplish each discrete task.

(4) The quantity and skill level of personnel to accomplish each discrete task.

(5) The elapsed clock time, in minutes, to accomplish each discrete task.

(6) The frequency of each maintenance action.

*The final summation of this data may be a part of the P&WA maintenance and overhaul manuals.

c. The analyses shall include an operating time oriented projection from zero operating hours to maturity for those requirements defined in Table IX. This prediction shall demonstrate a confidence of at least one standard deviation or better.

6.5.4 Data Requirements
The following data shall be provided to Boeing in accordance with the schedule specified.

6.5.4.1 Maintainability Program Plan
Pratt & Whitney Aircraft shall submit a maintainability program plan which explains how their maintainability program is to be accomplished. This plan will be the same plan submitted to the FAA in accordance with the RFP. After coordination with Boeing for overall program compatibility, the plan shall become the standard by which the P&WA maintainability program shall be conducted. Revisions to the plan will be submitted to Boeing for information and shall contain any negotiated agreements reached between P&WA and Boeing with respect to the conduct of the maintainability program.

6.5.4.2 Maintainability Progress Report
Reports shall be submitted at least bi-monthly through completion of Phase III. These may be included in periodic reports submitted to Boeing for other purposes, and shall include as a minimum, an accounting of the progress of each task item as specified or defined by the program plan. The bi-monthly reports shall include:

a. Results achieved to date.

b. Problems encountered and action taken or planned.

The maintainability portion of the P&WA final report shall be provided to Boeing for coordination prior to submittal to the FAA for approval and shall include a complete accounting of the Phase III Maintainability Program.

6.5.4.3 AIDS Interface Data
The B-2707 airplane will incorporate as an airline option an Airborne Integrated Data System (AIDS). This sytem is intended to augment ground inspection and other maintenance procedures and methods of measuring deterioration to permit maximum extension of TBO's. This system will receive data from, and monitor the operational condition of, selected airplane equipment and detect and identify actual or potential failures down to a line replaceable unit (LRU) level. The engine shall be included as a candidate for monitoring by AIDS.

Selection of engine and engine components to be monitored will be based on the potential maintenance savings, reduction of unscheduled maintenance, and increased utilization. To design the AIDS, it is necessary to identify failure modes of LRU and means to detect or predict these failures and/or LRU degradation. The data requirements specified below will be used to identify or verify AIDS requirements and performance. Data required in compliance with the Reliability provisions contained herein shall be used whenever possible.

Pratt & Whitney Aircraft shall furnish:

a. An out-of-tolerance failure criteria for each mode of failure identified in the P&WA failure mode and effect analysis and which is in P&WA's judgment, a suitable candidate for AIDS monitoring.

b. The measurement accuracies, recommended sampling rate, and sampling period based upon intended use of equipment for those performance parameters which must be monitored to detect the failure of an LRU and/or equipment unit. This shall include a definition of all required ancillary environmental parameters such as OAT, airplane velocity and altitude which must be derived from sources exterior to the equipments being monitored.

c. The measurement accuracies and recommended sampling rates and sampling periods to predict failure trends of an LRU and/or equipment unit. Selected sensing will be augmented by a substantiating analysis which will indicate the degree of success anticipated in predicting failures.

d. The recommended analytical logic to be used in fault detection, isolation and prediction down to the LRU level for (b) and (c) above which will satisfy the logic requirements.

e. Recommendations for location of pickup points and sensors for measuring those parameters of item (d) which must or can most conveniently be measured within the engine and engine accessories. Where a suitable sensor is not available, recommend a plan for its development.

f. Pertinent information relating to failure rate rapidity and/or a time history of failure substantiating (b) and (c) recommendations.

The data measure ing rates and processing for failure trending will in large me mined by the time history of failure.

g. All available AIDS data and requirements relating to (a) through (f) above shall be submitted to Boeing upon contract award. As additional data is developed in response to (a) through (f), it shall be submitted in bi-monthly and/or quarterly progress reports. A study report containing all recommendations and inclusions in response to (a) through (f) above will be submitted to Boeing for coordination during Phase III.