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MILITARY SPECIFICATION

ENGINES, AIRCRAFT, TURBOJET AND TURBOFAN, GENERAL SPECIFICATION FOR

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification establishes the performance, operating characteristics, design features, detailed interface configuration definitions, and installation envelopes for turbojet and turbofan engines. It also establishes the demonstrations, tests, reports, inspection procedures, and other data required for satisfactory completion and acceptance, by the Using Service, of the Preliminary Flight Rating Tests (PFRT) and the Qualification Tests (QT) for the engines. Further, this specification identifies the tests, procedures and data required for satisfactory completion of the Acceptance Tests (AT) of production units of either model engine Notwithstanding the requirements for test verification of individual points of performance or operating characteristics of the engines covered by this specification for purposes of PFRT, QT, or AT, the engine manufacturer/contractor shall continue to be fully responsible for all features, characteristics, and performance of the engine throughout the operating envelope, to the extent required by the applicable contract. This specification also establishes the content and format to be used by the engine contractor for the preparation of the engine specification in accordance with 6.5.

2. APPLICABLE DOCUMENTS

2.1 Documents. The applicable publications listed in the following document, of the issue specified in the engine specification, form a part of this specification to the extent specified herein:

MIL-BULLETIN-343	Documents Applicable to Aircraft Engines and Propellers, Use of

(Copies of listed federal and military specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

FSC 2840

3. REQUIREMENTS

3.1 Item Definition. A brief description of the salient features of the engine shall be provided in the engine specification. To be included in this description, where applicable, shall be a description of such components as compressor including number of stages, variable geometry provisions, bypass ratio, acceleration bleeds, combustor type including method of fuel injection, turbine components including number of stages, cooling provisions, augmentation provisions, exhaust nozzle including variable geometry features, thrust reversers, engine control features, accessory gearbox provisions, type of lubrication and scavenge system, starting and ignition system, number and location of main bearings, instrumentation and performance indicating provisions. The performance ratings shall be specified in the engine specification in accordance with Tables I and II. A detailed engine characteristics summary shall be included as shown in Tables III and IV. Terms, symbols and their definitions shall be in accordance with section 6.

3.1.1 Item Diagrams. Item diagrams shall be provided when required by the Using Service.

3.1.2 Interface Definition. The interface requirements include all physical installation requirements and performance requirements necessary for installation of the engine. All interface definitions shall be shown on the engine configuration and envelope drawing or in the text describing the applicable functional system

3.1.2.1 Drawings. The following drawings, as figures, shall form a part of the engine specification. Reduced size copies of these figures shall be included in the engine specification.

a. Engine Configuration and Envelope Figure - This drawing shall include detailed profiles in all planes to show and identify the physical interface features of the engine. The drawing shall show mounting details and tolerances for the engine and all installation items, clearances for installation and removal of accessories and components subject to separate removal, access for adjustments and other maintenance functions, and center of gravity of the complete bare engine, and center of gravity of the engine with fully loaded accessory interfaces. This drawing shall show the maximum space required by the engine including tolerances and dimensional changes due to manufacturing, thermal effects, vibration, and operating and externally-applied loads.

b. Electrical Installation Connection Figure - This drawing shall show and identify all engine systems' external electrical circuits and installation interface connection details.

3.1.2.2 Mockup. When required by Using Service, a full scale mockup shall be prepared and a mockup inspection shall be held in accordance with ANA Bulletin No. 406.

3.1.2.3 Installation Changes. Engine features affecting engine installation interfaces shall be established in the engine specification. Changes (additions, deletions, or modifications) shall be submitted to the Using Service for approval only after coordination between the interfacing contractors as required by the applicable contract.

3.1.2.4 Mass Moment of Inertia of Complete Engine. The maximum effective mass moment of inertia (slug - ft^2) of the complete dry engine about three mutually perpendicular axes with the origin at the center of gravity shall be specified in the engine specification. The maximum effective mass moment of inertia (slug - ft^2) about the resultant rotational axis of each engine rotor, together with the direction of rotation when viewed looking forward from the exhaust exit, shall also be specified.

3.1.2.5 Externally Applied Forces. The engine shall function satisfactorily under the conditions specified in 3.1.2.6 and on Figure 1 and shall withstand those conditions without permanent deformation. The engine shall also not fail when subjected to static loads equivalent to 1.5 times those values but the engine need not operate satisfactorily thereafter. The limit loads shall be based on a weight factor consisting of the dry weight of the engine, increased by the specific weight allowed for all engine mounted accessories and operating fluids. In installations where airframe components are supported by the engine, the weight of these components will also be included in the weight factor. A report shall be submitted to the Using Service prior to the initiation of the PFRT which shall contain a detailed structural analysis of the entire engine with regard to its capability to withstand the loads specified in this paragraph, 3.1.2.5.1 and 3.1.2.6.

3.1.2.5.1 Gyroscopic Moments. At maximum allowable steady state engine speed, the engine shall operate satisfactorily when a gyroscopic moment is imposed under the following:

a. A steady angular velocity of 3.5 radians per second in any axis in a plane perpendicular to the rotor axis, combined with a vertical load factor of either + 1g or - 1g for a total period of 15 seconds.

b. A steady angular velocity of 1.4 radians per second in any axis in a plane perpendicular to the rotor axis, and the maximum load factor shown in Figure 1, for infinite cyclic life.

3.1.2 6 Engine Mounts. The location, interface dimensions, and the maximum allowable load limits at each individual attachment point shall be shown on the engine configuration and envelope figure.

3.1 2.6.1 Ground Handling Mounts Ground handling mounts shall be provided on the engine to support the weight of the engine increased for all engine mounted equipment and accessories, components and operating fluids. The handling mounts shall withstand loads of 4g axial, 2g lateral, and 3g vertical, without permanent deformation, based on weight of the engine defined above. The location and dimensions for the individual ground handling mounts shall be shown on the engine configuration and envelope figure The arrangement shall be compatible with ground handling equipment specified by the Using Service.

3.1.2.7 Pads & Drives. Pads and drives suitable for mounting and driving the engine components and aircraft accessories shall be in accordance with the basic configuration and rating requirements specified in the engine specification and presented as shown in Table V. The engine component drive system and the accessory drive systems (engine accessory drive gearbox and PTO drive) shall be capable of simultaneous operation of all the drives when each drive is subjected to the maximum permissible torque or power rating specified for the individual drive. All drive splines, except the tachometer generator drive spline, shall be positively lubricated by engine oil. Complete dimensions and details of the drive pads together with clearance envelopes shall be shown on the engine configuration and envelope figure No part of the gearbox shall prevent independent removal of any one accessory mounted on these drives. Pads and drives for aircraft accessories and engine components shall conform to the appropriate MS 3325 through MS 3329 standards The tachometer drive shall conform to AND 20005. Gearing for the tachometer generator drive pad shall provide a speed of 4200 $\pm$ 25 RPM at 100 percent rotor speed.

3.1.2.7.1 Power Takeoff (PTO). When a power-takeoff shaft(s) is provided for driving remote mounted aircraft accessories, the ratings, clearance envelopes, dimensions, pad and connection details, accessibility and alignment requirements shall be specified in the engine specification and on the engine configuration and envelope figure. The design and configuration of the power takeoff shaft shall conform with the applicable portions of 3.1.2.7 and 3.7.9.

3.1.2.8 Engine Surface Temperature and Heat Rejection. The maximum operating surface temperatures of the engine and heat rejection rates shall be specified in an appendix to the engine specification. Factors such as accessory pad loadings, compressor air bleed conditions, oil system cooling requirements and air and gas leakage from engine case flanges and split lines shall be taken into consideration in establishing engine heat rejection rates The surface temperature and heat rejection rates shall be presented in graphical form as shown in Figure 2. The conditions surrounding the engine, the engine power condition, and the oil system temperatures for which the surface temperature are applicable shall be shown. For components and accessories on the surface of the engine, the specified component and accessory surface temperature and heat generation curves may differ from the engine temperature as shown by the dashed lines on Figure 2. The engine surface emissivity shall be presented as shown on Figure 3. The heat rejection and surface temperature data presented shall be for the conditions listed below. If heat rejection rates during flight and ground operating conditions other than those listed below are critical or limiting, that data shall also be presented.

a. Maximum Power, Sea Level, static 52°C (125°F) day.

b. Maximum Power, Sea Level, 39°C (103°F) ambient, Maximum stagnation inlet air temperature.

c. Maximum Power, 36089 Ft. maximum stagnation inlet air temperature.

3.1.2.8.1 Engine Component Limiting Temperature. Engine components mounted on the engine shall not exceed their allowable temperatures when surrounded by still air under the following conditions:

a. Continuous operation with ambient air at the maximum stagnation temperature.

b. Flight shutdown from the most adverse condition and continued soaking with ambient air at maximum stagnation temperature.

c. Ground shutdown with ambient air at the standard sea level temperature with no special cooling such as forced ventilation, refrigeration, or rotation of rotors.

A tabulation of the maximum ambient air temperature surrounding each component and the limiting surface temperatures for all components shall be provided. These temperatures shall reflect maximum stagnation temperature and engine surface temperature heating effects. The specific points of measurement, where the ambient air temperature and surface temperature with respect to the three coordinate axes of the component are maximum, shall be provided in the engine specification. Contractors shall tabulate, by components, the surface and air temperature(s) and time period(s) applicable to the most severe condition(s) of the intended application.

3.1.2.8.2 Heat Rejection and Cooling Test Report. An engine heat rejection and cooling requirements test report shall be submitted to the Using Service prior to the initiation of PFRT. This report, based upon test data, shall verify the analytical heat rejection and surface temperature data presented in 3.1.2.8.

3.1.2.9 Air and Gas Leakage. The location, amount, temperature and pressure of engine leakages shall be specified in the engine specification. There shall be no locations where leakage flow will be of sufficient temperature and concentrated impingement to present a safety hazard or affect installation requirements.

3.1.2.10 Engine Air Inlet System

3.1.2.10.1 Air Inlet Design and Dimensions. The engine shall have an intake attachment flange and this flange shall be designed to accept either axial through bolts or a quick-disconnect clamp, as specified by the Using Service. Interface dimensions for the attachment of the inlet duct shall be shown on the engine configuration and envelope figure.

3.1.2.10.2 Allowable Inlet Connection Stresses. The maximum allowable shear load, axial load, and overhung moment at the engine inlet flange shall be specified in the engine specification.

3.1.2.10.3 Transient Airflow. Engine airflow transient demands shall be specified for the engine operating envelope. These transients include augmentor light-off and termination, as applicable, as well as power lever advance and retard. The allowable tolerance of time-rate-of-change in dynamic airflow overshoot/undershoot for the transient conditions shall be presented in graphical form in the engine specification. The effects of customer bleed airflow and power extraction shall be included.

3.1.2.10.4 Inlet Airflow Distortion Limits. At the option of the Using Service, one of the following procedures will be used to define the inlet airflow distortion limits.

PROCEDURE I:

a. Not less than five (5) sets of inlet flow distortion data and corresponding engine operating conditions shall be defined and specified in the engine specification, for which stable engine operation shall occur. The inlet distortion criteria defined and specified shall result from one or more of the following at the discretion of the Using Service: technical coordination between the airframe and engine contractors, dictated by the government, or left to the engine contractor to define. Compressor surge or stall under the specified conditions shall be considered a flight safety item and shall not be tolerated For each set of inlet flow distortion data specified, the engine interface operating conditions shall be defined, as applicable, in terms of mach number, altitude, power setting, customer airbleed, power extraction, etc. Measurements of the engine inlet total pressure, temperature, and flow variation shall be made at the engine/inlet aerodynamic interface which shall be defined in the engine specification. All inlet instrumentation utilized in measuring airflow, pressure and temperatures, the arrangement, location, response and instrumentation accuracies shall be defined and specified in the engine specification. For each set of specified inlet flow distortion data, the total airflow, average total pressure recovery and pressure and temperature for each individual probe as they occur shall be tabulated in the engine specification.

PROCEDURE II·

a. A distortion index indicating the maximum distortion limits at which the engine will provide surge-free operation throughout the operating envelope, due to steady-state and time-variant inlet air total pressure and temperature variation, shall be defined in the engine specification. Where exhaust nozzle back pressure effects on the fan and/or gas generator affects the tolerance of the engine to inlet air pressure variation, the effect shall be specified in the engine specification. The maximum steady-state pressure distortion limits at which the engine shall provide surge-free operation shall also be specified in the engine specification for the inlet distortion conditions and in terms of the distortion parameters defined below:

(1) For steady-state circumferential pressure distortion,

$$K\theta = \frac{\left[(\theta/2\pi)\ (q/P)^{1/2}\right]_{\text{Reference}}}{\left[(q/P)\ /\ (\bar{q}/\bar{P})\right]^{1/2}}$$

where the distortion time constant, $\left[(\theta/2\pi)\ (q/P)^{1/2}\right]$ Reference

is defined for both $\theta = 90°$ and $180°$ sectors, and

where θ = spoiled sector angle at compressor face having a total

pressure less than average

P, q = Total and compressible dynamic pressures in distorted

sector

$\bar{P}$, $\bar{q}$ = Average total and compressible dynamic pressures at

compressor face

(2) For steady-state hub and tip radial pressure distortion,

$(\Delta P/\bar{P})_{HUB\ AND\ TIP\ SURGE}$

$(\bar{r}/r_t)\ (r_2 - r_1\ /r_t - r_h)_{HUB\ AND\ TIP\ SURGE}$ - defines radial extent of hub and tip distortions at surge

where $\Delta P/\bar{P} = (P_{min} - \bar{P}) / \bar{P}$

r_h, r_t = compressor first-stage hub and tip radii

r_1, r_2 = radial boundaries of low pressure region nearest to and farthest from compressor hub

$\bar{r}$ = radial distance to center of low pressure region

b. Not less than five (5) sets of inlet flow distortion data and corresponding engine operation conditions for which stable operation shall occur shall be defined by the engine contractor and specified in the engine specification Compressor surge or stall under the specified conditions shall not be tolerated For each set of inlet flow distortion data specified, the engine interface operating conditions shall be defined, as applicable, in terms of Mach number, altitude, power setting, customer airbleed, power extraction, etc. Measurements of the engine inlet total pressure, temperature and flow variation shall be made at the engine/inlet aerodynamic interface which shall be defined in the engine specification. All inlet instrumentation utilized in measuring airflow, pressures and temperatures, the arrangement, location, response, and instrumentation accuracies shall be defined and specified in the engine specification. For each set of specified inlet flow distortion data, the total airflow, average total pressure recovery, and pressure and temperature for each individual probe as they occur shall be tabulated in the engine specification.

3.1.2.10.5 Rate of Pressure and Temperature Change The maximum permissible rate of change of engine inlet total pressure and temperature without stall, surge, flameout or mechanical damage shall be specified in the engine specification.

3.1.2.10.6 Armament Gas Ingestion. The engine shall operate without stall, surge, flameout or mechanical damage as a result of armament gas ingestion. Any provisions incorporated in the engine for prevention of armament gas induced malfunctions shall be specified in the engine specification. Unless otherwise specified by the Using Service, the engine operating conditions and armament gas conditions and characteristics for demonstration shall be as follows:

a. Engine power setting — Intermediate

Engine power setting	Intermediate
Altitude	36,089 feet
Mach number	0.7
Rocket mass flow rate	30 pounds per second
Rocket firing duration	0.1 second
Rocket position	15 feet from the engine inlet face with the rocket exhaust perpendicular to the engine face and on the engine center line
Propellant Characteristics	Non-aluminized double base

b. Same as a. above except for the following:

Propellant Characteristics	Aluminized composite

c.

Engine power setting	intermediate
Altitude	7,500 feet
Mach Number	0.7
Rocket mass flow rate	80 pounds per second
Rocket firing duration	0.1 second
Rocket position	15 feet from the engine inlet face with rocket exhaust perpendicular to the engine face and on the engine center line
Propellant characteristics	Non-aluminized double base

d. Same as c. above except for the following:

Propellant characteristics	Aluminized composite

3.1.2.11 Air Bleed System. The engine shall provide for customer air bleed extraction for aircraft use from the compressor or fan. The location(s), number and interface dimensions at all customer air bleed ports shall be shown on the engine configuration and envelope figure. During compressor air extraction, power lever modulation shall not be required to maintain engine stability and limits within the operating envelope of the engine. The pressure and temperature of bleed air from idle to maximum power at all operating altitudes, air inlet temperatures, and flight speeds, and the effects upon engine performance when bleeding this air from the engine from any number of ports, shall be included in the performance computer program of 3.2.1.2.1. The maximum bleed air temperature and pressure and the stage from which it is extracted shall be specified in the engine specification. The maximum continuous flow capability of each bleed air port in percent of total airflow shall be specified in the engine specification. Provisions shall be made to prevent high pressure bleed air from entering lower pressure bleed ports. All air bleed ports shall be sized to prevent engine failure in event of a single failure in the aircraft bleed system. Bleed ducts with external surface temperatures exceeding 371°C (700°F) shall be insulated to prevent hazards from combustible fluid leakage. The bleed port internal pickup points shall be located at positions which have the least susceptibility to pickup of sand and dust, oil, moisture, or other foreign materials contained in the air which could enter the airbleed. The engine-provided bleed air extraction system shall insure that no upstream malfunction of the engine will cause specified contamination limits to be exceeded.

3.1.2.11.1 Allowable Bleed Connection Loads. The maximum allowable axial, shear, and moment loads on the customer air bleed connections shall be specified in the engine specification.

3.1.2.11.2 Start and Acceleration Air Bleed. Where overboard ducting of acceleration bleed airflow is necessary, the airflow conditions for which provision must be made shall be specified in the engine specification. The ducting attachment detail shall be shown on the engine configuration and envelope figure. Compressor air bleed required for compressor surge protection, which operates continuously during steady-state engine operation in a surge-sensitive regime, shall be defined in the engine specification as to the operating envelope involved and the penalty in specific fuel consumption.

3.1.2.11.3 Bleed Air Contamination Engine generated substances contained in the bleed air shall be within the threshold limit values specified below. The engine manufacturer shall demonstrate, by analysing bleed air samples, that the specified threshold limits for the substances are not exceeded. Where substances other than those listed are contrubuted to the extracted air by engine operation, the engine manufacturer shall report the substance(s) and the contamination in parts per million to the Using Service for determination of maximum limits. When two or more engine generated substances are present, their combined effect shall be determined and reported. In the absence of information to the contrary, the combined effects of the different substances shall be considered as additive. If cleaning fluids are specified for use during normal engine maintenance, consideration should be given to their effect on bleed air contamination.

Substance	Parts per Million
Carbon dioxide	5000.0
Carbon monoxide	50.0
Ethanol	1000.0
Fluorine (as HF)	0.1
Hydrogen peroxide	1.0
Aviation fuels	250.0
Methyl alcohol	200.0
Methyl bromide	20.0
Nitrogen oxides	5.0
Acrolein	0.1
Oil breakdown products (e.g., aldehydes)	1.0
Ozone	0.1

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

3.1.2.12 Radar Cross Section. The maximum radar cross section (RCS) of the engine inlet and exhaust systems, in terms of square meters over the frequency range from 2 to 18 GHz shall be specified in the engine specification. The median values of the RCS over 10 degree intervals shall be less than the specified value. The 10 degree intervals over which the median values are obtained shall extend, as a minimum, over the angular range of ±60 degrees in both azimuth and elevation as measured from the engine centerline at the inlet for the forward hemisphere and at the engine centerline at the exhaust position for the aft hemisphere. Where variable exhaust nozzle systems are used or IR suppression devices are incorporated in the nozzle system, the contractor shall specify RCS values for these devices in each mode appropriate to system operation. Any special provisions for reducing RCS shall be described in the engine specification.

3.1.2.13 Connections The engine shall be permanently marked to indicate all connections shown on the engine configuration and envelope figure for instrumentation, fuel, oil, air and electrical connections. Connections located in close proximity to each other shall be made physically non-interchangeable.

3.1.3 Major Component List. The major components or component functional subsystems of the engine which require component qualification testing shall be listed in the engine specification.

3.1.4 Government Furnished Property List. No Government furnished property is to be incorporated in the engine design.

3.1.5 Government Loaned Property List. No Government loaned property is to be incorporated into the engine design.

3.2 CHARACTERISTICS

3.2.1 Performance Characteristics. The engine performance characteristics defined by the engine contractor in the engine specification shall be the poorest performing engine that the engine contractor would expect to submit to the Using Service for acceptance. Unless otherwise specified, the engine performance characteristics shall be based on:

a. A fuel having a lower heating value of 18,400 BTU/lb, and otherwise conforming to the fuel specified in paragraph 3.7.3.2.1 and oil specified in 3.7.7.2.

b. US Standard Atmosphere 1962 (ASTIA 401813) (geopotential altitude).

c. No inlet air distortion.

d. An inlet pressure recovery as defined by the following equations and conditions:

$P_{t2}(ref)/P_{to}$ = 1.0 From Zero to 1.0 Mach Number

$P_{t2}(ref)/P_{to} = 1.0 - 0.075(Mo - 1)^{1.35}$ From 1.0 to 5.0 Mach Number

$$P_{t2}(ref)/P_{t0} = \frac{800}{M_0^4 + 935} \quad \text{Above 5.0 Mach Number}$$

$P_{t2}(ref)$ = referenced total pressure at the compressor inlet

$P_{t}0$ = Free stream total pressure

M_0 = Flight Mach Number

e. The designation exhaust pipe and jet nozzle, fan exit duct and fan nozzle.

f. No customer bleed airflow.

g. No accessory power extraction, other than that required for continuous engine operation.

h. The performance shall be determined using the engine control system specified in the specification. The specified performance shall be predicated on the tolerance of control system variation which produces minimum performance.

3.2.1.1 Performance Ratings. The performance ratings shall be specified in the engine specification in accordance with Tables I and II. Ratings obtained by means of augmentation shall be so designated.

3.2.1.2 Performance Presentation Steady-State. Engine performance data shall be provided in two forms; one in the form of standard day curves in the engine specification, the other a computer program suitable for use with an automatic digital computer. The computer program shall be primary, and forms a part of and shall be identified in the engine specification. The performance data shall cover the operating envelope of the engine. The engine rating points of Tables I and II and the curves shall agree with the computer program. Points of rated performance shall be identified on the curves. The engine specification shall contain a list of the symbols in section 6 and a diagrammatic sketch indicating station subscripts.

3.2.1.2.1 Performance Presentation Digital Computer Program. A steady-state performance computer program will be constructed and furnished to the Using Service. This computer program shall form a part of the engine specification and shall carry a suitable identification and date, including the engine model designation. The engine specification shall specify the manufacturer, model and location of the computer upon which the program will be installed to obtain the official engine performance data. Compilation and execution of the computer program with sample data shall be demonstrated on the specified computer prior to acceptance by the Using Service. The computer program shall be prepared in accordance with the practices of ARP 681, Gas Turbine Engine Steady-State Performance Presentation for Digital Computer Programs, except as modified herein.

a. Program Requirements. The performance program shall be a thermodynamic cycle simulation in which component identity is maintained, e.g., the compressor, turbine and combustor must each be identifiable as entities in the model logic as required to obtain and maintain an accurate simulation (e.g., fan/compressor stall characteristics, burner blowout and Reynolds Number effects). The computer program shall be submitted in source language compatible with the computer specified.

b. Program Capabilities. The program shall be capable of operating throughout the engine operating envelope. Compilation shall not be necessary for each different run. Capability for determination of installation effects shall be included in the computer program. Effects of distortion, ram recovery, customer air bleed, customer power extraction, nozzle effects, parasitic flows, engine anti-icing, liquid injection, windmilling, reverse thrust and variable geometry will be included as applicable for the engine.

c. Documentation requirements. A user's manual and source deck shall be provided along with the computer program.

(1) User's Manual. In addition to those items specified in ARP 681, the user's manual shall contain a general description of the simulation techniques, general overall model flow chart and detailed flow charts of the main program and each component subroutine, and a clear explanation of the calculation process and related assumptions for all engine components. A tabulation of all parameter limits and reference of all engine limits described in the engine specification, e.g., gas temperature, RPM, etc. shall be included in the User's Manual. Additionally, the User's Manual shall include graphic component performance maps, graphs of all empirical functions used, reference values for normalized parameters, an index of subroutines including their functions, and a listing of all test case program inputs and the corresponding required outputs.

(2) Source decks. A source program card deck and program listing shall be provided. These shall include all program subroutines with comment cards to identify subroutines and model logic. All cards in the source deck shall be consecutively numbered and clearly marked with the manufacturer's name, engine designation, appropriate engine specification number, revision and date, and the card deck identification number.

d. Inputs/outputs. The program shall be so organized that the input data shall print out separately from the output. All program inputs must be independently variable and the programs shall be capable of sequentially accepting multiple, numerical changes to the computer inputs. In addition to the inputs listed in ARP 681, the program shall provide for fuel heating value (FHV) and measured gas temperature (GT) as defined in the engine specification. The program shall be capable of calculating all the required output parameters of ARP 681, with input options of measured gas temperature (GT), engine pressure ratio (P5Q2) and the applicable shaft rotational speeds, in addition to the options of Rating Code and Power Lever angle or Power code, specified in ARP 681. Aero-thermodynamic cycle parameters used in component performance evaluation and calculations must be available as output without reprogramming and are for information only and shall not be considered to be specification data.

3.2.1.2.2 Performance Curves. Curves shall be furnished showing engine performance under standard conditions, including altitude effects (pressure level and Reynolds number) at sea level and at each 10,000 foot increment up to, and including the absolute altitude of the engine and at altitude of 36,089 feet. The method for interpolation shall be specified, shall include any discontinuities in the curves and be consistent with the computer program. Each performance curve shall show the variation of net thrust with Mach numbers for the following power settings: Maximum, minimum augmented, two other augmented conditions, intermediate, maximum continuous, 90, 75 and 60 percent of maximum continuous, and idle. Curves shall show the airflow rate in lbs/sec (for turbofan engines, show hot, cold and total airflow), specific fuel consumption in lbs/hr/lb, and engine RPM and other variables (such as engine pressure ratio) that are measured and displayed as an indication of engine thrust. These curves shall be drawn in accordance with Figure 4. Curves shall be furnished for maximum reverse thrust obtainable versus ambient temperature at sea level, 2,500 and 5,000 feet altitudes for Mach numbers of 0, 0.1, and 0.2. Additional curves shall be furnished when required by the Using Service for clarity or to describe the special characteristics of an engine. The family of curves shall be presented to facilitate ease of visual interpolation of engine data; i.e., extension past operating boundaries or limits or the addition of a line outside engine limits. For engines incorporating ejector nozzles, the ejector total pressure and associated secondary airflow characteristics curves shall be presented as follows:

a. Secondary airflow (W_{as}) variation with Mach number (Figure 5) for the altitudes and thrust conditions specified above.

b. Secondary air total pressure recovery variation with Mach number (Figure 6) for the altitudes and thrust conditions specified above.

c. The minimum secondary airflow required for nozzle cooling or to make rated performance for the altitude and thrust condition specified above.

3.2.1.3 Performance Verification. The method of verifying Table I and Table II performance shall be subject to approval by the Using Service.

3.2.1.4 Operating Limits. All engine steady-state and transient operating limits (maximum, minimum) shall be specified. The specified limits shall be predicated on the most critical tolerances of the engine.

3.2.1.4.1 Operating Envelope. The engine operating limits as defined by aero-thermodynamic and mechanical limitations shall be specified in the engine specification in accordance with the format shown in Figures 7 and 8. These operating limits are the limiting conditions within which the engine shall meet all specified steady-state and transient performance characteristics when operating with the fuel as specified in paragraph 3.7.3.2.1.

3.2.1.4.2 Sea Level Operating Limits. The engine ram pressure ratio limits for standard and MIL-STD-210 cold and hot day sea level operation shall be specified in the engine specification.

3.2.1.4.3 Absolute Altitude. The absolute altitude of the engine and the range of ram pressure ratios applicable at standard day conditions shall be specified in the engine specification.

3.2.1.4.4 Starting Limits. The starting and operating limits shall be specified in the engine specification in accordance with Figures 7 and 8. The engine shall start under no-ram conditions from sea level up to at least 10,000 feet. The minimum acceptable air start altitude limit shall be as specified in the engine specification. Differences in the altitude starting limits for "hot" and "cold" engines shall be specified in the engine specification. A "cold" engine shall be defined as one which has been allowed to windmill at the specified test conditions until engine combustor exit temperature is within 55°C of engine compressor inlet temperature before a start is attempted. A "hot" engine shall be defined as one where a start is attempted within 10 seconds after a flameout or shutdown. The engine specification shall also specify the starting limits with maximum customer air bleed and maximum customer power extraction. (For afterburning engines, the starting and operating limits of the afterburner shall be specified.)

3.2.1.4.5 Engine Temperature Limits. The maximum allowable average gas temperature at the combustor exit, under steady-state conditions shall be specified in the engine specification. The maximum allowable average steady-state measured (gas or metal) temperature, corresponding to the maximum allowable combustor exit temperature, and the location where it is measured shall also be specified in the engine specification. The maximum allowable combustor exit average steady-state gas temperature shall be no less than 28°C (50°F) above the highest average combustor exit steady-state gas temperature required to obtain Table I and Table II performance ratings. The engine contractor shall also specify in the engine specification the engine operating condition (including compressor inlet temperature) at which the highest average combustor exit steady-state gas temperature occurs. The maximum allowable transient measured (gas or metal) temperatures (starting and acceleration) shall be specified in the engine specification.

3.2.1.4.6 Rotor Speed Limits. The maximum and minimum engine fuel flow shall be specified in the engine specification.

3.2.1.4.7 Fuel Flow Limits. The maximum and minimum engine fuel flow shall be specified in the engine specification.

3.2.1.4.8 Oil Pressure and Temperature Limits. The maximum and minimum operating oil pressure limits and maximum transient and maximum allowable steady-state oil temperature limits shall be specified in the engine specification. The maximum and minimum oil pressures during starting and initial operation at -54°C (-65°F) predicated on a 20,000 centistoke oil viscosity, shall be specified in the engine specification. Minimum and maximum oil pressures during starting and inital operation shall not persist for more than 2.5 minutes.

3.2.1.4.9 Oil Consumption Limits. The oil consumption including all forms of oil loss shall not exceed the amount specified in the engine specification. If the average oil consumption rate during the qualification tests is less than one-third of the specified value, the specification oil consumption rate shall be adjusted to a value no greater than three times the qualification test average.

3.2.1.4.10 Vibration Limits. The maximum permissible engine vibration limits (overall velocity limit (true RMS)) at each accelerometer location on the engine compressor and turbine cases, accessory gearbox case, and if applicable, internal structure shall be specified in the engine specification. The overall velocity limit specified for each accelerometer shall be applicable up to a frequency of 10,000 Hz.

3.2.1.4.11 Compressor Bleed and Accessory Power Extraction Limits. All limits on engine loading by means of accessory pads or customer bleed ports shall be specified in the engine specification. Limits shall be specified for each port and pad individually and for all possible combinations.

3.2.1.5 Operating Characteristics

3.2.1.5.1 Operating Attitude and Conditions. The engine shall be capable of continuous satisfactory operation in the clear area and at least 30 seconds operation in the shaded areas shown in Figure 9. The engine shall function satisfactorily for at least 60 seconds under conditions of negative "g" and for at least 30 seconds under zero "g" conditions. The engine shall be capable of being started, stopped and stowed in any of the attitudes shown in the clear area on Fig. 9. For engine applications in V/STOL aircraft requiring engine attitude changes, the starting and stopping attitude limits shall be not less than 105° nose up, 20° nose down, and 30° to each side.

3.2.1.5.2 Starting. See 3.7.9 Starting System

3.2.1.5.3 Stopping. Stopping (termination of fuel flow) of the engine shall be accomplished by a single power lever motion of less than 0.5 second and it shall be possible to stop the engine by this means from any operating condition. Stopping of thrust augmentation shall be accomplished by placing the power lever in any position other than in the thrust augmentation range and shall occur with no objectionable fluctuations in thrust. No damage to the engine shall result from shutting off the fuel supply by the foregoing means or from shutting off the fuel supply to the engine inlet connection during any engine operating condition. If the provisions for normal stopping of the engine include systems other than mechanical, an additional completely mechanical emergency system for shutting off all fuel flow to the complete engine shall be provided. The specification shall indicate normal means of stopping and if applicable, emergency provisions.

3.2.1.5.4 Idle. With the power lever in the idle position, and with no customer air bleed or horsepower extraction, the thrust shall not exceed 5 percent of the intermediate thrust available at standard day conditions up to 10,000 ft unless otherwise specified by the Using Service. Curves showing the variation in idle thrust and RPM with temperature between sea level and an altitude of 10,000 ft shall be provided in the engine specification. The idle thrust between an altitude of 10,000 ft and the absolute altitude shall be shown of the performance curves. When the engine incorporates provisions for an additional lower idle power setting, the means of accomplishment, the thrust level, the corresponding RPM and the time required to restore idle thrust shall be specified in the engine specification.

3.2.1.5.5 Stability. Under steady-state operating conditions, throughout the complete operating envelope, engine thrust fluctuations shall not exceed ±1.0 percent of maximum continuous thrust between idle and maximum continuous thrust conditions or ±5.0 percent of the thrust available at the power level position and operating condition, whichever is less. During operation above maximum continuous thrust, fluctuations shall not exceed ±1.0 percent of the thrust available at that condition. During steady-state operating conditions, the period between discrete frequency fluctuations shall not be less than 5 seconds. Additional requirements related to stability during operation of the air bleed system are stated in 3.1.2.11.

3.2.1.5.6 Thrust Transients. During selection of the power lever positions in any sequence and at any rate, there shall be no overspeed or overtemperature beyond stated transient limits and no main burner, augmentor, fan or compressor instability. For power lever movements of 0.5 second or less, the time required to accomplish 95 percent of the thrust change shall not exceed the values specified below. All transients specified shall be based on standard day conditions, with no customer power extraction, customer air bleed or engine anti-icing air bleed, but with all other engine system air bleed requirements (e.g. acceleration air bleed, cooling air bleed). The total time required to accomplish each specified transient and reach stable operation shall be that time noted plus 10 seconds. Stable operation shall be as defined in 3.2.1.5.5.

a. From idle to intermediate thrust available, 5 seconds up to 150 knots indicated airspeed (IAS); and 4 seconds above 150 knots IAS from sea level to 10,000 feet.

b. From idle to intermediate thrust available, 12 seconds from 10,000 feet to the absolute altitude.

c. From idle to maximum reverse thrust available, 5 seconds from sea level to 10,000 feet, up to 150 knots IAS.

d. From idle to maximum thrust available, 7 seconds from sea level to 10,000 feet.

e. From 30 percent intermediate to intermediate thrust available, 4 seconds up to 150 knots IAS, from sea level to 10,000 feet.

f. From maximum thrust to maximum reverse thrust available, 2 seconds under all operating conditions.

g. From maximum reverse thrust to intermediate thrust available, 2 seconds under all operating conditions.

h. From maximum thrust to intermediate thrust available, 2 seconds under all operating conditions.

i. From intermediate thrust to maximum thrust available, 2 seconds under all operating conditions.

j. From intermediate thrust to idle thrust available, 5 seconds from sea level to 10,000 feet at a minimum of 150 knots IAS.

k. From 20% intermediate thrust to 30% intermediate thrust, and from 20% intermediate thrust to 10% intermediate thrust, 0.5 seconds up to 150 knots IAS at sea level standard conditions. Power lever movement shall not exceed 125% of that required to obtain a corresponding steady-state change.

The thrust versus time from idle and 10, 20, 30, 40, and 50% intermediate to intermediate thrust and to maximum thrust, from sea level to 10,000 feet altitude at standard atmospheric conditions, shall be presented in the engine specification as shown in Figure 10.

Thrust transient times shall not exceed 125% of the times for conditions (a) through (k) above, under any of the following conditions, singly or in any combination: non-standard day conditions throughout the complete operating envelope; customer power extraction; customer air bleed; engine anti-icing air bleed; inlet distortion; icing environment.

3.2.1.5.7 Engine Windmilling Capability. The engine shall be capable of at least 5 hours of continuous windmilling operation throughout its entire operating envelope without damage to the engine, without excessive loss of lubricating oil, and without affecting capability of air restart and operation. The following information shall be specified in the engine specification:

a. The limits of windmilling operation including curves showing windmilling rotor speed and windmilling drag vs flight Mach number.

b. The oil consumption rate during windmilling operation.

c. The time duration and limits of windmilling operation after depletion of oil supply.

d. The customer power extraction and customer air bleed available during windmilling operation.

3.2.1.5.8 Reverse Thrust. The engine shall operate satisfactorily in the reverse thrust mode to the limits specified in the engine specification. The reverser system shall be capable of operation from the fully stowed position to the fully deployed position in no more than two (2) seconds and from the fully deployed position to the fully stowed position in no more than five (5) seconds at all engine power settings and throughout the reverser operating regime. The thrust reverser operating envelope shall be specified in the engine specification.

3.2.2 Physical Characteristics

3.2.2.1 Dry Weight of Complete Engine. The dry weight of the complete engine shall not exceed that specified in the engine specification. If the specification value exceeds the dry weight of the official qualification test engine by more than 2 percent, the specification value shall be revised downward to within 1.5 percent of the dry weight of the test engine. The weights of engine components which are not mounted on the engine shall be listed and included in the dry weight of the engine.

3.2.2.2 Weight of Residual Fluids. The weight of residual fluids remaining in the engine after operation and drainage, while the engine is in a single specified attitude of the main rotor axis relative to the level plane, shall be specified in the engine specification.

3.2.3 Reliability. An engine failure mode and effect analysis shall be performed prior to PFRT and revised as required prior to QT. The analysis shall show probable frequency of failure values assigned to each failure mode. After completion of all qualification testing, the contractor shall prepare a reliability report based on the total development and qualification effort and based on data gathered through contractor reliability programs. When required by the Using Service, there shall be a demonstration of the reliability values specified in the engine specification and presented as shown in Table VI. The reliability values are subject to the failure definitions and exclusions specified in Section 6.

3.2.4 Maintainability. The engine shall be designed for ease of servicing and maintenance. The engine shall exhibit characteristics of design such that it can be retained in or restored to a working and usable, condition within a specified period of time, when the maintenance is performed in accordance with prescribed procedures and resources.

3.2.4.1 Numerical Requirements. When required by the Using Service, maintainability values shall be specified in the engine specification and presented as shown in Table VII. These values shall be derived from system maintainability allocations and shall be based upon the planned weapon system utilization rate and mission mix. Initial maintainability values shall be specified in the engine specification and presented as shown in Table VIII. When required by the Using Service, these values shall form the maintainability testing in accordance with MIL-STD-473. The primary parameter for assessing quantitative maintainability shall be maintenance manhours per engine flight hour (MMH/EFH). Other terms and definitions applicable to maintainability are set forth in MIL-STD-721.

3.2.4.1.1 Applicable Maintenance Functions. The following maintenance, repair, and inspection functions shall be applicable in determining the maintenance index:

a. Pre-flight and post-flight inspections.

b. Periodic inspections including hot section inspections.

c. Unscheduled organizational and intermediate level maintenance including time for trouble shooting, adjustment, repair and/or removal and replacement.

d. All engine overhaul and repair of components.

e. Engine servicing.

3.2.4.1.2 Excluded Maintenance Functions. The following maintenance and repair functions shall be excluded from the maintenance index calculation:

a. Technical Order and Time Compliance Technical Order compliance when related to upgraded engine performance or other changes in specification requirements.

b. Removal and installation of non-engine supplied equipment to perform engine maintenance (e.g., access panels, parts installed on the engine or nacelle by the weapon system Contractor).

c. Engine fuel servicing.

d. Engine removal/replacement in the aircraft except when required due to:

(1) Chargeable engine failures/malfunctions.

(2) Engine design which requires removal to perform routine maintenance on such items as igniters, fuel filters, oil filters, etc.

e. All maintenance tasks resulting from failures or discrepancies that are not chargeable to the engine.

f. All maintenance tasks required to position ground equipment, and/or move the aircraft.

3.2.4.2 Maintenance Inspection and Repair Cycles. The estimated maintenance, inspection, and repair periods, including depot overhaul, shall be specified in the engine specification together with the estimated time in manhours required to perform these functions. A tabulation shall be provided in the engine specification which gives the time to remove and replace the modules listed in

3.5.1.1 and also all externally mounted engine components that are separately removable such as fuel pumps, fuel controls, igniter plugs, etc.

3.2.5 Environmental Conditions

3.2.5.1 Ambient Temperature Conditions. The complete engine shall start and operate satisfactorily, using fuels and oils specified in the engine specification under the following conditions:

a. From sea level to the maximum altitude specified for the starting envelope, after a soaking period of 10 hours at an ambient temperature of 71°C (160°F) when supplied with fuel at 93°C (200°F) and inlet air at 52°C (125°F). Restart and operate satisfactorily from sea level to the maximum altitude specified for the starting envelope after a soaking period of 15 minutes at an ambient temperature of 135°C (275°F) when supplied with fuel at 93°C (200°F) and inlet air at 52°C (125°F).

b. From sea level to the maximum altitude specified for the starting envelope, after a soaking period of 10 hours at an ambient temperature of -54°C (-65°F) when supplied with oil, air and MIL-T-5624, grade JP-4 fuel, all at -54°C (-65°F). If a MIL-T-5624 fuel other than grade JP-4 is specified, the engine shall also start and operate from sea level to the maximum altitude specified for the starting envelope, after a soaking period of 10 hours when supplied with air and the specified fuel, all at a temperature corresponding to a fuel viscosity of not less than 12 centistokes.

c. Throughout the ambient air temperature ranges shown on Tables II and III of MIL-STD-210 and throughout the airspeed and altitude operating limits specified in the engine specification, when supplied with MIL-T-5624 fuel, grade JP-4, at any temperature between -54°C (-65°F), or that temperature corresponding to a fuel viscosity of 12 centistokes for other grades of MIL-T-5624, and the maximum fuel inlet temperature as specified in the engine specification.

3.2.5.2 Icing Conditions. The engine shall operate satisfactorily under the meteorological conditions shown in Figures 11 and 12, with not more than 5 percent total loss in thrust available and 5 percent total increase in specific fuel consumption at all operating conditions above 50 percent maximum continuous power setting. Operation at less than 50 percent maximum continuous power shall be such that 95 percent of the thrust desired above 50 percent maximum continuous power can be obtained within the specified acceleration time. If an anti-icing system is required in order to meet the above performance under the specified environmental conditions, the anti-icing system shall be in accordance with 3.7.1.

3.2.5.3 Fungus Resistance. The engine components shall be resistant to fungus as determined by selection of non-nutrient materials which are resistant to fungus and by satisfactory completion of component qualification.

3.2.5.4 Humidity Resistance. The engine components shall be resistant to malfunction and deterioration when subjected to 95% or higher humidity conditions for extended periods. This shall be demonstrated by satisfactory completion of component qualification.

3.2.5.5 Corrosion Susceptibility. The engine shall perform satisfactorily and the endurance capability and useful life shall not be adversely affected while operating in or after exposure to salt laden air or to 95 percent or higher humidity conditions. Selected materials and coatings shall also be corrosion tested under simulated engine environmental conditions appropriate to their final usage during operation, handling, and storage of the engine. A report of this testing shall be furnished to the Using Service prior to the start of the PFRT. The contractor shall submit the proposed test plans prior to initiation of the materials tests.

3.2.5.6 Environmental Ingestion Capability

3.2.5.6.1 Bird Ingestion. When required by the Using Service, the engine shall be capable of ingesting the number and different sizes of birds at the bird velocity and engine speed as described below. Under the conditions of a, b, and c, no failures shall result which will cause shutdown of the engine although some damage to engine parts may occur. No engine flameout will occur and the engine shall recover to the operating condition that existed prior to bird ingestion within the time specified in the engine specification for items a, b, and c. For item d no engine failure shall occur which would result in damage to the aircraft.

a. Birds weighing 2 to 4 ounces (a maximum of sixteen at a time) and birds weighing 2 pounds (one at a time) ingested at a bird velocity equal to the take-off flight speed, with the engine at maximum rated speed.

b. Birds weighing 2 to 4 ounces (a maximum of sixteen at a time) and birds weighing 2 pounds (one at a time) ingested at a bird velocity equal to the cruise flight speed with the engine at maximum continuous speed.

c. Birds weighing 2 to 4 ounces (a maximum of sixteen at a time) and birds weighing 2 pounds (one at a time) ingested at a bird velocity equal to the descent flight speed with the engine at an associated engine speed.

d. Birds weighing 4 pounds ingested at a bird velocity based on the most critical flight speed, with the engine at maximum rated speed.

e. The number of birds to be ingested shall be based on the area at the fan/compressor face. The number of birds to be ingested shall be one 2 or 4 ounce bird for each 50 square inches, or for each fraction larger than 50 percent thereof, one 2 pound bird for each 225 square inches, or for each fraction larger than 50 percent thereof, and one 4 pound bird for each 400 square inches, or for each fraction larger than 50 percent thereof. The birds shall be ingested at random intervals, and randomly dispersed over the engine inlet area. If any of the above sizes of birds cannot pass through the inlet, that portion of the requirement shall not be applicable.

3.2.5.6.2 Foreign Object Damage (FOD). The engine shall operate for two inspection periods or the number of hours specified in the engine specification after ingestion of foreign objects which produce damage with a minimum stress concentration factor (K_t) of 3 to fan and compressor blades and stators.

3.2.5.6.3 Ice Ingestion. The engine shall be capable of ingesting hail, and any ice which accretes on engine inlet parts without flameout, lengthy power recovery, sustained power loss exceeding 10% of the thrust at the operating condition, or catastrophic or critical engine failure. The time for power recovery shall be specified in the engine specification. When required by the Using Service, the engine shall also be capable of ingesting shed ice and shall be subjected to the sheet ice ingestion test of 4.6.1.6.b.

3.2.5.6.4 Sand Ingestion. The engine, including all components, shall operate satisfactorily throughout its operating range at ground environmental conditions with air containing sand and dust in concentrations up to 3.3×10^{-6} pounds of sand per cubic foot of air. The engine and its components shall be capable of operating at maximum continuous thrust with the specified concentration of sand and dust for a total period of 10 hours with not greater than 5 percent loss in thrust, 5 percent gain in specific fuel consumption, and no impairment of capability to execute thrust transients. The specified sand contaminant shall consist of crushed quartz with the total particle size distribution as follows:

Particle Size, Microns	Quantity, percent by weight finer than size indicated
1,000	100
900	98 - 99
600	93 - 97
400	82 - 86
200	46 - 50
125	18 - 22
75	3 - 7

3.2.5.6.5 Atmospheric Liquid Water Ingestion. The engine shall operate satisfactorily throughout the complete operating envelope up to 45,000 feet altitude at power settings from idle to maximum thrust with up to 5.0 percent of the total airflow weight in the form of water (liquid and vapor) and with 50 percent of the liquid water entering the engine inlet through a segment equivalent to one-third of the inlet area.

3.2.5.7 Noise Levels. The engine shall operate such that under all operating conditions the discrete frequency and broadband noise components of the total engine noise signature shall be minimized. The near and far field engine noise signatures at the Table I ratings shall be included in the engine specification.

3.2.5.8 Exhaust Gas Contamination

3.2.5.8.1 Exhaust Smoke Emission. The engine shall not emit visible exhaust smoke at any power setting throughout the engine operating envelope when using any primary fuel specified for the engine. The maximum allowable smoke emission level shall be specified in the engine specification as determined from Figure 13 and when measured by the method of SAE ARP 1179 and when using MIL-T-5624 grade JP-4 fuel with an aromatic content of 15% by volume. Toluene may be added to the fuel to attain the required aromatic content.

3.2.5.8.2 Invisible Exhaust Mass Emissions. The quantity in lb/1000 lb fuel of hydrocarbon, carbon monoxide, and NO_x emissions at maximum, intermediate, and idle power settings shall be specified in the engine specification. The procedure for measuring the amount of exhaust constituents emitted by the engine shall be as specified in ARP 1256. The hydrocarbons shall be specified on the basis of methane and the oxides of nitrogen shall be specified on the basis of nitrogen dioxide.

3.2.6 Transportability. The engine shall be suitable for movement on, and be compatible with, standard aircraft engine transportation trailers designated by the Using Service. The above requirements shall govern unless the engine size and weight characteristics are beyond the capabilities of the standard handling equipment. Adequate ground handling pads and other features shall be provided to permit installation on and use of appropriate static and mobile ground equipment.

3.3 Design and Construction

3.3.1 Materials, Processes, and Fasteners

3.3.1.1 Materials and Processes. When the engine manufacturer's documents are used for materials and processes, such documents shall be subject to review by Using Service prior to the start of the PFRT, and unless specifically disapproved, will be considered released upon approval of the PFRT and QT. The use of non-governmental documents shall not constitute waiver of Government inspection. The Using Service reserves the right to inspect any and all processes of manufacture. The use of magnesium requires specific application approval of the Using Service. Dissimilar metals as defined in MIL-STD-889 shall not be used in direct contact with each other.

3.3.1.1.1 Adhesives and Sealants. The use, in any location, of adhesive or sealant compounds shall require approval of the Using Service prior to its incorporation into the design of the engine and, as a minimum, shall be governed by the limitations listed in MS 18069 (ASG).

3.3.1.1.2 Shelf Life. All elastomeric parts shall be manufactured from materials having unlimited shelf life.

3.3.1.1.3 "O" Ring Seals and Packings. All non-metallic "O" ring seals and packings used in the engine, including vendor supplied components, shall conform to the applicable dimensions and tolerances shown on MS 33666 and MS 33668. Materials exposed to fuels and lubricants shall be compatible with such fluids throughout the entire fuel or lubrication system temperature cyclic envelope without experiencing swelling, shrinking, or other forms of material deterioration which would impair proper functioning or necessitate replacement to prevent impairment of function.

3.3.1.1.4 Corrosion Protection. The materials, coatings, and processes employed in the design and manufacture of the complete engine shall be corrosion resistant. The engine contractor shall identify all protective treatments in the engine specification.

3.3.1.1.5 Nonmetallic Hose. Nonmetallic hose, where used, shall be in accordance with MIL-H-27267. Hose assemblies shall comply with MIL-H-25579. Hose carrying flammable fluid shall comply with 3.3.6.1.

3.3.1.2 Fasteners

3.3.1.2.1 Self-Retaining Bolts. Self-retaining bolts in accordance with MIL-B-23964 shall be used at joints in control systems, at single attachments, and where loss of the bolt would affect safety of flight or ability to control the engine. Self-retaining bolts shall be used in accordance with MS 33602.

3.3.1.2.2 Securing of Fasteners. Where safety wiring or cotter pinning is used to secure fasteners, the practices in MS 33540 shall be followed. The general design and usage limitation of self-locking nuts specified in MS 33588 shall be applied.

3.3.1.2.3 Clamps. Single loop tube support clamps used in applications below 316°C (600°F) shall be selected from MS 9825 or MS 9826.

3.3.1.2.4 Screw Recesses. All screw recesses (internal drives) will conform to MS 33750, MS 33781, or MS 9006.

3.3.1.2.5 Helical Coil Installation. The dimensions and tolerances of the parent material threads intended for use with helical coil inserts shall comply with MS 33537.

3.3.1.2.6 Screw Threads. All screw threads shall conform to the requirements of MIL-S-8879 Classes 3A or 3B. The use of MIL-S-7742 is optional for threads used for:

a. Electrical connections

b. Screw threads .138 inch diameter and smaller

c. Interference fits and other applications where MIL-S-7742 threads are suitable for the intended purpose, such as installation end of studs or external thread of inserts and their mating tapped holes.

Duplicate parts differing only in thread form are not permitted.

3.3.1.2.7 External Fastener Drives. Wrenching elements for external drives shall conform to SAE AS 870 for twelve point threaded fastener, MS 33787 for spline drives, and the applicable MS drawings for hex-head threaded fasteners.

3.3.2 Electromagnetic Interference (EMI). All engine electrical and electronic systems and components shall comply with MIL-STD-461 and MIL-STD-462, equipment Class 1D. The engine shall not cause or be susceptible to interference beyond the limits specified in MIL-STD-461, Class 1D. An EMI control plan and an EMI/EMC test plan as required by MIL-STD-461 shall be prepared prior to PFRT and QT.

3.3.3 Nameplate and Product Marking

3.3.3.1 Identification of Product and Marking. Equipment, assemblies, modules, and parts shall be marked for identification in accordance with MIL-STD-130. The engine data plate shall include: (a) manufacturer's identification, (b) engine serial number, (c) purchase order or contract number, (d) engine model designation. Parts which are cyclic or life limited shall be serially numbered and shall have a designated space for marking the number of cycles and time accumulated between each overhaul period.

3.3.3.2 Drawing Revision Marking. In addition to identification marking, all parts shall be marked with the revision letter of the issue of the drawing to which the part was made.

3.3.4 Workmanship. Workmanship shall be in accordance with the applicable contract requirement.

3.3.5 Interchangeability. All parts having the same manufacturer's part number shall be functionally and dimensionally interchangeable and replaceable with each other with respect to installation and performance, except that matched parts or selective fits will be permitted where required. The use of matched parts and selective fits shall be held to a minimum. Such matched or selected fit parts shall be identified and a listing shall be provided to the Using Service, prior to PFRT and QT.

3.3.6 Safety. When required by the Using Service, the safety criteria and considerations set forth in MIL-STD-882 will be used in establishing engine safety design features.

3.3.6.1 Flammable Fluid Systems. All exterior lines, fittings, and components which convey flammable fluid shall be fire resistant (5 minutes at 1090°C (2000°F)), except that the lubricating oil system and hydraulic system components shall be fireproof (15 minutes at 1090°C (2000°F)). During exposure to the above conditions, the lines and components shall be conveying fluids under the worst possible combinations (i.e., lowest flow rate, highest pressure and temperature) of fluid parameters encountered over the complete engine operating range.

3.3.6.2 Fire Shield Attachment. When required by the Using Service, fire shield attachment provisions shall be provided on the engine. The type of attachment, location, dimensions and allowable loads at the interface shall be shown on the engine configuration and envelope figure.

3.3.6.3 Explosion-Proof. All electrical components (except igniter plug electrodes) shall not ignite any explosive mixture surrounding the equipment.

3.3.6.4 Fluid Leakage. There shall be no leakage from any part of the engine except at the drains provided for this purpose. The quantity of leakage from all drains, except that specified in 3.3.6.5, shall not exceed 5 ml. per minute for afterburning engines.

3.3.6.5 Combustible Fluid Drains. Provisions shall be made for automatically clearing the combustion areas of combustible fluids after each false start and for preventing excess combustible fluids from entering the combustion areas after shutdown with the engine in either a level position, 15 degrees nose up, or 20 degrees nose down. 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. When required by the Using Service, these same provisions shall be made for the engine in the vertical position. The maximum allowable quantity of combustible fluid which will discharge from the engine drains after shutdown from normal operation and if applicable from augmented operation shall be specified in the engine specification.

3.3.6.6 Ground Safety. Warning notices shall be provided, where applicable, for high voltage ignition systems and other high voltage electrical sources, radioactive devices, and explosive devices.

3.3.6.7 Survivability and Vulnerability

3.3.6.7.1 Nuclear Safety and Hardening. The engine and all components shall be hardened in order to have a nuclear survival capability when operating in the nuclear environment specified by the Using Service.

3.3.6.7.2 Non-Nuclear. The engine design shall optimize the survival capability of the engine in the hostile environment specified by the Using Service.

3.3.7 Human Performance and Human Engineering. The principles, criteria, and procedures of human engineering shall be applied to the design of the engine in accordance with the applicable contract requirements.

3.3.8 Structural Performance

3.3.8.1 Structural Life. The engine shall be designed for a structural life, with repair, consistent with system life requirements. The contractor shall specify in the engine specification the structural life in hours. If the system mission requirements are defined, the structural life shall be based on the appropriate duty cycle specified by the Using Service for that system. If system mission requirements are not defined, the structural life shall be based upon the distribution of power settings for the requirements and utilization rates specified in Table IX and for the ambient temperature distribution shown in Figure 14. Contractor shall include in the specification parts life in hours for expendable parts such as:

Ignitor Plugs
O-Rings
Gaskets and Seals
Filter Elements

3.3.8.2 High Cycle Fatigue Life. All parts of the engine shall have the following minimum high cycle fatigue life:

a. Steel parts 10^7 cycles

b. Non ferrous alloy parts $3x10^7$ cycles

3.3.8.3 Low Cycle Fatigue Life. The minimum operational Low Cycle Fatigue (LCF) life of the engine shall be as specified in Table IX. LCF life requirements apply to all parts of the engine and include both pressure and temperature cyclic effects. Both components and complete engine LCF testing shall be required. All components requiring LCF test shall be tested to 2 times the life value specified in Table IX for LCF life. Component repair will be permitted at the completion of one life. In addition, a complete engine test equivalent to one LCF life shall be conducted.

3.3.8.4 Engine Pressure Balance. The engine pressure balance system shall provide unidirectional thrust loads sufficient to assure bearing operation without skid damage at all power settings throughout the engine operating envelope. An analysis of the loads shall be performed and a report verifying these loads shall be submitted to the Using Service prior to PFRT.

3.3.8.5 Engine Pressure Vessel/Case Design. Each engine case and each gas pressure loaded component of the engine shall withstand at least 2.00 times its maximum operating pressure without rupture.

3.3.8.6 Strength and Life Analysis. A strength and life analysis shall be performed and a report submitted, for information only, prior to PFRT and updated prior to QT. Stress analysis shall include items such as engine cases, disk, vanes, blades, mounts, combustion liners, bearing supports, gears, brackets, and tubing. The report shall contain a study to establish the LCF test duty cycle and duty time required for the engine LCF test.

3.3.8.7 Design Material Properties. Allowable strength and life material properties shall be based on minus three (-3) sigma value. Fracture toughness properties shall be considered when choosing materials.

3.3.8.8 Creep. The engine static and rotating parts shall not creep to the extent that engine operation is impaired for the operating conditions and the lifetime specified in Table IX. It also shall not affect disassembly and reassembly of the engine. The engine specification shall state the rate of part growth as it varies with operational time during the endurance portion of qualification and the LCF testing.

3.3.8.9 Containment and Rotor Structural Integrity

3.3.8.9.1 Containment. The engine shall completely contain a fan, compressor, or turbine blade failure at the blade airfoil section in the fillet above the platform at maximum allowable transient rotor speeds. In addition, the engine shall contain all parts damaged and released by the failure of a single blade. The engine shall incorporate a fail safe design to eliminate catastrophic failure including the following:

a. Fan, compressor, and turbine disks shall be protected by having blades fail first during overspeed or over temperature malfunctions.

b. A main rotor shaft bearing or lubrication system failure shall not cause parting or decoupling of the shaft(s).

c. In the event of shaft decoupling, the turbine blading shall contact the turbine vanes to arrest the turbine to preclude a turbine overspeed.

d. In the event of a rotor bearing failure, the structures supporting the rotating masses shall be designed to minimize the probability of gross misalignment of the engine rotating parts.

3.3.8.9.2 Rotor Integrity. To provide a necessary margin for rotor structural integrity, the rotors shall be of sufficient strength to withstand the following abnormal conditions:

a. Rotor speeds of 115 percent of maximum allowable steady state speed at maximum allowable measured gas temperature for 5 minutes.

b. Measured gas temperature at least 42°C (75°F) in excess of the maximum allowable measured gas temperature and at maximum allowable steady state rotor speed for 5 minutes.

3.3.8.9.3 Disk Burst Speeds. Disk design burst speeds shall be no less than 122 percent of the maximum allowable steady state speed.

3.3.8.10 Vibration. The engine shall be free of destructive vibration at all engine speeds and thrusts, including steady-state and transient operation throughout the complete operating range of the engine. The engine mechanical vibration limits shall be specified in 3.2.1.4.10. Vibrations generated by the engine outside the specified frequency range shall not be detrimental to engine operation. The limits shall be based on the engine being installed in a mounting system which has the following dynamic characteristics: The natural frequencies of the mounting system with the engine installed shall be no higher than 80 percent of the idle rotor speed(s) in all modes of vibration which can be excited by the residual rotor unbalances.

Acceleration spectrograms shall be provided at the highest vibrational level in the operating envelope (which shall be identified) and each of the engine rating points. These spectrograms are to be generated from each accelerometer shown on the engine configuration and envelope figure for engine vibration monitoring. Critical components of the engine shall be identified on each spectrogram. Each spectrogram shall cover the frequency range of 5Hz to 10kHz and present acceleration data in peak g's.

3.3.8.10.1 Critical Speeds. For designs with a fundamental critical speed above the maximum operating speed, a minimum of 20% margin shall exist between the maximum operating speed and critical speed. Adequate damping shall be provided if an engine passes through a critical speed below idle.

3.3.8.10.2 Vibration and Stress Analysis. A vibration and stress analysis shall be accomplished on fan, compressor, and turbine stage blade, disk, and vane designs including fan, compressor, and turbine shafts and other components where high vibration and stress occur. The vibratory stress distribution and the various modes of vibration including complex modes shall be obtained. The critical speeds, excitation frequencies and stress values for the vibratory stress distributions and nodal patterns shall be determined and correlated with the strength and life analysis. The report shall include the results of actual engine operation or where that is impractical by component test and analytical study. Analysis of the data shall include the measured and referred stress values at high stress areas on the cases, blades, vanes, disks, shafts, spacers, engine mounts, and other instrumented parts. Equations and sample calculations for all analytical methods used shall be included in the report. The data shall show the effects on stress levels due to vibration throughout the operating range of the engine. The report shall show modified Goodman and Campbell diagrams for each component design. Plots of excitation frequency vs rotor speed showing the primary orders of excitation and the modes of vibration shall be plotted with points noting stress, measured and referred. A summary of all critical speeds shall be defined in the report. The vibration and stress analysis report shall be submitted prior to PFRT.

3.3.9 Design Control

3.3.9.1 Standardization. Standardization principles, standard parts, materials, processes, tools, subsystems, and components shall be used to the maximum extent possible without compromise in design or performance of the engine. All parts, materials, and processes, whether or not identified as a Government, industry or contractor standard shall be qualified for the intended use as a part of the qualification specified herein. Items already in the Government inventory shall be used to the maximum extent possible where suitable for the intended purpose. Variation in similar components or parts shall be held to the absolute minimum. Proprietary designs shall be kept to a minimum. Under conditions wherein economics of production conflict with standardization objectives, the latter group will govern, or the Using Service shall be requested to select the component desired for use.

3.3.9.1.1 Design Standards. MS and AND design standards shall be used wherever applicable.

3.3.9.1.2 Standard Parts. The military standard parts developed specifically for use in aircraft engines shall take precedence over any other military standards. Where general purpose standards, as defined by envelope dimensions or Qualified Products List (QPL), are used in critical or high strength application, they shall be identified by the vendor or engine manufacturer's part number. Parts derived from general purpose standards solely on an inspection or selection basis shall be identified by engine manufacturer parts numbers and all previous identification marks shall be removed.

3.3.9.2 Parts List. The parts list for the engine which successfully completes either the PFRT or the QT shall constitute the approved parts list for any subsequent engines of the same type and model to be delivered to the Using Service. Changes to the approved engine parts list shall be in accordance with the applicable contract requirement.

3.3.9.3 Assembly of Components and Parts. Equipment, parts, and components which are not structurally or functionally interchangeable shall not be physically interchangeable. Parts and components shall be designed such that it is physically impossible to install them backwards, upside down, reversed in an assembly, or installed in the wrong location in an assembly. Connections located in close proximity to each other shall be made physically non-interchangeable.

3.3.9.4 Design and Construction Changes

3.3.9.4.1 Changes in Design. No changes shall be made in the design or material of parts listed in an approved engine parts list, except when such changes are in accordance with the applicable contract requirement.

3.3.9.4.2 Changes in Vendors or Fabrication Process. Changes in vendor, fabrication source, or fabrication process of those parts used in the Qualification Tests shall be in accordance with the following procedure:

The contractor shall prepare and submit to the Using Service a list of those parts, components, and assemblies which require a substantiation test to qualify an alternative vendor source or process. The specific test required to substantiate their capability to qualify as an engine part shall be defined. The fabrication source and process of selected vendor components will be included in this list. The list is subject to review and disapproval by the Using Service in regard to its completeness and to the suitability of the tests. The contractor thereafter shall be responsible for insuring that all parts, components, and assemblies on the substantiation list comply with the qualified fabrication source and process, and that any changes to those sources or processes are effectively controlled. The contractor shall be responsible for performance of substantiation tests to establish satisfactory alternate vendors or fabrication sources or processes. A fabrication source is defined as the prime physical source producing the part, component, or assembly. Changes of fabrication location, such as to another plant of an individual vendor, shall be construed as a change of fabrication source.

3.4 Documentation. Documentation to be supplied shall be in accordance with applicable contract requirements.

3.5 Logistics

3.5.1 Maintenance

3.5.1.1 Modular Concept. When required by the Using Service, the engine shall be designed for ease of replacement of major engine sections by incorporating the modular concept. The separate modules shall be listed in the engine specification.

3.5.1.2 Maintenance Inspection Techniques. The engine shall be designed to permit maximum use of nondestructive inspection techniques and multi-purpose test and inspection equipment. Provisions for inspection of the installed engine by borescope (or equivalent devices) shall be made for the fan, compressor, combustor, and turbine sections of the engine. A positive means of slowly rotating the rotor system(s) shall be provided to facilitate borescope inspection. Radiographic inspection capability shall be provided for the completely assembled engine. The extent of inspection coverage by the above techniques shall be stated in the specification. Location of the inspection provisions shall assure port access and radiographic access for the installed engine. Inspection provisions including access envelopes shall be shown on the engine configuration and envelope figure.

3.5.1.3 Service and Accessibility. Parts of the engine requiring routine service, checking, adjustment or frequent replacement shall be made readily accessible without removal of other parts or components, and without disassembly of the engine.

3.5.1.4 Tools. The engine shall be designed to make maximum use of standard hand tools (as identified by the Using Service) for servicing, adjustment, assembly, and disassembly. Where provisions for basic hand tools are not feasible, the design shall provide, wherever possible, for special tools and test equipment that are available and in use on other in-service propulsion systems, as identified by the Using Service. The requirement for new special tools, fixtures and test equipment shall be held to the absolute minimum.

3.5.1.5 Repair Procedures and Wear Limits. Prior to QT, the contractor shall establish after-run wear limits, standards, and parts repair procedures.

3.5.2 Supply. Supply provisions shall be in accordance with the applicable contract requirement.

3 5.3 Facilities and Facility Equipment The impact on existing facilities or the need for new facilities shall be in accordance with the applicable contract requirements.

3 6 Personnel and Training. Personnel and training requirements shall be in accordance with the applicable contract requirements.

3 7 Major Component Characteristics

3.7.1 Anti-Icing System. The engine anti-icing system shall prevent the accumulation of ice on any engine part while operating under the icing conditions specified in 3.2.5 2. The total loss in performance of 5% specified in 3.2.5.2 shall include the effects of operation in the icing environment. The effect of anti-icing system operation in a non-icing environment shall be specified in the engine specification.

3.7.1 1 Anti-Icing Interface

3.7.1.1.1 Anti-Icing System Actuation. Actuation of the system shall be accomplished either automatically or manually and the signal requirements for the actuation of the system shall be specified in the engine specification. If an ice detector physically separate from the engine is provided, a means of automatically actuating the engine anti-icing system shall be required. Manual override shall be provided if the system is automatically actuated. The anti-icing system shall provide a signal for indication that the anti-icing system is operating.

3.7.1.1.2 Anti-Icing Inlet Dome or Accessory Sections. Anti-icing shall be provided at the front of the engine for anti-icing a customer supplied inlet dome or accessory section Details of the connection shall be shown on the engine configuration and envelope figure. If compressor bleed air is used for this purpose, it shall be considered part of the quantity specified in 3.1.2.11.

3.7.1 2 Type of Anti-Icing. A description of the system shall be included in the engine specification. If failure of the anti-icing system occurs, it shall remain in or revert to the anti-icing mode. Continuous operation of the anti-icing system throughout the operating envelope shall not damage the engine. The acceleration performance of the engine when using anti-icing air bleed shall be as specified in 3.2.1.5.6. For electrical anti-icing systems, the engine shall be capable of simultaneous operation of the anti-icing system and all other engine electrical systems.

3.7.2 Engine Control System. The engine control system shall include all control units such as fuel control, variable area jet nozzle control, compressor bleed or geometry control, temperature control, afterburner control, inlet guide vane control, and any other control units required for proper and complete automatic or manual control of the engine. The engine control system shall provide complete automatic and, when required by the Using Service, manual control of the engine. Both the automatic and manual system shall be completely self-sufficient and shall require no external power from the airframe electrical system. Provision shall be made in the engine control system to allow ready attachment of remotely actuated devices for all adjustments which may be required in service. When required by the Using Service, electronic power control components shall provide for protection against jamming devices. The engine control system shall be described and each control unit with its function shall be listed in the engine specification.

3.7.2.1 Engine Control System Interface

3.7.2.1.1 Power Lever

3.7.2.1.1.1 Power Lever Angle. A single power lever shall be provided on the engine to modulate thrust. The power lever shall have a total travel of 130 degrees ±1° and shall provide the fuel shutoff. Dwell bands shall be located as specified herein. A readily visible indexing plate shall be provided at the power lever input. The length of the dwell bands shall be 3.0° ±0.25°. Positive stops shall be located at zero and 130 degrees positions. Rigging pin locations shall be provided at idle, intermediate and, if required, other rigging pin locations shall be specified in the engine specification.

Power Lever

Augmented Engines	Augmented Engines with Thrust Reverser	Non-Augmented Engines	Non-Augmented Engines with Thrust Reverser	Power Lever Angle
Maximum	Maximum	Maximum	Maximum	127° to 130°
-	Intermediate	-	-	95° to 98°
Intermediate	-	-	-	81° to 84°
-	Idle	-	Idle	35° to 50°
Idle	-	Idle	-	15° to 18°
Off	Maximum Reverser	Off	Maximum Reverser	0° to 3°

For engines with thrust reverser, a separate level with total travel of 90 degrees ±1° shall be provided for fuel shut off as shown below. Positive stops shall be located at zero and 90 degree positions

SHUT OFF LEVER

Shut Off	0 to 40 degrees
Open	55 to 90 degrees

A readily visible indexing plate shall be provided for the shut off lever

3.7.2.1.1.2 Lever Torque. The torque required to operate the engine power lever through its range of travel shall not exceed 25 pound-inches The power lever shall not move with the engine operating unless external torque is applied. Movement of the power lever throughout the operating range shall be free of abrupt changes in actuating torque, and the maximum permissible variation shall not exceed 10 pound-inches. The maximum torque required to operate any additional levers shall not exceed 25 pound-inches. If the torque is different when the engine is not running, this shall be specified in the engine specification. The relationship between power lever torque and power lever angle shall be shown as in the example of Figure 15 The maximum allowable axial, torsional, and overhung moment loads and the maximum allowable throttle shaft loading in pound-inches when the shaft is against its travel stops shall be specified in the engine specification.

3.7.2.1.2 Control Signals. The engine control system shall provide for external inputs as required by the Using Service. The engine control system shall also provide for output signals required for interrogation by systems external to the engine. Control input and output signal requirements, input and output parameters, and related functions shall be specified in the engine specification.

3.7.2.2 Engine Control System Performance. The engine control system shall provide control of engine operation to obtain the steady state and transient engine performance specified in the engine specification. The engine control system shall automatically prevent the engine from exceeding any of its limits throughout the engine operating envelope. With any electrical failure, the engine shall operate to at least 80% of minimum thrust normally obtainable. The engine control system shall provide the proper relationship between power lever position and controlled engine variables throughout the complete operating range of the engine. The tolerance on power lever position, for any given value of a controlled variable shall be ±2.5 degrees.

3.7.2.2.1 Thrust Modulation. The relationship between thrust and power lever position shall be of the fully modulated type, free of abrupt changes, and essentially linear with a thrust step of not more than 4 percent of intermediate rated thrust when augmentation is initiated or terminated. If a thrust reverser is supplied as part of the engine the relationship between reverse thrust and reverse thrust lever position shall be free of abrupt changes and essentially linear.

3.7.2.2.2 Region of Control Limiting Functions Regions of control limiting functions at intermediate and maximum power as a function of altitude and Mach Number for hot, standard, and cold ambient conditions, shall be shown as in Figure 16. The limiting values used to establish the various regions shall be specified on the figures.

3.7.2.2.3 Manual Fuel Control. When a manual fuel control is required by the Using Service, it shall control fuel flow independent of the automatic system to the extent defined below:

a. It shall be possible to modulate the engine's power between idle plus 5 percent and 90 percent of the intermediate power normally available on a standard day from sea level to 30,000 feet altitude.

b. It shall be possible to air-start the engine and operate it thereafter in accordance with a.

c It shall be possible to prevent engine operation beyond established limits. Preventive action shall be possible in a period of time such that damage to the engine will not occur.

3.7.2 3 Engine Control System Design. The engine control system design shall provide for simple adjustments and for easy accessibility. The design of the fuel control unit shall be such that it may be removed from the engine separately from any input system (such as inlet temperature sensing system) and replaced without calibration or matching with such input system.

3.7.2.3.1 Engine Control System Adjustment. External adjustments to the controls shall be limited to adjustment which can be made correctly with the engine assembled and with reference only to the operating characteristics of the engine on the ground. These adjustments shall be brought to a central trim panel which shall be clearly marked, accessible and adjustable with the engine running and adjusters shall be self-locking under all operating conditions. All other adjustments will be protected to prevent tampering. When once adjusted, no further adjustment shall be necessary to provide within-limits operation throughout the entire engine operating envelope All adjustment provisions shall be shown on the engine configuration and envelope figure.

3.7.2.3.1.1 Fuel Grade Adjustment The engine may provide either automatic or manual adjustment features for specific gravity. The full range of adjustments shall be obtained within a maximum arc of 360 degrees Stop provisions for the different fuels shall be clearly indicated on a dual scale showing average setting for fuel type and graduation in terms of specific gravity The adjustable range for specific gravity shall be specified in the engine specification. No adjustment shall be required for variations in specific gravity within the specification range of each specified fuel grade

3.7.2.3.1.2 Idle Speed Adjustment Idle rotor speed shall be adjustable within a range of ±5 percent of the specified idle speed. This adjustment shall be independent of and shall not affect maximum speed setting

3.7.2.3.1.3 Maximum Speed Adjustment. The maximum engine rotor speed shall be adjustable within the range of ±5 percent of the intermediate rated value. If the engine has more than one rotor and each rotor speed is adjustable, the engine specification shall specify the range of adjustments and how the adjustments are made.

3.7.2 3.1.4 Measured Engine Temperature Adjustments. When adjustable, the maximum measured engine temperature shall be adjustable within the range of ±5% of the intermediate rated value.

3.7.2.3.2 Cooling Provisions If the engine requires a component environmental control system (ECS) to meet the requirements of 3 1 2.8.1, the contractor shall specify the type and describe the system to be used.

3.7.3 Fuel System

3.7.3.1 Fuel System Interface

3.7.3.1.1 Fuel Flowmeter(s). Provisions shall be made for installing fuel flowmeter transmitter(s) in the engine fuel system where the nonaugmented engine fuel flow to the combustion chambers can be measured. For engines which include an augmentation system, the provisions for measuring augmentation fuel flow shall be specified herein when required by the Using Service. The flowmeter type(s), the installation provisions, and the installation envelope shall be described in the engine specification and shown on the engine configuration and envelope figure.

3.7.3.1.2 Maximum Fuel Flow. The maximum flow, including that required for acceleration overshoot requirements throughout the complete operating envelope, shall be specified in the engine specification.

3.7.3.1.3 Fuel Inlet

3.7.3.1.3.1 Fuel Inlet Dimensions. The location and interface dimensions at the engine fuel inlet connection(s) shall be shown on the engine configuration and envelope figure.

3.7 3.1 3.2 Allowable Fuel Inlet Connection Loads. The maximum allowable loads on the fuel inlet connection shall be specified in the engine specification

3 7.3.1.3.3 Fuel Inlet Pressure and Temperature. The maximum and minimum fuel inlet pressures shall be specified in the engine specification. The maximum fuel inlet temperature allowable for continuous operation shall not be less than 93°C (200°F) and shall be specified in the engine specification. Fuel temperatures above that specified as the maximum allowable for continuous operation shall be specified for special operating conditions and for limited durations. Minimum fuel inlet temperature shall be in accordance with 3.2.5.1.

3.7.3.2 Fuels

3.7.3.2.1 Primary Fuel. The engine shall function satisfactorily throughout its complete operating range for any steady-state and transient operation conditions when using fuel conforming to and having any of the variations in characteristics permitted by MIL-T-5624 of the grades specified in the engine specification.

3.7.3.2.2 Alternate Fuel. When required by the Using Service, the engine shall also start and operate using the alternate fuels specified The operating limits, thrust outputs and thrust transients specified in the engine specification shall not be adversely affected when using alternate fuel. The effects on the engine performance characteristics, changes in SFC, changes in starting and stopping time, and effects on the aircraft mission(s) when using alternate fuels shall be specified. There shall be no effect on the established overhaul time for the engine in 3.2.4.2. Only those external adjustments permitted in 3.7.2.3 1.1 shall be allowed in order to meet this requirement. The engine shall function satisfactorily with the alternate fuels specified containing anti-icing additive conforming to MIL-I-27686 and added in a concentration up to 0.15 percent by volume.

3.7.3.2.3 Emergency Fuel. When required by the Using Service, the engine shall also start and operate using the emergency fuels specified. The engine shall function satisfactorily for a time period of at least 6 hours from sea level to 35,000 feet altitude, at least throughout a range from idle to 90 percent of maximum thrust, at no greater than 120 percent of the specification rated or estimated specific fuel consumption when using fuels conforming to MIL-G-5572, MIL-G-3056, and VV-G-76 Only the external control adjustments permitted in 3 7.2.3.1.1 will be allowed to meet this requirement. If applicable, operating limitations, special inspection or maintenance actions required as a result of using this fuel shall be specified.

3.7.3.3 Fuel System Performance

3.7.3.3.1 Fuel System Calibration Limits. Whenever fuel flow calibrations are required for fuel system components, and applicable limits for this calibration, using test fluid in accordance with MIL-C-7024, Type II, shall be furnished to the Using Service.

3.7 3.3.2 Fuel Contamination. The engine shall function satisfactorily when using fuel contaminated in any amount up to the extent specified in Table X.

3.7.3 3.3 Fuel System Performance with External Assistance The engine fuel system shall supply the required amount of fuel at the required pressures for operation of the engine throughout its complete operating envelope including starting and augmentation, (if provided) with the following conditions at the fuel inlet connection on the engine·

a Fuel temperature: From a minimum of -54°C (-o5°F) (when using MIL-T-5624, grade JP-5 fuel) or that temperature corresponding to a fuel viscosity of 12 centistokes (when using MIL-T-5624, grade JP-5 fuel) to a maximum as specified in 3.7.3.1.3 3

b. Fuel pressure: From a minimum of 5 psi above the true vapor pressure of the fuel to a maximum of 50 psig with a vapor/liquid ratio of zero.

3.7.3.3.4 Fuel System Performance with No External Assistance The engine fuel system shall supply the required amount of fuel at the required pressures for engine operation, (including augmentation if provided) from sea level up to 30,000 feet altitude and ground and air starting up to 10,000 feet altitude under the following conditions:

a. All fuel flow requirements up to at least those conditions corresponding to inlet ram pressure ratio varying linearly from 1 15 at sea level to 1 70 at 30,000 feet.

b. Ambient air temperature at standard day conditions.

c. Fuel temperature at the fuel inlet connection up to at least a minimum of 57°C (135°F).

d. Vapor/liquid ratio of fuel at the engine fuel inlet connection from zero to 0.45.

3.7.3.3.4.1 Pump Priming The engine fuel pump shall be capable of priming itself when subjected to a dry lift of one foot at an inlet pressure of 9 inches of mercury absolute at the pump inlet with a fuel Reid Vapor Pressure not exceeding 3.0 psi, and at a fuel temperature of up to at least 38°C (100°F). The requirements of this paragraph shall not apply to operation with emergency fuel.

3.7.3.3 5 Fuel System Performance under Conditions of Excessive Fuel Vapor. Under the conditions of vapor/liquid ratio greater than 0 45 at the fuel inlet, it shall not be necessary for the engine fuel system to supply the amount of fuel required for engine operation. However, it shall be possible to accomplish normal starts after the conditions specified in 3.7.3 3.4 have been re-established.

3.7.3.3.6 Fuel Resistance. The materials and designs used in engine and components shall be satisfactory when tested with TT-S-735, types I and II test fluids, when used in any sequence.

3.7 3.4 Fuel Filter. If fuel filtration finer than 1,500 microns is required, it shall be provided as part of the engine. The type and filtration rating of the main engine fuel filter(s) shall be specified in the engine specification. The filter shall have sufficient capacity to permit a cumulative fuel flow equivalent to a minimum of 12 hours of continuous engine operation at intermediate sea level thrust with fuel contaminated as specified in Table X without being cleaned. The filter assembly shall incorporate a pressure relief bypass and be of a design which will prevent the discharge of filter contaminant through the bypass The filter assembly will provide a signal for remote indication of filter bypass. The filter assembly also shall incorporate an integral differential pressure activated pop-out device that will give visual warning of impending bypass, raising a red indicator. Once activated, the red indicator shall remain extended until manually reset internally after filter element removal. A drain valve shall be provided at the low point of the filter assembly to drain the filter element cavity and for purging the fuel system of air following filter element replacement

3.7.4 Electrical Systems

3.7.4 1 Electrical Power. The primary electrical power for engine ignition and control system operation during starting and throughout the complete operating range shall be supplied by the engine.

3.7.4.1.1 Generator/Alternator. The engine generator/alternator shall provide the required electrical power from the specified minimum firing speed to maximum engine speed The generator/alternator shall not be adversely affected by continuous operation at a generator/alternator speed equivalent to 106% maximum allowable engine speed under full electrical load, and shall withstand 5 minutes of operation at overspeeds equivalent 115% maximum allowable steady state engine speed without electrical load. The generator/alternator housing shall completely contain all damage if a mechanical failure should occur when operating at maximum design speed

3.7.4.2 Alternate Electrical Power In the event of a power failure of the self-contained power system such that any functions cease satisfactory operation, the engine shall have the capability of being switched to an external electrical power source. Engine electrical equipment, when utilizing external power, shall operate with power defined in MIL-STD-704, utilization category B. The electrical requirements of the engine under this condition shall be specified in the engine specification.

3.7.4.3 Electrical Interface

3.7.4 3.1 External Electrical Power. Engine electrical equipment normally utilizing external power shall operate with power defined in MIL-STD-704, utilization category B The type and quantity of electrical power from external sources required by this electrical equipment shall be specified in the engine specification. In the event of loss of externally supplied electrical power, the engine shall accomplish satisfactory air starts and shall operate safely at all engine speeds at or above idle and throughout the complete thrust range. Any limitations or loss of function caused by loss of externally supplied electrical power shall be specified in the engine specification.

3.7.4.3.2 Electrical Connectors and Cable. Electrical connectors shall comply with MIL-STD-454, Requirement 10. At a temperature of -54°C (-65°F) it shall be possible to flex electrical cable and conductors during routine maintenance without damage to these items, and to connect or disconnect electrical connectors using normal maintenance procedures.

3.7.4.4 Electrical and Electronic Equipment. All electrical and electronic components shall undergo component qualification testing as specified in section 4. All electrical and electronic equipment requiring periodic or routine checkout shall be located on the engine for easy access and shall be provided with test connections to facilitate checkout without removal from the engine.

3.7.4.5 Electrical Bonding. The internal and external bonding/grounding requirements and design shall be described in the engine specification.

3.7.4.6 Potting Compounds. All potting compounds used shall require the specific application approval of the Using Service.

3.7.5 Ignition System

3.7.5.1 Ignition System Interface. The engine ignition system shall have provisions to allow its external activation and termination. The interface requirements shall be shown on the electrical installation connection figure.

3.7.5.2 Ignition System. The engine ignition system shall be electrically self-sufficient requiring no external power. The ignition system shall provide a minimum of two separate ignitors and two independent exciter output circuits, and each separate ignitor and circuit shall release sufficient energy for all ground and air starting requirements. The engine ignition system (excluding the A/B ignition system) shall have continuous duty capability. The ignition system shall function satisfactorily throughout the complete operating envelope of the engine. A means shall be provided to deactivate the ignition system, and it shall be described in the engine specification. The ignition system and its power source shall be described in the engine specification including the ratings, in terms of stored energy level and delivered energy level to each ignitor, in joules per spark and frequency of spark. The minimum stored and delivered energy level in joules per spark and the minimum frequency of spark, at the point in the starting envelope where these minimums occur, shall also be specified. Augmentor ignition shall be automatically activated by placing the engine power lever to any position in the augmentation range.

3.7.5.3 Automatic Relight. When required by the Using Service, the engine shall incorporate an automatic rapid relight system which will be capable of immediately re-establishing burner operation after a flameout has occurred. System response time, sensitivity, and time duration ignition remains on after activation shall be specified in the engine specification.

3.7.6 Instrumentation Systems

3.7.6.1 Instrumentation Interface

3.7.6.1.1 Condition Indication. The engine shall incorporate sensors (pressure, temperature, quantity, warning, etc.) which are required to provide information to permit safe engine operation and operation within the established operating limits. The instrument range, system accuracy, time response, and electrical characteristics for each parameter shall be presented in tabular form in the engine specification.

3.7.6.1.2 Engine Condition Monitoring. When required by the Using Service, the engine shall incorporate equipment to monitor engine mechanical condition and performance during flight and to provide ground analytical and condition checkout capability. Sufficient engine parameters shall be made available to detect early failure symptoms and performance degradation, permit fault isolation and provide long term failure trending information. The ranges, limits, output signal characteristics and accuracies of the condition sensors together with their location shall be specified in the engine specification. Electrical connections and circuit details shall be shown on the electrical installation connection figure.

3.7.6.2 Pressure Connections. Connections on the engine for mounting fuel, oil, and hydraulic pressure transmitters shall conform to MS 33649-12, and a clearance envelope in accordance with MS 33587 shall be provided. Connections on the engine for transmitting air pressures shall conform to MS 33649-4.

3.7.6.3 Special Maintenance Instrumentation Provisions. When required by the Using Service, provisions shall be made for special instrument sensing equipment necessary to evaluate engine performance at acceptance and overhaul testing.

3.7.6.4 Temperature Sensing Systems. The temperature sensing systems of the engine shall provide a signal for the aircraft instrument system and, if required, to the engine power control and condition monitoring systems. An electrically independent temperature sensing system shall be provided for each component or system requiring a temperature signal input. The output of the sensing devices as a function of temperature and range of normal operation shall be shown in the engine specification. If thermocouples are used, the relationship between temperatures and output signal shall be in accordance with the applicable calibration of National Bureau of Standards Monograph 125. The accuracy of the signals in relation to the actual measured temperature and transient time response characteristics shall be specified. The engine specification shall contain a brief description of each sensing system including circuitry, construction, number of thermocouples or measuring devices and their locations. When a multi-probe thermocouple system is provided to measure gas temperature, the system shall provide for individual thermocouple probe readings for maintenance temperature spread checks and trouble-shooting. Connectors shall be provided in the thermocouple harness at a convenient location to interface with ground test equipment. Optical or radiation pyrometer temperature sensing systems shall not require frequent removal for cleaning. The cleaning interval shall be specified in the engine specification.

3.7.6.5 Vibration Measurement. Engine vibration shall be measured with accelerometer vibration detectors. The engine shall incorporate provisions (brackets, mountings) for determination of vibration in three mutually perpendicular planes at appropriate locations on the engine cases and accessory gearbox. Additional locations external or internal (e.g. main bearing locations) may be specified as necessary for the particular engine design. The points of attachment for the vibration detectors shall be shown on the engine configuration and envelope figure. The engine contractor shall specify the output signal characteristics of any vibration sensors which are a part of the engine.

3.7.6.6 Thrust Indication. The engine shall provide a signal for thrust computation. The method for computing thrust from these signals shall be shown in the engine specification.

3.7.6.7 Low Cycle Fatigue Counter. When required by the Using Service, the engine shall incorporate a digital counter which will record engine low cycle fatigue (LCF) cycles. The LCF counter shall have provisions for counting separately at least four LCF events such as those listed in Table IX. The counter shall be located for convenient readout by ground maintenance personnel. A brief description of the counter and the system and means by which the counter is activated shall be presented in the engine specification.

3.7.6.7.1 Relative Damage Chart. The contractor shall provide a relative damage chart showing the damage assessment (using Miner's Rule) for each LCF event of Table IX, in percent of the takeoff damage, for each rotor system based on the most critical component in that rotor system. This chart shall be submitted prior to the initiation of the QT.

3.7.6.8 Speed Indication (RPM). The engine shall provide signals for rotor speed indication. The signals will be of the same characteristics as that from a standard tachometer generator conforming to MIL-G-26611. When a standard tachometer generator is used, the drive shall be in accordance with 3.1.2.7. For multi-rotor engines, an RPM signal shall be provided for each rotor system.

3.7.7 Engine Lubricating System. The lubricating system shall satisfactorily lubricate the engine throughout its operating envelope without a change in lubricant. The complete lubricating system, including oil cooler(s) and oil reservoir, shall be furnished as part of the engine. The engine oil system shall not provide a function for other aircraft accessories or components The engine lubrication system shall be designed to prevent contamination of the oil by seepage of fuel or other fluids into the oil system.

3.7.7.1 Lubricating System Interface

3.7.7.1.1 Oil System Installation and Servicing. The location and pertinent features of oil system interfaces, such as the oil reservoir filler cap, pressure fill ports, drains, oil level indication and vents, shall be shown on the engine configuration and envelope figure.

3.7.7.2 Lubricating Oil. The engine shall use lubricating oils conforming to MIL-L-7808 and MIL-L-23699, and having any of the variations in characteristics permitted by the oil specifications. No special provisions such as oil preheaters or oil dilution shall be required for starting and operation throughout the complete environmental temperature range and operating envelope for the engine, except that with MIL-L-23699 oil, operation is not required at oil temperatures below that temperature corresponding to an oil kinematic viscosity of 13,000 centistokes.

3.7.7.3 Lubricating System Performance. The engine shall function satisfactorily throughout the operating range and at any of the flight maneuver forces and attitudes of 3.1.2.4 and 3.2.1.5.1 when the oil reservoir contains more that that quantity of oil which is defined as "unusable". The lubrication system shall provide its function within the oil pressure and temperature limits of 3.2.1.4.8 and shall not exceed the oil consumption rate specified in 3.2.1.4.9.

3.7.7.3.1 Oil Flow and Heat Rejection. The performance of oil systems and associated cooling provisions and cooling requirements, including sample calculations of the oil system heat balance, shall be furnished in the engine specification. The oil flow and heat rejection data and vent airflow based upon the maximum limiting temperatures of 3.1.2.8.1 shall be furnished in the engine specification. When an oil-to-air heat exchanger is used, the required airflow and pressure drop shall be specified for all applicable airspeed, altitude, and ambient temperature conditions. When fuel-oil coolers are used, heat balance data shall be based on 15°C (59°F), 57°C (132°F) and maximum fuel temperatures at the fuel inlet connection on the engine, together with the minimum fuel flow for each operating condition as would be encountered by an engine having the best possible projected SFC. A complete oil system heat balance shall be presented in the engine specification with the maximum limiting temperatures of 3.1.2.8.1 and with 51°C (59°F), 57°C (132°F) and maximum oil cooler cooling medium temperatures as specified in the engine specification. The heat balance shall also take into consideration effects of maximum accessory gearbox loading, variations in engine internal cooling requirements, bleed air extraction, and the conditions that would impose the greatest cooling requirement on the system. A report verifying the heat balance analysis shown in the engine specification shall be submitted to the Using Service prior to the initiation of the qualification endurance test. The instrumentation requirements and sensor locations for evaluation of the oil system performance shall be specified in the engine specification.

3.7.7.3.2 <u>Internal Oil Leakage</u>. The lubricating system shall be such that oil leakage within the engine shall not cause oil discharge from the engine upon subsequent starting after shutdown, adversely affect oil supply-determination, cause contamination of bleed air, cause residual fires in the engine, or cause deposits.

3.7.7.3.3 <u>Oil Flow Interruption</u>. The engine shall operate at intermediate power for a period of 30 seconds during which no oil is supplied to the engine oil pump inlet. As a result of this operation, there shall be no detrimental effects to the engine during the oil flow interruption period or engine operation thereafter.

3.7.7.3.4 <u>Oil Wetted Surfaces</u>. The flow characteristics and temperatures at oil wetted surfaces and vents shall be such as to prevent coking and sludge build-up.

3.7.7.4 <u>Lubrication System Components and Features</u>

3.7.7.4.1 <u>Oil Reservoir</u>. Engine mounted oil reservoir(s) and mountings shall be constructed of corrosion resistant material capable of withstanding, without permanent deformation, the stresses imposed by reservoir pressurization, engine vibration, and cyclic stresses imposed by variations in ambient pressure and internal reservoir pressure. The oil reservoir shall withstand a differential pressure of 15 psi positive and negative or twice the maximum reservoir operating differential pressure within the operating envelope of the engine, whichever is greater, without visible leakage or deformation. The reservoir shall also withstand satisfactorily 10,000 cyclic pressure reversals at the maximum reservoir operating pressure within the operating envelope of the engine without visible leakage or permanent deformation. The oil reservoir shall meet the requirements of 3.3.6.1.

3.7.7.4.1.1 Oil Reservoir Capacity. The total enclosed capacity of the oil reservoir, usable oil volume, gulping oil volume, unusuable oil volume, and expansion space in gallons shall be specified in the engine specification. The oil reservoir shall contain an expansion space equal to or greater than 20 percent of the total oil quantity of the reservoir. The oil reservoir shall be of sufficient capacity to:

a. Provide a "usable" oil quantity equal to a minimum of 12 times the maximum hourly oil consumption specified in the engine specification.

b. Insure that with up to a maximum of 1/2 of the "usable" oil supply depleted the low level warning will not be activated within the engine operating envelope under the forces and attitudes of 3.1.2 5 and 3.2 1.5.1.

3.7.7.4.1.2 Oil Reservoir External Features. The oil reservoir shall contain the following external features necessary to determine the oil level and to service the drain and reservoir:

a. Gravity-fill port including a scupper with a overboard drain and a port cap in accordance with MIL-C-38373, of the size specified by the Using Service.

b. An indicating device on or in the oil reservoir which signifies to the maintenance personnel when the tank needs servicing.

c. Remote filling and overflow provisions. The pressure fill connector shall be in accordance with MS-24476-1 and the overflow return connection in accordance with MS-24476-2.

d. A low level oil warning device shall be provided and incorporated in the oil reservoir. The device shall furnish a warning signal for a cockpit warning light when one hour of "usable" oil remains in the reservoir.

e. When specified by the Using Service a continuous oil quantity gaging system shall be provided, incorporating provisions to interface with a quantitative cockpit readout instrument. The system shall have a measuring range over the "usable" oil quantity and an accuracy within ±4 percent of the "usable" oil volume. The type of system provided shall be described in the engine specification.

f. A conveniently accessible self-locking drain valve shall be provided for draining the oil reservoir.

3.7.7.4.2 Oil Drains. Drain ports shall be provided at appropriate low points in the oil system for draining the engine oil while the engine is in attitudes ranging from horizontal to 15 degrees nose up and 20 degrees nose down. A readily accessible self-locking drain valve shall be provided at an optimum location in the oil system for obtaining representative oil samples for spectrometric analysis. The locations of these drains shall be shown on the engine configuration and envelope figure.

3.7.7.4.3 Oil Filter. An oil filter shall be provided in the engine oil system. The type of element, filtration rating in microns, and capacity shall be specified in the engine specification. The filter assembly shall incorporate a pressure relief bypass and be of a design which will prevent the discharge of filter contaminant through the bypass. The filter housing shall incorporate an automatic shutoff device to prevent oil drainage when the filter bowl is removed. The filter assembly shall be equipped with a differential pressure activated pop-out device that will give visual warning of impending bypass, by raising a red indicator, when the differential pressure across the element exceeds a specified value. Once activated, the red indicator shall remain extended until manually reset internally after filter element removal.

3.7.7.4.4 Chip Detector. Magnetic chip detectors, of a self-closing design with features permitting electrical continuity checkout, shall be installed in all oil drain ports or in strategic locations where ferro-magnetic particles in the oil would most likely be deposited. The electrical characteristics of these chip detectors shall be described in the engine specification.

3.7.7.4.5 Oil Coolers. The type and number of oil coolers used in the oil system shall be specified in the engine specification. Oil coolers shall incorporate a pressure relief bypass valve and features which will permit disassembly of the cooler for cleaning and inspection.

3.7.7.4.6 Wear Rate Analysis. A report shall be provided to the Using Service, prior to the endurance portions of the PFRT and QT, which provides guidelines and trend analysis data on spectrometric oil analysis for the chemical elements in the particular model engine. The report shall list the chemical elements, and the locations of these elements within all oil wetted systems, for use during test and maintenance operations involving spectrometric oil analysis.

3.7.8 Engine Hydraulic and Pneumatic Systems

3.7.8.1 Hydraulic System. The engine hydraulic system shall be furnished as a part of the engine and shall utilize either engine fuel or oil. The system shall function properly in the engine environment under the engine flight maneuver forces, operating attitudes, and environmental extremes of 3.1.2.5, 3.2.1.5.1, and 3.2.5.1 respectively. A brief description of the engine hydraulic system shall be included in the engine specification.

3.7.8.1.1 Hydraulic System Interface

3.7.8.1.1.1 Hydraulic Test Provisions. The hydraulic system shall include a set of self-sealing couplings and sealing caps, conveniently located on the engine for easy access and attachment of ground test equipment.

3.7.8.1.1.2 Hydraulic Fluid Pressure and Temperature Indication. When required by the Using Service, the hydraulic system shall include provisions for fluid working pressure and temperature indications. The location and interface connection shall be shown on the engine configuration and envelope figure.

3.7.8.1.2 Hydraulic System Performance and Limits. Nominal and maximum system working pressure and maximum operating fluid temperature shall be specified in the engine specification. Peak pressure (ripple or surge) resulting from any phase of the system operation shall not exceed 135 percent of maximum system working pressure. The hydraulic system shall undergo a proof pressure test to twice the maximum system working pressure.

3.7.8.1.3 Hydraulic System Fire and Safety Hazards. The design of the hydraulic system shall be such as to minimize fire hazards caused by proximity of system plumbing and components to heat sources and electrical equipment. Sources of inadvertent flammable fluid leakage from removal joints in lines and equipment shall be protected to prevent fluid ignition. All lines and components which convey flammable fluid shall meet the requirements of 3.3.6.1. All hydraulic operated services which are essential to safe engine operation shall be designed with redundancy or shall have provisions for emergency activation.

3.7.8.1.4 Hydraulic Fluid. The fluid used in the hydraulic system shall be specified in the engine specification.

3.7.8.1.5 Hydraulic System Design. A means (such as bleeder valve) shall be provided for removal of entrapped air where it could interfere with the proper functioning of the hydraulic system. (Disconnection of lines or loosening of fittings is not acceptable.) Equipment and system configuration shall, insofar as practicable, be designed to automatically scavenge free air to reservoir or other collection points where operation will not be affected and where release can be conveniently accomplished. Systems employing power-operated pumps shall utilize a pressure-regulating device and an independent means of limiting excessive pressure.

3.7.8.1.5.1 Hydraulic Fluid Filters. Filters for the hydraulic system shall be provided as follows:

a. Filters in the system pressure line, located such that all fluid from the engine pumps and ground test equipment pressure connections will be filtered prior to entering components of the system.

b. Filters in the return circuit, located such that all fluid will be circulated through the filter prior to entering the return line relief valve, pumps or reservoir.

c. Additional filters at critical component locations shall be provided where filter protection is necessary.

The filtration ratings of the filters in microns, nominal and absolute, shall be specified in the engine specification. Each filter housing shall be provided with an automatic shutoff device to prevent fluid drainage during filter element removal. Each filter assembly shall incorporate an integral differential pressure activated pop-out device that will give visual warning by raising a red indicator when the differential pressure across the element exceeds a specified value. Once activated, the red indicator shall remain extended until manually reset internally after bowl removal.

3.7.8.1.5.2 Hydraulic Fluid Reservoir. The total volume of the hydraulic fluid reservoir and the usable quantity in gallons shall be specified in the engine specification.

3.7.8.2 Pneumatic System. When a pneumatic system is utilized, the complete system shall be furnished as a part of the engine. A description of the system shall be included in the engine specification giving pressure, temperature, and flow requirements.

3.7.8.2.1 Pneumatic Air Contamination. Pneumatic system components requiring fan or compressor air shall operate satisfactorily with engine inlet air contamination as defined in 3.2.5.6.4. Air filters may be used to meet the above requirement.

3.7.9 Starting System

3.7.9.1 Starting System Interface

3.7.9.1.1 Starting Torque and Speed Requirements. The required starter torques and drive speeds shall be included in the engine specification and presented as shown in Figure 17. The figures shall identify and include engine drag, and customer accessory gearbox drag. The figure shall show the effects, singly and in combination, of ambient temperatures, altitudes from sea level to 10,000 feet, and alternate fuels. Figures shall be presented for each of the following:

a. No customer air bleed, no customer power extraction.

b. Maximum allowable air bleed, no customer power extraction.

c. No customer air bleed, customer power extraction as specified in the engine specification.

d. Maximum allowable air bleed, customer power extraction as specified in the engine specification.

3.7.9.1.2 Moment of Inertia of Rotating Parts. The maximum effective mass moment of inertia (slug-ft^2) of engine rotating parts to be rotated by the starter, referred to the starter drive, and the speed ratio between the starter pad and the driven rotor system shall be specified in the engine specification.

3.7.9.1.3 Torsional Spring Constant. The torsional spring constant (pound inches per radian) for the engine starting drive system at the starter drive pad shall be specified in the engine specification.

3.7.9.1.4 Starter Train Backlash. The maximum backlash of the starting drive system in radians at the starter drive pad shall be specified.

3.7.9.2 Starting Requirements. Using the starting procedure of 3.7.9.3, the engine shall consistently make satisfactory starts, within the envelope, altitude, attitude, temperature, air bleed, and power extraction limits of 3.2.1.4.4, 3.2.1.5.1, and 3 2.5.1. A satisfactory start shall be a start during which the engine rotor is accelerated to idle speed from either rest or windmilling speed when using the procedure specified in 3.7.9.3 provided that:

a. The engine stays within operating limits.

b. The total starting time for starts made with no ram, from sea level to 10,000 feet shall be equal to or less that those specified in Figure 18.

c. The total starting time for windmilling starts is equal to or less than 60 seconds. Windmilling starts are considered acceptable only if the engine lights-off within 30 seconds and accelerates to idle speed in a total elapsed time that is equal to or less than 60 seconds. Starting time shall be measured from the initiation of the starting sequence to the attainment of a stabilized uncorrected engine idle rotor speed.

During windmilling starts the engine rotor load shall be at least 5% of the total maximum accessory drive load specified for the drives shown in Table V.

d. The minimum assist torque is provided by a starter or ram air, as specified in the engine specification.

3.7.9.2.1 Restart Time. The minimum allowable time between shutdown and ground starts, or between starting attempts as determined by engine limitations shall be specified in the engine specification. The times specified shall in no case exceed 30 seconds after the driven rotor system stops turning.

3.7.9.3 Starting Procedure. The starting procedure shall be simple and shall not require critical timing. For normal starting, with the power lever in the idle position and after initiation of the starting sequence, the fuel control shall provide for ground and air starting and satisfactory acceleration to stabilize idle operating conditions. The engine shall have the capability of being started with the power lever in idle and above and, after initiation of the starting sequence, being accelerated immediately to any selected steady-state operating condition. This shall be accomplished within specified engine operating limits and without adversely affecting the engine durability or structural integrity. During all starting, simultaneous manual operation or actuation of switches or levers or combinations thereof shall not be required. If the engine provides for thrust augmentation, initiation of augmentation shall be accomplished solely and automatically by movement of the power lever to any position in the thrust augmentation range.

3.7.9.4 Starting Drive Train. The engine starting drive train shall contain a shear section to be the weakest part of the engine starting drive system. This shear section shall have a shear strength of at least 10% above the engine starting torque acceptance capability. The engine starting torque acceptance capability shall be at least 3.33 times the starting torque required to provide a 15-second acceleration from start initiation to minimum starter cutout speed under the conditions specified under 3.7.9.1.1.d and based on sea level static, 15°C (50°F). The starter drive pad characteristics shall be included in Table V. The direction of rotation shall be clockwise when facing the starting pad on the engine.

3.7.10 Exhaust Nozzle System

3.7.10.1 Exhaust Nozzle Attachment

3.7.10.1.1 Allowable Exhaust System Connection Loads. Maximum allowable shear load, axial load, and overhung moment for any interface connections between the engine and parts of the exhaust system not supplied with the engine shall be specified in the engine specification. Exhaust attachments shall be of the bolted type.

3.7.10.2 Exhaust Nozzle, Engine Furnished. A brief description of the exhaust nozzle including the method of attachment shall be included in the engine specification.

3.7.10.2.1 Exhaust Nozzle External Asymmetrical Air Pressure Loads. The engine shall withstand without permanent deformation and asymmetrical air pressure loads resulting from the external flow field pressure distribution on the nozzle and exhaust systems. The limits shall be specified in the engine specification.

3.7.10.2.2 Jet Wake Diagrams. Jet wake diagrams showing the temperature and velocity profiles in the jet wake at sea level static idle, intermediate and maximum power settings shall be presented in the engine specification.

3.7.10.2.3 Exhaust Nozzle Operation. The exhaust nozzle operation and any interface requirements shall be specified in the engine specification and shown on the engine configuration and envelope figure, including emergency or manual provisions, nozzle position indication and other characteristics associated with interface.

3.7.10.2.4 Variable Exhaust Nozzle. For variable geometry nozzles, the descriptive material shall include method of nozzle actuation, type and number of actuators, control sensing parameters, provisions for nozzle position feedback, cooling provisions, fail safe characteristics, degree of deflection if directionally controlled, external geometric contour and surface anomalies which may affect aerodynamic drag or gross thrust of the nozzle and any other features unique to the particular design. Failure of any single part of the actuating mechanism on a controllable nozzle shall not cause asymmetric thrust relative to the nozzle. The operational mode and limits resulting from any single part failure in the actuating mechanism of a vectoring nozzle shall be specified. Provisions shall be made to actuate the nozzle for ground maintenance checkout, rigging and adjustment without the engine running.

3.7.10.3 Infrared Radiation (IR). The maximum IR levels for the following azimuth, elevation, bandpass, altitude, and engine power settings shall be submitted to the Using Service prior to PFRT.

a. Azimuth Angles: 0°, 5°; 10°, 15°, 20°; 30°, 40°, 60°, 90°, 135°, and 180°. (An extension of the centerline aft of the engine shall define the 0° azimuth and 0° elevation position. The 0° azimuth angle, 0° elevation angle and centerline are defined as being in a plane parallel to a level ground plane. If the radiation pattern is symmetrical about the centerline, a polar plot with a notation indicating symmetry may be used.)

b. Elevation Angles: 0°, 5°; 10°; 15°; 20°, 30°; 40°; 60°, and 90° (Above and below horizontal).

c. IR Bandpass Conditions: 1-3 microns and 3-5 microns, 8-10 microns, 10-12 microns, and 12-14 microns.

d. Altitudes: Sea level, 36,089 feet; and the absolute for the engine.

e. Engine Power Settings: Maximum; intermediate; and maximum continuous.

The standard source used as a reference for both the radiation patterns and the measurement equipment shall be specified.

3.7.10.3.1 Infrared Suppression System. When an infrared suppression system is required by the Using Service, the maximum IR levels in accordance with 3.7.10.3 with and without suppression shall be included in the engine specification. A description of the system shall be provided including method of actuation, operating limitations in the suppression mode, and fail-safe provisions. The detailed effects of the IR suppression system operation upon thrust, SFC and other performance parameters shall be included in the engine performance computer program.

3.7.11 Thrust Reverser System. When required by the Using Service, a thrust reverser shall be provided.

3.7.11.1 Thrust Reverser Interface. Interface dimensions required for nacelle installation, clearances, and connections shall be shown on the engine configuration and envelope figure. The reverser mechanism shall provide a signal indicating whenever the reverser is in the unlocked condition.

3.7.11.2 Thrust Reverser. The thrust reverser system shall be designed for the minimum total operating life cycles specified in the engine specification. The cycle, consistent with aircraft mission requirements, shall also be specified. A positive mechanical locking arrangement shall be provided to prevent the reverser from deploying to the extended position in the event of a system failure or inadvertent actuation of the control system. Thrust reversing systems intended for ground operation only or for inflight and ground operation shall be designed such that no single failure or malfunction of the thrust reverser system under any anticipated flight and ground conditions will result in unwanted reverse thrust. Thrust reversing systems intended for inflight use shall be designed such that no unsafe conditions will result from inadvertent deployment throughout the operating envelope.

3.7.12 Water Injection System. When required by the Using Service a water injection system shall be provided.

3.7.12.1 Water Injection System Interfaces. Interface dimensions required for the water injection system shall be shown on the engine configuration and envelope figure and electrical connection and circuit details shall be shown on the electrical installation connection figure.

3.7.12.2 Injection System Characteristics. A description of the water injection system shall be provided in the engine specification and shall include such information as: water injection system flow limits, accuracies, adjustments, temperature and pressure limits, and system limitations

3.7.12.3 Fluid. The fluid used in the water injection system shall be specified in the engine specification. The water used in preparing the fluid shall not exceed the following purity limits·

Impurities	Quality
Total Solids (max) p.p.m	35
Dissolved Solids (max) p.p.m	25
pH Factor	6.5 - 7.5

3.8 Precedence. This specification establishes the requirements for the engine and shall take precedence over referenced documents.

3.9 Quality Verification

3.9.1 Engineering Evaluation Tests. Engineering evaluation tests shall be conducted for the purposes of acquiring data (for safety, installation, maintainability, quality, etc.) demonstrating results to support analysis, and to establish an engine configuration capable of satisfactorily completing the PFRT and QT. The configuration of each test article and its difference from the PFRT or QT engine configuration shall be identified and justified in each test report. The engineering evaluation test reports shall be submitted as required by the applicable test requirement or test paragraph for each test, or prior to the PFRT and QT as applicable, if no specified delivery dates are given. All required engineering evaluation tests shall be specified in section 4.4 of the engine specification.

3.9.2 Preliminary Flight Rating Test (PFRT). The acceptability of the engine for use in experimental flight testing shall be predicated on the satisfactory completion of PFRT tests in accordance with 4.5 and acceptance by the Using Service of all test reports and analysis required for PFRT.

3.9.3 Qualification Test. Qualification of the complete engine as a production model shall be predicated on the satisfactory completion of qualification tests in accordance with 4.6 and acceptance by the Using Service of all required qualification test reports, inspection reports, and analysis. Failures or deficiencies in any of the tests will be considered as a failure to qualify the engine model.

3.9.4 Acceptance Test. A test shall be conducted on each engine to be delivered to the procuring service and shall consist of those acceptance test requirements specified in 4.7. Engines submitted for engineering evaluation tests, PFRT or QT need not be subjected to acceptance testing. The engine contractor shall prepare and submit for approval by the Using Service, a detailed Acceptance Test Procedure in accordance with 4.7.

4. QUALITY ASSURANCE PROVISIONS

4.1 General. Verification that the engine meets the requirements specified in Section 3 shall be by inspection, analysis, demonstration or test and shall be as specified in this section.

4.1.1 Responsibility. The engine contractor is responsible for performing all verification requirements and quality assurance provisions.

4.2 Quality Conformance Inspections. Engines, components and test apparatus shall be subject to inspection by authorized Government officials who will be given the necessary information and facilities to determine conformance with this specification.

4.2.1 Quality Evidence. Quality evidence and records thereof shall be maintained as required by the applicable contract.

4.3 Manner of Test and Reporting

4.3.1 Test Surveillance. Each test and demonstration described herein shall be subject to witnessing by authorized Government representatives. At convenient times prior to the tests and during teardown inspections, the engine and components shall be examined to determine if they conform to all requirements of the contract and specifications under which they were built. At no time during the PFRT or QT shall any part of the engine or component be disassembled, adjusted, cleaned, replaced, or removed without prior approval of the Government representative.

4.3.2 Test Article Configuration. The configuration of each test article shall be identified by a specific parts list. The configuration of each test article and its differences from the PFRT or QT endurance engine configuration shall be identified and justified in each detailed test procedure. The parts list for the engine which successfully completes the PFRT or QT tests shall constitute the approved parts list for the engine model. Design corrections and improvements as substantiated by development tests are allowed in the identification of parts differences for each test engine, however, the mixing of parts of the same or different design such as blades in a disk, or the mixing of different vendor's components and parts in a multiple assembly such as a segmented stator assembly is not allowable.

4.3.2.1 Test Engines. The particular engine intended for a specific test or demonstration shall be officially designated by the contractor prior to the start of testing.

4.3.3 Test Apparatus

4.3.3.1 Automatic Recording Equipment. Automatic continuous recording equipment shall be used to record data during the execution of those parts of the tests requiring the evaluation of time versus engine variables.

4.3.3.2 Vibration Measuring Equipment and Response Characteristics. The engine vibration shall be measured with accelerometer vibration detectors. The vibration measurement and analysis equipment shall operate over a frequency band of at least 5 Hz to 10,000 Hz and produce acceleration spectrograms with a demonstrated accuracy confidence level of 95 percent. The maximum allowable effective filter bandwidth of the spectrum analysis equipment shall be 30 Hz. The vibration measuring equipment shall be calibrated as a complete system. The frequency response of the system, when calibrated by applying a known sinusoidal motion to the accelerometer pickup, shall not deviate by more than ±3dB from the known sinusoidal input at frequencies from 5 Hz to 10,000 Hz. If high pass filters are required when the vibration measuring system is measuring overall velocity levels, they shall have the following characteristics, the filters shall be 3 dB down at frequencies of 30 Hz, 70 Hz, 110 Hz, as appropriate, with a roll-off of at least 18 dB per octave. High pass filters shall not be used to produce acceleration spectrograms.

4.3.3.3 Test Stand Dynamic Characteristics. Vibratory velocity and acceleration shall be measured with the engine operating on a test stand which has the following dynamic characteristics: The natural frequencies of the test stand with the engine installed shall be no higher than 80 percent of the idle rotor speed in all modes of motion which can be excited by residual rotor unbalances.

4.3.3.4 Starter. During PFRT and QT, starting shall be performed with a starter that has torque characteristics within 5% of the minimum required torque shown in Figure 17.

4.3.4 Test Condition

4.3.4.1 Servicing

4.3.4.1.1 Oil Servicing. The oil system shall be drained and filled with new oil at the start of the specific engine test or demonstration. Oil shall be drained from the system only when authorized by the Government representative. The use of external oil filters shall not be permitted.

4.3.4.2 Inlet and Exhaust Duct Connections. During the test of 4.6.1 and 4.6.6.6 the inlet and exhaust duct connections shall be loaded as specified in 3.1.2.10.2 and 3.7.10.1.1.

4.3.4.3 Air Bleed Connections. During the tests of 4.6.1 and 4.6.6.6, the bleed connection loads shall be as specified in 3.1.2.11.1.

4.3.4.4 Accessory Drive Gearboxes. During the tests of 4.5.1.3 and 4.6.1.3, the engine accessory drive gearbox and PTO shall be loaded to the rated loads and overhung moments specified in 3.1.2.7.

4.3.4.5 Accreditable Test Time. Test time shall not be credited by increments shorter than 15 minutes except when shorter periods are a test requirement.

4.3.4.6 Fuel Properties for Test. The fuels used for the PFRT and QT tests shall be in accordance with Table XI, except when otherwise noted in a particular test paragraph.

4.3.5 Data. Data shall be submitted or recorded during tests in accordance with the following subparagraphs.

4.3.5.1 Pre-test Data. The following data shall be submitted to the Using Service for approval prior to initiation of each test or demonstration required in 4.4, 4.5 and 4.6 which is to be conducted on a specific test engine, test component or component assembly. One document for each test is required. This shall include:

a. The detailed test procedure to be used during the conduct of the test by test personnel.

b. An appropriate configuration identification of the engine, component, or assembly in accordance with 4.3.2.

4.3.5.2 Preliminary Data. The dry engine weight, center of gravity, location, photographs and other pertinent data shall be obtained and recorded at the time the engine is being prepared for test. The weight shall be measured before the engine has been serviced with fuel or oil.

4.3.5.3 Accuracy of Data. For all engine and component calibrations and tests, or demonstrations, reported data shall have a steady-state accuracy within the tolerances shown below. The accuracy of transient data and the corresponding instrument calibration methods shall be subject to the approval of the Using Service and shall be described in the test reports. All instruments and equipment shall be calibrated as necessary to ensure that the required degree of accuracy is maintained.

ITEM OF DATA	
Rotor speed (s)	±0.2 percent of the value obtained at maximum rating
Thrust and fuel flow at and above minimum augmented	±1.0 percent of the value being measured
Thrust and fuel flow at and below intermediate	±1.0 percent of the value obtained at intermediate thrust
Airflow	±0.5 percent of the value being measured
Temperature	±1.0 percent of the value being measured
Engine weight	±1.0 lbs or ±0.1 percent of the weight being determined, whichever is greater
Vibration velocity	±5.0 percent of specified engine limit
All other data	±2.0 percent of the value obtained at maximum rating

4.3.5.4 Steady-State Data. During operation at each specified steady-state condition and after performance stabilization, data shall be recorded as specified in Table XII.

4.3.5.5 Transient Data. For each transient performed during the thrust operations (and reverse thrust runs, if applicable), the data shall be recorded as specified in Table XII.

4.3.5.6 Starting Data. During altitude tests and static sea level tests, the data shall be recorded as specified in Table XII

4.3.5 7 Miscellaneous Data. The date, test title, engine model designation, and serial number shall be recorded on each log sheet.

4.3.5.8 Test Notes. Notes shall be placed on the log sheet of all incidents of the run, such as leaks, vibrations and other irregular functioning of the engine or the equipment, such as "flat spots" in acceleration, and corrective measures taken.

4.3.5.9 Barometer Reading. The barometer reading shall be corrected for temperature and shall be read and recorded at intervals not exceeding 3 hours

4 3 5.10 Fuel and Oil Data. Samples of the fuel and oil shall be taken at the start and completion of the tests of 4.5.1 and 4.6.1 and for other tests as applicable. The fuel and oil samples shall be analyzed for physical and chemical properties to determine conformance with the applicable fuel and oil specifications and Table XI. The results of these analyses shall be included as part of the final endurance test report and for other test reports as applicable.

4.3.6 Reports

4.3.6.1 Test Reports. Following completion of each separate engine or component test demonstration or consecutive group of tests or demonstrations conducted on any single test assembly or component, a report shall be submitted. These reports, certified by a Government representative as to proper conduct of the tests, will constitute the basis for approval of the individual tests. Each report shall contain but is not limited to the following items:

a. Cover (title of report, number of the report, source of report, date, name(s) of the author(s), and contract number).

b. Title page (title of report, number of report, source of the report, date, name(s) of the author(s), and contract number).

c. Abstract (a brief statement of the contents of the report, including the objective).

d. Table of contents.

e. List of illustrations (provide figure numbers and captions of all illustrations. Photographs, charts and graphs should be treated as illustrations and given figure numbers. When used in a separate series, tables should be given Roman numerals. Examples figure 1, figure 2, etc., table I, table II, etc.).

f. Summary (a brief resume of the test conducted, including objective, procedure, results, conclusions and recommendations referencing the applicable paragraph of the engine specification.)

g. Body of the report

(1) Brief general description of the engine or of the component(s) and a detailed description of all features which differ from the previous model, if applicable.

(2) If approval is being requested, without test, based on similarity to the component or assembly for which previous test approval was obtained, any physical or functional dissimilarities or differences in testing requirements with respect to the tested component and reference to the approved component test report shall be included.

(3) Method of test (general description of test facility, equipment and methods used in conducting the test).

(4) Record of test (chronological history of all events and incidents in connection with all of the testing, including details of all leaks, vibrations and other irregular functioning, and any adjustments, repairs, replacements of parts and the corresponding engine operating time)

(5) Analysis of results (a complete discussion of all phases of the test, such as probable reason for failure or unusual wear, comparison in performance with previous models, analysis of general operation and any items that are significant from an engineering viewpoint).

(6) Calibrations and recalibration data including acceptance limits (Data in uncorrected form and corrected form if applicable, shall be shown by suitable curves. A plot of vibration characteristics in three planes shall be provided for both calibration and recalibration runs.)

(7) For the altitude tests specified in 4.5.3 and 4.6.3 the data shall be corrected by application of the correction methods specified for the engine in 3.2.1.3.

(8) Tabulated data for all pertinent instrument readings and all required instrument readings taken during the test.

(9) Description of the condition of the engine or components at disassembly inspection and material discrepancy description shall be provided for each identified discrepancy.

(10) Conclusions and recommendations, with respect to approval of the engine or component tests, supplemented by such discussion as is necessary for their justification.

h. Appendix (final approved test procedure).

4.3.6.2 Summary Reports. Following completion of the preliminary flight rating requirements and qualification requirements specified herein, a summary report for each shall be prepared. These reports shall contain essentially the following items:

a. Cover (title of report, number of the report, source of report, date, security markings).

b. Title page (title of report, number of report, source of report, name of author(s), contract number).

c. Abstract (a brief statement of the contents of the report, including the objective).

d. Table of contents.

e. Summary (a brief resume and summary of each of the tests conducted, giving the title of each test, test report number, the item tested, dates of testing, and a general statement of the results).

f. Conclusions and recommendations.

4.4 Engineering Evaluation Tests

4.4.1 Customer Air Bleed. An engine, having substantially the same parts list and configuration as the endurance test engine, shall be subjected to a fan/compressor bleed air test to verify the total pressure, temperature and air bleed air flows available in accordance with 3.1.2.11 to be furnished for aircraft system use. Verifications at sea level from idle to maximum power for inlet air temperatures from -54°C (-65°F) to 52°C (125°F) (a minimum of five test temperatures) shall be accomplished. The test is to be conducted in such a manner as to demonstrate the amount of bleed air available over and above that required for engine systems such as acceleration and engine anti-icing. A final report shall be submitted prior to the start of the preliminary flight rating endurance test.

4.4.2 Engine Heat Rejection and Oil Cooling. Engine heat rejection and cooling requirements data, including the oil system, will be obtained from an engine having substantially the same parts list and configuration as the PFRT endurance test engine. This data shall include cooling requirements, heat rejection rates, and corresponding skin temperatures for various engine components and stations of the engine. The data necessary to define the installed cooling requirements shall be obtained for various engine operating conditions, horsepower extraction, and air bleed conditions throughout the engine operating envelope. Reports for the above cooling requirements, including sample calculations, shall be furnished in accordance with the requirements of 3.1.2.8.2 and 3.7.7.3.1.

4.4.3 Oil Flow Interruption Test. An engine having substantially the same parts list and configuration as the PFRT endurance test engine, shall be subjected to an oil flow interruption test. The engine shall be operated at the intermediate power setting for 30 seconds with only air supplied to the inlet of the oil pump. The engine shall operate without damage during the oil flow interruption period and for 30 minutes thereafter with the normal lubrication having been restored. The engine shall be disassembled and inspected to ensure that no damage has occurred.

4.4.4 Engine Electrical Power Failure Tests. An engine, having substantially the same parts list and configuration as the PFRT endurance test engine, shall be subjected to the following tests to demonstrate compliance with 3.7.2.2, 3.7.4.2, and 3.7.4.3.1.

a. Operate the engine at intermediate thrust for 5 minutes, switch off the electrical power to the control system. After the engine has stabilized and run for 5 minutes, at or above 80 percent of the maximum thrust normally obtainable, switch to alternate electrical power and return to stabilized intermediate thrust for 5 minutes. Decelerate to maximum continuous power, switch back to engine supplied electrical power.

b. Interrupt electrical power to the control during the most critical point during an acceleration.

c. Interrupt electrical power to the control at the most critical point during a deceleration.

d. With engine operating at idle and above, switch off the normally supplied external power and check for limitation or loss of functions.

e. After the engine has been shut down, and with alternate electrical power on and engine electrical power off, restart and accelerate to idle. Accelerate to the highest thrust obtainable and operate there for 5 minutes. Decelerate to idle, operate at idle for two minutes and shut down.

4.4.5 Engine Vibration Survey. A vibration survey which demonstrates compliance with the requirements of 3.2.1.4.10 and 3.3.8.10 shall be conducted and a report submitted to the Using Service prior to the initiation of the endurance portion of the PFRT. The vibration survey shall include, but not necessarily be limited to, data showing true RMS velocity spectrograms and peak acceleration spectrograms for each accelerometer location and for each internally mounted accelerometer at the highest vibration point in the operating envelope (which shall be identified) and at each of the engine rating points. The spectrograms shall cover the frequency range of at least 5 Hz to 10,000 Hz. Critical components of the engine shall be identified on both velocity and acceleration spectrograms. The method used for determining the overall true RMS velocity from the velocity spectrogram and the maximum permissible overall true RMS velocity limit shall be described.

4.4.6 Starting Torque. Prior to start of PFRT an engine shall be tested to demonstrate the starting torque and speed requirements of 3.7.9.1.1. The procedure for accomplishing this demonstration shall be submitted to the Using Service for approval prior to initiation of test. A test report shall be furnished to the Using Service prior to the initiation of the PFRT.

4.4.7 Verification of Correction Factors. When correction factors are used to convert engine performance data to standard conditions, sea level and altitude tests shall be conducted over the necessary range of environmental conditions to verify the correction factors used to correct performance data. A test report shall be submitted to the Using Service prior to the initiation of the PFRT.

4.4.8 Maintainability/Maintenance Demonstration. A maintainability/maintenance demonstration shall be performed by the contractor on an engine substantially identical to the QT endurance engine and having an accumulated operating time of 300 hours or more to demonstrate compliance with 3.2.4 and 3.5.1. The demonstration activity shall cover complete disassembly and reassembly of the engine including a demonstration of the length of time and procedures used to remove and replace engine modules and engine components that are separately removable. During this demonstration, the extent to which standard tools can be used for engine disassembly and reassembly and the suitability of all special tooling shall be demonstrated.

A demonstration of engine maintenance inspection provisions including borescope, radiographic or other special inspection provisions shall be performed to demonstrate that location and access will permit suitable inspection.

After the engine has been reassembled, a demonstration of engine rigging procedures (control, exhaust nozzle, guide vanes, etc.) shall be performed to evaluate the equipment used, checking procedures and range of tolerances. In addition, all components which require routine or relatively frequent removal and replacement in service such as fuel and oil filter ignitor plugs, oil tank filler caps, etc., shall be removed and reassembled at least 100 times.

At the completion of the above demonstrations, the reassembled engine shall be installed on a test stand and subjected to a test run of sufficient duration to check steady-state and transient performance.

4.4.9 Material Corrosion Test. Material corrosion tests shall be conducted on selected materials and coatings in accordance with 3.2.5.5. After test, specimens shall be free of reaction products.

4.5 Preliminary Flight Rating Test (PFRT)

4.5.1 Endurance Test

4.5.1.1 Pre-Test Verification

4.5.1.1.1 Engine Dry Weight. Prior to initiation of calibrations, the dry weight of the engine, as specified in 3.2.2.1 shall be verified in accordance with 4.3.5.2.

4.5.1.1.2 Power Lever Torque. Prior to the initiation of the endurance test, power lever torque loads shall be measured for verification of 3.7.2.1.1.2.

4.5.1.2 Calibration

4.5.1.2.1 Temperature Sensing System Calibration. The engine temperature sensing system(s) shall be checked on the bench and on the engine to establish its proper functioning and calibration over the range of the engine operating conditions. The performance shall meet the tolerance range and thermal response characteristics of 3.7.6.4.

4.5.1.2.2 Engine Control System Calibration. Prior to the initiation of the engine calibration specified in 4.5.1.2.3, all fuel nozzles, and the components of the engine control system, shall undergo bench calibrations using fluid in accordance with 3.7.3.3.1. The system shall conform to the design tolerance range required by the applicable design specifications.

4.5.1.2.3 Engine Calibration. The procedure during the engine calibration shall be such as to establish the performance characteristics of the complete engine. Prior to the beginning of the calibration all engine controls shall be adjusted and shall not be readjusted throughout the calibration. Calibrations shall be made initially with no customer accessory power extraction and no bleed airflow other than that required for continuous engine operation. During calibration, engine inlet air shall be controlled to the temperature specified for the engine rating. Data indicated for calibration in 4.3.5.4 and 4.3.5.5 shall be recorded. During calibration, conformance with the leakage requirement of 3.3.6.4 and shutdown drainage requirements of 3.3.6.5 shall be demonstrated. The following data shall be obtained.

a. Data required to establish compliance with sea level performance ratings in Table I of the engine specification.

b. Data required to establish compliance with 3.2.1.5.6, Thrust Transients and 3.7.9, Starting.

c. Repeat items "a" and "b" with maximum permissible bleed airflow.

d. Repeat item "c" with accessory power extraction as specified by the Using Service.

4.5.1.2.3.1 Compressor Bleed Air Analysis. The compressor bleed air shall be sampled from each bleed air outlet during a maximum continuous thrust run. A sample of air entering the compressor inlet shall be taken at the same time the bleed air samples are obtained. The samples shall be properly identified and processed through laboratory analysis to determine whether the contaminant levels are within the limits specified in 3.1.2.11.3. The results of the analysis and the methods and test apparatus used shall be detailed in the engine test report.

4.5.1.3 Endurance Test Procedure. Following the calibration run, the power lever shall be placed in the maximum thrust position and the engine shall be adjusted to produce an average steady-state measured gas temperature at least 8°C (15°F) above the maximum allowable steady-state average measured gas temperature specified in 3.2.1.4.5. This value shall be re-established at the beginning of each cycle. The number of adjustments required shall be recorded.

The engine shall be subjected to an endurance test consisting of 10 cycles of 6 hours each in accordance with Part 1 and Part 2 Each cycle shall be preceded by a 2-hour shutdown The test runs in each cycle shall be conducted in the order given. The time for changing thrust shall be charged to the duration of the lower setting. For all power lever movements, the power lever shall be advanced or retarded, as applicable, in not more than 0.5 second. The developed thrusts shall be as established by the engine control. If the engine does not provide for augmented thrust, maximum thrust shall be substituted for augmented thrust throughout the test schedule.

The 2nd and 7th cycles shall be accomplished with maximum permissible air bleeds (customer and engine systems), all other cycles shall be with no customer air bleed.

The oil pressure, if adjustable, shall be adjusted at the beginning of the test to the minimum steady-state value specified in 3.2 1.4.8 at maximum rated engine speed. No further adjustment shall be permitted during the test except when authorized by the Using Service Oil consumption shall be determined and reported after each cycle. Samples of oil shall be taken and spectrometric oil analysis performed, after the calibration run and at the completion of each endurance cycle. Analysis and reporting of any one sample shall not lag the actual sampling by more than three cycles. Oil drained for analysis shall not be charged to engine oil consumption and shall be replaced by an equivalent amount of new oil.

When the engine control system includes a manual control, this feature shall be tested during the endurance test schedule During the 5th and 10th cycles, the engine shall be run with the control in the manual mode during runs (a) and (e) of Part 1 for the times designated.

The ignition system shall be in operation at all times after a normal start sequence has been completed.

The accessory pads shall be subjected to rated loads and overhung moments. The actual torque loading and overhung moments imposed during the endurance test shall be stated in the test report.

The test shall consist of two parts as follows:

Part 1. Part 1 shall consist of 8 cycles to be conducted in accordance with the schedule listed below, using inlet fuel and air at the ambient temperature·

a. Maximum-idle thrust run This run shall consist of 6 successive periods of 10 minutes each, including 5 minutes with the power lever in the maximum thrust position and 5 minutes with the power lever in the idle position

If the engine provides for anti-icing, at the end of each period at maximum thrust, anti-icing controls shall be operated for one minute with maximum anti-icing air bleed before the power setting is changed. During the 5th and 10th cycles, 3 minutes of each 5-minute period at maximum shall be run with the control in the manual mode. Transient data recording systems are to be on when switching the control from the automatic to the manual mode, and also when switching back to the automatic mode from manual.

b. Incremental rotation speed run. This run shall consist of 12 periods of 8 minutes duration each at approximately equal rotational speed increments between maximum rotor speed and idle speed conditions. For engines operating essentially at constant rotational speed, thrust may be varied throughout the non-augmented range in lieu of rotational speed. In the event significant peak vibration points exist at any conditions between idle and maximum rotational speed or throughout the non-augmented thrust range as applicable, the number of increments chosen may be altered at the option of the Using Service, to increase the amount of running time obtained at the peak vibration points up to an amount not to exceed 50 percent of the total time of the incremental run.

c. Thrust transient run. This run shall consist of 39 minutes of thrust transients as follows:

(1) Two periods of 4 minutes at idle power lever position, 30 ±3 seconds at maximum power lever position.

(2) Two periods, each consisting of 3 minutes of operation, making a total of 6 minutes. Each period shall be run as follows: With the power lever in the idle thrust position, advance toward the intermediate power lever position, and as soon as the engine reaches the condition of minimum surge margin (i.e., rpm or gas temperature), retard the power lever to the idle thrust position.

(3) Two periods, each consisting of 3 minutes of operation and with the final period followed by an additional 2 minutes at idle making a total of 8 minutes. Each period shall be run as follows: With the power lever in the idle thrust position, advance toward the maximum power lever position, and as soon as the engine reaches the condition of minimum surge margin (i.e., rpm or gas temperature) retard the power lever to the idle thrust position. (For afterburning engines, as soon as the engine reaches the condition of minimum surge margin after lighting the afterburner, retard the power lever to the idle thrust position.)

(4) Two periods, each consisting of 3 minutes of operation and with the final period followed by an additional 2 minutes at maximum making a total of 8 minutes. Each period shall be run as follows: With the power lever in the maximum thrust position, retard toward the idle power lever position, as soon as the engine reaches the condition of minimum surge margin (i.e., rpm or gas tempreature), advance the power lever to the maximum thrust position. (For afterburning engines, as soon as the engine reaches the condition of minimum surge margin below intermediate power lever position, advance the power lever to the maximum thrust position.)

(5) Two periods, each consisting of 3 mintues of operation and with the final period followed by an additional 2 minutes at intermediate making a total of 8 minutes. Each period shall be run as follows· With the power lever in the intermediate thrust position retard toward the idle power lever position, and as soon as the engine reaches the condition of minimum surge margin (i.e., rpm or gas temperature), advance the power lever to the intermediate thrust position.

d. <u>Reverse thrust run</u>. This run shall consist of 9 minutes of operation in the sequence of power lever positions and time duration as follows: One minute idle, 3 minutes maximum reverse thrust, 1 minute maximum thrust, 3 minutes maximum reverse thrust, and 1 minute of idle. If the engine does not provide reverse thrust, substitute intermediate for maximum reverse thrust in this run.

e. <u>Intermediate thrust run</u>. This run shall consist of 30 minutes with the power lever in the intermediate thrust position. During the 5th and 10th cycles, 26 minutes of this period shall be run with the control in the manual mode. Transient data recording systems are to be on when switching the control from the automatic to the manual mode and also when switching back to the automatic mode from manual.

f. <u>Maximum continuous thrust run</u>. This run shall consist of 20 minutes with the power lever in the maximum continuous thrust position.

g. <u>Intermediate thrust run</u>. This run shall consist of 15 minutes with the power lever in the intermediate thrust position.

h. <u>Maximum continuous thrust run</u>. This run shall consist of 15 minutes with the power lever in the maximum continuous thrust position.

i. <u>Modulated augmentation run</u>. This run shall consist of 6 minutes at each of the power lever positions which produces the following percentages of augmented thrust (the difference between maximum and minimum augmentation provided), 80, 60, 40, 20, and minimum in the order listed. Modulation shall be accomplished in accordance with the above for all odd numbered cycles.

For even number cycles, the sequence of scheduling shall be reversed, beginning with operation at minimum thrust augmentation. If the engine does not provide for modulation of thrust augmentation, this run shall consist of six 5 minute periods alternating between intermediate power lever position and maximum power lever position. If the engine does not provide for thrust augmentation, this run shall consist of six 5 minute periods alternating between intermediate power lever position and maximum power lever position.

j. Maximum continuous thrust run. This run shall consist of 16 minutes with the power lever in the maximum continuous thrust position.

k. Intermediate-maximum thrust run. This run shall consist of 15 minutes with the power lever in the intermediate thrust position followed by 15 minutes with the power setting at maximum thrust. When the engine has a maximum thrust rating limited to less than 15 minutes, the maximum thrust then shall be for that time duration and the remainder of the time shall be with the power lever in the intermediate thrust position. At 5-minute intervals during the run, anti-icing controls shall be operated for one minute with maximum anti-icing air bleed.

Part 2. This part shall consist of two six-hour cycles identical to the first 8 cycles as conducted in Part 1, except that for operation during runs "e" through "j", the engine inlet air and the air which passes over the engine shall be at simulated flight temperature conditions, corresponding to the maximum steady-state stagnation temperature possible inflight, at any altitude, and flight speed condition within the engine steady-state flight operation envelope. For operation during run "k", the engine inlet air shall be simulated flight temperature and pressure conditions corresponding to the maximum stagnation temperature and pressure possible in flight, at any altitude, and flight speed conditions within the engine's flight operating envelope. For both complete cycles, the inlet fuel shall be at the minimum pressure and at the maximum temperature specified in 3.7.3.1.3.3. For all operations during runs "e" through "k", the oil temperature shall be maintained at no less than the maximum oil temperature specified in 3.2.1.4.8.

4.5.1.3.1 Starts. A minimum of 60 starts shall be made on the endurance test engine. In addition to the 60 endurance test starts, there shall be 5 false starts (a starting sequence without benefit of light-off followed immediately after the permissible engine draining time by a successful start), and 5 restarts (a start within a maximum of 14 minutes time from shutdown). Additional starts required to bring the total of endurance starts to 60 may be made at the end of the endurance run. During these additional starts, after the engine has reached idle speed, an immediate acceleration to maximum continuous conditions shall be accomplished by moving the engine power lever within 0.5 second from idle to maximum continuous thrust position. The engine shall be held at maximum continuous for 30 seconds and then shutdown. The shutdown time between additional starts shall vary from a minimum of 45 minutes to a maximum of 90 minutes. Starts shall be performed with a starter that is acceptable to the Using Service.

4.5.1.4 Recalibrations

4.5.1.4.1 Engine Recalibration. After completion of the tests specified in 4.5.1.3 and 4.5.1.3.1, a recalibration check in accordance with the requirements of 4.5.1.2.3 and 4.5.1.2.3.1 shall be made on the endurance test engine. The recalibration check run shall be conducted with the engine adjusted to produce, under the rated inlet temperature conditions, the values of thrust obtained during the initial calibration. The recalibration may be preceded by a specified run during which the cleaning procedure outlined in the pre-test data and recommended for field use by the contractor may be applied.

4.5.1.4.2 Temperature Sensing System Recalibration. After completion of the engine recalibration, the engine temperature sensing system shall be rechecked to establish its proper functioning and calibration in accordance with 4.5 1.2.1 The performance shall meet the tolerance range and thermal response characteristics of 3.7.6.4.

4.5.1.4.3 Engine Control System Recalibration. After completion of the engine recalibration, all components, including fuel nozzles, of the engine control system shall undergo a bench recalibration to determine conformance with the design tolerance range required by the applicable design specifications For this recalibration, external engine control adjustments shall be established at their pretest bench calibration physical settings

4.5.1.5 Engine Disassembly and Inspection. The engine completing the endurance test shall be completely disassembled for examination of all parts. Prior to cleaning, the engine parts shall be given a "Dirty Inspection" to inspect for evidence of leakage, oil coking, unusual heat patterns and other abnormal conditions. Following the "Dirty Inspection" the engine parts shall be cleaned and measurements shall be taken as necessary to inspect for excessive wear or distortion. These measurements shall be compared with the engine manufacturer's drawing dimensions and tolerances and with similar measurements made prior to the test. All parts shall then be subjected to a "Clean Inspection" consisting of a visual examination and condition assessment.

4.5.1.6 Endurance Test Completion. The endurance test will be considered to be satisfactorily completed when the engine has completed the endurance test of 4.5.1 and during the engine recalibration, the steady-state measured gas temperature does not exceed a value of the measured gas temperature obtained for the initial calibration plus 30 percent of the difference between the maximum allowable steady state measured temperature specified in the engine specification and the highest measured temperature specified to obtain Table I and II performance ratings, the corrected specific fuel consumption does not exceed 102.5 percent of the initial calibration values; the engine meets all other specified performance requirements which can be checked by the calibration procedure, and, in the judgement of the Using Service, the test engine and components are operating satisfactorily at the end of the tests, recalibrations do not reveal excessive performance deteriorations, and teardown inspections do not disclose parts failure nor indicate imminent failures which might compromise safety of flight. Parts will not be judged to have passed the endurance test until they have successfully completed the entire 60 hours of the endurance test. Engine temperature deterioration and SFC increase shall be determined at the same rated thrust values.

4.5.2 Engine Component Tests. The following tests shall be conducted on components conforming to the same parts list and configuration used on the PFRT endurance test.

4.5.2.1 Previous Component Approval. Engine components requiring testing as specified herein may have these tests waived at the option of the Using Service, if the component has been previously approved by the Using Service for use on another engine. All such components must conform to the same parts list and configuration as the components previously approved.

4.5.2.2 Explosion-proof Test. All electrical components, including electrical connectors, not hermetically sealed shall be subjected to explosion-proof testing in accordance with MIL-STD-810, method 511, Procedure 1. During the test, components shall have maximum input voltage applied to them and shall be operated continuously at their maximum loads. During each altitude condition, all make and break contacts shall be operated at least 10 times. An overvoltage power supply transient shall be applied to the components at least 4 times during each altitude condition. At least four of these power supply transients shall be applied during operation of make and break contacts. Power supply transients shall consist of the application of an overvoltage for the times specified in MIL-STD-704. The four points selected for performance of an overvoltage shall include points within 10 percent of the following: 150, 140, 130, and 125 volts ac, rms line to neutral, or 80, 60, 40, and 34 volts dc. Ignition components or systems shall be operated continuously. Electrodes of spark igniters shall be mounted in such a manner that the explosive vapor in the test chamber shall not be contacted. Electrically self-sufficient ignition systems shall be exempted from the application of power supply transients.

4.5.2.3 Fuel Pump Altitude-proof Test All independent and separately replaceable fuel pumps shall be operated for 5 hours at flow and pressure conditions corresponding to those required by design maximum engine performance at 30,000 feet standard altitude absolute. During the course of this proof test, a vapor liquid (V/L) ratio of 0.45 or greater shall be imposed on the pump at its inlet. The pump performance during the course of testing and performance deterioration, as determined from calibration runs, shall conform to the requirements established by the applicable design specification and shall not adversely affect engine performance. The definition and calculation of V/L ratio shall be based on ARP 492.

4.5.2.4 Oil Reservoir Pressure Test. The tank with filler cap installed shall be subjected to positive and negative differential pressures in accordance with 3.7.7.4 1 for a period of 30 minutes. No leakage or deformation shall occur.

4.5.2.5 Fire Test. Lines, fittings and components, including engine furnished oil tank, which convey flammable fluids shall be tested to verify conformance with 3.3.6.1. Individual lines, fittings, components or assemblies shall be tested as specified in ARP 1055 while conveying fluids at the lowest flow rate, highest system pressure and highest fluid temperature possible over the complete engine operating range. The requirements of 3.3.6.1 shall be considered verified, if at the completion of the test period, there are no leaks.

4.5.3 Altitude Tests. An engine, conforming to the same parts list and configuration as the endurance test engine, shall be subjected to altitude tests which shall consist of operation and air starting checks at several selected conditions within the operating limits envelope specified for the engine and at least those given in the engine specification as shown in Figure 19. The test points shall include the effects of power extraction, inlet recovery, bleed air extraction and inlet distortion on engine performance and stability. Data to be taken and recorded during the test shall be as specified in Table XII. Control system adjustments shall not be made without approval of the Government representative. The altitude tests shall be accomplished using MIL-T-5624, grade JP-5, in accordance with Table XI and the oil specified in the engine specification. Fuel temperature shall be varied over a range sufficient to encompass all anticipated engine operating environments. The continuous ignition system shall be in operation at all times after the start sequence has been completed.

Overall true RMS velocity measurements and acceleration spectrograms shall be obtained for each accelerometer mounted on the engine case and accessory gearbox case at the engine speeds and thrusts selected for the test. The points selected shall include at least the altitude rating points and the point in the operating envelope where the highest engine vibrational levels are generated. Critical components of the engine shall be identified on each spectrogram.

4.5.3.1 Altitude Engine Calibration. Prior to initiation of the testing described in 4.5.3.2, the engine shall be calibrated in accordance with 4.5.1.2.3 and 4.5.1.2.3.1. No control readjustments shall be made after the initial adjustments at the beginning of the calibration.

4.5.3.2 Altitude Test Procedure. Operation at each test point shall be of sufficient duration to stabilize the engine and to establish the performance and operating characteristics of the engine. When a manual control mode is included in the control system, this feature shall be evaluated and its effects on engine performance and operating characteristics shall be determined during the test schedule. Operation shall be conducted to obtain the following data:

a. Altitude Rating Points. The test conditions shall be those specified for altitude ratings in Table II of the engine specification. A sufficient additional number of engine thrust settings shall be selected for each specified altitude test point to establish operating and performance characteristics at the rated condition. The effects of bleed air and power extraction on steady-state performance shall be obtained at each specified test point. With the power settings of idle, maximum continuous, intermediate, and maximum thrust, time elapsed versus engine speed, engine temperature and fuel flow shall be obtained for stability verification The time period for stability verification shall be a minimum of 5 minutes at each power setting.

b Transient Operation. The applicable transient performance specified in 3.2.1.5.6 and the transient air flow performance specified in 3.1.2.10.3 shall be demonstrated. Effects of maximum bleed air and power extraction singularly and in combination on transient performance shall be determined.

c. Functional Test. The operating envelope of the engine shall be verified by running the engine at the extremities of the operating envelope. Engine steady-state and transient characteristics shall be determined at each test point over the range of power settings. Effect of inlet distortion on transient operation and steady-state performance shall be determined. The engine operating characteristics determination shall be accomplished with and without customer bleed air and power extraction. If the engine incorporates an augmentation system, the augmentor blowout limits shall be determined.

d. Start and Restarts. Engine air starts and restarts, with and without starter assist after an engine shutdown, shall be accomplished at each start test point shown on Figure 19. If an automatic relight system is provided, engine restarts shall also be demonstrated with this system. Each relight test condition shall be accomplished at 4 power settings: idle, maximum continuous, intermediate, and maximum. The tests shall be conducted with and without customer bleed air and power extraction. If the engine incorporates an augmentation system, the augmentor restart limits shall be determined.

4.5.3.3 Altitude Test Completion. Comparison of observed data obtained during the test to the specified performance and operating characteristics shall be made by a method acceptable to the Using Service to determine compliance with the engine specification. The test shall be considered to be satisfactorily completed when, in the judgement of the Using Service:

a. The minimum engine performance is as specified in Table II of the engine specification and the ratio of measured performance at altitude to measured performance at sea level is equal to or better than the ratio of specified altitude performance to specified performance at sea level.

b. The altitude starting and transients conducted during the test are in accordance with the engine specification requirements.

c. The functional test points demonstrate satisfactory engine operation and do not show any discrepancies with the rating points, altitude starting data and transient data.

d. The engine operates satisfactorily under the distortion and windmilling conditions specified for the test.

4.5.4 Detail Tests. Engines or components conforming to the parts list and configuration of the PFRT endurance test engine shall be used for the following tests.

4.5.4.1 Engine Pressure Tests. Each engine case and all gas pressure loaded components of the engine subjected to compressor discharge pressure shall be tested to 2.0 times maximum operating pressure without rupture to verify the requirements of 3.3.8.5. These tests shall be conducted at the maximum allowable temperature of the component or the test pressure shall be adjusted for material properties at the test temperature.

4.5.4.2 Rotor Structural Integrity

4.5.4.2.1 Overspeed. Turbine and compressor rotors shall be subjected to engine operation for a stabilized period of at least 5 minutes duration, at maximum allowable measured gas temperature at 115 percent of maximum allowable steady-state RPM.

Following the test, parts and assemblies shall be within allowable dimensional limits and there shall be no evidence of imminent failure.

4.5.4.2.2 Overtemperature. Upon successful completion of the overspeed test of 4.5.4.2.1, the same engine shall be operated at an average steady-state measured gas temperature of at least 42°C (75°F) in excess of the maximum allowable average steady-state measured gas temperature and at no less than maximum allowable steady-state speed for 5 minutes. Following the test, parts and assemblies shall be within allowable dimensional limits and there shall be no evidence of imminent failure.

4.5.4.2.3 Disc Burst Test. Spin pit testing shall be conducted on all critical rotating disc components of the engine. Components shall be operated to a minimum of 122 percent of maximum allowable steady-state speed with the bore metal at maximum design metal temperature without failure or evidence of imminent failure.

4.5.4.3 Engine Static Load Test. The engine cases and mounts of the endurance engine configuration shall be subjected to a static test to verify the requirements of 3.1.2.5 and 3.1.2.6. A static rig test utilizing the applicable engine static structure shall be conducted to demonstrate the capability of the engine and its supports to withstand maximum externally applied forces specified in 3.1.2.5 without permanent deformation of any component and 1.5 times those forces without failure of any component. In this test, maximum thrust loads, "G" loads, gyroscopic moments, torque and engine reaction loads will be applied separately and then in combination. Stress and deflection data will be obtained at critical locations as determined by analysis and preliminary stress coating tests.

4.5.4.4 Attitude Test. The engine shall be subjected to an attitude test to demonstrate compliance with the requirements of 3.2.1.5.1 and 3.7.7.3. The engine shall be started, and operated at intermediate power lever position for at least 30 minutes, at each of the six test points shown in the clear area of Figure 9. The engine shall also be operated at intermediate power lever position for at least 30 seconds at each of the two test points shown in the shaded area of Figure 9. This test will be considered satisfactorily completed when, in the judgement of the Using Service, the engine started satisfactorily, remained within all operating limits, and there is no evidence of mechanical damage.

4.5.4.5 Electromagnetic Interference and Susceptibility Tests. Electromagnetic interference and susceptibility tests shall be made on all electrical and electronic components or systems of the engine prior to initiation of the endurance test. The components or systems shall meet the requirements and test limits set forth in MIL-STD-461 for equipment class 1D, using the measuring equipment described therein. The tests shall be conducted in accordance with the methods, procedures and techniques of MIL-STD-462.

4.6 Qualification Test (QT)

4.6.1 Endurance Test. The endurance test shall consist of two segments of 150 hours each conducted on each of two engines in accordance with the following calibration and endurance test schedules and procedures. If more than one fuel is specified in the engine specification, then one engine shall be tested using one fuel, and the second engine shall be tested using the other fuel.

4.6.1.1 Pre-Test Verification

4.6.1.1.1 Engine Dry Weight. Prior to initiation of the calibration, the dry weight of the engine as specified in 3.2.2.1 shall be verified in accordance with 4.3.5.2.

4.6.1.1.2 Electromagnetic Interference and Susceptibility Tests. Electromagnetic interference and susceptibility tests shall be made on all electrical and electronic components or systems of the engine prior to initiation of the endurance test. The engine shall meet the requirements and test limits set forth in MIL-STD-461 for equipment class 1D using the measuring equipment described therein. The tests shall be conducted in accordance with the methods, procedures, and techniques of MIL-STD-462.

4.6.1.1.3 Power Lever Torque. Prior to initiation of the endurance test, the power lever torque loads shall be measured for verification of 3.7.2.1.1.2.

4.6.1.2 Calibrations

4.6.1.2.1 Temperature Sensing System Calibration. The engine temperature sensing system(s) shall be checked on the bench and in the engine to establish its proper functioning and calibration over the range of the engine operating conditions. The performance shall meet the tolerance range and thermal response characteristics specified in 3.7.6.4.

4.6.1.2.2 Engine Control System Calibration. Prior to the initiation of the engine calibration specified in 4.6.1.2.3 all fuel nozzles, and the components of the engine control system, shall undergo bench calibrations using fluid in accordance with 3.7.3.3.1. The system shall conform to the design tolerance range required by the applicable design specifications

4.6.1.2.3 Engine Calibration. The procedure during the engine calibration shall be such as to establish the performance characteristics of the complete engine. Prior to the beginning of the calibration, all engine controls shall be adjusted and shall not be readjusted throughout the calibration. Calibrations shall be made initially with no customer accessory power extraction and no bleed airflow other than that required for continuous engine operation.

During calibration, engine inlet air shall be controlled to the temperature for the engine rating. Data indicated for calibration in 4.3.5.4 and 4.3.5.5 shall be recorded. During calibration conformance with the leakage requirements of 3 3.6.4 and the shutdown drain requirements of 3.3.6 5 shall be demonstrated. The following data shall be obtained:

a. Data required to establish compliance with the sea level performance ratings in Table 1 of the engine specification.

b. Data required to establish compliance with 3.2.1.5.6 Thrust Transients and 3.7.9 Starting.

c. Repeat items "a" and "b" with maximum permissible bleed airflow.

d. Repeat "c" with accessory power extraction as specified by the Using Service.

4.6.1.2.3.1 Compressor Bleed Air Analysis. Prior to initiation of the endurance test, a compressor bleed air analysis shall be performed. The compressor bleed air shall be sampled from each bleed air outlet during a maximum continuous thrust run. A sample of air entering the compressor inlet shall be taken at the same time the bleed air samples are obtained. The samples shall be properly identified and processed through laboratory analysis to determine whether the contaminant levels are within the limits specified in 3.1 2.11.3. The results of the analysis, the methods and test apparatus used shall be detailed in the engine test report.

4.6.1.3 Endurance Test Procedure. Following the calibration run, the power lever shall be placed in the maximum thrust position and the engine shall be adjusted to produce an average steady-state measured gas temperature at least 8°C (15°F) above the maximum allowable steady-state average measured gas temperature specified in 3.2.1.4.5. This value shall be re-established at the beginning of each cycle. The number of adjustments required shall be recorded.

The engine shall be subjected to an endurance test segment consisting of 25 cycles of 6 hours each in accordance with the schedule listed below. Each cycle shall be preceded by a 2-hour shutdown. The test runs in each cycle shall be conducted in the order given The time for changing thrust shall be charged to the duration of the lower setting. For all power lever movements, the power lever shall be advanced or retarded, as applicable, in not more than 0.5 second. The developed thrusts shall be as established by the engine control. If the engine does not provide for augmented thrust, maximum thrust shall be substituted for augmented thrust throughout the test schedule.

For operation during runs "e" through "j", the engine inlet air and the air which passes over the engine shall be at simulated flight temperature conditions, corresponding to the maximum steady-state stagnation temperature possible in flight, at any altitude, and flight speed condition within the engine steady-state flight operation envelope. For operation during run "k", the engine inlet air shall be at simulated flight temperature and pressure conditions corresponding to the maximum stagnation temperature and pressure possible in flight, at any altitude, and flight speed conditions within the engine's flight operating envelope.

Inlet fuel shall be maintained at the minimum specified fuel pressure throughout the test. During five successive cycles of the endurance test, the temperature of the fuel shall be maintained at the maximum temperature specified in 3.7.3.1.3.3.

The 4th, 9th, 14th, 19th, and 24th cycles shall be accomplished with maximum permissible air bleeds (customer and engine systems), all other cycles shall be with no customer air bleed The amount of bleed air required for continuous engine operation and the maximum permissible bleed air taken during the above cycles, and the bleed air temperatures and pressures, shall be stated in the test report.

For all operations during runs "e" through "k", the oil temperature shall be maintained at no less than the maximum oil inlet temperature specified in 3.2.1.4.8. The oil pressure, if adjustable, shall be adjusted at the beginning of the test to the minimum steady-state value specified in 3.2.1.4 8 at maximum rated engine speed No further adjustment shall be permitted during the test except when authorized by the Using Service. Oil consumption shall be determined and reported after each cycle. Samples of oil shall be taken and spectrometric oil analysis performed, after the calibration run and at the completion of each endurance cycle Analysis and reporting of any one sample shall not lag the actual sampling by more than three cycles. Oil drained for analysis shall not be charged to engine oil consumption and shall be replaced by an equivalent amount of new oil.

When the engine control system includes a manual control, the engine shall be run with the control in the manual mode during runs (a) and (e) of every 5th cycle for the times designated.

The ignition system shall be in operation at all times during each cycle.

Accessory pads shall be subjected to rated loads and overhung moments. The actual torque loading and overhung moments imposed during the endurance test shall be stated in the test report.

During the test, the exhaust duct, intake duct, and air bleed duct connections shall be loaded as specified in the engine specification.

If the engine is supplied with an infrared suppression system, it shall operate continuously during runs "e" and "f". If the engine provides special features such as fuel heaters, indicator lights and switching functions, these items shall be actuated during selected test runs as specified in the detailed test procedures as approved by the Using Service. If the engine incorporates an engine condition monitoring system, the system shall be in operation throughout the endurance test.

Each cycle shall consist of the following runs:

a. Maximum-idle thrust run. This run shall consist of 6 successive periods of 10 minutes each, including 5 minutes with the power lever in the maximum thrust position and 5 minutes with the power lever in the idle position. If the engine provides for anti-icing, at the end of each period at maximum thrust, anti-icing controls shall be operated for one minute with maximum anti-icing air bleed before the power setting is changed. During the 5th, 10th, 15th, 20th, and 25th cycles, 3 minutes of each 5-minute period at maximum shall be run with the control in the manual mode. Transient data recording systems are to be turned on when switching the control from the automatic to the manual mode, and also when switching back to the automatic mode from manual.

b. Incremental rotational speed run. This run shall consist of 12 periods of 8 minutes duration each at equal rotational speed increments between maximum rotor speed and idle speed conditions. For engines operating essentially at constant rotational speed, thrust may be varied throughout the non-augmented range in lieu of rotational speed. In the event significant peak vibration points exist at any conditions between idle and maximum rotational speed or throughout the non-augmented thrust range, as applicable, the number of increments chosen may be altered at the option of the Using Service, to increase the amount of running time obtained at the peak vibration points up to an amount not to exceed 50 percent of the total time of the incremental run.

c. Thrust transient run. This run shall consist of 39 minutes of thrust transients as follows:

(1) Two periods of 4 minutes at idle power lever position, 30 ±3 seconds at maximum power lever position.

(2) Two periods, each consisting of 3 minutes of operations, making a total of 6 minutes. Each period shall be run as follows: With the power lever in the idle thrust position, advance toward the intermediate power lever position, and as soon as the engine reaches the condition of minimum surge margin (i.e., rpm or gas temperature), retard the power lever to the idle thrust position.

(3) Two periods, each consisting of 3 minutes of operation and with the final period followed by an additional 2 minutes at idle making a total of 8 minutes. Each period shall be run as follows: With the power lever in the idle thrust position, advance toward the maximum power lever position, and as soon an the engine reaches the condition of minimum surge margin (i.e., rpm or gas temperature), retard the power lever to the idle thrust position. (For afterburning engines, as soon as the engine reaches the condition of minimum surge margin after lighting the afterburner, retard the power lever to the idle thrust position.)

(4) Two periods, each consisting of 3 minutes of operation and the final period followed by an additional 2 minutes at maximum making a total of 8 minutes. Each period shall be run as follows: With the power lever in the maximum thrust position, retard toward the idle power lever position, as soon as the engine reaches the condition of minimum surge margin (i.e., rpm or gas temperature), advance the power lever to the maximum thrust position. (For afterburning engines, as soon as the engine reaches the condition of minimum surge margin below intermediate power lever position, advance the power lever to the maximum thrust position.)

(5) Two periods, each consisting of 3 minutes of operation and with the final period followed by an additional 2 minutes at intermediate making a total of 8 minutes. Each period shall be run as follows: With the power lever in the intermediate thrust position, retard toward the idle power lever position, and as soon as the engine reaches the condition of minimum surge margin (i.e., rpm or gas temperature), advance the power lever to the intermediate thrust position.

d. Reverse thrust run. This run shall consist of 9 minutes of operation in the sequence of power lever positions and time duration as follows: One minute idle, 3 minutes maximum reverse thrust, 1 minute maximum thrust, 3 minutes maximum reverse thrust and 1 minute idle. If the engine does not provide reverse thrust, substitute intermediate thrust for maximum reverse thrust in this run.

e. Intermediate thrust run. This run shall consist of 30 minutes with the power lever in the intermediate thrust position. During the 5th, 10th, 15th, 20th, and 25th cycles, 26 minutes of this period shall be run with the control in the manual mode. Transient data recording systems are to be on when switching the fuel control from the automatic to the manual mode and also when switching back to the automatic mode from manual.

f. Maximum continuous thrust run. This run shall consist of 20 minutes with the power lever in the maximum continuous thrust position.

g. Intermediate thrust run. This run shall consist of 15 minutes with the power lever in the intermediate thrust position.

h. Maximum continuous thrust run. This run shall consist of 15 minutes with the power lever in the maximum continuous thrust position.

i. Modulated augmentation run. This run shall consist of 6 minutes at each of the power lever positions which produces the following percentages of augmented thrust (the difference between maximum and minimum augmentation provided); 80, 60, 40, 20, and minimum in the order listed. Modulation shall be accomplished in accordance with the above order for odd numbered cycles. For even number cycles, the sequence of scheduling shall be reversed, beginning with operation at minimum thrust augmentation. If the engine does not provide for modulation of thrust augmentation, this run shall consist of six 5 minute periods alternating between intermediate power lever position and maximum power lever position. If the engine does not provide for thrust augmentation, this run shall consist of six 5 minute periods alternating between intermediate power lever position and maximum power lever position.

j. Maximum continuous thrust run. This run shall consist of 16 minutes with the power lever in the maximum continuous thrust position.

k. Intermediate-maximum thrust run. This run shall consist of 15 minutes with the power lever in the intermediate thrust position followed by 15 minutes with the power setting at maximum thrust. When the engine has a maximum thrust rating limited to less than 15 minutes duration, the maximum thrust then shall be for that time duration and the remaining time shall be with power lever in the intermediate thrust position. At 5-minute intervals during the run, anti-icing controls shall be operated for one minute with maximum anti-icing air bleed.

4.6.1.3.1 Starts. A minimum of 200 starts shall be made on the endurance test engine. In addition to the 200 endurance test starts there shall be 10 false starts (a starting sequence without benefit of light-off followed immediately after the permissible engine draining time by a successful start), and 10 restarts (a start within a maximum of 14 minutes time from shutdown). Additional starts required to bring the total of endurance starts to 200 may be made at the end of the endurance run. During these additional starts, after the engine has reached idle speed, an immediate acceleration to maximum continuous conditions shall be accomplished by moving the engine power lever within 0.5 second from idle to maximum continuous thrust position. The engine shall be held at maximum continuous thrust for 30 seconds and then shutdown. The shutdown time between additional starts shall vary from a minimum of 45 minutes to a maximum of 90 minutes. Starts shall be performed with a starter that is acceptable to the Using Service.

4.6.1.4 Recalibrations

4.6.1.4.1 Engine Recalibration. After completion of the tests specified in 4.6.1.3 and 4.6.1.3.1, a recalibration check in accordance with the requirements of 4.6.1.2.3 and 4.6.1.2.3.1 shall be made on the endurance test engine. The recalibration check run shall be conducted with the engine adjusted to produce, under the rated inlet temperature conditions, the values of thrust obtained during the initial calibration. The recalibration may be preceded by a specified run during which the cleaning procedure outlined in the pre-test data and recommended for field use by the contractor may be applied.

4.6.1.4.2 Temperature Sensing System Recalibration. After completion of the engine recalibration, the engine temperature sensing system shall be rechecked to establish its proper functioning and calibration in accordance with 4.6.1.2.1. The performance shall meet the tolerance range and thermal response characteristics of 3.7.6.4.

4.6.1.4.3 Engine Control System Recalibration. After completion of the engine recalibration, all components, including fuel nozzles, of the engine control system, shall undergo a bench recalibration to determine conformance with allowable service limits specified by the applicable design specifications. For this recalibration, external engine control adjustments shall be established at their pretest bench calibration physical settings.

4.6.1.5 Engine Disassembly and Inspection. Each engine completing a 150 hour endurance test segment shall be completely disassembled for examination of all parts. Prior to cleaning, the engine parts shall be given a "Dirty Inspection" to inspect for evidence of leakage, oil coking, unusual heat patterns and other abnormal conditions. Following the "Dirty Inspection", the engine parts shall be cleaned and measurements shall be taken as necessary to inspect for excessive wear or distortion. These measurements shall be compared with the engine manufacturer's drawing dimensions and tolerances and with similar measurements made prior to the test. All parts shall then be subjected to a "Clean Inspection" consisting of a visual examination and condition assessment.

4.6.1.6 Engine Reassembly and Retest. Following the clean disassembly inspection, each engine shall be reassembled and subjected to a second endurance test segment in accordance with 4.6.1.2, 4.6.1.3, and 4.6.1.4. At the completion of the second endurance test segment, each engine shall undergo a second teardown inspection in accordance with 4.6.1.5.

4.6.1.7 Endurance Test Completion. The endurance test will be considered to be satisfactorily completed when both engines have completed both segments of the endurance test of 4.6.1 and during each final engine recalibration, the steady-state measured gas temperature does not exceed a value of the measured gas temperature obtained for the initial calibration plus 30 percent of the difference between the maximum allowable steady-state measured temperature specified in the engine specification and the highest measured temperature specified to obtain Table I and II performance ratings; the corrected specific fuel consumption does not exceed 102.5 percent of the initial calibration values; the engine meets all other specified performance requirements which can be checked by the calibration procedure, and in the judgement of the Using Service, the test engine and components are operating satisfactorily at the end of the tests, recalibrations do not reveal excessive performance deteriorations, and teardown inspections do not disclose parts failure or impending failures. Parts will not be judged to have passed the endurance test until they have successfully completed both 150 hour segments of the endurance test. Engine temperature deterioration and SFC increase shall be determined at the same rated thrust values.

4.6.2 Engine Component Tests. The following tests shall be conducted on all components listed under 3.1.3 of the engine specification. All components shall conform to the same parts list and configuration as those used on the endurance test engines.

4.6.2.1 Previous Component Approval. Engine components requiring testing as specified herein may have these tests waived at the option of the Using Service, if the component has been previously approved by the Using Service for use on another engine. All such components must conform to the same parts list and configuration as the components previously approved.

4.6.2.2 Simulated Operational Component Tests. The following tests pertain to the fuel system, ignition system, engine anti-icing system, hydraulic system, and engine control systems, including temperature sensing and actuation components. Tests shall be conducted in the order listed. All simulated operational tests shall be conducted on the same test assemblies, consisting of groups of related components so arranged and interconnected as to simulate their normal relationship and function on the engine. However, subassemblies or components of a system may be tested separately if such separation does not prevent simulation of the complete function of the components or subassemblies. Insofar as practicable, components shall be mounted in their normal position as mounted on the engine. No adjustments shall be made subsequent to the component calibration.

4.6.2.2.1 Component Calibration. Prior to the initiation of the simulated operational tests, each component for which the establishment of input-output relationships is a function of the component, shall be subjected to a calibration. The calibration shall be extensive enough to cover the engine steady-state and dynamic ranges of operation of the component on the engine and shall indicate conformance with the design tolerance range of the component. The engine control components shall be shown to conform to accuracy, stability, and response requirement(s) stated in the component test procedure. Each calibration shall be recorded. Components not subjected to calibration shall be operated under normal operating conditions to demonstrate satisfactory functioning.

4.6.2.2.2 Component Test Procedures. All components shall be cleaned of oil, grease, or other corrosion-preventive compounds prior to the start of testing. Test assemblies or components shall be subjected to operating loads simulating those encountered on the engine. Sufficient instrumentation shall be provided to indicate the performance of each component and to indicate that the functional relationships of components are maintained as required by the applicable test schedule. Functional checks shall be performed at the end of each test or group of tests, and at other times at the option of the contractor, to indicate that no calibrated component has changed its calibration beyond allowable service limits and that the function of uncalibrated components is unimpaired. All components shall be supplied with such fluids as they normally handle or contact, except components normally in contact with fuel will be supplied with test fluids as specified for the individual tests. All shaft driven accessories shall be operated under maximum allowable axial and angular misalignment conditions at the drive pad.

4.6.2.2.3 Component Test Cycles. All engine components excluding the fuel pump, engine control system, and ignition system shall have a test cycle defined by the contractor and submitted to the Using Service in the pretest data. Test cycles shall be consistent with the following requirements:

a. Each component shall pass through its maximum range of function at least once during each cycle.

b. Components in test assemblies shall function in their normal sequence of operation on the engine.

c. Cycling shall be controlled by varying simulated inputs to the test assembly or component. Pilot-controlled inputs, such as power lever position, shall be varied in single step changes over their extreme range and shall not be changed again until all variables have reached the demanded values. Engine-supplied inputs shall be varied in their usual relations to component outputs.

d. Input variables substantially independent of other control inputs, such as altitude pressure, shall be cycled at a rate faster or slower than the basic functional cycle in order that every component shall eventually have accomplished each part of its function at each value of the independent variables.

e. When manual or automatic transfer from one mode of operation to another is provided, the manual or automatic means shall be used to obtain transfer during the cycle.

f. Components designed to prevent the engine from exceeding its operating limits, but which are not actuated by normal operation, shall be actuated at least once during each cycle by causing their input variables to reach the necessary range of values.

4.6.2.2.3.1 Fuel Pump Test Cycle. The cycle to be used for fuel pump tests shall be as defined herein. Fuel flow is to be measured at the entrance to the fuel pump. Fuel pressure is to be measured at both the inlet and outlet of the pump. Pump speed, acceleration fuel flow and other unspecified variables shall not be prevented from assuming normal responses to transient stimuli. Transients shall be accomplished by varying the usual system inputs to achieve the specified steady-state flow conditions. Input variables substantially independent of the pump inputs such as altitude, pressure, and fuel temperatures, shall be cycled at a rate faster or slower than the basic functional cycle in order that the pump shall eventually have accomplished each part of its function at each value of the independent variables. Fuel pumps in test assemblies shall function in approximately their normal sequence of operation as on the engine. When the pumps contain special emergency features, such as dual-element or a back-up pumping system, these features will be cycled for 100 hours at room temperature in addition to the 300 hours in 4.6.2.2.6b.

a. For fixed displacement pumps, the cycle shall be as defined below. Ten minutes of each twelve minute cycle is accreditable running time. The time specified for the transients below shall not be charged to the accreditable running time.

1. Linearly increase speed and/or flow from 0 to 60% of the maximum speed and/or flow required by the engine at any point within its operating envelope, in 45 ±5 seconds, and hold at this point for 2 minutes. Augmentation mode to be "off".

2. Linearly increase speed and/or flow from 60% to 100% of the maximum speed and/or flow required by the engine at any point within its operating envelope in 25 ±5 seconds, and hold at this point for 2 minutes. Augmentation mode to be "on".

3. Hold at the speed and/or flow for 100% of the maximum speed and/or flow required by the engine at any point within its operating envelope for 1 minute. Augmentation mode to be "off".

4. Linearly decrease speed and/or flow from 100% to 90% of the maximum speed and/or flow required by the engine at any point within its operating envelope, in 10 ±5 seconds, and hold in this mode for one minute. Augmentation mode to be "off".

5. Linearly decrease speed and/or flow from 90% to 60% of the maximum speed and/or flow required by the engine at any point within its operating envelope in 15 ±5 seconds and hold at this point for 2 minutes. Augmentation mode to be "off".

6. Linearly decrease speed and/or flow from 60 to 0% of the maximum speed and/or flow required by the engine at any point within its operating envelope within 45 ±5 seconds, and remain shut down for a minimum of 2 minutes. Augmentation mode to be "off".

b. For variable flow or displacement fuel pumps, a test cycle with ten minutes of accreditable running time shall be defined in the pre-test data by the engine contractor and submitted to the Using Service. During this cycle, all valves, clutches, and any other variable flow or variable displacement features of the pump shall be cycled in a manner to simulate their normal operation.

4.6.2.2.3.2 <u>Engine Control System Test Cycle</u>. The engine control system shall be considered as the group of components whose primary function is to control the engine. All inputs or sensors which are required by the engine control system shall be included in the test. A ten minute cycle, consistent with the following requirements, shall be defined by the contractor and submitted to the Using Service, in the pretest data.

a. All input variables shall be cycled in accordance with cycles described in the pretest data. Each limiting function shall be demonstrated to provide limiting, as required by the design, at least once in every 10 cycles.

b. Input variables which are independent of the engine (such as engine face total temperature and pressure) shall be cycled at a rate faster or slower than the basic functional cycle in order that every component shall eventually have accomplished each part of its function at each value of the independent variable.

c. Cycling shall be controlled by varying simulated inputs to the test assembly or component. Pilot-controlled inputs (such as power lever position) shall be varied in single step changes over their extreme range and shall not be changed again until all variables have reached their demand values. Engine-supplied inputs shall be varied in their usual relations to component outputs

d. When automatic transfer from one mode of operation to another is provided, the automatic means shall be used to obtain transfer during the cycle.

The pretest data shall include a list of inputs to be cycled, the corresponding ranges for each input, and procedures to be used in testing. Disturbing functions such as variations in fuel pressure and bleed airflow shall be included in the list of inputs. Continuous data recording of input and output parameters versus time shall be taken throughout the test.

4.6.2.2.3.3 Ignition System Test Cycle. The self-contained ignition system or component test assemblies shall be tested in accordance with the following four hour schedule(s). For the purpose of these tests the minimum and maximum voltages and frequencies shall correspond to those extreme conditions permitted on the engine for satisfactory functioning of the ignition system. The engine contractor shall submit, in the test report, the ignition system's output characteristics. The ignition system shall be tested with the same number of ignitors connected, as used on the engine. The ignitors shall be installed in a suitable chamber and the chamber shall be purged with air or nitrogen, at a rate specified in the pretest data. The chamber pressure shall be regulated to simulate the internal engine pressures from minimum windmilling pressure to the maximum pressures the ignitors will see in the engine flight envelope. The complete ignition system shall be placed in a suitable chamber to simulate conditions of 95% (±5%) relative humidity, during the high temperature test. The ignition systems shall be tested according to the schedules listed below:

a. Continuous duty ignition system. The continuous duty start and augmentor ignition systems shall be cycled simultaneously according to the schedules specified.

For the start ignition system, each cycle shall consist of the following:

	ON	OFF
(1) NOM voltage	1 hour	20 minutes
(2) MAX voltage	40 minutes	20 minutes
(3) MIN voltage	30 minutes	20 minutes
(4) NOM voltage	40 minutes	10 minutes

For the continuous duty augmentor ignition system, each cycle shall consist of the following:

		ON	OFF
(1)	NOM voltage	5 minutes	20 minutes
(2)	NOM voltage	5 minutes	5 minutes
(3)	NOM voltage	5 minutes	40 minutes
(4)	MAX voltage	5 minutes	15 minutes
(5)	MAX voltage	5 minutes	5 minutes
(6)	MAX voltage	5 minutes	25 minutes
(7)	MIN voltage	5 minutes	10 minutes
(8)	MIN voltage	5 minutes	30 minutes
(9)	MAX voltage	5 minutes	5 minutes
(10)	MAX voltage	25 minutes	15 minutes

b. Intermittent ignition system. Intermittent augmentor ignition systems shall be cycled according to the following schedules:

	CONDITIONS	ON	OFF	REPEAT
(1)	MIN voltage	30 seconds	4½ minutes	4X
(2)	MAX voltage	30 seconds	4½ minutes	4X
(3)	MAX voltage	5 minutes	5 minutes	1
(4)	NOM voltage	5 minutes	5 minutes	1
(5)	MIN voltage	5 minutes	5 minutes	2X
(6)	NOM voltage	1 minute	2 minutes	7X
(7)	MIN voltage	5 minutes	5 minutes	2X
(8)	MIN voltage	5 minutes	4 minutes	1
(9)	MAX voltage	30 seconds	4½ minutes	6X
(10)	MIN voltage	5 minutes	5 minutes	1
(11)	MAX voltage	5 minutes	5 minutes	1
(12)		OFF 10 minutes		
(13)	MAX voltage	1 minute	4 minutes	4X
(14)		OFF 10 minutes		
(15)	NOM voltage	5 minutes	5 minutes	2X

4.6.2.2.4 Accelerated Aging. Upon completion of the component calibrations all components containing non-metallic parts shall be placed dry, in an air oven and maintained in an ambient temperature of not less than 71°C (160°F) for a minimum of 168 hours. Components may be aged individually or in test assemblies.

4.6.2.2.5 High Temperature. Upon completion of the accelerated aging, the necessary test assemblies shall be assembled and each test assembly or component shall be operated as specified in the following subparagraphs. Components normally in contact with fuel shall be supplied with the fuel specified in the engine specification but with an aromatic content of at least 25%. Toluene may be added to the fuel to attain the required aromatic content.

a. Engine components (excluding fuel pump, engine control system, and ignition system). Each test assembly or component shall be operated according to an appropriate test cycle for 100 hours or 600 cycles, whichever represents the longer period. If a component has been subjected to its component limiting temperature throughout the high temperature portion of the engine endurance test, this high temperature test shall be reduced to 20 hours or 120 cycles, whichever represents the longer period. During this cycling, ambient and fluid temperatures shall be maintained as follows:

(1) The ambient temperature shall be maintained at 71°C (160°F) for 60 minutes. The ambient temperature shall then be increased, within 1 minute, to the maximum temperature for the component specified in the engine specification and maintained at this temperature for 120 minutes. The ambient temperature shall then be returned to 71°C (160°F) within 5 minutes. This procedure shall be repeated until completion of the test.

(2) Components normally in contact with fuel shall be supplied with the fuel controlled to the maximum temperature specified in 3.7.3.1.3.3.

(3) Other fluids used for cooling or control purposes shall be maintained at their maximum allowable temperatures.

b. Fuel pump. Each fuel pump shall be operated, according to the test cycle specified in 4.6.2.2.3.1 for 100 hours, or 600 cycles, whichever represents the longer period. During this cycling, ambient and fluid temperatures shall be maintained as described in "a." above.

c. Engine control system. The engine control system shall be operated in accordance with 4.6.2.2.3.2 for 100 hours or 600 cycles, whichever represents the longer period. During this cycling, ambient and fluid temperatures shall be maintained as described in "a." above.

d. Ignition system The ignition system shall be operated for 300 hours of cycling in accordance with appropriate schedule outlined in 4.6.2.2.3.3 and at the maximum component limiting temperature given in 3.1.2.8.1. A 2 hour shutdown shall follow each cycle at the temperature conditions corresponding to the requirements of 3.1.2.8.1.c. At the conclusion of testing, checks shall be made of insulation resistance, over-voltage capability, and ignitor output energy.

4.6.2.2.6 Room Temperature Endurance. Each test assembly or component shall undergo functional cycling in accordance with the following subparagraphs. Test assemblies containing components normally in contact with fuel shall be supplied with fluid conforming to TT-S-735 Type I, contaminated downstream from the fluid tank with at least the amount of contaminant specified in 3.7.3.3.2. The solid contaminant shall not be recirculated. During the above testing, the fuel filter(s), if furnished for the engine fuel system, shall be serviced as recommended by the engine manufacturer, but at intervals representing a cumulative fuel flow equivalent to not less than that obtained in 12 hours continuous operation at intermediate rated thrust.

Components utilizing bleed air or requiring pneumatic input signals shall be subjected to air at pressure and temperature values corresponding to those occurring throughout the range of engine operation. During the first hour and each succeeding tenth hour of testing this air shall be contaminated as follows:

3 parts/million engine lubricating oil by weight.

A salt concentration of 0 2 parts salt (NaCl)/million parts of air by weight (salt shall be introduced using four percent water solution).

Distilled water to saturate the air at 52°C at an ambient pressure of 29.92 "Hg.

Crushed quartz, 1 46 X 10^{-4} pounds of quartz/pound of air.

Microns	Percent
0-5	39 ± 2
5-10	18 ± 3
10-20	16 ± 3
20-40	18 ± 3
40-80	9 ± 3

a. Engine components (excluding fuel pump, engine control system and ignition system). Each test assembly or component shall undergo functional cycling for at least 300 hours or 1800 cycles, whichever represents the longer period. The test cycle shall be in accordance with 4.6.2.2.3. Control of ambient or fluid temperatures shall not be required during this test.

b. Fuel pump. The fuel pump(s) shall undergo functional cycling for at least 300 hours or 1800 cycles, whichever represents the longer period. The test cycle shall be in accordance with 4.6.2.2.3.1. Control of ambient or fluid temperatures shall not be required during this test. During this test the inlet pressure at the first pump in each assembly shall not exceed 5 psi plus the true vapor pressure of the fuel.

c. Engine control system. The engine control system shall be operated in accordance with 4.6.2.2.3.2 for 300 hours or 1800 cycles, whichever represents the longer period. Prior to the start of the endurance test, the engine control system shall be cleaned of any corrosion-preventive compounds used for preparation for storage. The following procedure shall be used for room temperature endurance test:

(1) The engine control system shall be subjected to a high humidity atmosphere of clear water vapor and high temperature soak (95 ± 5% relative humidity and 60°C ± 4°C (140°F ± 10°F)) for 120 hours before cyclic endurance.

(2) Operate the engine control system per 4.6.2.2.3.2 for 100 hours or 600 cycles, whichever represents the longer period. Temperature and humidity control are not required.

(3) Repeat (1), except the temperature will be 21° ± 4°C (70° ±10°F) for the 120 hours.

(4) Repeat (2).

(5) Repeat (1).

(6) Repeat (2).

d. Ignition system. The ignition system shall be operated at an ambient temperature between 38°C (100°F) and 16°C (60°F) for 100 hours of cycling in accordance with the appropriate schedule outlined in 4.6.2.2.3.3.

4.6.2 2.7 Low Temperature. Upon completion of the room temperature endurance test, each test assembly or component shall be soaked in an ambient temperature of lower than -54°C (-65°F) for a minimum period of 10 hours. Upon completion of soaking, the soaking temperature -54°C (-65°F) shall be maintained while each test assembly or component is operated as detailed below. During the entire low temperature test, fluid conforming to TT-S-735, Type I, shall be present in each test assembly or component part normally coming in contact with fuel. Prior to each cycling period the test fluid temperature shall be reduced to below -54°C (-65°F). Other fluid temperatures may rise as anticipated in service operation under similar ambient conditions. If -34°C (-30°F) is reached before completion of a cycling period, the cycling shall be stopped and restarted when the fluid temperature has been reduced to below -54°C (-65°F).

a. Engine components (excluding fuel pump, engine control system, and ignition system). Each assembly or component shall undergo a test of functional cycling for at least a total of 20 hours or 120 cycles, whichever represents the longer period. The test shall consist of at least 10 separate runs with the cycle sequence of operation in each run as defined in 4.6.2.2.3.

b. Fuel pump. The fuel pump(s) shall undergo a test of functional cycling for at least a total of 20 hours or 120 cycles, whichever represents the longer period. The test shall consist of at least 10 separate runs with a cycle sequence of operation in each run as defined in 4 6 2.2.3 1.

c. Engine control system. The engine control system shall undergo a test of functional cycling for at least a total of 20 hours or 120 cycles, whichever represents the longer period The test shall consist of at least 10 separate runs with a cycle sequence of operation in each run defined in 4.6 2.2.3.2

d Ignition system. The ignition system shall be tested for 24 hours at an ambient temperature of -54°C (-65°F). The system shall be operated for 12 hours of cycling in accordance with the appropriate schedule outlined in 4.6.2.2.3.3 followed by a 10 hour minimum inoperative soaking period, and a final 12 hours of cycling.

4.6.2.2.8 Fuel Pump Cavitation. For the fuel pump cavitation test, the portion of the fuel system from the inlet of the engine to the primary and augmentation pump, if applicable, shall be simulated in the test assembly. This shall include lines, fittings, filters, and other items as applicable between the engine inlet and fuel pump inlet as well as any elements of the fuel system downstream of the pump which might have an effect on the pump inlet conditions. Prior to the start of this test, the system shall have had fluid passed through it at maximum continuous engine fuel flow for 2 hours contaminated with at least twice the amount of contaminant specified in 3.7.3.3.2. Unweathered, clean fluid may be used to conduct the test. The fluid shall be in accordance with MIL-T-5624, Grade JP-4. The primary and secondary pumps shall be operated for 47 hours at intermediate rated speed and at the maximum flow and discharge pressure required by the engine at sea level standard altitude absolute condition and a ram pressure ratio of 1.15. Pressure on the fuel tank will be maintained at 20 inches Hg absolute during the cavitation test. An additional restriction will be introduced ahead of the pump inlet to provide the required vapor/liquid ratio. The fluid vapor/liquid ratio and the engine inlet shall be maintained at not less than 0.45 and the fluid temperature shall be at least 57°C (135°F). Augmentation pumps shall be operated at the above conditions at least 12 hours continuously. Except as stated above the test procedure shall be in accordance with ARP 492.

4.6.2 2.9 Recalibration. Upon completion of the preceding tests, component calibrations shall be repeated and shall indicate that no component has changed its calibration beyond allowable limits specified in the pretest data. Components not subjected to calibration shall be operated under normal operating conditions to demonstrate satisfactory functioning. During recalibration the same fluids, inputs, and operating cycles shall be used as in the calibration. All components shall then be completely disassembled and inspected for indications of failure or excessive wear. Each recalibration shall be recorded.

4.6.2.2.10 Component Test Completion. The simulated operational tests shall be considered to be satisfactorily completed when, in the judgment of the Using Service·

a. During the tests, component performance and function were within established limits.

b. During the tests, there was no fluid leakage from any component other than that of a nature and rate specified in the engine specification

c. Recalibrations indicate that no component has changed its calibration beyond allowable service limits.

d. The component teardown inspection shows no indication of failed, excessively worn, distorted, or weakened parts. During this teardown inspection, the components shall be completely disassembled for examination of all parts, and measured as necessary to disclose excessively worn, distorted, or weakened parts. These measurements shall be compared with the engine contractor's drawing dimensions and tolerances or with similar measurements made prior to the test.

4.6.2.3 Environmental Component Tests. The following tests apply to electrical components or sub-components, including electrical connectors, and electrical and electronic portions of the engine control system. Electrical components and sub-components not mounted on the engine shall also be subjected to these environmental tests. In addition, all non-electrical components listed in 3.1.3 of the engine specification shall be subjected to the vibration test of 4.6 2.3.9. Tests of additional components shall be conducted when specified in the engine specification. The same physical components shall be subjected to all the following tests.

4.6.2.3.1 Component Calibrations. Before and after each of the following tests, each component subject to calibration shall be calibrated. These calibrations shall indicate that each component is operating within its design tolerance range. Components not subject to calibration shall be operated at maximum and minimum input voltage to demonstrate satisfactory functioning.

4.6.2.3.2 Component Test Procedures At the option of the contractor, these tests may be conducted on test assemblies or individual components, either of which may be new and not previously subjected to any testing. Prior to the start of any testing, all components shall be cleaned of any corrosion-preventive compounds used for storage protection. Components shall be subject to operational loads simulating the maximum operating loads encountered on the engine. Power supply transients, when required herein, shall consist of the application of an overvoltage for the times specified in MIL-STD-704. The four points selected for performance of an overvoltage shall include points within 10 percent of the following· 150, 140, 130, and 125 volts ac, rms line to neutral, or 80, 60, 40, and 35 volts dc. Transient spike voltages shall consist of the application of a spike voltage of +200 volts and -170 volts for $5x10^{-5}$ seconds and a spike voltage of ±600 volts for 1×10^{-5} seconds each to be applied five times within one minute. When a single hermetically sealed component is used in a series of the tests below, the component need not be disassembled for inspection until the last test of such series has been completed. At this time, the components will be inspected for defects or damage which may have been incurred during any of the tests performed. In addition, hermetically sealed components need not be subjected to the explosion-proof, sand and dust, and fungus tests. Prior to disassembly, a test to determine hermetic seal integrity shall be performed. Failure of the hermetic seals during any test shall disqualify that component.

4.6.2.3.3 Humidity. Components shall be subjected to an atmosphere of clear water vapor under the conditions and cycle as specified herein for a period of 15 days. Immediately after 12 hours of the first test cycle, all components shall be checked for proper operation with the maximum specified voltage. During the last cycle of the 15-day test each component shall be operated throughout its entire range of operation under each of the ambient conditions specified. At the end of the 15 days of test, the components shall be dried without forced convection for 12 hours in air at less than 21°C (70°F) with not less than 50 percent relative humidity. At the conclusion of this period, four power supply overvoltage transients, and transient spike voltages, shall be applied to the components. After recalibration, components shall be disassembled and inspected. There shall be no corrosion or other defects present that affect the function or structural strength of the component.

Humidity Conditions Test Cycle

Time Period (Hours)	Relative Humidity (Percent)	Ambient Temperature (°C)
8	95 ± 5	54 ± 3
4	Holding chamber moisture content constant	54 ± gradually down to 21 ± 3
8	Holding chamber moisture content constant	21 ± 3
4	Up to 95 ± 5, Holding chamber moisture content constant or adding vapor to reach required value	21 ± 3 uniformly up to 54 ± 3

4.6.2.3.4 Fungus. Components shall be subjected to a fungus test in accordance with MIL-STD-810, method 508. Evidence that all materials used do not support fungus growth shall constitute grounds for waiver of this test, when approved by the Using Service. Components shall be subject to pre and post test calibrations or functional checks as applicable, but need not be operated during the test. Criteria for passing the test shall be as defined in MIL-STD-810, method 508.

4.6.2.3.5 Explosion-Proof. All electrical components not hermetically sealed shall be subjected to explosion-proof testing in accordance with MIL-STD-810, method 511, Procedure I. During the test, components shall have maximum input voltage applied to them and shall be operated continuously at their maximum loads. During each altitude condition, all make and break contacts shall be operated at least 10 times. An overvoltage power supply transient shall be applied to the components at least 4 times during each altitude condition. At least four of these power supply transients shall be applied during operation of make and break contacts. Power supply transients shall be as stated in 4.6.2.3.2. Ignition components or systems shall be operated continuously. Electrodes of spark ignitors shall be mounted in such a manner that the explosive vapor in the test chamber shall not be contacted. Electrically self-sufficient ignition systems shall be exempted from the application of power supply transients. Failure criteria shall be as defined in MIL-STD-810, method 511.

4.6.2.3.6 Sand and Dust. Components shall be subjected to a sand and dust test in accordance with MIL-STD-810, method 510. Components need not be operated during the test; however, at the conclusion of the test, and prior to any cleaning of the components, 4 power supply transients, covering the transient range, shall be applied to the component. Criteria for passing the test shall be as defined in MIL-STD-810, method 510.

4.6.2.3.7 Sustained Acceleration. Components shall be subjected to an acceleration test in accordance with MIL-STD-810, method 513.1. The test item shall be subjected only to the operational test in accordance with Procedure II and Table 513.I-II for the airplane vehicle category. Test time may be increased beyond the minimum specified if necessary to determine proper operation.

4.6.2.3.8 Impact. Components shall be subjected to an impact test in accordance with MIL-STD-810, method 516.1, Procedure I. The shock pulse shape shall be in accordance with figure 516.1-1 of amplitude a and time duration c. Tests shall be conducted under room ambient conditions. Components shall be subject to pre and post test calibrations or functional checks as applicable, but need not be operated during the test. Post-test inspection procedures shall be in accordance with MIL-STD-810, method 516.1.

4.6.2.3.9 Vibration. Components shall be subjected to a vibration test in accordance with MIL-STD-810, method 514.1. Tests shall be conducted in accordance with Procedure I for equipment category "b" (table 514.I-II) and curve "F" and "L" (figure 514.1-2). Components may be tested in test assemblies or as individual units. During the test the component shall be subjected to its maximum limiting component temperature specified in the engine specification.

4.6.2.3.10 Ignition System Fouling. The following tests, in addition to the other environmental tests, are applicable to all ignition systems and are required to demonstrate that the ignition system will be capable of consistently starting the engine under fouling conditions. The power input for the tests shall be the minimum defined by 4.6.2.2.3.3.

4.6.2.3.10.1 Carbon Fouling. The spark ignitors of the ignition system test assembly shall demonstrate sparking performance with spark gaps covered, filled or bridged with a generous application of graphite petrolatum compound MIL-T-5544. With the minimum power input supplied as specified in the specification, the ignition system shall demonstrate satisfactory operation. Under these carbon fouling conditions, the sparking rate shall not be less than the minimum design value.

4.6.2.3.10.2 Water Fouling. With the spark ignitors positioned in a manner simulating the mounted position in the engine, the minimum power input specified in the specification shall be supplied. The spark ignitors of the ignition system test assembly shall be thoroughly drenched with water to simulate extreme atmospheric conditions. The ignition system shall then demonstrate satisfactory operation, with the sparking rate being not less than the minimum design value.

4.6.2.4 Individual Components Tests

4.6.2.4.1 Oil Reservoir. The filler cap and other fittings shall be installed, the tank mounted in a manner similar to that as found on the engine, and the entire test assembly shall be subjected to the following tests:

a. Cyclic Fatigue Test - The oil tank shall be cycled between the minimum and maximum differential pressure limits of 3.7.7.4.1 at a rate no more than 4 times per minute for a minimum of 10,000 cycles. The maximum ΔP to be used in the cyclic fatigue test shall be stated in the pretest data. For the purpose of this test, the differential pressure (ΔP) shall mean the absolute value of the difference between external and internal pressure of the oil tank. During the first 5,000 cycles, the oil reservoir shall be kept at the nominal operating temperature, and during the last 5,000 cycles the reservoir temperature shall be kept at the maximum oil operating temperature. Throughout this cycling, no leakage or permanent deformation of the oil reservoir, filler cap, or fittings shall occur.

b. Proof Pressure Test - Upon successful completion of the cyclic fatigue test, the same oil reservoir assembly shall be subjected to a proof pressure test to demonstrate compliance with 3.7.7.4.1. The proof pressure shall be held for a minimum of 10 minutes with the oil reservoir at the maximum oil operating temperature. The contractor shall specify in the pre-test data the pressure to be used for the proof pressure test. No leakage or permanent deformation of the reservoir, filler cap, or fittings shall occur.

c. Valve Tests - If the oil reservoir assembly incorporates a pressurizing valve or pressure relief valve, the assembly shall be tested in such a manner as to demonstrate proper functioning. The contractor shall specify in the pre-test data the procedure to be used.

4.6.2.4.2 Accessory Drive/Power Takeoff. The engine drive train and the external engine gearbox(s) which drives engine components and customer accessories or power takeoff shall be subjected to a 300 hour laboratory endurance test. Prior to the endurance running, the gearbox shall undergo a static torque test wherein the input shaft shall be held stationary and all pad drives except the starter pad simultaneously loaded to 150 percent of the maximum static torque values specified in the engine specification for a period of five seconds. During this 5 second period the starter drive shall be loaded to 250 percent of the maximum starting torque specified for this pad in the engine specification and in a direction that will not unload any other component of the accessory drive train. Following the static torque test, the gearbox, with all accessories and components installed, shall be subjected to a vibratory scan and resonant search while operating throughout the speed range from idle to maximum speed under varying loads including maximum rated pad loads. The endurance test shall be run on the gearbox with all accessories and components installed, using the specified oil at the maximum oil inlet temperature and minimum oil flow and pressure specified in 3 2.1.4.8. During the test, all drives shall be loaded to at least the maximum overhung moment rating of the drive and subjected to at least the maximum spline misalignment allowed in the engine specification. Elements or components of the engine lubrication system such as filters and oil reservoirs may be incorporated in the test rig to simulate system characteristics. Where applicable, pad seal drain leakage shall be monitored throughout the test. Data to be recorded and frequency of recordings shall be as specified in the pretest data. The gearbox endurance test shall be run in accordance with the following schedule:

a Maximum Rated Speed Run. This segment shall consist of 20 hours of continuous running at a speed corresponding to maximum rated engine speed and with all pad drives loaded to the maximum allowable torque values for this speed condition.

b. Idle Speed Run. This segment shall consist of 15 hours of continuous running at a speed corresponding to engine idle speed and with all pad drives loaded to nominal torque values. During this run, the customer accessory pad drive(s) shall be subjected to five 5 second overload conditions as defined in the pre-test data.

c. Speed Transient Run. This segment shall consist of 15 hours of running during which the gearbox, with all pad drives loaded to nominal torque values, is subjected to 180 successive 5 minute cycles of acceleration from idle RPM to maximum allowable RPM and return to idle During each 5 minute cycle, the gearbox drive RPM shall be accelerated once from idle to maximum allowable RPM in no more than seven seconds, held at maximum allowable RPM for 3 minutes, and then decelerated to idle RPM for the remainder of the cycle.

d. Incremental Speed Run. This segment shall consist of ten periods of 5 hours duration each at approximately equal RPM increments from idle speed to and including maximum allowable speed with all drive pads loaded to the maximum allowable torque values for each speed condition. During the maximum allowable speed run, three 5 minute periods of overspeed to 115 percent of maximum speed shall be accomplished. During the overspeed segment, all gearbox pad drives shall be loaded to nominal torque values. In the event significant peak vibration points exist at conditions between idle and maximum speed, as determined during the vibration scan, the number of increments chosen may be altered at the option of the Using Service to distribute a portion of the running time over speeds and loads correspon-ding to those at which peak vibration points were obtained up to an amount not to exceed 50 percent of the total time of the incremental run.

e. Continuous Speed Run. This segment shall consist of 50 hours of contin-uous running at a speed corresponding to 70 percent maximum rated engine speed with all gearbox pad drives loaded to the maximum continuous torque rating specified in the engine specification.

f. Maximum Speed Run. This segment shall consist of 150 hours of continuous running at a speed corresponding to maximum allowable engine torque rating for this speed condition, except that during each 10 hour increment a 5 min-ute overload condition will be imposed to the overload torque rating specified in the engine specification. During this run, the gearbox external surfaces shall be maintained at the maximum component temperature specified for the gearbox in the engine specification.

Following the test, scavenge oil filter and magnetic plug residue shall be collected and separated into magnetic and non-magnetic material This mate-rial shall then be weighed, analyzed, and the results reported. At the completion of the test the gearbox shall be completely disassembled, cleaned, and parts inspected. There shall be no evidence of material defects, undue wear, or impending failure. Conformance with the fluid leakage requirements of 3.3.6.4 shall be demonstrated during this test.

4.6.2.4.3 Generator/Alternator Tests. The following tests, in addition to the environmental tests, shall be conducted on each generator/alternator:

a. Overspeed - The generator/alternator shall be operated at a speed which corresponds to 115 percent of maximum allowable engine speed for 5 minutes. At the completion of the test there shall be no evidence of mechanical or electrical damage or failure.

b. Load Test - The generator/alternator shall be operated at a speed corresponding to 106 percent of maximum allowable engine speed under full rated electrical load for one hour. During this test, the alternator shall be subjected to its maximum component limiting temperature. At the comple-tion of the test there shall be no evidence of mechanical or electrical damage or failure.

c. Containment - The generator/alternator shall be operated at the maximum design speed in a manner to cause a mechanical failure of the rotor system. All damage shall be contained within the generator/alternator housing.

4.6.2.4.4 Heat Exchangers Heat exchangers for cooling or heating of engine fluids or components shall be subjected to the following tests. If non-metallic parts are included in the heat exchanger assembly, the entire assembly shall be subjected to the accelerated aging test per the requirements of 4.6.2.2.4. If the heat exchanger assembly incorporates a bypass valve, regulator or indicating feature, appropriate tests shall be conducted to demonstrate proper functioning and shall be specified in the pre-test data.

a. Flow, pressure, and temperature cycling test - The heat exchanger shall be subjected to a flow, pressure, and temperature cycling test for one design life. The number of cycles shall be specified in the pre-test data, with a cycle defined as follows: Simultaneously introduce both fluids at ambient temperature and pressure to the heat exchanger, then while increasing the flow to the maximum value encountered in the operating envelope, raise the temperature and pressure of the fluids to their corresponding maximum values. Once the output flow conditions have stabilized, begin decreasing the flow to the minimum value encountered in the operating envelope, and decreasing accordingly the temperature and pressure of the fluids to their ambient values. Once output flow conditions have been stabilized, the flow of both fluids shall be terminated. 25 percent of the test cycles shall be run with the ambient air surrounding the heat exchanger at its maximum component limiting temperature and the balance of the cycles shall be run with the surrounding air at ambient temperatures. At the completion of this test there shall be no evidence of leakage or permanent deformation.

b. Heat exchanger proof pressure Upon successful completion of the flow, pressure and temperature cycling the same heat exchanger shall be subjected to a proof pressure test. Each fluid side of the heat exchanger shall be individually subjected to twice its maximum working pressure for at least two successive times and held two minutes for each pressure application During the application of pressure to one side the other element shall be dry. There shall be no evidence of external leakage or internal leakage into the dry side. Following this test, both sides of the heat exchanger shall be simultaneously subjected to their maximum working pressures for at least two successive times and held two minutes for each pressure application. At the completion of this test there shall be no evidence of leakage or permanent deformation.

4.6.2.4.5 Fire Test. Lines, fittings, and components, including engine furnished oil tank, which convey flammable fluids shall be tested to verify conformance with 3.3.6.1. Individual lines, fittings, components or assemblies shall be tested as specified in ARP 1055 while conveying fluids at the lowest flow rate, highest system pressure and highest fluid temperature expected over the complete engine operating range. The requirements of 3.3.6.1

shall be considered verified, if at the completion of the test period, there are no leaks. The above test may be waived for identical components which have successfully completed the test of 4.5.2.5

4.6.2.4.6 Hydraulic System. The complete hydraulic system shall be tested to demonstrate compliance with the requirements of 3.7.8.1.2. The hydraulic system testing may be conducted either in a complete system rig test or as installed on an engine substantially identical to the QT engine. The hydraulic system high pressure side shall be subjected to a proof pressure test to twice the maximum working pressure for at least two successive times and held two minutes for each pressure application. Hydraulic test fluid shall be maintained at maximum system working temperature. The equipment shall be operated in its normal function between applications of the test pressure. At test completion there shall be no evidence of external leakage, excessive distortion or permanent set. Components which require varying test pressures in different elements may have these pressures applied either separately or simultaneously, as specified in the pre-test data.

4.6.3 Altitude Tests. An engine, conforming to the same parts list and configuration as the endurance test engine, shall be subjected to altitude tests which shall consist of operation and air starting checks at selected conditions within the operating limits envelope specified for the engine and at least those given in the engine specification as shown in Figure 19. The test points shall include the effects of power extraction, inlet recovery, bleed air extraction and inlet distortion on engine performance and stability. Control system adjustments shall not be made without approval of Government representative. The altitude tests shall be accomplished using all the oils and fuels specified in the engine specification. Fuel temperature shall be varied over a range sufficient to encompass all anticipated engine operating environments. The continuous ignition system shall be in operation at all times after the start sequence has been completed. All power take-off pads shall be loaded as specified by the Using Service for a particular test phase. Data to be taken and recorded during the test shall be as specified in Table XII.

Overall true RMS velocity measurements and acceleration spectrograms shall be obtained for each accelerometer mounted on the engine case and accessory gearbox case at engine speeds and thrusts selected for the test. The points selected shall include at least the altitude rating points and the point in the operating envelope where the highest engine vibrational levels are generated. Critical components of the engine shall be identified on each spectrogram.

The compressor bleed air shall be sampled from each bleed air outlet during a maximum continuous thrust run. A sample of air entering the compressor inlet shall be taken at the same time the bleed air samples are obtained. The samples shall be properly identified and processed through laboratory analysis to determine whether the contaminant levels are within the limits specified in 3.1.2.11.3. The results of the analysis and the methods and test apparatus used shall be detailed in the engine test report.

4.6.3.1 Altitude Engine Calibration. Prior to initiation of the testing described in 4.6.3.2, the engine shall be calibrated in accordance with 4.6.1.2.3. No control readjustments shall be made after the initial adjustments at the beginning of the calibration.

4.6.3.2 Altitude Test Procedure. Operation at each test point shall be of sufficient duration to stabilize the engine and to establish the performance and operating characteristics of the engine. When a manual control mode is included in the control system, this feature shall be evaluated and its effects on engine performance and operating characteristics shall be determined during the test schedule Operation shall be conducted to obtain the following data:

a. Altitude Rating Points. The test points shall be those specified for altitude ratings in Table II of the engine specification. A sufficient additional number of engine thrust settings shall be selected for each specified altitude test condition to establish operating and performance characteristics at each rated point. The effects of bleed air and power extraction on steady-state performance shall be obtained at each specified test point. The time elapsed versus engine speed, engine temperature and fuel flow shall be obtained for stability verification with the power setting at idle, maximum continuous, intermediate and maximum thrust. The time period for stability verification shall be a minimum of 5 minutes at each power setting.

b. Transient Operation. The applicable transient performance specified in 3.2.1.5.6 shall be demonstrated at each rating condition. The transient air flow performance specified in 3.1.2.10.3 shall be demonstrated. Effects of maximum bleed air and power extraction singly and in combination on transient performance shall be determined.

c. Functional Test. The operating envelope of the engine shall be verified by running the engine at the extremities of the operating envelope. Engine steady-state and transient characteristics shall be determined at each test point over the range of power settings. The engine operating characteristics determination shall be accomplished with and without customer bleed air and power extraction. If the engine incorporates an augmentation system, the augmentator blowout limits shall be determined.

d. Inlet Distortion. The inlet airflow distortion limits of the engine shall be demonstrated at the inlet conditions specified in 3.1.2 10.4. Effect of inlet distortion on transient operation and steady-state performance shall be determined. Also the effects of customer bleed air and power extraction on engine tolerance to inlet airflow distortion shall be determined.

e. Starts and Restarts. Flameouts, with the ignition system not operating, shall be accomplished by means specified in the engine specification. The following tests shall be conducted with and without customer bleed air and power extraction. (1) Engine air starts and restarts, with and without starter assist, after an engine flameout shall be accomplished at each of the specified air starting points. (2) If a continuous ignition system or an automatic relight system is provided, an additional demonstration shall be conducted at the same points and utilizing the same flameout technique, but with these systems operating. The engine shall demonstrate that it will re-ignite and return to stable operation without any manipulation of the engine power lever. (3) If the engine incorporates an augmentation system, the augmentor light-off limits shall be verified.

f. Altitude Windmilling Test. Altitude windmilling tests shall be conducted within the windmilling envelope to verify the requirements of 3.2.1.5.7 a. and d.. In addition, testing shall be accomplished to verify that the lubricating system will provide proper lubrication, as defined in the pre-test data, and operate without excessive loss of oil during windmilling operation.

4.6.3.3 Altitude Test Completion. Comparison of observed data obtained during the test to the specified performance and operating characteristics shall be made by a method acceptable to the Using Service to determine compliance with the engine specification. The test shall be considered to be satisfactorily completed when, in the judgement of the Using Service:

a. The minimum engine performance is as specified in Table II of the engine specification and the ratio of measured performance at altitude to measured performance at sea level is equal to or better than the ratio of specified altitude performance to specified performance at sea level.

b. The altitude starting and transients conducted during the test are in accordance with the engine specification requirements.

c. The functional test points demonstrate satisfactory engine operation and do not show any discrepancies with the rating points, altitude starting data and transient data.

d. The engine operates satisfactorily under distortion and windmilling conditions specified for the test.

4.6.4 Engine Environmental and Ingestion Tests. The tests in the following subparagraphs shall be conducted on engines having the same parts list and configuration as the endurance test engine of 4.6.1. Unless otherwise specified in the individual test, the engine shall be calibrated before and recalibrated after each test, but only to the extent necessary to determine any deterioration in steady state or transient performance capability which occurred during the course of testing. The tests shall be conducted using the fuel specified in Table XI for the particular test. All starts shall be performed with a starter in accordance with 4.3.3.4. Unless otherwise specified for a particular test, the test shall be conducted at the ambient conditions which prevail at the test site.

4.6.4.1 Low and High Temperature Starting and Acceleration Test. The test engine shall be subjected to low and high temperature tests to demonstrate compliance with 3.2.1.4.8, 3.2.5.1, 3.2.1.5.6, 3.7.9.2 and 3.7.9.3. All data required in 4.3.5.6 shall be recorded during each start. Starting and operating capabilities shall be accomplished with the torque loading as specified in the engine specification applied to the accessory drive pads, and with no customer air bleed. Recalibration shall not be required

a. Low temperature test - The engine, serviced with the oil specified in the engine specification, shall be subjected to a soaking period of at least 10 hours duration at an ambient temperature of -54°C (-65°F). The 10 hour soaking period shall be started after the main bearings of the engine have reached -54°C (-65°F). At the end of the low temperature soaking period, the electrical connectors shall be disconnected and reconnected to verify the requirements of 3.7.4.3.2. In addition, the oil reservoir filler cap and the other servicing feature shall be functionally checked to demonstrate their proper functioning under cold soak conditions. After the soak period and when supplied with fuel, and inlet air at a temperature of -54°C (-65°F) a start shall be made with the power lever in the idle position. After the engine has reached idle speed, an acceleration to intermediate thrust shall be accomplished by moving the engine power lever within 0.5 seconds from idle to intermediate power lever position. The engine shall then be returned to idle and shutdown. The above procedure, including the soak period, shall be repeated twice. If more than one fuel or oil is specified in the engine specification, the complete test above shall be repeated using these fuels or oils. The soak, oil, air and fuel temperatures shall be subject to fuel or oil temperature limitations of 3.2.5 1 and 3.7.7.2 respectively.

The test will be considered to be satisfactorily completed when, in the judgement of the Using Service· the above three successive starts have been satisfactorily accomplished within the time limits specified in Figure 18, the engine has demonstrated its ability to accelerate to intermediate thrust without exceeding any engine starting or operating limits; there were no fuel or oil leaks, functional checks of electrical connectors and servicing features have revealed no damage or difficulties during operation.

b. High Temperature Test - The engine, serviced with the oil specified in the engine specification shall be subjected to a soaking period of at least 10 hours duration at an ambient temperature of 71°C (160°F). The 10 hour soaking period shall be started after the main bearings of the engine have reached 71°C (160°F). After the soak period and when supplied with fuel at a temperature of 93°C (200°F) and air at 52°C (125°F), a start shall be made with the power lever in the idle position. After the engine has reached idle speed, an acceleration to intermediate thrust shall be accomplished by moving the engine power lever within 0.5 seconds from idle to intermediate power lever position. The above procedure, including the soak period, shall be repeated.

If more than one fuel or oil is specified in the engine specification, the complete test above shall be repeated using these fuels or oils.

The test will be considered to be satisfactorily completed when, in the judgement of the Using Service, the above two successive starts have been satisfactorily accomplished within the time limits specified in Figure 18, the engine has demonstrated its ability to accelerate to intermediate thrust without exceeding any engine starting or operating limits and there were no fuel or oil leaks.

4.6.4.2 Environmental Icing Test. The engine shall be subjected to an environmental icing test to demonstrate compliance with 3.2.5.2. For this test, the engine shall be operated under the free air conditions listed in Table XIII. For each test run, the liquid water content and droplet size, shall be measured at a distance within five feet of the engine inlet face and still within the engine inlet duct. The liquid water content measured at this station shall correct to the free air conditions as specified in Table XIII. This meteorological data shall be recorded at suitable intervals during each test run. The method and procedure for collecting and determining the water droplet size and liquid content shall be specified in the pretest data. During the testing, thrust, RPM, and vibration shall be continuously recorded and high speed photographic coverage of the engine inlet shall be provided. The base line for determining engine performance loss shall be established by operating the engine with no customer air bleed or power extraction and under the inlet temperature conditions of Table XIII with air between 80 and 100% relative humidity and zero liquid water content. The thrust and specific fuel consumption losses shall be determined by comparison of engine performance when operating at the icing conditions defined in Table XIII with the aforementioned base line values. The test shall consist of two parts as follows:

a. This part shall consist of two runs at each of several engine power settings under each of the conditions in part 1 of Table XIII. The engine power settings shall include idle; 25 percent, 50 percent, 75 percent of

Maximum Continuous; Maximum Continuous and Intermediate Power. At each icing condition and at each power setting, the engine shall be operated for a period of not less than 10 minutes. During each period, at intervals after ice buildup, the engine shall be rapidly accelerated to intermediate power to demonstrate acceleration response.

b. This part shall consist of a 1 hour run at idle with no throttle movement, followed by an acceleration to maximum thrust at the end of the period. During this run the engine shall be operated under the conditions listed in part 2 of Table XIII.

If the engine incorporates an anti-icing system, the above tests shall be performed using the anti-icing system to demonstrate the requirements of 3.2.5.2 and 3.7.1.

The testing will be considered satisfactorily completed when, in the judgement of the Using Service, there was no damage to the engine and performance was within the requirements of 3.2.5.2 and 3.7.1.

4.6.4.3 Corrosion Susceptibility Test. A new or newly overhauled test engine shall be subjected to a corrosion susceptibility test to demonstrate compliance with 3.2.5.5. Prior to starting the test, the engine shall be disassembled sufficiently to inspect the surface condition of all parts normally exposed to atmospheric conditions. Detailed photographic coverage of these parts shall be provided. Upon reassembly and after a performance check, the engine shall be subjected to 25 cycles of testing conducted in accordance with the cyclic schedule specified in Table XIV.

The spray solution injected during the cycles designated shall be composed of the following materials dissolved with sufficient distilled water to make one liter of salt spray solution:

Chemical Designation	Quantity per liter of Spray Solution
NaCl(c.p.)	23 grams
Na_2SO_4 $10H_2O$	8 grams
Stock Solution	20 milliliters

The stock solution shall be composed of the following materials dissolved with sufficient distilled water to make one liter of stock solution:

Chemical Designation	Quantity per liter of Stock Solution
KCl(c.p.)	10 grams
KBr	45 grams
$MgCl_2 \cdot 6H_2O$ (c.p.)	550 grams
$CaCl_2 \cdot 6H_2O$ (c.p.)	110 grams

During the test, the engine shall be subjected to internal inspections to detect any evidence of corrosion or progression of corrosion of internal parts at intervals as specified in the engine specification.

At the completion of the test, a performance check shall be conducted and the engine shall be disassembled and inspected for evidence of corrosion. Detailed photographs shall be taken of all parts which show evidence of corrosion. The contractor shall present test specimen evidence or metallurgical analyses that completely characterize the types of corrosion found. The test will be considered to be satisfactorily completed when, in the judgement of the Using Service, the extent of corrosion is not of such a magnitude as to impair structural integrity, component operation or be a cause for significantly reducing performance, engine durability or parts life.

4.6.4.4 Bird Ingestion Test. The test engine shall be subjected to a bird ingestion test conducted in such a manner as to verify the requirements of 3.2.5.6.1. The birds shall be ingested in a random sequence, dispersed over the inlet area, to simulate an encounter with a flock. If approved by the Using Service, synthetic "birds" may be used for testing. The contractor shall specify in the pretest data the critical target areas for each bird size and the procedure to be used for bird ingestion. High speed photographic coverage of the inlet is required during the ingestion test. The test will be considered to be satisfactorily completed when, in the judgement of the Using Service, the performance criteria of 3.2.5.6.1 have been met and there is no evidence of major structural damage which could cause the engine to fail.

4.6.4.5 Foreign Object Damage Test. The test engine shall be subjected to a foreign object damage test to demonstrate compliance with 3.2.5.6.2. Simulated foreign object damage shall be applied to three first stage blades at one or more sections of the leading edge at a location where high steady-state and vibratory stresses occur at maximum engine speed. The damage applied shall produce at least a stress concentration factor (K_t) of 3. Following the foreign object damaged application, the engine, with damage blades installed shall be subjected to one 6 hour cycle of running in accordance with the cycle of operation in 4.6.1.3. No calibration or recalibration shall be required for this test. At the completion of the running there shall be no evidence of blade failure or cracking as the result of the foreign object damage.

Subject to approval of the Using Service, the foreign object damage test may be conducted by bench testing on individual blades or rig testing on full scale fan or compressor components in lieu of complete engine testing.

If the test is to be conducted on a component basis, details of the test shall be presented in the pretest data. However, conditions, duration and severity of testing shall be equivalent to the complete engine test described above.

4.6.4.6 Ice Ingestion Test. The test engine shall be subjected to an ice ingestion test to demonstrate compliance with the requirements of 3.2.5.6.3. The type of ice and the conditions for ingestion shall be as follows:

a. One, two (2) inch diameter hailstone and two, one (1) inch diameter hailstones of 0.80 to 0.90 specific gravity for each 400 square inches, or fraction thereof, of inlet area at the engine face at typical takeoff (maximum), cruise, and descent conditions.

b. Sheet ice of 0.80 to 0.90 specific gravity in typical sizes, forms and thicknesses, as approved by the Using Service representative of inlet duct and lip formations in quantities likely to be ingested during takeoff and cruise conditions.

The contractor shall specify in the pretest data the procedures to be used for introduction of ice at the engine inlet and the engine power settings and speed at which the ice or hailstones are to be ingested. The time for engine power recovery shall be recorded. During the tests, high speed photographic coverage of the inlet is required. The test will be considered to be satisfactorily completed when, in the judgement of the Using Service, the performance criteria of 3.2.5.6.3 has been met and there is no evidence of major structural damage which could cause the engine to fail.

4.6.4.7 Sand Ingestion Test. The test engine shall be subjected to a run of ten hours' duration at maximum continuous thrust, with sand contaminant in accordance with 3.2.5.6.4 introduced into the engine inlet. During each hour of operation at least one deceleration to idle and acceleration to maximum continuous thrust shall be made with throttle movements within 0.5 seconds. During the first hour, ten one-minute operations of the anti-icing system, if provided, shall be performed. During the entire test, maximum customer bleed air shall be extracted from the engine. This air shall be continually filtered, the total deposits measured and results reported. Following the 10-hour run and post test performance check, the engine shall be disassembled as necessary to inspect for the extent of sand erosion and the degree to which sand may have entered critical areas in the engine's internal air cooling system. The test will be considered to be satisfactorily completed when in the judgement of the Using Service the performance criteria of 3.2.5.6.4 have been met and teardown inspection reveals no failure or evidence of impending failure.

4.6.4.8 Atmospheric Water Ingestion Test. The test engine shall be subjected to a water ingestion test to demonstrate compliance with the requirements of 3.2.5.6.5. With the engine operating at maximum thrust, 2, 3.5 and 5 percent of the total airflow weight in the form of water (liquid and vapor) shall be introduced into the inlet of the engine with 50 percent of the liquid water entering the engine inlet through a segment equivalent to one third the inlet area. The engine shall be operated at each condition for 5 minutes. The above procedure shall be repeated with the engine operating at idle. During the test, the effects of the water ingestion on engine performance shall be noted and recorded. At the completion of the test, the engine shall be shut down and allowed to cool to ambient temperature before making the post-test performance check. Following the performance check, the engine shall be disassembled sufficiently for inspection. This test shall be considered to be satisfactorily completed when in the judgement of the Using Service, adequate clearances where maintained, no damaging or detrimental rubbing occurred during the test, the performance has not deteriorated, and the gas-flow path parts show no damage.

4.6.4.9 Armament Gas Ingestion Test. The test engine shall be subjected to an armament gas ingestion test to demonstrate compliance with 3.1.2.10.6. Unless otherwise specified in the engine specification, the engine operating conditions and armament gas conditions and characteristics shall be in accordance with 3.1.2.10.6. No recalibration shall be required after this test. This test will be considered satisfactorily completed when, in the judgement of the Using Service, the requirements of 3.1.2.10.6 have been met.

4.6.4.10 Noise Survey. The engine shall be mounted on an outdoor test stand with a minimum clearance of 7 feet between the lowest part of the engine and the ground. Microphones shall be located in relatively flat terrain free of excessive ground absorption characteristics. There shall be no obstructions that significantly influence the engine noise field. The weather shall be free of precipitation with relative humidity between 30% and 90%, ambient temperature between 0°C (32°F) and 30°C (86°F), wind velocity less than six miles per hour and no temperature inversions or anomalous wind conditions. No post-test engine recalibration shall be required. The signal level shall be at least 10dB greater than the background noise-level in each third octave band in the frequency range of interest.

a. Data Presentation. The engine noise level data shall be presented as follows:

1. Equal overall sound pressure level contours (db reference of 0.0002 micro bars) as shown in Figures 20 and 21.

2. One-third octave frequency spectra from a center frequency of 20 Hz to 10,000 Hz at the positions A through G specified in Figure 22 shall be tabulated. All near field sound pressure levels shall be based on measurements at head level where personnel must be located during engine maintenance or other operation. In addition, one-third octave band sound pressure levels from a center frequency of 20 Hz to 10,000 Hz in the form of uncorrected data (e.g., uncorrected for weather, terrain, etc.) shall be tabulated for all thrust conditions and for 19 positions. The 19 positions shall be based on measurements located 250 feet (75 meters) radially from the center of the engine's exhaust plane at 10 degree increments starting at 0 degrees directly in front of the engine and ending at 180 degrees directly behind the engine.

3. Equal sound pressure level contours plotted for octave bands with center frequencies of 250, 500, and 1,000 Hz shall be as shown in Figure 22 for the maximum and maximum continuous thrust conditions only.

4. Equal perceived noise level (tone-corrected) contours in five PNdB increments shall be shown in Figure 23 for all thrust conditions.

5. Three narrow band spectrum plots from 20 Hz to 10,000 Hz for the inlet and exhaust noise shall be shown in figures. These narrow band spectrum plots shall be presented in a spectral density format (e.g., sound pressure spectrum level) which normalizes the data to account for changing analysis bandwidth. (Position and power setting for the narrow band data should be determined for an examination of the third-octave spectra.)

6. The total acoustic power (dB ref 10^{-12} watts) generated at the maximum thrust condition.

7. The contractor shall provide sufficient data in the report to enable prediction of the engine noise signatures at any power setting. The required data should include rotor speed, number of blades, hub to tip ratio, diameter, discharge total temperature, pressure ratio, exit velocity, exhaust mass flow and ambient temperature and pressure.

b. Measurement System. The acoustical measurement system must consist of approved equipment equivalent to the following:

1. A microphone system with frequency response compatible with measurement and analysis system accuracy as stated in c. below.

2. Tripods or similar microphone mountings that minimize interference with the sound being measured.

3. Recording and reproducing equipment with characteristics, frequency response, and dynamic range compatible with the response and accuracy requirements of c. below.

4. Acoustic calibrators using sine wave or broadband noise of known sound pressure level. If broadband noise is used, the signal must be described in terms of its average and maximum rms value for a non-overload signal level.

5. Analysis equipment with the response and accuracy requirements of d. below.

c. Sensing, Recording and Reproducing Equipment. The sound produced by the engine shall be recorded in such a way that the complete data history is retained. A magnetic tape recorder is acceptable.

1. The characteristics of the system must comply with recommendations given in International Electrotechnical Commission IEC PUB 179 with regard to the microphone and amplifier characteristics.

2. The response of the complete system to a sensibly plane progressive sinusoidal wave of constant amplitude must lie within the tolerance limits specified in IEC Publication No. 179 over the frequency range of interest.

3. The equipment must be acoustically calibrated using facilities for acoustic free field calibration and electronically calibrated as stated in d. below.

d. Analysis Equipment. A frequency analysis of the acoustical signal shall be performed using one-third octave filters complying with the recommendations given in IEC Publication No 225.

1. The analyzer indicating device must be analog, digital, or a combination of both. The preferred sequence of signal processing is:

(a) Squaring the one-third octave filter outputs.

(b) Averaging of integrating and linear to logarithmic conversion.

2. The indicating device must have a minimum crest factor capacity of 3 and shall measure, within a tolerance of ±1.0dB, the true root-mean-square (rms) level of the signal in each one-third octave band. If other than a true rms device is utilized, it must be calibrated for nonsinusoidal signals. The calibration must provide means for converting the output levels to true rms values.

3. The amplitude resolution of the analyzer must be at least 0.25dB.

4. Each output level from the analyzer must be accurate within ±1.0dB with respect to the input signal, after all systematic errors for each of the output level must not exceed ±3dB. For continuous filter systems, the systematic correction between adjacent one-third octave channels may not exceed 4dB.

5. The dynamic range of the analyzer must be at least 55dB in terms of the difference between full-scale output level and the maximum noise level of the analyzer equipment.

6. The complete electronic system must be subjected to a frequency and amplitude electrical calibration by the use of sinusoidal or broadband signals at frequencies covering the range of interest of known amplitudes covering the range of signal level furnished by the microphone. If broadband signals are used, they must be described in terms of their average and maximum rms values for a non-overload signal level.

7. Narrow band analysis must be conducted with a maximum bandwith of 5 Hz in the 20 to 500 Hz frequency range, 20 Hz in the 500 to 5000 Hz frequency range, and 100 Hz in the 5000 to 10,000 Hz frequency range.

e. Noise Measurement Procedures. In order to insure uniform practices relative to acoustic testing of turbojet and turbofan engines, the following procedures are required.

1. Immediately prior to and after each test, a recorded acoustic calibration of the system must be made in the field with an acoustic calibrator to check system sensitivity and provide an acoustic reference level for the analysis of the sound level data.

2. For the purpose of minimizing equipment or operator error, field calibrations must be supplemented with the use of an insert voltage device to place a known signal at the input of the microphone, just prior to and after recording engine acoustic test data.

3. The ambient noise, including both acoustical background and electrical noise of the measurement system, must be recorded and determined in the test area with the system gain set at levels which will be used for aircraft engine noise measurements.

f. Reporting and Correcting Measured Data. Data representing physical measurements or corrections to measured data must be recorded in permanent form and included in the final report. Estimates must be made of the individual errors inherent in each of the operations employed in obtaining the final data.

1. Measured and corrected sound pressure levels must be presented in one-third octave band levels obtained with equipment conforming to the standards described in previous paragraphs.

2. The type of equipment used for measurement and analysis of all acoustic, meteorological, and engine performance data must be reported.

3. The following atmospheric environmental data must be measured at representative microphone positions.

(a) Air temperature in degrees Celsius (Fahrenheit) and relative humidity in percent.

(b) Maximum, minimum and average wind velocity in knots and wind direction relative to engine centerline.

(c) Atmospheric pressure in inches of mercury.

4. Comments on local topography, ground cover, and events that might interfere with sound recordings must be reported.

(b) Ambient temperature of 25°C (77°F) (ISA + 10°C).

(c) Relative humidity of 70 percent.

(d) Zero wind.

4.6.4.11 Exhaust Gas Emission Test

4.6.4.11.1 Exhaust Smoke Emission. The engine shall be subjected to an exhaust smoke emission test to demonstrate compliance with the requirements of 3.2.5.8.1. Engine exhaust smoke measurements shall be taken using the equipment, instrumentation and test procedures set forth in ARP 1179. Smoke level will be determined at four engine power settings: Intermediate, Maximum Continuous, 75 percent Maximum Continuous, and Idle. Prior to sampling at a particular power setting a 10 minute stabilization run will be made at that power setting. A performance check need not be made after this test.

4.6.4.11.2 Invisible Exhaust Mass Emissions. During the test of 4.6.4.11.1, the engine exhaust gases shall be analyzed for non-visible contamination using the equipment, instrumentation and procedures set forth in ARP 1256. The tests shall be conducted at maximum, intermediate and idle power settings to demonstrate the levels of invisible exhaust mass emissions specified in 3.2.5.8.2 of the engine specification. A performance check need not be made after this test.

4.6.4.12 Nuclear Hardening Tests. The engine shall undergo tests to determine its ability to meet the nuclear survivability/vulnerability requirements specified in the engine specification. The test requirements shall be as specified in the pre-test data.

4.6.5 Engine Characteristics and Fuel Tests. The tests in the following subparagraphs shall be conducted on engines having the same parts list and configuration as the endurance test engine of 4.6.1. Unless otherwise specified in the individual test, the engine need not be calibrated before and recalibrated after each test. Unless otherwise specified for a particular test, the test shall be conducted at the ambient conditions which prevail at the test site, using the fuel specified in the engine specification.

4.6.5.1 Starting Torque. The engine shall be subjected to a test to demonstrate the starting torque and speed requirements of 3.7.9.1.1. The measurement procedures and the calibration and use of test equipment shall be defined in the pretest data.

4.6.5.2 Radar Cross Section (RCS). The engine RCS shall be determined to substantiate the levels specified in 3.1.2.12 of the engine specification by taking radar reflectivity measurements of the engine inlet and exhaust. The radar reflectivity determinations shall be conducted at an outdoor test site with the engine both static and operating. Prior to engine installation, the background shall be measured with all support columns in place and shall be at least 20 dB below the ten degree median values measures. The calibration standard shall be a sphere or cylinder. RCS measurements shall be performed at a minimum of one frequency per octave over the specified frequency range and at those frequencies specified by the Using Service. The radar illumination field at the engine shall be probed and its variation in power density in the vertical plane of the engine shall be less than ±0.5 dB about the mean value. Sufficient data shall be taken to construct a table of median values of RCS over 10 degree intervals in the area bounded by ±60 degrees in both azimuth and elevation about the engine inlet centerline for the forward hemisphere and about the engine centerline at simulated exhaust nozzle operating positions for the aft hemisphere. The maximum RCS value for each hemisphere (fore and aft), expressed in square meters, shall be determined by obtaining the arithmetic average of the median values contained in the above referenced table.

4.6.5.3 Infrared Radiation Test. Peak engine infrared radiation and radiation patterns shall be determined to substantiate the requirements of 3.7.10.3. The I.R. signature shall be measured as total (hot parts + reflection + plume) effective radiation for the uninstalled engine. The infrared intensity and spectral response of the IR instruments shall be determined by calibration before and after infrared test measurement and these data shall be recorded. The measurement instruments shall be calibrated with a field standard I.R. source to determine their effective response to infrared radiation during the I.R. test. The standard source used as a reference for both the radiation patterns and the measurement equipment shall be specified. Atmospheric conditions (temperature, humidity, precipitation, cloud formation, meteorological range, sun location and test location) shall be recorded to aid in the calculation of the field standard and engine effective I.R. radiation. The measurement technique shall be such that extraneous radiation from the background and external regions of the engine normally covered by aircraft structure is minimized. The engine shall be set up in an outdoor test facility and operated at the power conditions specified in 3.7.10.3. Each power condition shall be maintained until exhaust system component temperature is stabilized before taking I.R. readings. Infrared radiation measurements shall be taken at angles specified in 3.7.10.3 in the increments required to determine the peak radiation and overall emission patterns. Total I.R. signature shall be verified by band with radiometers, sensitive in the 1-3, 3-5, 8-10, 10-12 and 12-14 micron wave lengths. In addition, spectral measurements shall be made with a spectrometer having a resolution of at least .05 microns at each aspect angle from 0 to 180 degrees to identify the exhaust gas "plume" contributions. For engines incorporating special I.R. suppression system features, the above tests shall be accomplished with the engine running both in and out of the suppression mode.

4.6.5.4 Alternate Fuel Test. The test engine shall be subjected to a 60 hour test run consisting of 10 cycles of 6 hours each in accordance with 4.6.1.3 using the alternate fuel specified in the engine specification. The engine shall be calibrated before and recalibrated after the test to the extent necessary to determine any deterioration in steady state or transient performance. At the completion of the test, the engine shall be disassembled to the extent necessary to perform a hot section inspection. The test will be considered satisfactorily completed, when, in the judgement of the Using Service, engine performance meets the requirements specified in 3.7.3.2.2, and results of the hot section inspection do not reveal abnormal hot section distress.

4.6.5.5 Emergency Fuel Test. The engine shall be subjected to an emergency fuel test consisting of one 6-hour cycle of the endurance test in accordance with 4.6.1.3 using the emergency fuel specified in the engine specification. Changes in performance due to the use of emergency fuel shall be determined by calibrations with primary and emergency fuel prior to the test and recalibrations with both fuels after the test. Calibrations shall be made to the extent required to establish performance levels and as defined in the pre-test data. At the completion of the test, the engine shall be disassembled to the extent necessary to perform a hot section inspection. This test will be considered satisfactorily completed, when in the judgement of the Using Service, engine performance meets the requirements specified in 3.7.3.2.3, and results of the hot section inspection do not reveal abnormal hot section distress.

4.6.6 Structural Tests. Engines or components conforming to the parts list and configuration of the QT endurance test engine shall be used for the following tests.

4.6.6.1 Engine Pressure Tests. Each engine case and all gas pressure loaded components of the engine subjected to compressor discharge pressure shall be proof tested to 2.00 times the maximum operating pressure without rupture. These tests shall be conducted at the maximum operating temperature of the component or the pressure shall be adjusted for materials properties at the test temperature. The above test may be waived for identical components which have successfully completed the test of 4.5.4.1.

4.6.6.2 Low Cycle Fatigue Tests

4.6.6.2.1 Low Cycle Fatigue Component Tests. The parts shall be subjected to testing to comply with the requirements of 3.3.8.3 and shall be subjected to damaging cycles equivalent to at least 2.0 times the LCF cyclic life values shown in the appropriate duty cycle of Table IX. The specific test procedures shall be as specified in the pre-test data. During these tests, no repair shall be permitted for the first equivalent life time. Permissible component repair intervals after the first equivalent life time shall be specified in the engine specification. Except for the tests conducted on the combustor, these tests shall be performed either with high temperature and loads appropriate for simulating engine and maneuver load conditions, or with loads adjusted for materials properties at the test temperature. The combustor shall be tested only at high temperature conditions.

4.6.6.2.2 Low Cycle Fatigue Engine Test. A cyclic endurance test, which shall subject an engine to at least one lifetime of cycling, shall be performed. Prior to the test, the engine control fuel schedule shall be adjusted to obtain starts, restarts, accelerations and to provide starting and acceleration temperatures all at or above rated or maximum values, as applicable. Deceleration fuel schedules shall be preset to provide maximum thermal shock. The customer air bleed shall be set with a fixed orifice to provide maximum permissible bleed air flow. The accessory and customer power takeoff pads shall be loaded to provide max continuous loads.

All repairs and parts replacement shall be recorded and reported. The actual number of cycles, duty times and length of cool down time shall be based upon the study of 3.3.8.6 and shall be that required to obtain at least the same LCF damage on the test engine as one operational lifetime predicted in the strength and life analysis. This test substantiation of one life may require certain parts to receive more than one lifetime of damage. If this damage on those parts exceeds the parts' required operation life, part replacement or repair may be accomplished in order to continue the test. Following completion of the test, the engine shall be disassembled and inspected for evidence of cracking and shall be within the allowable dimensional limits.

The duty cycle shall be defined as follows with the times as specified by the engine contractor.

TOTAL TIME	SCHEDULED TIME	EVENT
___ sec.	___ sec.	Start Engine and Accelerate to Idle.
___ sec.	___ sec.	Run at Idle.
___ sec.	___ sec.	Accelerate to Max. RPM and Maintain as specified.
___ sec.	___ sec.	Decelerate from Max. RPM to Idle and Hold as specified.
___ sec.	___ sec.	Shut engine down and Coast to Stop - Cool down.

4.6.6.3 Containment. The requirement of 3.3.8.9.1 shall be demonstrated by full scale engine test or spin pit testing of rotor assemblies. This test (or tests) shall be conducted at or above the maximum allowable rotor speeds and maximum component operating temperatures with selected blades from the fan, compressor and turbine sections, determined to be most critical by analysis, undercut to fail at a pre-determined speed. The test will be considered satisfactorily completed when in the judgement of the Using Service, all damage is contained.

4.6.6.4 Rotor Structural Integrity

4.6.6.4.1 Overspeed. Turbine and compressor rotors shall be subjected to engine operation for a stabilized period of at least 5 minutes duration, at maximum allowable measured gas temperature at 115 percent of maximum allowable steady-state RPM.

Following the test, parts and assemblies shall be within allowable dimensional limits and there shall be no evidence of imminent failure. This test may be waived for components identical to those successfully completing the test in 4.5.4.2.1.

4.6.6.4.2 Overtemperature. Upon successful completion of the overspeed test of 4.6.6.4.1, the same engine shall be operated at an average steady-state measured gas temperature of at least 42°C (75°F) in excess of the maximum allowable average steady-state measured gas temperature and at no less than maximum allowable steady-state speed for 5 minutes. Following the test, parts and assemblies shall be within allowable dimensional limits and there shall be no evidence of imminent failure. This test may be waived for components identical to those successfully completing the test in 4.5.4.2.2.

4.6.6.4.3 Disc Burst Test. Spin pit testing shall be conducted on all critical rotating disc components of QT engine configuration. Components shall be operated to a minimum of 122 percent of maximum allowable steady-state speed with the bore metal at maximum design metal temperature without failure or evidence of imminent failure. This may be waived for components identical to those successfully completing the test of 4.5 4.2.3.

4.6.6.5 Engine Static Load Test. The engine cases and mounts of the endurance engine configuration shall be subjected to a static test to verify the requirements of 3.1.2.5 and 3.1.2.6. A static rig test utilizing the applicable engine static structure shall be conducted to demonstrate the capability of the engine and its supports to withstand maximum externally applied forces specified in 3.1.2.5 without permanent deformation of any component and 1.5 times those forces without failure of any component. In this test, maximum thrust loads, "G" loads, gyroscopic moments, torque and engine reaction loads will be applied separately and then in combination. Stress and deflection data will be obtained at critical locations as determined by analysis and preliminary stress coating tests. This test may be waived for identical components which have successfully completed the test of 4.5.4.3.

4.6.6.6 Vibration and Stress Test. A vibration and stress test shall be conducted on an engine to obtain data to substantiate the vibration and stress survey report of 3.3.8.10.2 and the requirements of 3.3.8.6. Prior to the test, the engine shall be disassembled sufficiently to install test instrumentation. A sufficient number of blades and vanes in each stage of the compressor shall be instrumented with strain gauges in order to obtain continuous strain gauge data. Each strain gauge shall be mounted in a location on the blade or vane where the highest stress occurs, as determined from the vibration and stress analysis. Sufficient instrumentation shall be installed at appropriate locations on main bearings to permit measurement of bearing loads, cage rotation and rotor deflections. During buildup, the engine shall be assembled with at least the maximum allowable imbalances specified for the engine rotating components and assemblies. External components such as fuel controls, fuel pumps, valves, plumbing lines, etc., shall be instrumented at appropriate locations with accelerometer vibration equipment as detailed in the pretest data. Following assembly, the engine shall be installed in a test stand having engine mounting arrangements and test stand dynamic characteristics as defined by the engine contractor, subject to approval of the Using Service. Inlet or exhaust systems that are mounted directly on or supported by the engine in the aircraft installation shall be mounted in the same manner for this test The test shall check all critical engine speeds where by analysis substantial stress or vibratory conditions occur on any component. Vibration and stress measurements shall be made during all engine operating modes and shall include but not be limited to conditions of maximum inlet distortion, stall, limits of variable geometry travel if applicable, maximum compressor air bleed and power extraction, maximum inlet pressure and temperature capabilities of the engine and combinations thereof. During the test, overall true RMS velocity measurements and acceleration spectrograms shall be obtained for each accelerometer mounted on the engine core and external accessory components. The test will be considered to be satisfactorily completed when in the judgement of the Using Service, the vibration stress and load measurements are within acceptable design limits.

4.6.6.7 Gyroscopic Test. An engine shall be subjected to a gyroscopic test to demonstrate compliance with the requirement of 3.1.2.5.1. Prior to the test, the engine shall be assembled with special emphasis placed on measuring and recording clearances between blades and cases and radial and axial rotor clearances. Rub probes shall be installed around compressor and turbine cases at symmetrical locations and at blade tip locations as designated in the pre-test data. Instrumentation shall be sufficient to permit measurement of rotor deflection and shift under gyroscopic loads. Strain gage instrumentation shall be provided to measure stresses at critical locations. Sufficient instrumentation of the oil system shall be provided to evaluate the oil system's ability to scavenge and function properly during the test. Test data to be taken during the test, in addition to the data required above, shall include vibration measurements at locations as specified in 3.7.6.5.

The engine shall be installed on a gyro test stand with an inlet configuration and exhaust nozzle as designated in the pretest data. Prior to the test, the engine shall be subjected to an engine performance check.

The test shall be conducted with the gyro rig operated in steps from 0.5 rad/sec to and including 3.5 rad/sec in step increments of 0.5 rad/sec. At each step, the engine shall be operated as follows:

a. Idle for 1 minute.

b. Accelerate from idle to maximum allowable rotor speed in 30 seconds.

c. Dwell at maximum allowable rotor speed 10 seconds or time sufficient to record data.

d. Decelerate from maximum allowable rotor speed to idle in 30 seconds.

e. Stop rig and engine for visual check of rub.

NOTE: At gyro loads above 1.5 rad/sec, snap accelerations and decelerations may be made to reduce time exposure.

The above test shall be conducted with the gyro rig rotating in one direction and then the test shall be repeated with the rig rotating in the opposite direction. At the completion of the test, the engine shall be subjected to a post test performance check and then disassembled for inspection.

The test shall be satisfactorily completed when, in the judgement of the Using Service: the post test calibration reveals no significant loss in performance, the engine and its systems operated properly during the test, structural loads were within acceptable limits and teardown inspection reveals no evidence of excessive blade rubbing or evidence of impending failure.

4.7 Acceptance Test. An acceptance test, as specified herein, shall be conducted on each engine submitted for delivery. The engine contractor shall prepare and submit for approval by the Using Service a detailed Acceptance Test Procedure. Engines submitted for PFRT or Qualification testing need not be subjected to accpetance tests.

4.7.1 Test Apparatus

4.7.1.1 Automatic Recording Equipment. Automatic continuous recording equipment shall be used to record data during the execution of that part of the engine tests requiring the evaluation of engine variables vs time.

4.7.1.2 Vibration Measuring Equipment and Response Characteristics. The engine vibration shall be measured with accelerometer vibration detectors. The vibration measurement and analysis equipment shall operate over a frequency band of at least 5 Hz to 10,000 Hz and produce acceleration spectrograms with a demonstrated accuracy confidence level of 95%. The maximum allowable effective filter bandwidth of the spectrum analysis equipment shall be 30 Hz. The vibration measuring equipment shall be calibrated as a complete system. The frequency response of the system, when calibrated by applying a known sinusoidal motion to the accelerometer pickup, shall not deviate by more than ±3 dB from the known sinusoidal input at frequencies from 5 Hz to 10,000 Hz. If high pass filters are required when the vibration measuring system is measuring overall velocity levels, they shall have the following characteristics: the filters shall be 3 db down at frequencies of 30 Hz, 70 Hz, of 110 Hz as appropriate, with a roll-off of at least 18 dB per octave. High pass filters shall not be used to produce acceleration spectrograms.

4.7.1.3 Test Cell and Test Equipment. Engines shall be subjected to acceptance testing in a test cell and with test equipment that is acceptable to the Using Service. The natural frequencies of the test stand with the engine installed shall be no higher than 80 percent of the idle rotor speed in all modes of motion which can be excited by residual rotor unbalances. The test cell "cell factor" shall be derived from engine test data acquired from both outside testing and test cell testing by a method satisfactory to the Using Service.

4.7.1.4 Starter. Starting shall be performed with a starter that has torque characteristics within 5% of the minimum required torque shown in Figure 17.

4.7.2 Test Conditions

4.7.2.1 Servicing

4.7.2.1.1 Oil Servicing. The oil used for acceptance testing shall be as specified in the engine specification. All oil filter inspection results shall be recorded in the engine records.

4.7.2.1.2 Fuel Servicing. The fuel used for acceptance testing shall be as specified in the engine specification.

4.7.3 Test Records

4.7.3.1 Acceptance Test Log Sheet. The following information shall be recorded on the test log sheets for each engine run:

(1) Date

(2) Engine Type and Model

(3) Engine Serial Number

(4) Cell Number

(5) Bellmouth Serial Number and Area, Sq. In.

(6) Exhaust Nozzle Serial Number and Area, Sq. In.

(7) Type of Fuel Used

(8) Type of Oil Used

(9) Fuel Lower Heating Value

(10) Total Running Time and Total Number of Starts

(11) Vibration (Max Recorded in 4.7.4)

(12) All Data Required in 4.7.4

The contractor shall retain copies of acceptance test log sheets for each engine for two years. Copies of test sheets shall be furnished to the Using Service upon request.

4.7.4 Test Data. The data in the following subparagraphs shall be taken during the acceptance test and recorded in the acceptance test log sheets.

4.7.4.1 Preliminary Data. The engine weight shall be determined and recorded. If the engine weight is measured after the engine has been serviced with fuel and oil, and after subsequent draining, the dry weight may be calculated by subtracting the weight of residual fluids specified in 3.2.2.2 from the measured engine weight.

4.7.4.2 Steady-State Data. During operation at each specified steady-state condition and after performance stabilization, the following minimum data shall be recorded once during each test period.

(1) Time of day.

(2) Total running time.

(3) Power lever position.

(4) Engine rotor(s) speed(s), rpm.

(5) Thrust, lb.

(6) Fuel consumption, lb/hr.

(7) Data for determining airflow (including "hot" (W_{ah}) and "cold" (W_{ac}) airflow for turbofan engines, and secondary airflow (W_{as}), where applicable).

(8) Engine inlet total pressure, in. Hg abs.

(9) Engine inlet total temperature, °C (°F).

(10) Turbine discharge total pressure, in. Hg abs.

(11) Exhaust static pressure, in. Hg abs.

(12) Breather pressure, in. Hg abs.

(13) Oil temperature at point shown on installation drawing °C (°F).

(14) Oil pressure at point shown on installation drawing, psig.

(15) Fuel pressure at fuel system inlet, psig.

(16) Fuel pressure at point shown on installation drawing, psig.

(17) Measured steady-state gas temperature, °C (°F).

(18) Afterburner fuel flow, lb/hr.

(19) Liquid injection flow, lb/hr.

(20) Accessory compartment temperature, °C (°F).

(21) Engine case vibration at points shown on installation drawing, inches per second, true RMS velocity.

(22) Additional data as required by the Using Service.

4.7.4.3 Transient Data. For each transient performed during the thrust transient operations and, if applicable, reverse thrust runs, the power lever angle, measured gas temperature, engine speed, fuel flow, and thrust shall be continuously recorded vs time, during the transient.

4.7.4.4 Starting Data. For each start performed, the time required from initiation of the start to ignition, to starter cutout, and to stabilized engine idle speed, the engine speed where each of the foregoing occurs, the maximum measured gas temperature and any noticeable flat spots in the acceleration curve shall be recorded.

4.7.4.5 Miscellaneous Data. All stops and coastdown times shall be measured and recorded. At least once during each test, readings shall be taken of barometric pressure, ambient air temperature, and fuel specific gravity. Oil consumption for the entire test run shall be measured and recorded. Notes shall be placed on the log sheets of all incidents of the run, such as leaks, unusual vibrations, and other irregular functioning of the engine together with corrective measures taken.

4.7.4.6 Accuracy of Data. For all engine acceptance testing, reported data shall have a steady-state accuracy within the tolerances shown below. The accuracy of transient data and the corresponding instrument calibration methods shall be subject to the approval of the Using Service and shall be described in the test procedure. All instruments and equipment shall be calibrated as necessary to insure that the required degree of accuracy is maintained.

	Item of Data
Rotor speed(s)	±0.2 percent of the value obtained at maximum rating.
Thrust and fuel flow - at and above minimum augmented	±1.0 percent of the value being measured.
Thrust and fuel flow - at and below intermediate	±1.0 percent of the value obtained at intermediate thrust.
Temperature	±1.0 percent of the value being measured.
Airflow	±0.5 percent of the value being measured.
Engine weight	±1.0 lbs or ±0.1 percent of the weight being determined whichever is greater.
Vibration velocity	±5.0 percent of specified engine limit.
All other data	±2.0 percent of the value obtained at maximum rating.

4.7.5 Test Procedure. The acceptance test shall consist of the initial and final runs specified below. When special engine features which would not function under the following test schedules are provided, these features shall be tested in a manner approved by the Using Service. Recorded time at each thrust condition shall start upon completion of the power lever movement necessary to obtain that thrust condition. Prior to initiation of the final run, the engine controls shall be adjusted while installed on the engine, using only routine field adjustments, to produce at standard sea level static conditions rated thrust, or higher, and rated specific fuel consumption, or lower, within the limits of the measured gas temperatures and rotor speeds associated with the ratings. If any further adjustment to the engine or its components becomes necessary, a re-run of those portions of the test run already completed shall be required.

4.7.5.1 Initial Run. The engine shall be subjected to an initial run in accordance with the following running schedule. The steady-state thrust times may be increased at the option of the engine contractor if needed to obtain stable performance data required to verify sea level static rated performance. For non-augmented engines and engines without thrust reversers, augmented and reverse thrust time specified herein may be deleted. All power lever movements shall be accomplished in one-half second or less except where otherwise stated. The nature and extent of checks, adjustments, and running prior to the initial run shall be specified by the contractor.

a. Intermediate and Maximum Thrust Transients Run. This run shall consist of 13 minutes in the sequence of power lever positions and time durations as follows: Four minutes at idle, 3 minutes at intermediate, 3 minutes maximum, 3 minutes intermediate.

b. Reverse-Maximum Run. This run shall consist of 11 minutes of operation in the sequence of power lever positions and time durations as follows: Two minutes idle, 4 minutes maximum reverse, 3 minutes maximum and 2 minutes maximum reverse.

c. Transients Run. This run shall consist of approximately 19 minutes of thrust transients as follows: Three minutes of operation with the power lever in idle position, then advancing toward maximum power lever position, and as soon as the engine reaches the anticipated condition of minimum surge margin (after lighting the afterburner for augmented engines), retard the power lever to the idle position. Three minutes of operating with the power lever in idle position, then advancing toward intermediate power lever position, and as soon as the engine reaches the anticipated condition of minimum surge margin (i.e., rpm or gas temperature), retard the power lever to idle position, and maintain this position for 3 minutes. Three minutes of operation with the power lever in the intermediate position, then retarding toward idle power lever position, and as soon as the engine reaches the anticipated condition of minimum surge margin (i.e., rpm or gas temperature), advancing the power lever to intermediate position and maintaining this position for 3 minutes. Three minutes of operation with the power lever in the maximum position, then retarding toward idle position, and as soon as the engine reaches the anticipated condition of minimum surge margin (i.e., rpm or gas temperature), advancing the power lever to maximum position and maintaining this position for a minimum of one minute.

d. Short Transients Run. This run shall consist of 12 minutes of operation in the sequence of power lever positions and time durations as follows: Three minutes idle, 3 minutes maximum, 3 minutes at 40 percent maximum continuous and 3 minutes at intermediate.

e. Modulated Augmentation Run. This run shall consist of 10 minutes of operation in the sequence of power lever positions and time durations as follows: Two minutes at 80 percent maximum augmented, two minutes at 60 percent maximum augmented, two minutes at 40 percent maximum augmented, two minutes at 20 percent maximum augmented, and two minutes at minimum augmented.

f. Performance Run. This run shall consist of 28 minutes of operation in the sequence of power lever positions and time durations as follows: Three minutes idle, 5 minutes at 75 percent maximum continuous, 5 minutes at 90 percent maximum continuous, 5 minutes at maximum continuous, 5 minutes at intermediate, and 5 minutes at maximum.

g. Slow Transient Run. This run shall consist of 7 minutes of operation as follows: After three minutes at idle the engine shall be accelerated in 90 seconds from idle to the maximum power lever position at a uniform rate of power lever movement, and after 1 minute of operation at the maximum power lever position, the engine shall be decelerated in 90 seconds to idle at a uniform rate of power lever movement. Throughout this run the engine vibration shall be continuously recorded using vibration equipment in accordance with 4.7.1.2. The engine vibration shall not exceed the levels specified in 3.2.1.4.10.

4.7.5.1.1 Inspection after Initial Run. Upon completion of the initial run, the engine shall be disassembled sufficiently to allow a detailed inspection of all vital working parts. The extent of disassembly is to be decided by the Government representative. If any part is found to be defective, an approved part shall be supplied to replace it, and at the discretion of the Government representative, a penalty run of suitable duration shall be made.

4.7.5.1.2 Penalty Run. The duration of the penalty run shall be at the discretion of the Government Representative. The maximum penalty run shall be a complete repetition of the initial run. Additional running-in prior to the penalty run may, at the option of the contractor, be performed for the accommodation of replaced parts.

4.7.5.1.3 Inspection after Penalty Run. Upon completion of the penalty run, the engine shall, at the discretion of the Government representative, be disassembled to allow for inspection of the replaced parts

4 7.5.2 Final Run. The final run shall consist of a repeat of the initial run of 4.7.5.1.

4.7.5.3 Rejection and Retest. Whenever there is evidence that the engine is malfunctioning or is not meeting engine specification requirements, the difficulty shall be investigated and its cause corrected to the satisfaction of the Government representative before the test is continued. If such investigation requires disassembly of the engine or any of its components, this shall be considered a rejection of the engine. A complete re-run or a repetition of the portion of the test prior to encountering the difficulty shall, at the option of the Government Representative, be made.

4.7.5.3.1 Engine Vibration. When any engine exceeds the vibration limits as specified in the engine specification, this shall be considered a malfunction.

4.7.5.3.2 Over-temperature. If at any time the temperature exceeds the maximum allowable measured temperatures specified in the specification, this shall be considered a malfunction.

4.7.5.3.3 Stoppage. Interruptions or stoppage from any cause other than an engine malfunction shall require a repetition of the particular period during which the interruption or stoppage occurred.

4.7.5.3.4 Fluid Leakage. If fluid leaks beyond the limits specified in 3.3.6.4 are discovered, a check run or a complete re-run after correction of the leak shall be made at the discretion of the Government representative.

4.7.5.3.5 Maximum Hours of Running. Any engine which has more than a total of 16 hours of operation, or more than a total of 25 starts including all runs, checks, and adjustments of 4.7.5 and any runs, checks, and adjustments prior to the initial run shall stand rejected. Parts and components from these rejected engines may be used in other engines being built, provided these parts and components from the rejected engines are resubmitted for inspection required for new parts and components, with full particulars being given the Government Representative concerning previous rejection of the engine.

4.7.6 Test Completion. The acceptance test shall be considered to be satisfactorily completed when the conditions of 4.7.5 have been met and the data demonstrates compliance with applicable portions of the following engine specification requirements.

a. 3.2.1.1 - Ratings (Table I) NOTE: All data used for comparative purposes shall be based on rated thrust

b. 3.2.1.4.8 - Oil Pressure and Temperature Limits

c. 3.2.1.4.9 - Oil Consumption

d. 3.2.1.4.10 - Vibration Limits

e 3.2.1.5.3 - Stopping

f. 3.2.1.5.5 - Stability

g. 3.2.1.5.6 - Thrust Transients

h. 3.2.2 1 - Dry Weight of Complete Engine

i. 3.3.6.4 - Fluid Leakage

j. 3.7.9 - Starting

4.7.7 Sampling Plan. When a sampling plan is invoked, those engines to be run to a reduced acceptance test shall be run in accordance with 4.7.5 2.

5. PREPARATION FOR DELIVERY

5.1 Preparation for Storage and Shipment. The engine shall be prepared for storage and shipment in accordance with MIL-E-5607. The level of preservation of the engine, the type of shipping container for the engine and the furnishing of engine historical records shall be in accordance with contract requirements. A packing list shall be furnished with each engine which includes all components and tools which are not installed on the engine, but which are shipped with the engine.

6. NOTES

6.1 Intended Use. Engines covered by this specification are intended for aircraft propulsion.

6.2 Definitions and Symbols used herein and in the engine specification will be as specified below.

6.2.1 Definitions

6.2.1.1 Preliminary Flight Rating Test (PFRT). The Preliminary Flight Rating Test is the sum of test, demonstration and analysis activity accomplished on engines and components to demonstrate suitability of an engine model for limited use in experimental aircraft flight testing. For reference purposes the tests, demonstrations and analysis required for PFRT are listed in Appendix "A".

6.2.1.2 Qualification Test (QT). The qualification test is the sum of test, demonstration and analysis activity accomplished on engines and components submitted for qualification to demonstrate the suitability of an engine model for production and service use. For reference purposes the tests, demonstrations and analysis required for QT are listed in Appendix "B".

6.2.1.3 Acceptance Test (AT). The acceptance tests are those tests conducted on engines submitted for acceptance under contract to demonstrate correct assembly and performance to the extent specified in the engine specification.

6.2.1.4 Procuring Service. The procuring service is the service which negotiates the engine contract.

6.2.1.5 Using Service. Using Service is the service whose model dash number has been assigned to the engine in accordance with MIL-STD-879.

6.2.1.6 Rating. A rating is a performance characteristic value specified in table I or II or the engine specification.

6.2.1.7 Maximum Thrust. Maximum thrust is the highest thrust which the engine will consistently deliver at any point specified within the operating envelope when the power lever is placed in the maximum position. Engine operation at maximum thrust may have an incremental duration time limit.

6 2.1.8 Intermediate Thrust. Intermediate thrust is the highest thrust which the engine will consistently deliver at any point specified within the operating envelope when the power lever is placed in the intermediate position. Engine operation at intermediate thrust may have an incremental duration time limit but this limit shall not be less than 30 minutes.

6.2.1.9 Maximum Continuous Thrust. Maximum continuous thrust is the highest thrust which the engine will consistently deliver at any point specified within the operating envelope for continuous operation when the power lever is placed in the maximum continuous position

6.2.1.10 Maximum Reverse Thrust. Maximum reverse thrust is the highest thrust the engine will consistently deliver at any point specified within the reverser operating envelope when the power lever is placed in the maximum reverse position.

6.2.1.11 Minimum Augmented Thrust. Minimum augmented thrust is the lowest thrust which the engine will consistently deliver with augmentation at any point specified within the augmentor operating envelope when the power lever is placed in the minimum augmented position.

6.2.1.12 Gross Thrust. Gross thrust is the thrust delivered at the exhaust nozzle exit, which includes the thrust generated by the outgoing momentum of the exhaust gases and the force resulting from the difference between static pressure at the nozzle and the static pressure of the ambient air.

6.2.1.13 Net Thrust. Net thrust is the gross thrust minus the product of the engine air mass flow and the free stream velocity.

6.2.1.14 Maximum Allowable Speed. Maximum allowable speed as specified for either steady-state or transient conditions, is the limit beyond which operation of the engine is not allowed.

6.2.1.15 Rated Engine Speed. Rated engine speeds are the maximum engine rotor speeds permitted to attain Table I or II ratings, at or below measured rated gas temperature limits.

6 2.1 16 Idle Speed. Idle speed is the rotor speed attained with the power lever in the idle position.

6.2.1.17 Maximum Allowable Gas Temperature. The maximum allowable gas temperature, as specified for either steady-state or transient conditions, is the limit beyond which operation of the engine is not allowed.

6.2.1.18 Rated Gas Temperature. The rated gas temperature is the maximum measured temperature permitted to attain a given Table I or Table II thrust rating.

6.2.1.19 Specific Fuel Consumption (SFC). SFC is the weight in pounds of fuel consumed per hour per pound of net thrust

6.2.1.20 Surge Margin. Surge margin is the calculated and/or demonstrated tolerance of the engine to adverse operating conditions while maintaining the required steady-state and transient performance capability.

6.2.1.21 Stall. Stall is an internal aerodynamic disturbance in the engine compression system which does not result in total loss of function.

6.2.1.22 Surge. Surge is an internal aerodynamic disturbance in the engine compression system which results in total loss of function.

6.2.1.23 Standard Condition. Standard conditions are the values of air temperature and pressure given in the US Standard Atmosphere 1962, ASTIA Document No. 401813. The standard humidity, for the purpose of this specification, is zero vapor pressure at all altitudes. All heights noted in the specification shall be geopotential altitudes.

6.2.1.24 Absolute Altitude. The absolute altitude is the maximum altitude at which the engine will function satisfactorily under specified ram pressure ratios.

6.2.1.25 Windmilling Drag. Windmilling drag is the momentum of the air entering the fan and compressor(s) minus the momentum of the air leaving the defined exit duct and nozzle(s).

6.2.1.26 Air Starting. Air starting is engine starting in flight under a specified range of airspeed, altitude, air temperature and temperature soak conditions, and is obtained using the starting method (windmilling and/or starter assist) and procedure specified in the specification.

6.2.1.27 Satisfactorily. The words "satisfactorily" or "satisfactory" as used in this specification in conjunction with works or terms relating to operation or performance of the engine described in the engine specification, shall mean: Under the condition specified, throughout the entire operating envelope, the engine operating characteristics and performance are not affected, and the operating and physical limits shown in the specification are not exceeded and no permanent deformation or other damage to the engine occurs.

6.2.1.28 Catastrophic Engine Failure. A failure which results in engine stoppage and extensive damage to the engine. This is distinguished from those failures which cause only a partial degradation of capability or a gradual degradation over an extended period of time.

6.2.1.29 Customer Air Bleed. Customer air bleed is that air which may be bled from the engine for use in any system external to the engine and is that quantity available over and above the bleed air needed for engine acceleration, engine anti-icing and any other engine system requirements.

6.2.1.30 Engine Components. Engine components are items of equipment, furnished as part of and qualified with the engine, whose size, conformation, and dynamic and static characteristice are essential to attain the engine performance specified in the engine specification. Fuel pumps, engine controls, jet nozzle and actuators, anti-icing valves, and the temperature sensing system(s) or device(s) are included in this category. Components may require separate qualification, calibration, or adjustment.

6.2.1.31 Accessories. Accessories are items of engine-mounted equipment not furnished by the engine manufacturer, which are required for aircraft operation or as auxiliaries for engine operation. Starters, tachometer generators, aircraft hydraulic pumps, air pumps, electrical generators are included in this category.

6.2.1.32 Gulping Volume. Gulping volume is the difference between oil reservoir levels with the engine at zero speed, oil at 15°C (59°F), and with the engine at stabilized maximum continuous speed. The gulping volume represents the initial amount of oil required to fill the lubrication systems lines, pumps, sumps, bearing cavities, etc., each time the engine is started.

6.2.1.33 Unusable Oil. Unusable oil is the maximum quantity of oil in the lubrication system which is not available to meet engine lubrication requirements throughout the operating envelope under the maneuver forces and attitudes specified in the engine specification.

6.2.1.34 Mission. A mission is defined as that period beginning with the start of the engine prior to flight and engine at engine shutdown at the completion of the flight.

6.2.1.35 Mission Profile. A representation of a specific mission in terms of flight conditions, including airspeed, altitude, power lever setting and duration.

6.2.1.36 Mission Mix. The relative frequency that each mission profile is encountered during a specified time period.

6.2.1.37 Engine Design Duty Cycle. The engine design duty cycle is a composite cycle derived from the mission profiles and mission mix.

6.2.1.38 Engine Maintainability. The capability (i.e., the inherent design characteristics) of an engine and its parts which permits its maintenance (inspection, adjustment, removal, test, repair and overhaul) within specified periods of time without excessive expenditure of maintenance manpower, personnel skill levels, test equipments, and maintenance support facilities.

6.2.1.39 Scheduled Maintenance. Maintenance work occurring at prearranged times and consisting of modification tasks, and a "Look Phase" and a "Fix Phase" of inspections; the look phase being preventive maintenance and the fix phase being the corrective and other maintenance required as a result of the look phase.

6.2.1.40 Unscheduled Maintenance. Maintenance occurring during the interval between scheduled maintenance periods.

6.2.1.41 Non-Concurrent Downtime Rate (NCDR). The summation of time rates for certain maintenance tasks or types of tasks specified as downtime tasks by the Using Service. For each task the time in hours per task is multiplied by the task frequency expressed as tasks per unit time (flight hour, operating hour, etc., as specified).

6.2.1.42 Time Between Overhaul. Time between overhaul is the sum of actual number of hours flown on each individual engine between depot overhauls (or between manufacture and first overhaul) divided by the number of overhauls, including those overhauled for minimum time removals.

6.2.1.43 Reliability Definitions

6.2.1.43.1 Engine Failure. For reliability determinations, engine failures shall be defined as follows:

a. The inability to obtain or sustain thrust at any of the required levels as a result of an engine component failure An in-flight thrust loss of 10% or greater of the minimum power normally available for the specific power setting at which the failure occurs will constitute a failure for the purpose of measuring this characteristic.

b. A condition directly charged to the engine which causes or generates a decision to shut down an engine or retard the throttle to reduce engine thrust greater than 10% of the proper desired value. Engine flameouts (even if a successful restart is achieved) are included if the flameout is chargeable to the engine.

c. The inability to start within 15 minutes of the initial attempt directly chargeable to the engine.

d. Low oil levels measured after flight will be counted as failures if the rate of oil loss was sufficient to cause a low oil warning when extrapolated to a 12 hour flight.

e. High vibration will be counted as failure if the levels are beyond acceptable limits and the engine is subsequently repaired or rejected and replaced for this cause.

f. A failure will be counted if the fault is subsequently corrected by a component replacement, even though bench testing of the affected component may not confirm the component failure.

g. Multiple part removals performed to correct a single failure are counted as one failure against the engine.

h. Failure events which result from fluid leaks exceeding the amounts specified in 3.3.6.4 from fittings or connectors will be considered as engine responsible.

i. An engine shutdown due to evidence of an engine malfunction or impending malfunction.

6.2.1.43.2 Excluded Failures

a. Failures resulting where transportation, storage, inspection, maintenance, repair, installation, overhaul, or replacements were improperly performed, contrary to currently applicable instructions, or reasonable standards of aircraft quality workmanship.

b. Failures resulting when the engine was operated beyond engine specification defined environmental conditions and time cycle limitations, or with fuels or lubricants not conforming to applicable specifications.

c. Failures where the primary failure cause was not directly attributable to the design or quality of the engine, such as failures attributed to foreign object damage (FOD).

d. Starting failures where a start was accomplished within two minutes after the initial attempt to start the engine and no maintenance action has been performed.

e. Failures of equipment not furnished by the engine contractor, which do not occur as a result of failure of the engine to provide a proper function or interface within the limits stated in this specification.

f. Failures which are the result of fuel system contamination, where the contamination levels are outside the limits specified in this specification, unless evidence exists that the contamination was engine generated.

g. Any malfunction reported by the pilot or flight crew which cannot be verified by subsequent investigation, flight, or ground testing.

h. Failures for which a corrective engine design change or an operational procedure change has been engineering approved by the appropriate Using Service will not be counted after date of approval, unless taken and it has been determined that the prescribed corrective action procedures have been utilized.

6.2.1.43.3 Mean Time Between Failure. Mean Time Between Failure is defined as the total engine hours accumulated in the measurement period divided by the number of failures in the measurement period.

6.2.1.43.4 Adjusted Mean Time Between Failure. Adjusted Mean Time Between Failure is the Mean Time Between Failure calculated after adjustment has been made to the observed failure rate for failures on which Engineering Change Proposals have been submitted and approved prior to the time of the occurrence of the specified failure events covered by the ECP's.

6.2.2 Symbols, Subscripts, and Abbreviations. The symbols, subscripts, and abbreviations used in this specification, and in those specifications referenced herein, are listed below. In addition to the basic symbols, those symbol-subscript combinations which are used repeatedly or have particular association with aircraft engine terminology are also listed. Various ratios and specific equations are further defined in the appropriate sections of the specifications where use of such relationships is required. Use of superscripts ( ) and parenthetical identifications are similarly defined in the sections requiring their use.

6.2.2 1 Symbols. The symbols used in this specification are defined as follows:

Symbol	Quantity	Unit
C	Correction factor	Nondimensional
F	Thrust	lb.
F_g	Gross thrust, including the effects of secondary (ejector) airflow, when applicable	lb.

Symbol	Quantity	Unit
F_n	Net jet thrust = F_g - F_r	lb.
F_r	Ram drag, including secondary (ejector) flow airflow, when applicable	lb.
g	Acceleration due to gravity	ft/sec.^{2}
M_o	Flight Mach No.; free stream Mach No.	Nondimensional
N	Engine rotor speed	rpm.
P	Any gas static pressure, absolute	psia.
P_{sls}	Standard sea level static pressure, absolute	psia.
P_o	Free stream static pressure, absolute	psia.
P_t	Any gas total pressure, absolute	psia.
P_{t2}/P_o	Ram pressure ratio	Nondimensional
T	Any gas static temperature	°Celsius
T_{sls}	Standard sea level static temperature	°Celsius
T_o	Free stream static temperature	°Celsius
T_t	Any gas total temperature	°Celsius
V	Velocity	ft/sec.
W_a	Airflow rate	lb/sec.
W_f	Fuel flow rate	lb/sec.
W_g	Gas flow rate	lb/sec.
W_{ac}	Engine airflow - cold, (fan flow - turbofan engines)	lb/sec.
W_{ah}	Engine airflow - hot, (gas generator flow)	lb/sec
W_{as}	Secondary airflow rate (for ejector)	lb/sec.

Symbol	Quantity	Unit
W_{at}	Engine airflow -- total (total engine flow W_{ac} plus W_{ah})	lb/sec.
W_{bl}	Bleed airflow rate	lb/sec.
δ	Relative pressure, P/P_{sls}, δ and P have subscripts referring to any particular station.	Nondimensional
Θ	Relative temperature, T/T_{sls}, Θ and T have subscripts referring to any particular station	Nondimensional
$\dot{\theta}$	Pitching velocity about the center of gravity of the engine	rad/sec
$\ddot{\theta}$	Pitching acceleration about the center of gravity of the engine	rad/sec ^{2}
$\dot{\psi}$	Yawing velocity about the center of gravity of the engine	rad/sec.
$\ddot{\psi}$	Yawing acceleration about the center of gravity of the engine	rad/sec ^{2}

The engine contractor shall furnish a list in accordance with this format and shall include any additional symbols used for such items as rotor speeds, fuel flow, thrust, temperatures, pressures, correction factors, and vibration instrumentation symbols and locations.

6.2.2.2 Subscripts.

a	Air
c	Cold
f	Fuel, fluid, liquid
g	Gas, gross
h	Hot
j	Jet

n	Net
r	Ram
s	Secondary
t	As initial subscript indicates total or stagnation
T ( )	Corrected for temperature
x	Extracted
0, 1, 2,	Stations through unit (station subscripts should succeed other subscripts). Sometimes it is desira-able to use subscripts, such as P_{t2}, T_{t2}, P_{t4}, T_{t4}, and so forth, for pressure and temperature at compressor stations, turbine stations, and so forth. Contractors will include, with each presentation of performance data, a diagram or sketch identifying internal and external stations.

The contractor shall furnish any additional appropriate subscripts and related nomenclature.

6.2.2.3 Abbreviations.

am	ambient-static values of undisturbed air mass
bl	bleed
ej	ejector
ref	reference
std	standard
sls	sea level static

The contractor shall provide additional abbreviations, such as EMI and corresponding non-abbreviated words covering all abbreviations used in the contractor proposed specification.

6.3 Ordering Data

6.3.1 Procurement Requirements. The Using Service may exercise any desired options herein. The procurement documents should specify the following:

a. Title, number, and date of this specification.

b. A full-scale mockup when required by the Using Service (see 3.1.2.2.)

c. Level or preservation and type of shipping container (see 5.1).

6.3.2 Contractor Data Requirements

6.3.2.1 Structural Load Analysis. A structural load analysis in accordance with the requirement of 3.1.2.5 shall be submitted prior to the initiation of PFRT.

6.3.2.2 Engine Heat Rejection and Cooling Report. An engine heat rejection and cooling report, in accordance with the requirements of 3.1.2.8.2, shall be furnished six months prior to PFRT.

6.3.2.3 Verification of Performance. Engine test data and analyses required for performance verification, in accordance with 3.2.1.3, shall be submitted prior to initiation of the PFRT endurance test and updated prior to initiation of the QT endurance test.

6.3.2.4 Failure Mode and Effect Analysis. A failure mode and effect analysis in accordance with 3.2.3 shall be submitted prior to the initiation of the PFRT and updated prior to initiation of the QT.

6.3.2.5 Reliability Analysis Report. An engine reliability report in accordance with 3.2.3 shall be submitted at the completion of QT.

6.3.2.6 Corrosion Susceptibility. A report covering the testing of all selected materials and coatings, as required by 3.2.5.5, shall be furnished prior to the start of the PFRT.

6.3.2.7 Materials and Process Documents. Engine manufacturer's materials and process documents shall be submitted to the Using Service, as required by 3.3.1.1, prior to the start of PFRT.

6.3.2.8 Electromagnetic Interference. An interference control plan and an EMI/EMC test plan, in accordance with 3.3.2, shall be submitted to the Using Service six months prior to PFRT and six months prior to QT.

6.3.2.9 Interchangeability and Replaceability. A listing which identifies matched or selected fit parts shall be submitted to the Using Service prior to PFRT and QT in accordance with 3.3.5.

6.3.2.10 Strength and Life Analysis. A strength and life analysis report shall be submitted to the Using Service prior to PFRT and updated prior to QT as required by 3.3.8.6.

6.3.2.11 Vibration and Stress Report. A vibration and stress analysis in accordance with 3.3.8.10.2 shall be submitted to the Using Service prior to PFRT.

6.3.2.12 Fuel System Calibration Limits. A report in accordance with 3.7.3.3.1 shall be furnished to the Using Service.

6.3.2.13 Oil Flow and Heat Rejection Report. An oil flow and heat rejection report, in accordance with 3.7.7.3.1, shall be submitted to the Using Service prior to the initiation of the QT endurance test.

6.3.2.14 Infrared Radiation Report. An infrared radiation report in accordance with 3.7.10.3 shall be submitted prior to the initiation of the PFRT.

6.3.2.15 Pretest Data. The pretest data specified in 4.3.5.1 shall be submitted to the Using Service for approval prior to initiation of each test required in 4.4, 4.5 and 4.6.

6.3.2.16 Engine Heat Rejection and Oil Cooling Report. The contractor shall supply to the Using Service the report containing the heat rejection and cooling requirements data as required in 4.4.2.

6.3.2.17 Oil Flow Interruption Test Report. The contractor shall supply to the Using Service the oil flow interruption test report as required in 4.4.3.

6.3.2.18 Engine Electrical Power Failure Test. Prior to PFRT, a final report shall be supplied to the Using Service pertaining to the engine electrical power failure test. The data in this report shall result from 4.4.4.

6.3.2.19 Engine Vibration Survey Report. A vibration survey report, in accordance with 4.4.5, shall be submitted to the Using Service for approval prior to the endurance portion of the PFRT.

6.3.2.20 Starting Torque Demonstration Procedure. Prior to the start of PFRT, the procedure for demonstrating the starting torque and speed requirements shall be submitted to the Using Service for approval. After approval of the procedure, the report on the actual demonstration shall be submitted to the Using Service as required in 4.4.6.

6.3.2.21 Maintainability/Maintenance Demonstration Report. A report describing the procedure and results of the demonstrations and test run of 4.4.8 shall be submitted to the Using Service prior to completion of the QT.

6.3.2.22 Infrared Radiation Test Report. The infrared radiation test report, in accordance with 4.6.5.3, shall be submitted to the Using Service prior to the completion of the QT.

6.3.2.23 Test Reports. Separate test reports, prepared in accordance with 4.3.6.1, covering each individual test of 4.5 and 4.6 shall be submitted to the Using Service within 30 days after completion of the individual test

6.3.2.24 Summary Reports. Separate reports summarizing the results of the preliminary flight rating test specified herein and the qualification test specified herein, prepared in accordance with 4 3.6.2, shall be submitted to the Using Service within 30 days after completion of the last individual test.

6.4 International Standardization. Certain provisions of this specification are the subject of international standardization agreements ASCC AIR STANDARD 17/42, 17/43 and 17/45. When amendment, revision, or cancellation of this specification is proposed, the department custodians will inform their respective Departmental Standardization Offices so that appropriate action may be taken respecting the international agreement concerned

6.5 Engine Specification Preparation. A complete engine specification conforming to the instructions for preparation contained herein shall be prepared and submitted by the contractor for approval by the Using Service.

6.5.1 Instructions for Preparation. The engine specification shall be prepared as follows:

a. The headings and numbering of sections and paragraphs shall correspond to those of this specification.

b. Paragraphs herein which are applicable as written shall be copied into the specification. Any change, addition or deletion shall be identified by placing an identifying mark or symbol in the margin.

c. Paragraphs herein which are not applicable to the particular engine design shall have the words "not applicable" entered following the appropriate paragraph number and headings.

d. Paragraphs requiring modification to define a particular design shall be modified only to the extent necessary to describe the characteristics of that particular engine and model.

e. New requirements or additions shall be added as additional subparagraphs or as new paragraphs in logical sequence and location.

f. Items such as tables, figures, drawings, diagrams and appendices, shall be presented in complete form in the specification. Complete statements calling out these items shall be included in the text of the specification.

g. All curves shall be presented on graph paper having an adequate number of subdivisions to permit necessary interpolations.

h. The prepared specification shall have identifying dividers between major sections and indices to provide easy access and reference.

i. The specification number and engine model identification shall be displayed on the spine of the document.

j The engine sea level and altitude performance tables shall be designated as Table I and Table II respectively. If the specification covers two engines differing in performance, eg. YF and F, the sea level and altitude performance tables for the additional engine shall be designated as Table IA and Table IIA respectively.

6.5.2 Approval Status. The first page of the engine specification shall contain information indicating the approval status of the specification in the upper left hand corner. If approval has been obtained, enter the word "approved" and cite the communication which conveys the approval. If the specification is not yet approved, enter the words "not approved".

6.5.3 Specification Dates. The date of the specification shall be provided in the upper right hand corner.

6.5.4 Revisions. When revisions are made, they shall be designated by the use of a letter following the specification number with a revision date therefor, which shall be shown on page 1 only of the engine specification. Only the specification number and revision suffix letter, if applicable, shall be shown on subsequent pages. Revision by preparation of revised pages for insertion into previously submitted copies of the engine specification shall not be used.

6.5.5 Verification Tables. The requirements of the PFRT and QT verification tables (Appendix A and Appendix B) included in this specification shall be included in the engine specification.

6.6 Instructions for Preparation of Engine Summaries. Instructions for preparation of engine summaries (See Tables III and IV) shall be as follows:

BLOCK 1 SECURITY CLASSIFICATION - Indicate the highest classification of the data presented on the summary. Include the special notation which identifies its status in the automatic, time-phased downgrading and declassification system, in accordance with current applicable security regulations.

BLOCK (2) MILITARY DESIGNATION - Show the official military designation. If there is none assigned, show all other designations by which the particular engine is identified.

BLOCK (3) CONTRACTOR'S DESIGNATION - Show the contractor's designation and popular name for the engine. If not applicable, insert "None".

BLOCK (4) SPECIFICATION DATA - Insert contractor's name, location (city and state), model specification number from which the data is derived (if none, indicate the source and date of data such as report number, bulletin, or progress reports), the latest date of the specification, and whether it has been approved or not approved by the cognizant Government agency.

BLOCK (5) PICTORIAL DATA - Furnish a glossy photograph (side view) with the exhaust nozzle to the right. If there is none available, a linear drawing, blueprint drawing, or artist's sketch will be satisfactory. This pictorial data may be furnished in its original form.

BLOCK (6) SPONSORING AGENCY - Show name of Government agency originally sponsoring the project, i.e., ARMY, NAVY, USAF, NASA, SANDIA, ARPA, etc. If not Government sponsored, indicate responsible contractor.

BLOCK (7) FEATURES - Show a general description as well as special data relative to cooling, liquid injection, afterburning, reliability, specialties, limitations, engine life expectancy, advancements and similarities over previous models, etc., as applicable.

BLOCK (8) AVAILABILITY

a. Program Initiated. . . . . ____________________
(Give month and year program was initiated.)

b. Development Contract Award. . . . . . ____________________
(Give month and year of contract award. If not applicable, insert "None".)

c Engine Mock-Up Inspection. . . . . . ____________________
(Give month and year scheduled for official completion. If not applicable, insert "None".)

d. Experimental Engine. . . . . ________________
(Give month and year scheduled for initial operation as a complete assembly. If not applicable, insert "None". An experimental engine is basically defined as an engine that has not completed the Preliminary Flight Rating Test.)

e Mock-Up for Vehicle. . . . . . . ________________
(Give month and year scheduled for official completion If not applicable, insert "None")

f. Installation Engine. . . . . ________________
(Give month and year that first flight engine could be or is made available for prototype vehicle application. If not applicable, insert "None".)

g. Preliminary Flight Rating Test. . . . ________________
(Give month and year scheduled for official completion. If not applicable, insert "None".)

h. Qualification Test. . . . . ________________
(Give month and year scheduled for official completion. If not applicable, insert "None". If demonstration or FAA Certification only is required, indicate month and year scheduled and insert below the Qualification Test line.)

BLOCK 9 CONTRACTUAL - If demonstration, experimental, or research engine, give all contract numbers, contract coverage, and total contract cost If production or service test engine, give all contract numbers, quantities per contract, and unit cost.

BLOCK 10 STATUS - Give current status, i.e., in design stage, undergoing component development, first firing date, in production, production completed in (mo-year), currently undergoing production buildup, number of engines produced to date, etc., as applicable. Also, give approximate lead time that the engine would be available after contract initiation. Give the full story as required to fully portray the current status, stage of development, and availability.

BLOCK 11 GENERAL - All applicable performance and characteristics parameters are based on sea level static, standard day conditions

a. (If single rotor compressor, show)

Compressor. . . . . ________________
(Show type, single rotor, number of stages (includes ___ fan stages), variable geometry, etc.)

(If dual rotor compressor, show)

Compressor. . . . . ______________________
LP Rotor. . . . . ______________________
HP Rotor . . . . ______________________
(Show compressor type, dual rotor, number of stages for each rotor (includes ____ fan stages), variable geometry, etc.)

b. (If single rotor compressor, show)

Max Design Pressure Ratio/SLS:
Fan . . . . ________________:1
Overall . . . . ________________:1
(Express to nearest 0.1)

(If dual rotor compressor, show)

Max Design Pressure Ratio/SLS:
Fan . . . . ________________:1
LP Rotor . . . . ________________:1
HP Rotor . . . . ________________:1
Overall . . . . ________________:1
(Express to nearest 0.1)

c. Bypass Airflow Ratio (Turbofan engine only) .__________:1
(Bypass airflow to HP compressor airflow, express to nearest 0.1.)

d. Max Allowable Air Bleed. . . . . ________%
(Equals compressor air bleed divided by Max Rated Power compressor airflow, express to nearest 0 1.)

e. Max Rated Airflow/SLS . . . . ______________lb/sec
(Show at Max or Takeoff Rated Power, as applicable, express to nearest unit.)

f. Combustion Chamber . . . . ____________________
(Show type, number, flow, etc.)

g. (If single rotor turbine, show)

Turbine . . . . ____________________
(Show type, single rotor, number of stages, variable geometry, etc.)

(If dual rotor turbine, show)

Turbine. . . . . ____________________
LP Rotor . . . . ____________________
HP Rotor . . . . ____________________
(Show turbine type, dual rotor, number of stages per rotor, variable geometry, etc.)

h. Turbine Cooling . . . . ____________________
(Show type, i.e., air, liquid, none, etc.)

i. Max Allowable Ave. Steady-State Temp (Combustor Exit) . . . . ____________________ °C (°F)

j Max Allowable Ave. Steady-State Measured Temp (Combustor Exit) . . . . ____________________ °C (°F)

k. Max Rated Turbine Inlet Temp/SLS . . ____________________ °C (°F)
(Show at Max or Takeoff Rated Power, as applicable)

l. Exhaust Nozzle. . . . . ____________________
(Show type, variable, convergent, divergent, two position, fixed area, exit area, etc.)

m Regeneration . . . . ____________________
(Show type, location, none, etc.)

n. Max Rated Exhaust Temp/SLS. . ____________________ °C (°F)
(Show at Max or Takeoff Rated Power, as applicable, at exit point.)

o Electrical System . . . ____________________
(Show voltage, cycle and max amperage requirements.)

p. Ignition. . . . . ____________________
(Show type, number of igniters, etc.)

q. Power Control. . . . . . . ____________________
(Show type, i e., electrical, hydromechanical, pneumatic, digital computer, etc.)

r. Fuel. . . . . ____________________
(List designation type and Military Specification for both primary and alternate fuels.)

s. Oil . . . . ______________________
(List designation type, grade and Military Specification.)

t. MCP Oil Consumption . . . . ______________gal/hr
(Show at Max Continuous or Normal Rated Power, as applicable, express to nearest 0.1.)

u. Accessory Drive Provisions . . ____________________
(List number of drives provided.)

v. Thrust to Weight Ratio . . . . . ____________________:1
(Based on Max Rated Power, express to nearest 0.1.)

BLOCK (12) SIZE & WEIGHT - Show all data at room temperature.

a. Length, Overall . . . . ________in.
(Parallel to centerline axis, express to nearest 0.01.)

b. Diameter, Nominal. . . . . ________in
(Perpendicular to the centerline axis, express to nearest 0.01.)

c. Max Radial Projection . . . . ______________in.
(Perpendicular to the centerline axis, express to nearest 0.01.)

d. Weight, Dry. . . . . ______________lb.
(Items which are not engine components but which are furnished with the engine shall not be included, express to nearest lb.)

e. Weight, Wet. . . . . ______________lb.
(Equals the dry weight plus residual fluids after operation and drainage, express to nearest lb.)

BLOCK (13) UTILIZATION - Indicate the vehicle application by both nickname and military designation. Include number of engines per application, and indicate the Using Service for each vehicle.

BLOCK (14) DATE - Add date indicating currency of summary.

BLOCK (15) PERFORMANCE - Show performance from the Performance Table(s) from the applicable Engine Specification.

BLOCK (16) GRAPHIC PERFORMANCE - Show thrust vs SFC curves for selected sea level, altitude, and flight speeds. Selection should be based on vehicle application requirements as well as the engine capability. The basic data is generally obtained from the Performance Table(s) and the G&A performance curves from the applicable Engine Specification. Indicate the ram efficiency and model atmosphere used. This data may be furnished in its original form.

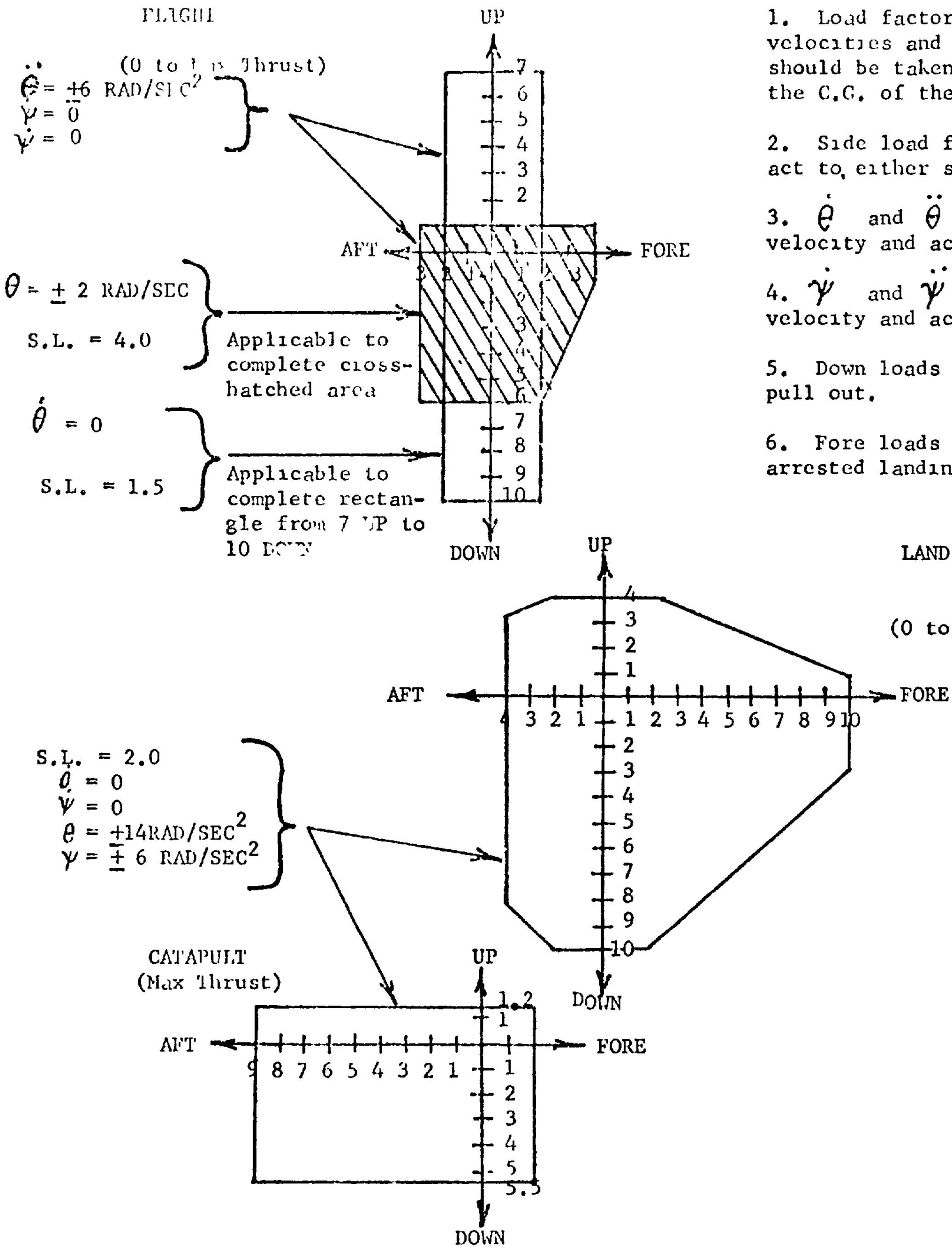
BLOCK (17) NOTES - To be used, if required, for any additional information deemed necessary to fully portray the engine presentation or capability

Custodians:
  Army - AV
  Navy - AS
  Air Force - 11

Review Activities:
  Air Force - 71, 82

Preparing Activity:
  Air Force - 11

Project No. 2840-0029



1. Load factors and angular velocities and accelerations should be taken at or about the C.G. of the engine.

2. Side load factors (S.L.) act to either side.

3. $\dot{\theta}$ and $\ddot{\theta}$ are pitching velocity and acceleration.

4. $\dot{\psi}$ and $\ddot{\psi}$ are yawing velocity and acceleration.

5. Down loads occur during pull out.

6. Fore loads occur during arrested landing.

FIGURE 1. Externally Applied Forces
REF.- 3.1.2.5

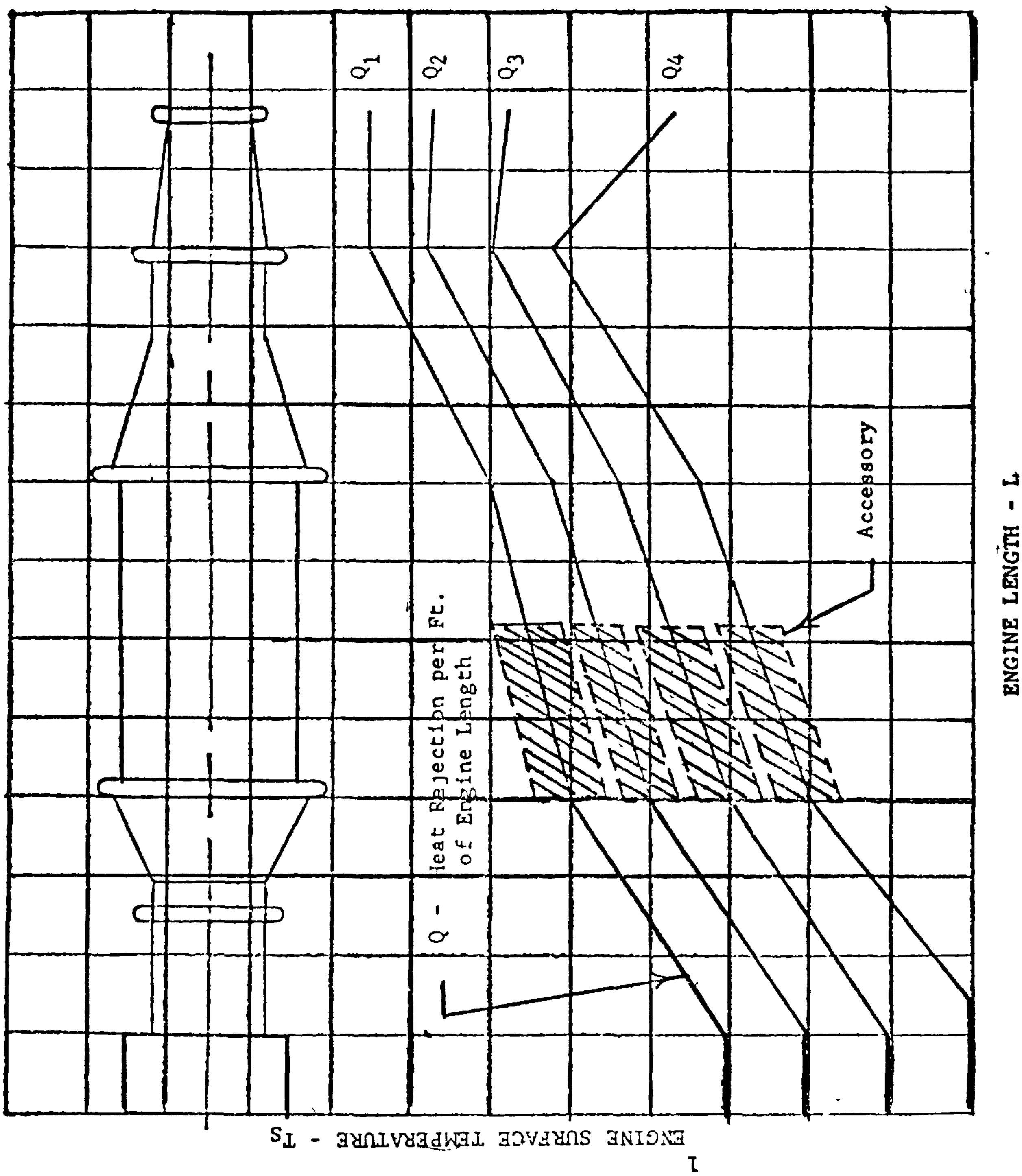
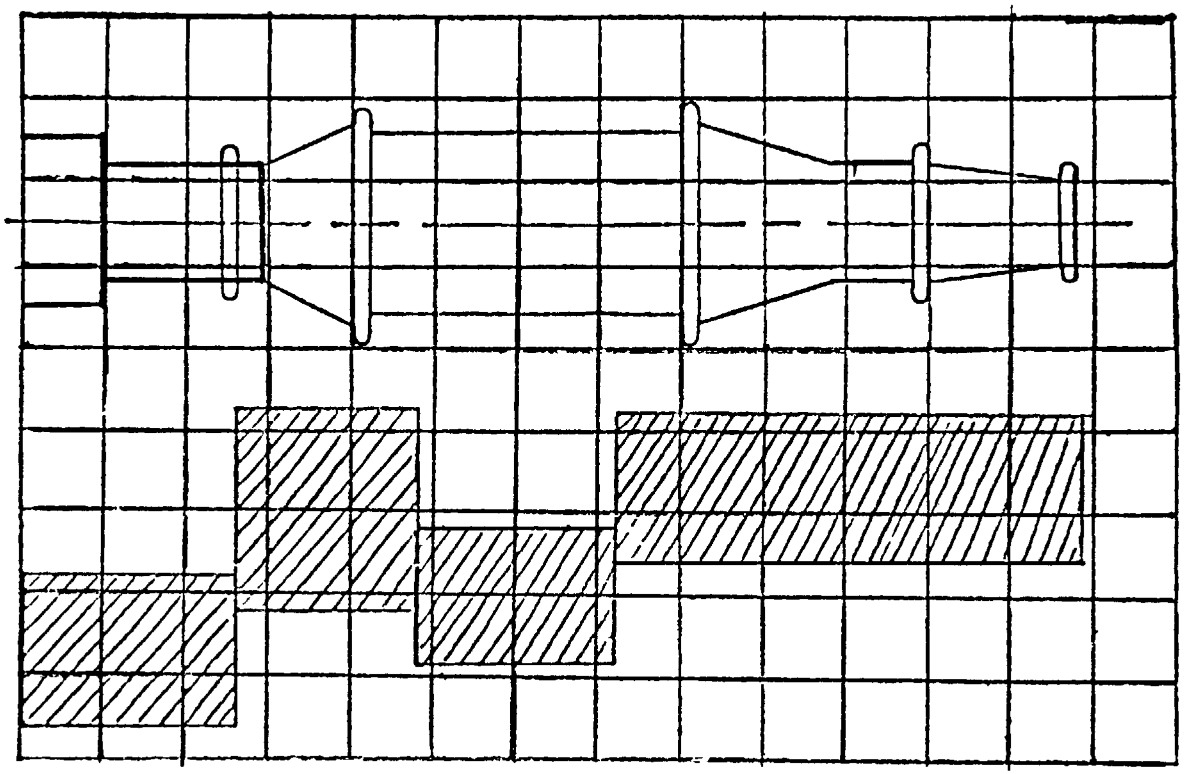


FIGURE 2. Engine Surface Temperature vs Engine Length
REF.- 3.1.2.8



SECTION	MATERIAL	EMISSIVITY
I		
II		
↓		

1. (Restrictions or Conditions for Data.)
2.
3.

↓

FIGURE 3. Basis for Engine Heat Emissivity Analysis and Calculations
REF.- 3.1.2.8

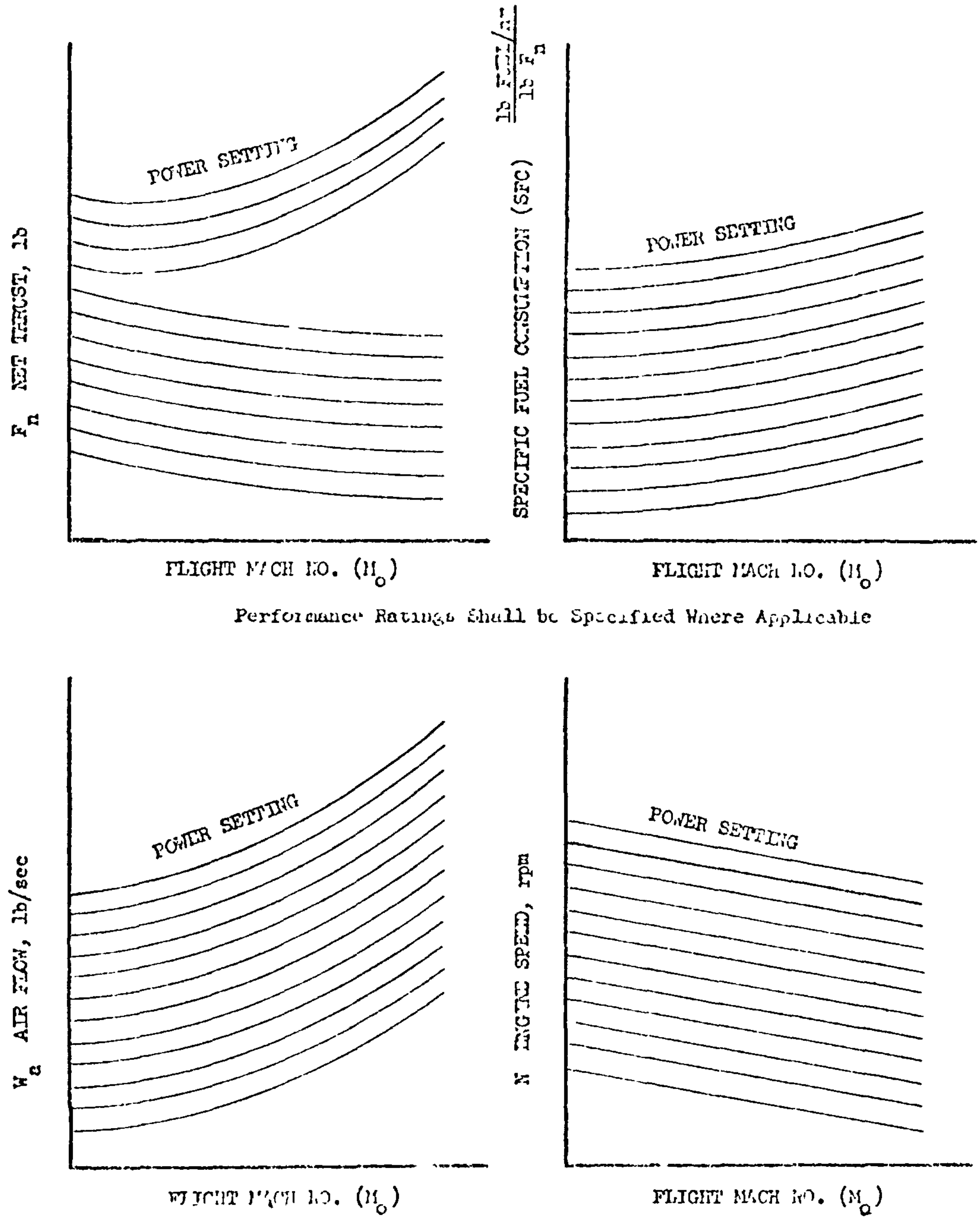


FIGURE 4. Estimated Performance Curves

REF.- 3.2.1.2.2

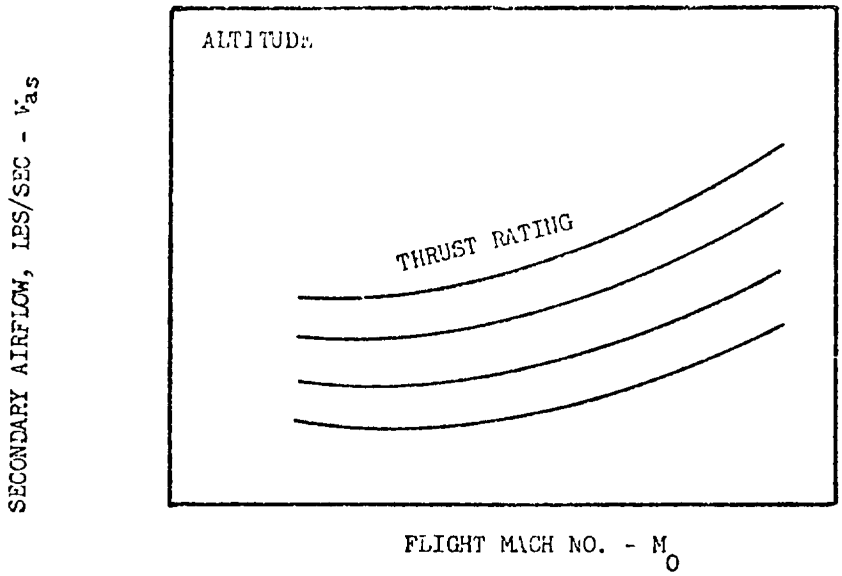


FIGURE 5 CURVES FOR SECONDARY AIRFLOW

REF. - 3.2.1.2.2

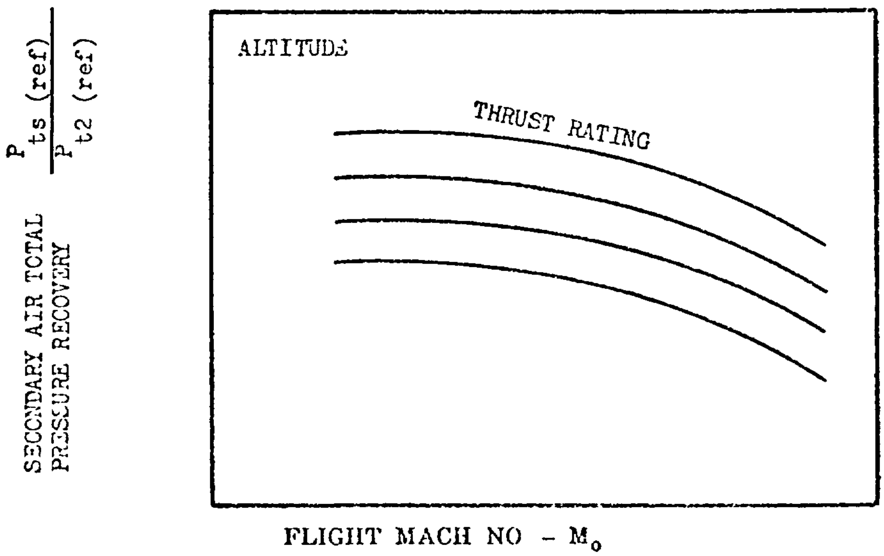


FIGURE 6. Curves for Secondary Air Pressure Recovery

REF.- 3.2.1.2.2

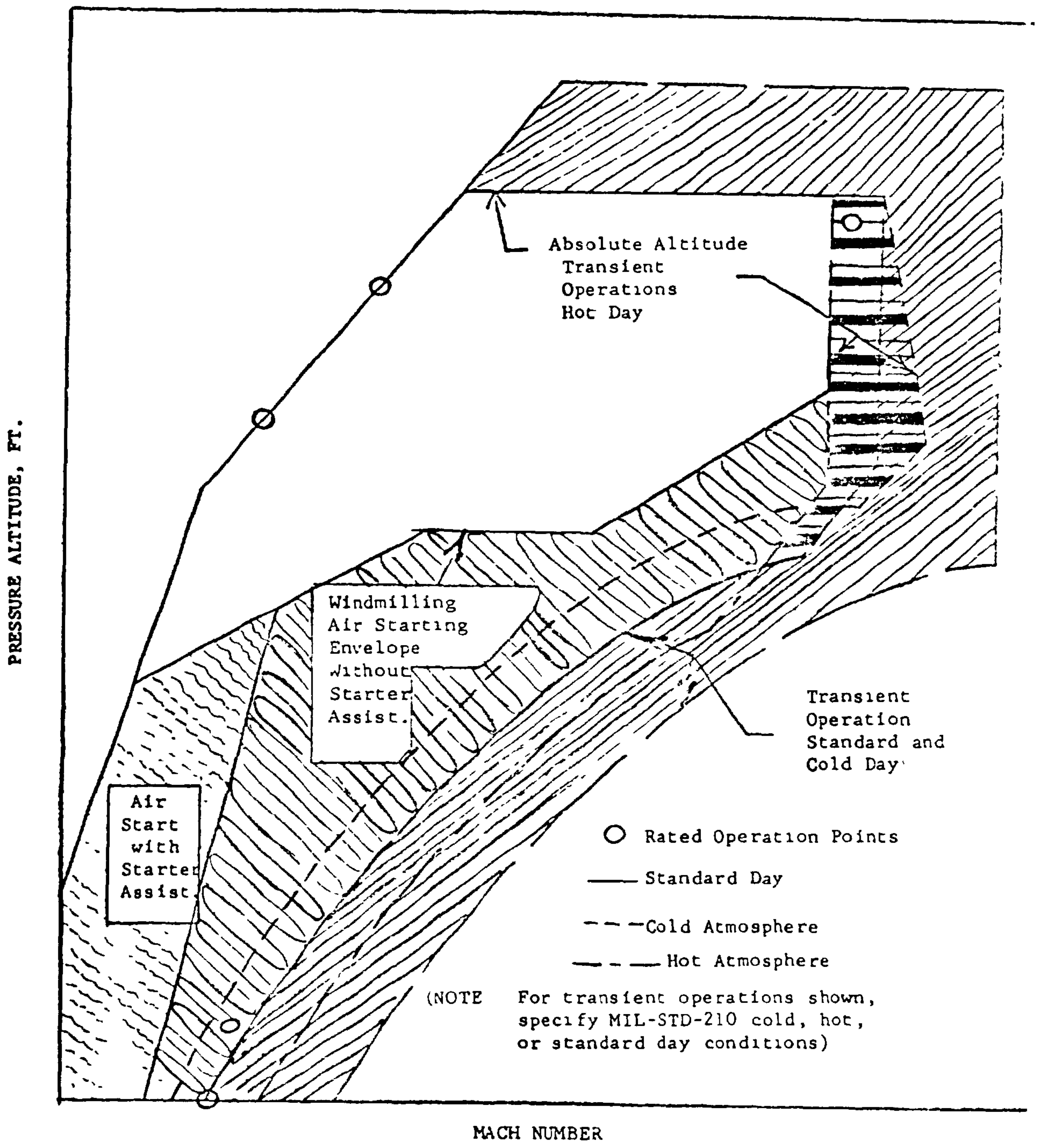


FIGURE 7. Operating Envelope

REF.- 3.2.1.4.1

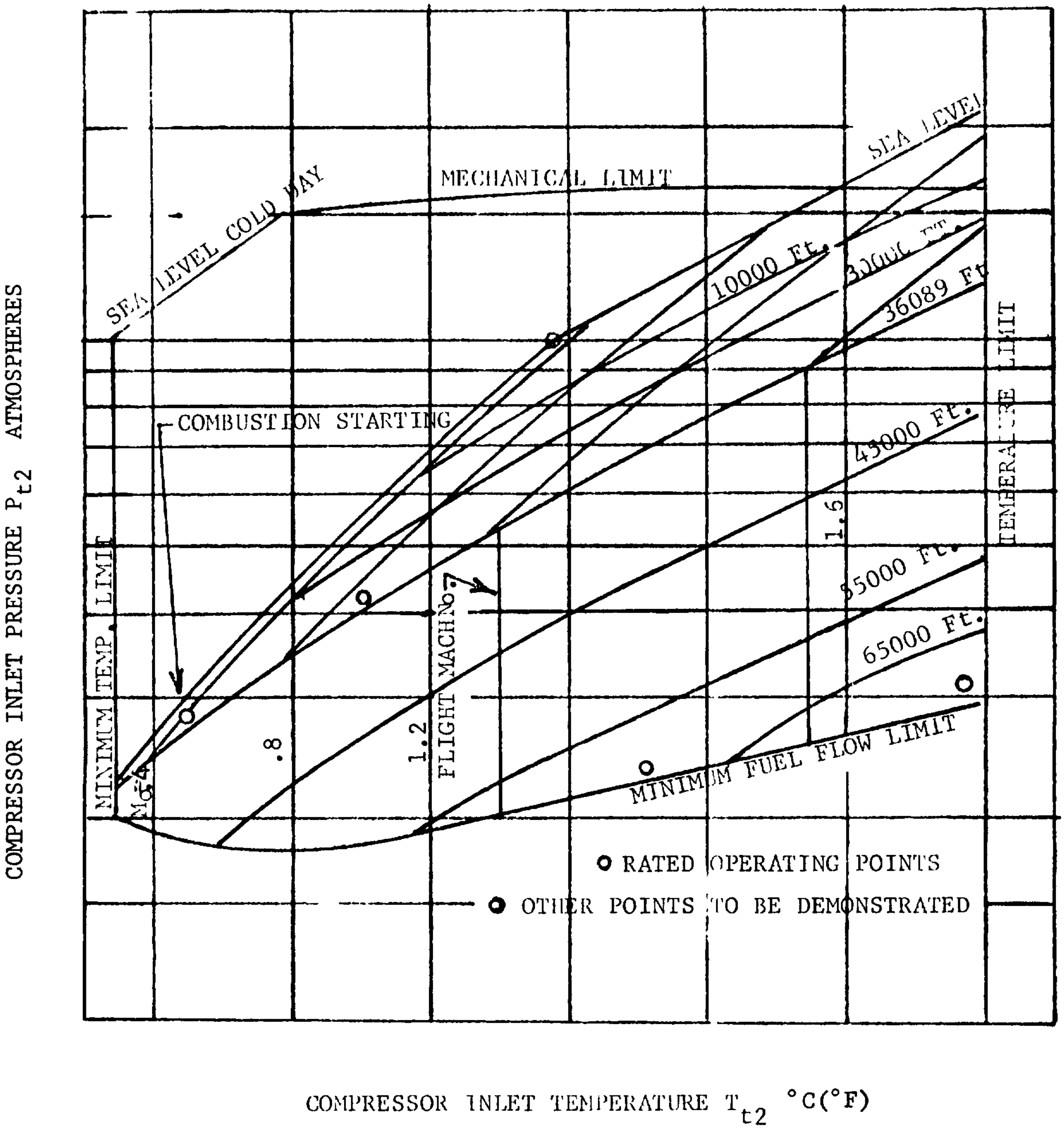
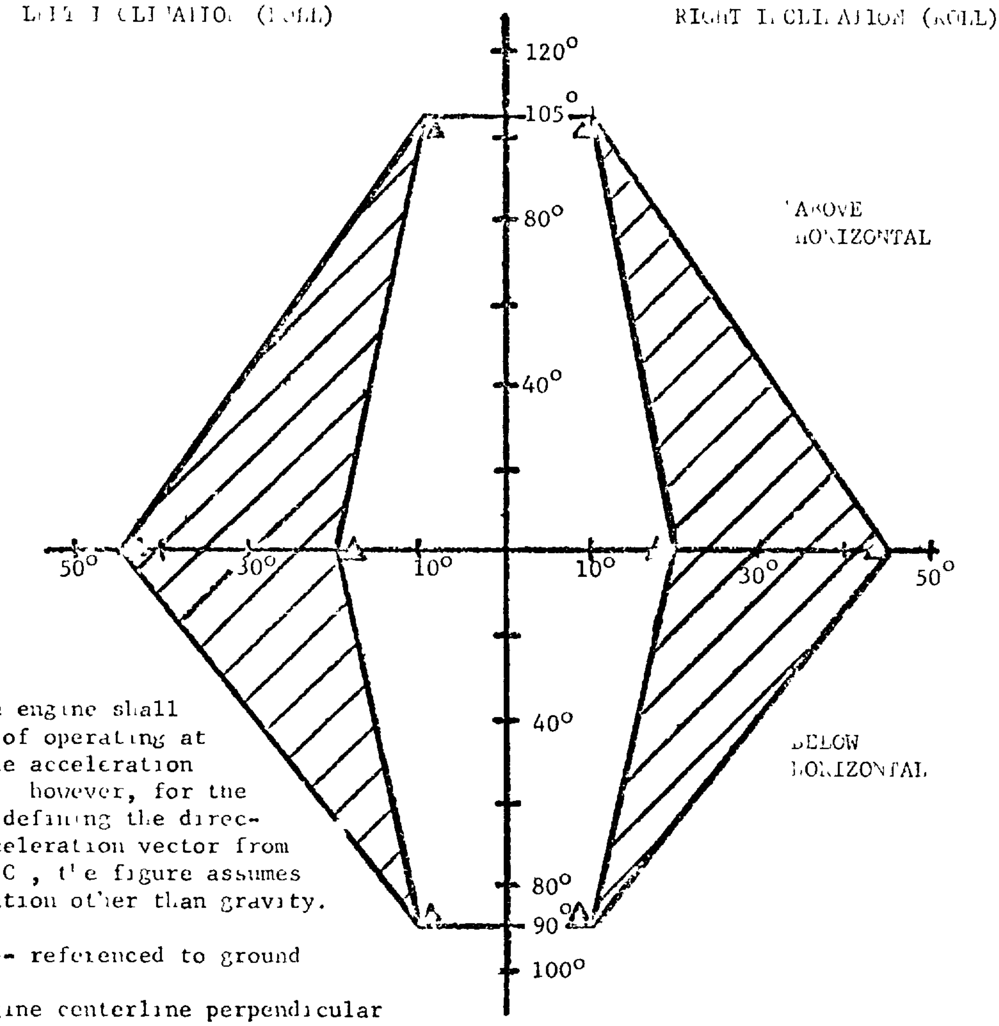


FIGURE 8. Estimated Engine Operating Limits
REF.- 3.2.1.4.1



NOTES

(1) The engine shall be capable of operating at all possible acceleration conditions; however, for the purpose of defining the direction of acceleration vector from the engine C , the figure assumes no acceleration other than gravity.

(2) · -- referenced to ground

(3) Engine centerline perpendicular to plane of paper.

(4) Continuous operation in clear area.

(5) 30 second operation in shaded area

(6) Symbols "A" indicate points for test .

FIGURE 9. Engine Attitude Limits

REF.- 3.2.1.5.1, 4.5.4.4

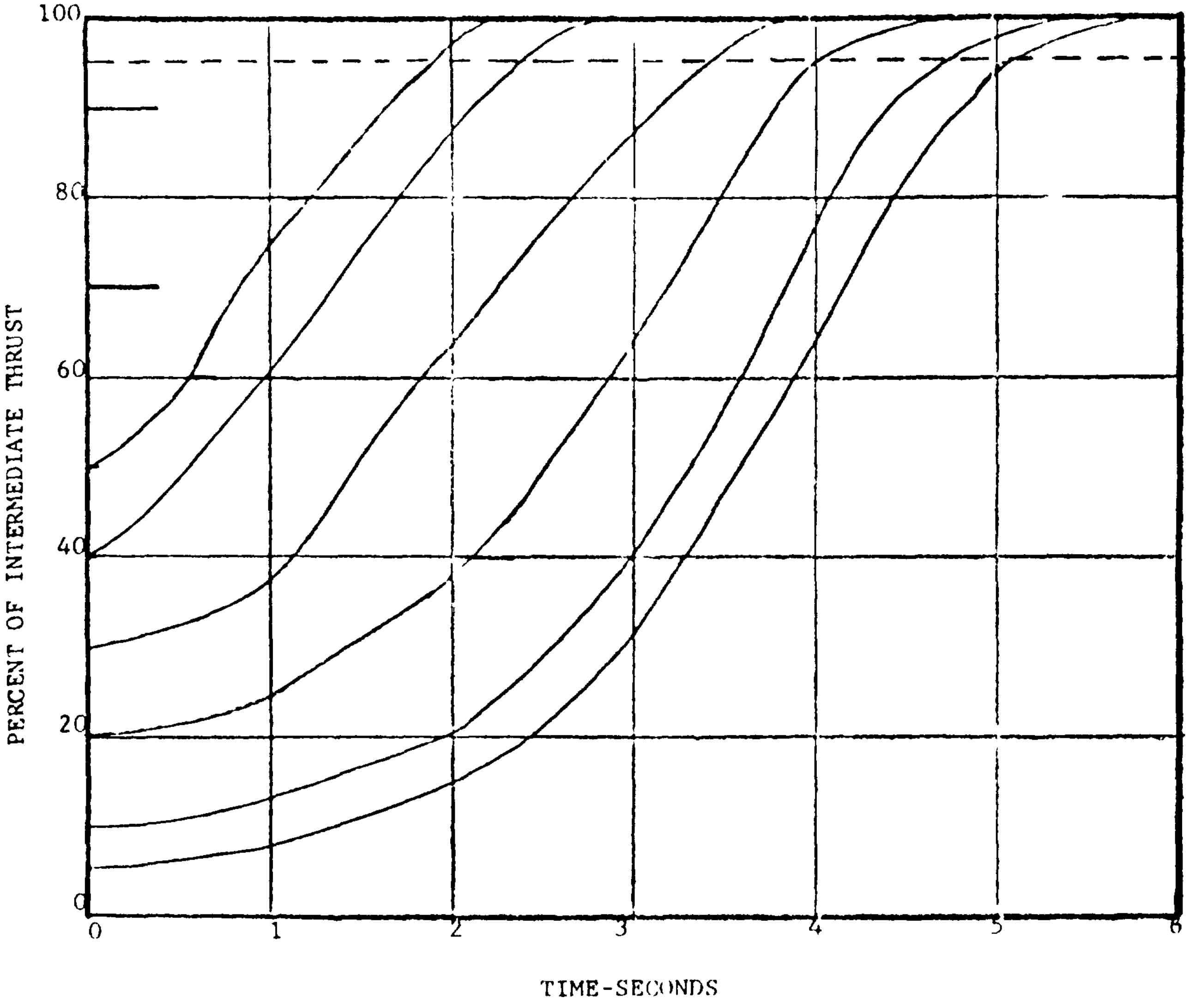


FIGURE 10 Acceleration Schedule - Sea Level to 10,000 Feet, Airspeeds to 150 Knots, Standard Conditions
REF.- 3.2.1.5.6

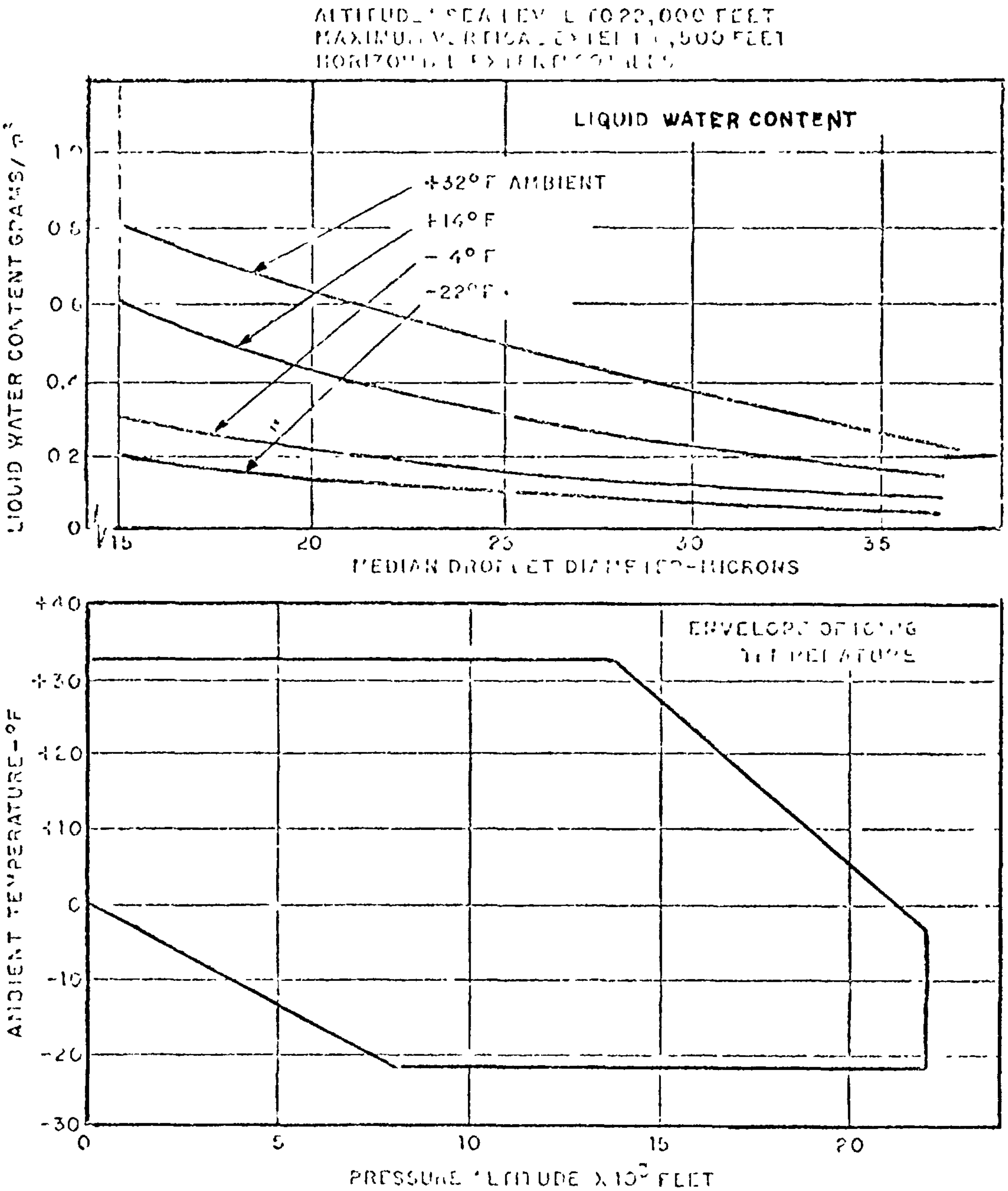


FIGURE 11. Continuous Maximum Icing Conditions
REF.- 3.2.5.2

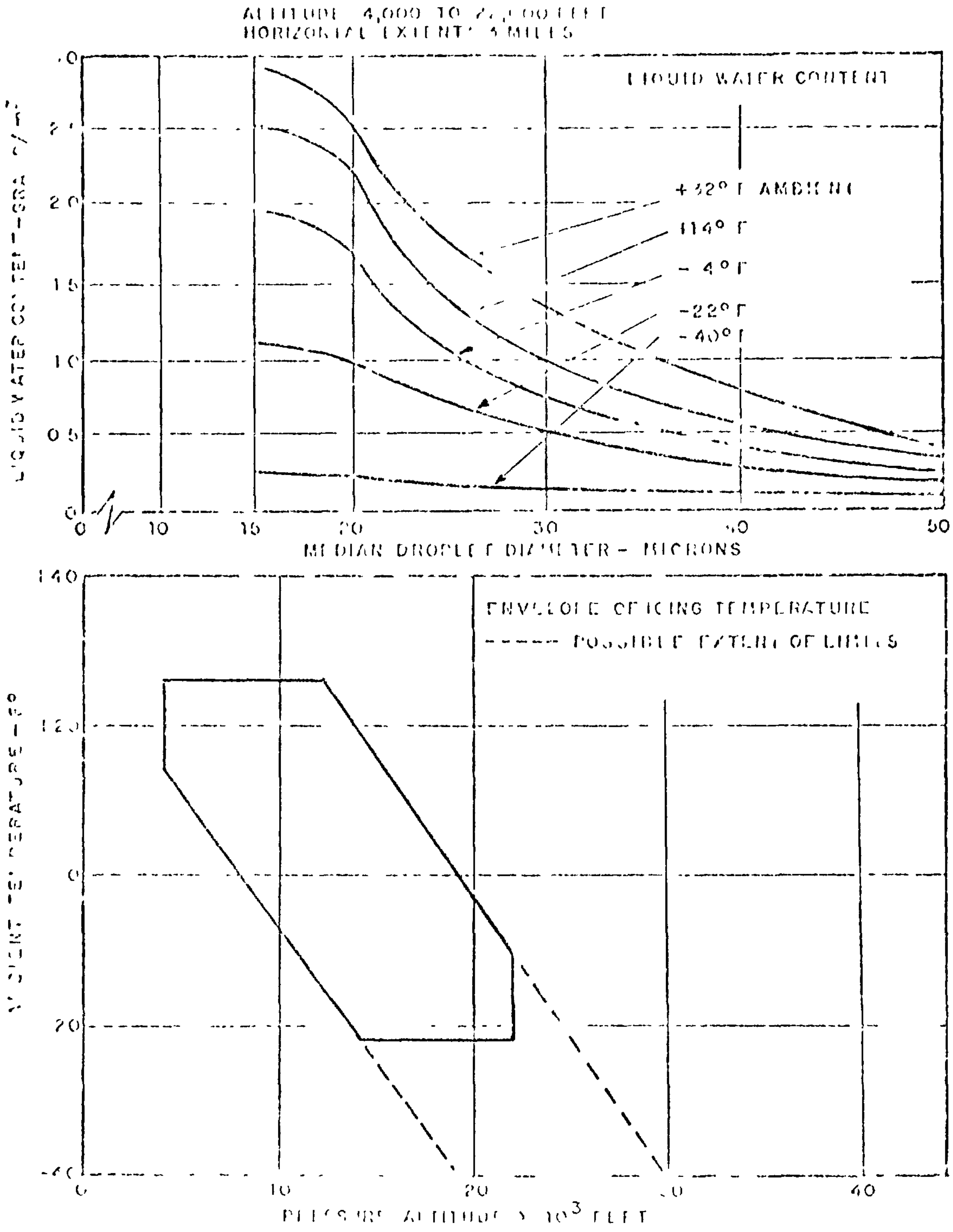
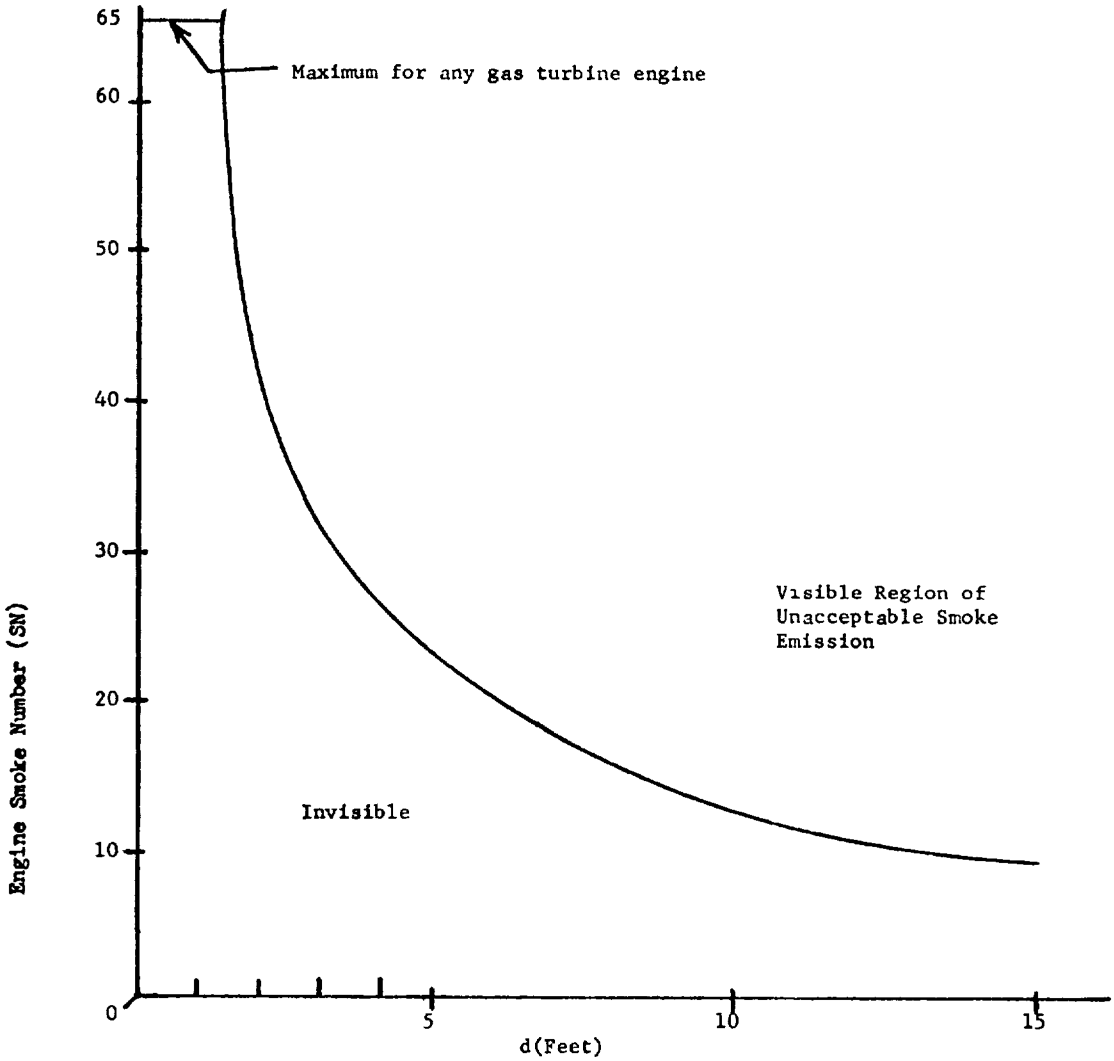


FIGURE 12. Intermittent Maximum Icing Conditions
REF.- 3.2.5.2



d: Diameter of the vitiated airflow exhaust nozzle at the engine exhaust exit plane (ft). The exhaust exit plane is the first downstream plane, normal to the exhaust stream, that does not contain a solid surface around the stream. For engines with variable area exhaust nozzles, d shall be the mean of values attainable when not afterburning. For engines with non-circular exhaust nozzle areas, d shall be the diameter of the smallest circle circumscribing the actual nozzle. For engines with vitiated airflow leaving the engine through an annulus, d shall be the diameter of a circle having the same cross-sectional area as the annular exhaust stream.

FIGURE 13. Exhaust Invisibility Limit

REF.- 3.2.5.8.1

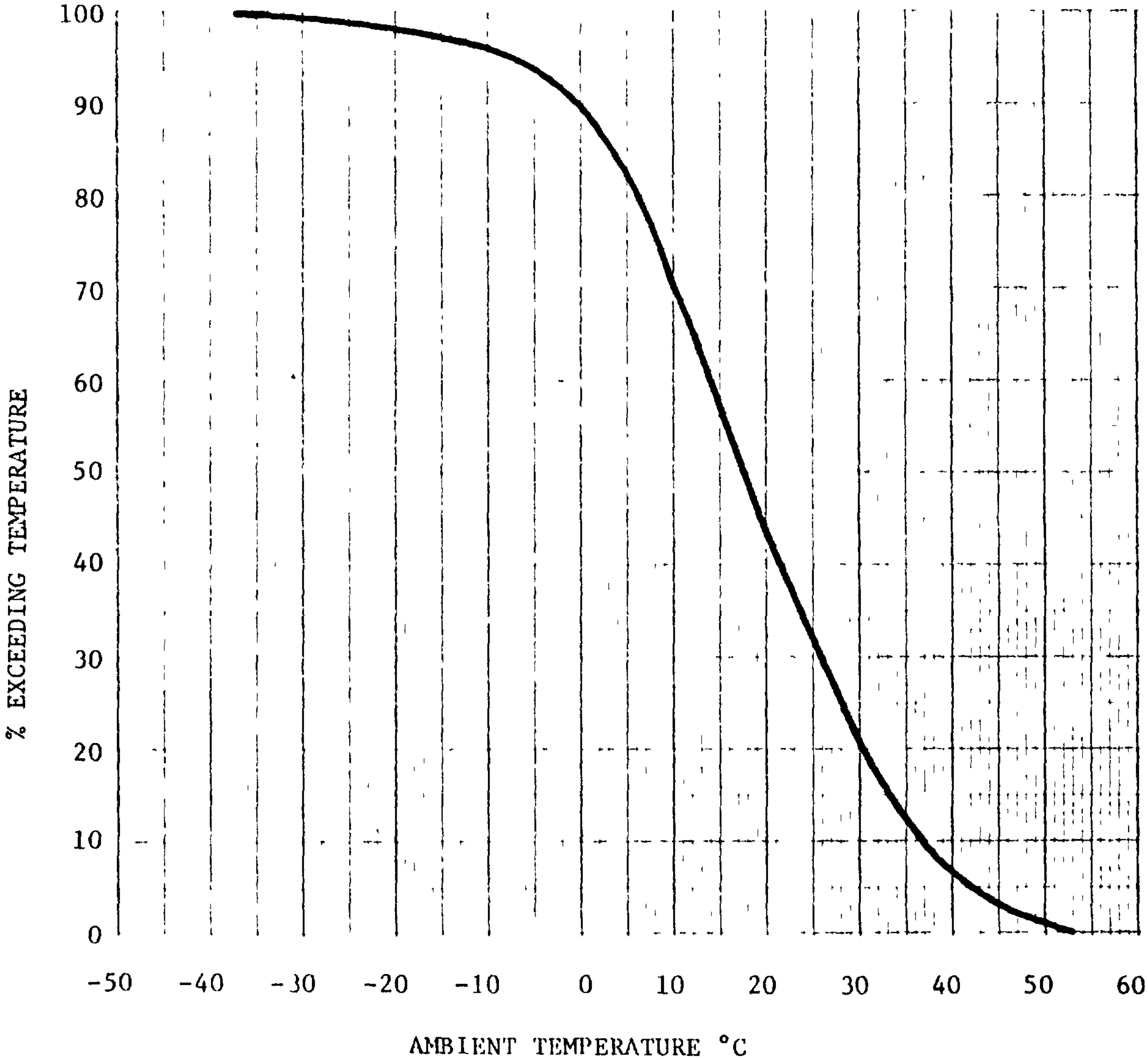


FIGURE 14. AMBIENT TEMPERATURE DISTRIBUTION

REF. 3.3.8.1

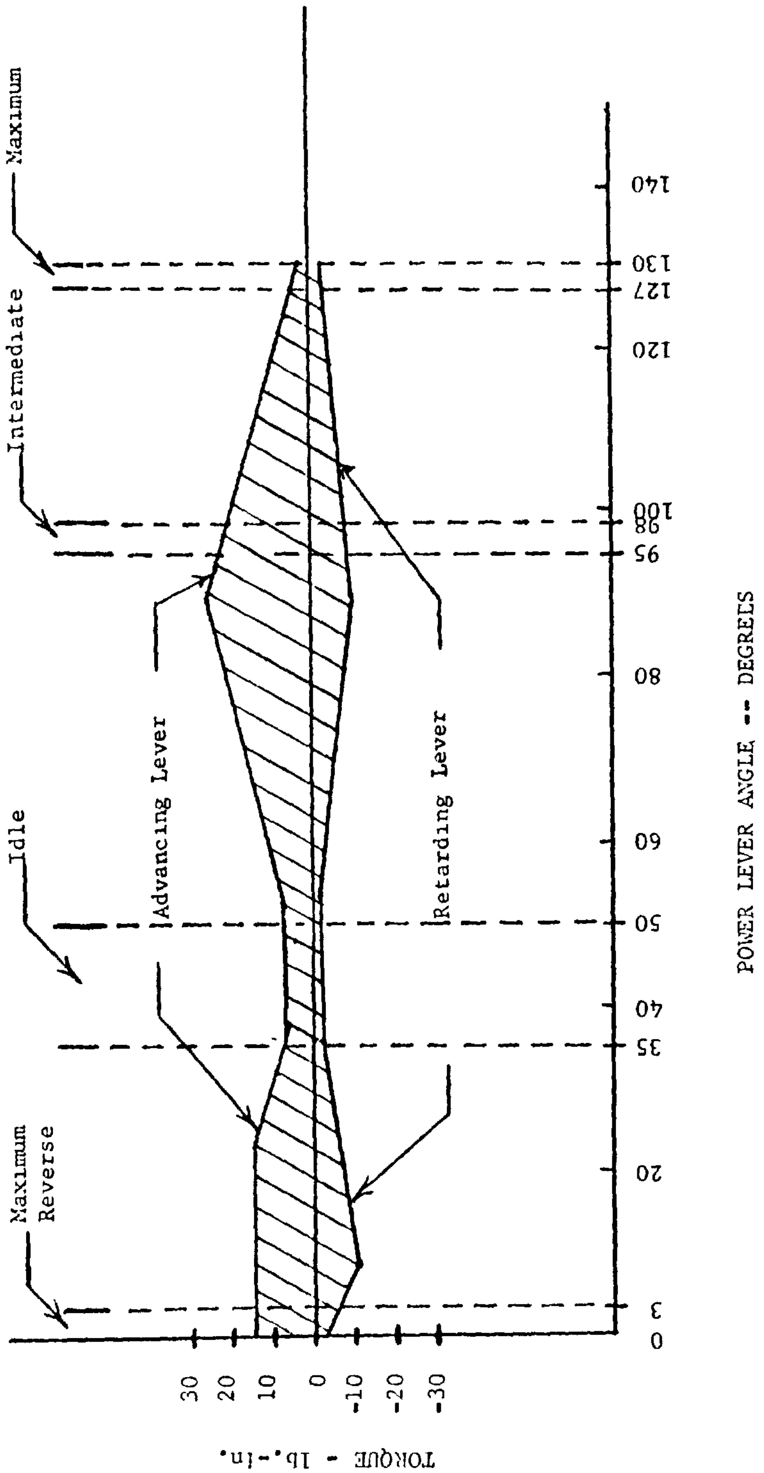


FIGURE 15. Power Lever Angle vs Power Lever Torque

REF.- 3.7.2.1.1.2

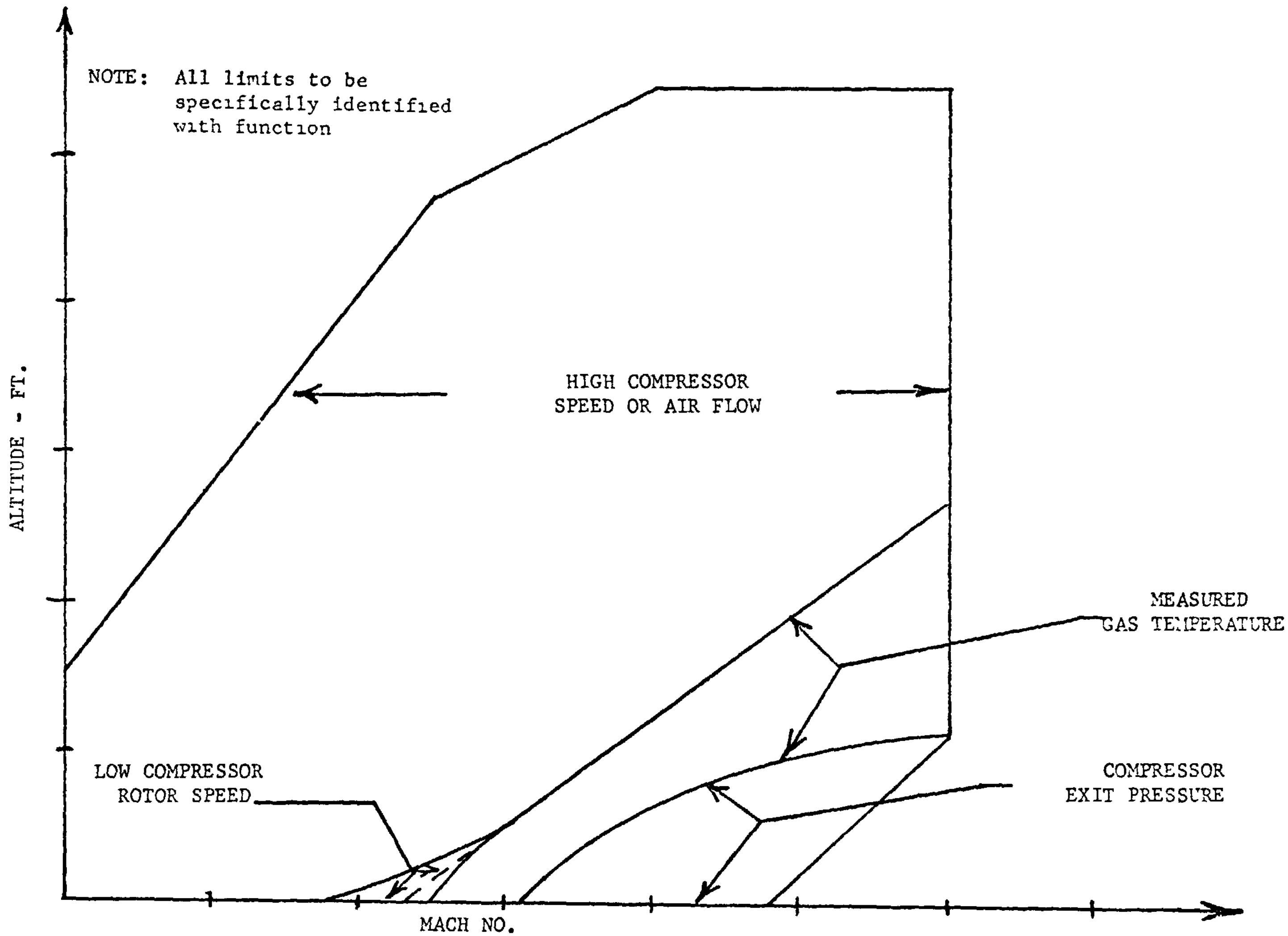
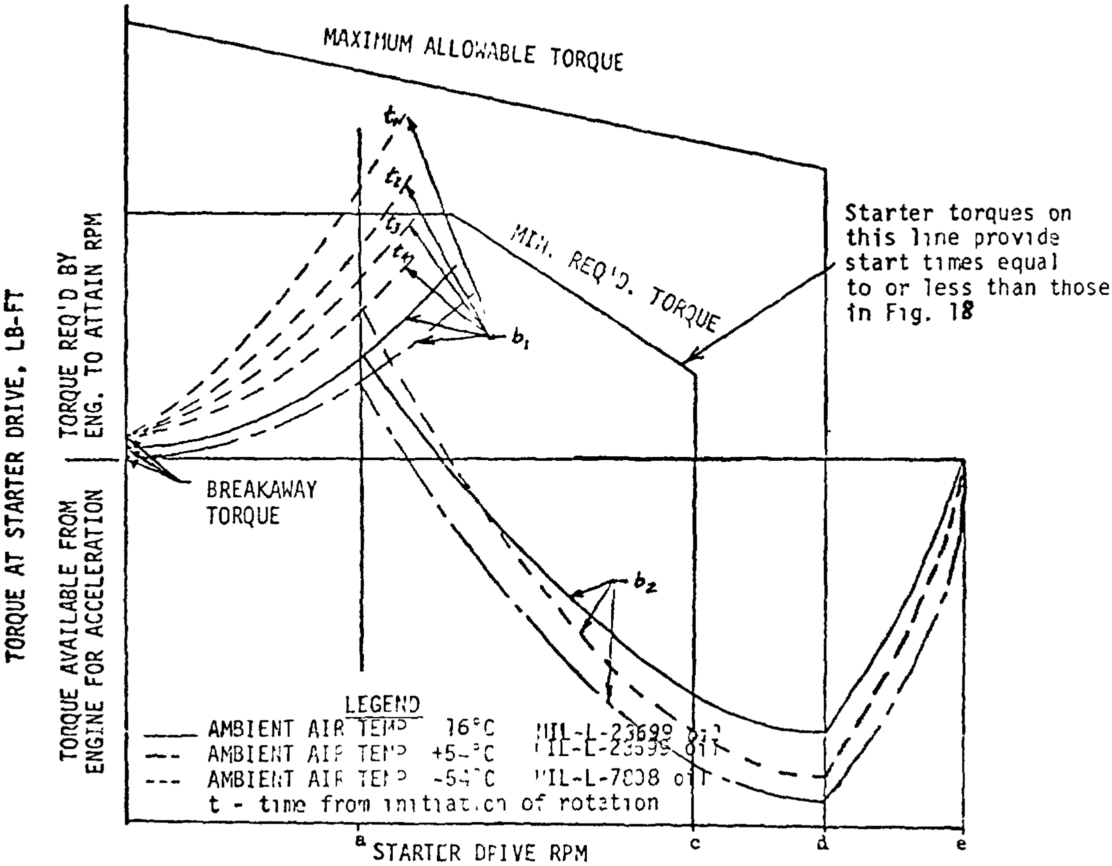


FIGURE 16. Control Limiter Regimes
U.S. Standard Ambient Conditions

REF.- 3.7.2.2.2



a. REQUIRED RPM BEFORE FIRING
(WHERE APPLICABLE THE ENGINE MANUFACTURER SHALL STATE THE MINIMUM TIME AND THE NUMBER OF REVOLUTIONS OR ANY COMBINATION OF CONDITIONS THAT MUST BE SATISFIED BEFORE FIRING.)
MAXIMUM REQUIRED CRANKING TIME AT FIRING SPEED----SEC

b. STEADY-STATE TORQUE AT THE STARTER DRIVE
   1. IN AN UNFIRED ENGINE. (CURVES AT -54°C SHOW DRAG TORQUE AFTER TIME FROM INITIATION OF ROTATION.)
   2. IN A FIRED ENGINE.

c. MINIMUM STARTER CUTOUT SPEED----RPM

d. MAXIMUM STARTER CUTOUT SPEED----RPM. (MAXIMUM CUTOUT SPEED SHOULD BE AT LEAST 10 PERCENT ABOVE MINIMUM CUTOUT SPEED.)

e. ENGINE NO LOAD CONDITION (EXAMPLE FOR STANDARD DAY)

FIGURE 17. Starting Torque and Speed Requirements
(sea level static conditions)

REF.- 3.7.9.1.1, 4.3.3.4, 4.7.1.4

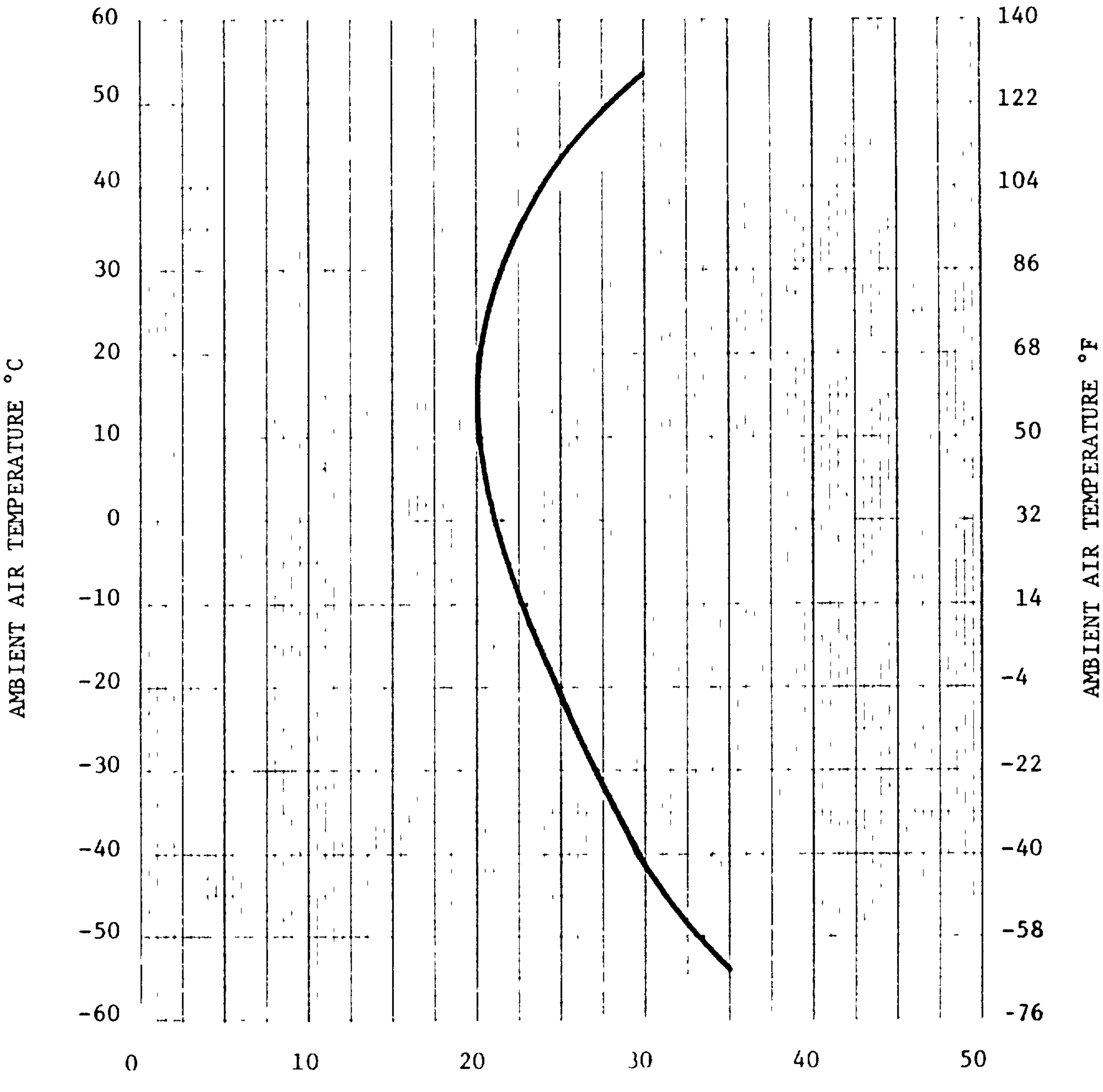


FIGURE 18. ENGINE GROUND STARTING TIME VERSUS AMBIENT AIR TEMPERATURE (STATIC NO RAM SEA LEVEL TO 10,000 FEET)

REF - 3.7.9.2, 4.6.4.1

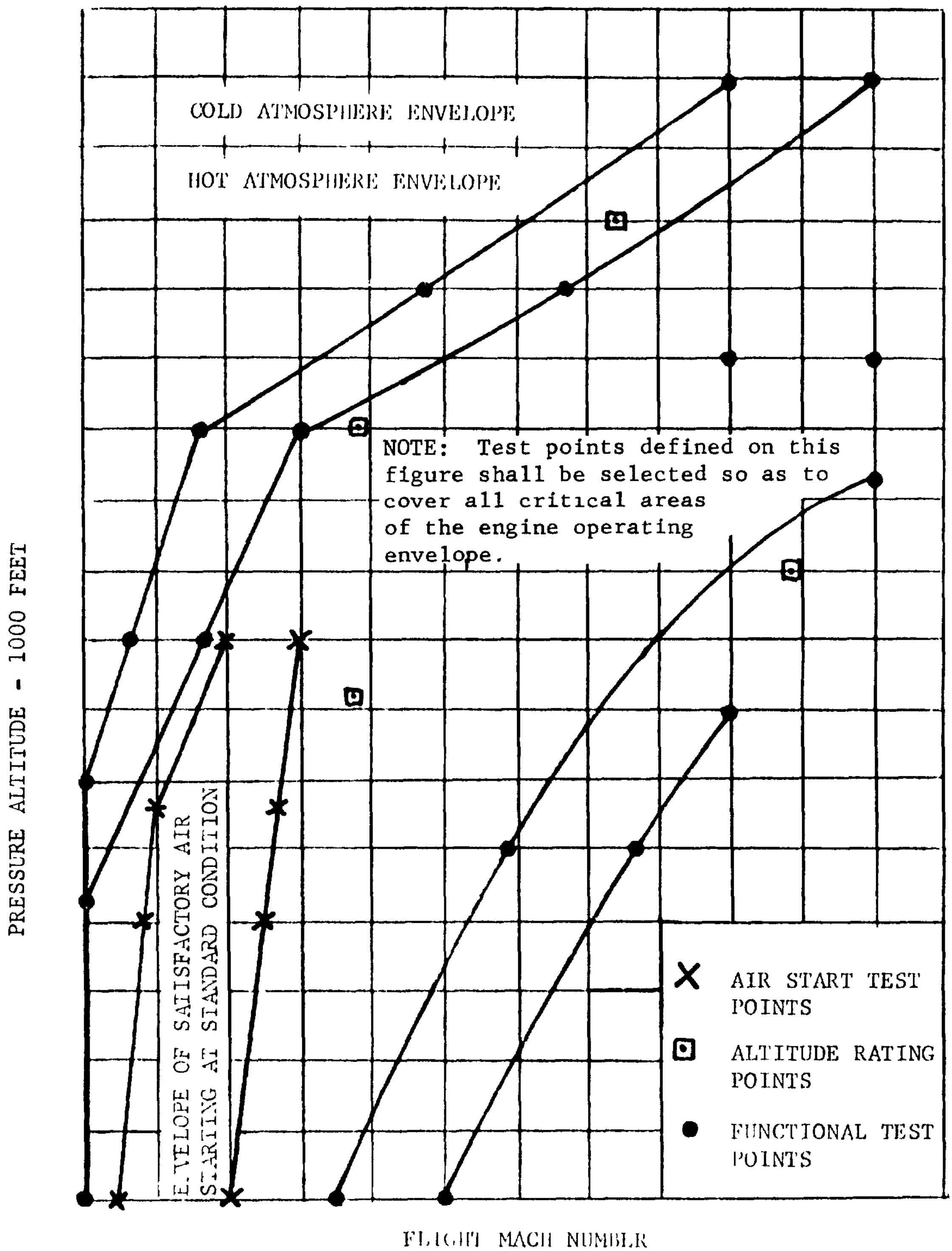


FIGURE 19. Engine Altitude and Starting Test Points
REF. - 4.5.3, 4 6 3

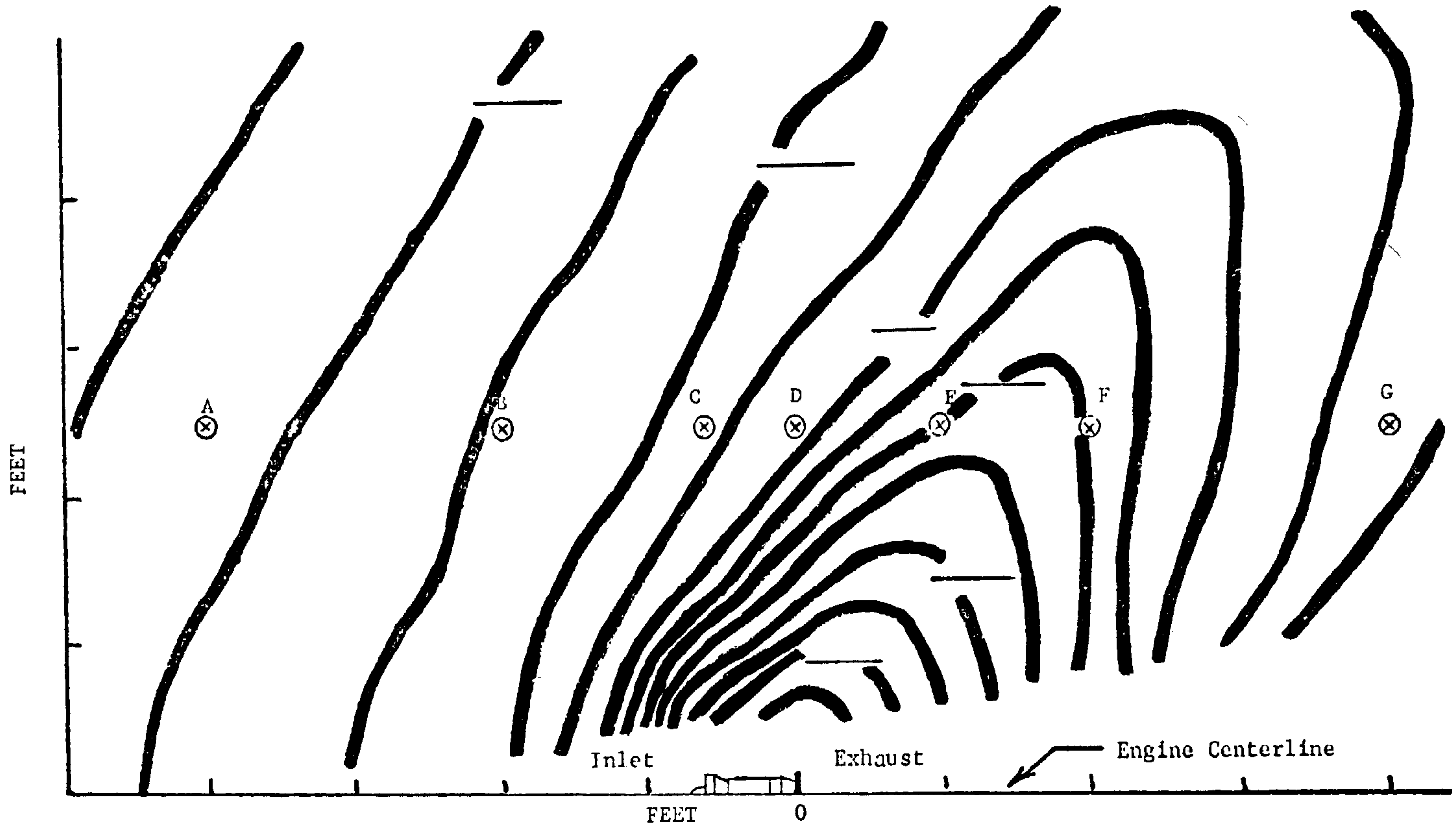


FIGURE 20. Near Field Overall Sound Pressure Level Contours (dB-REF.0.0002 μ Bars)
REF.- 4.6.4.10

FIGURE 22. Near Field Octave Band Sound Pressure Level Contours (dB-REF.0.0002 μ Bars) Center Frequency - 250 Hz
REF.- 4.6.4.10

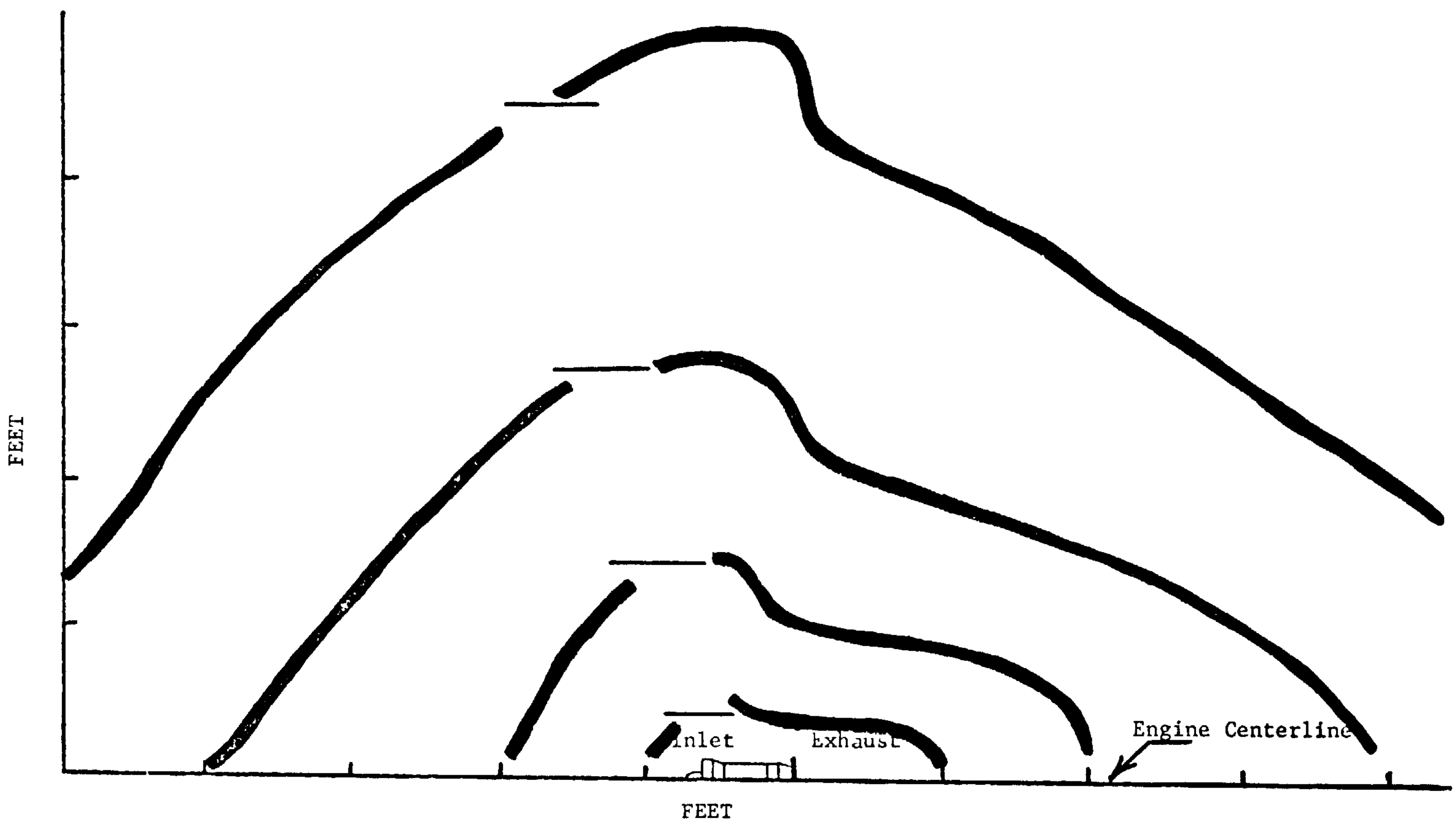


FIGURE 21. Far Field Overall Sound Pressure Level Contours
(dB - REF.0.0002 μ Bars)
REF.- 4.6.4.10

FIGURE 23. Far Field Overall Perceived Noise Level Contours
(dB - REF.0.0002 μ Bars)
REF.- 4.6.4.10

TABLE I. Performance Ratings at Standard Sea Level Static Conditions

REF.- 3.1, 3.2.1.1, 3.2.1.3, 4.5.1.2.3, 4.5.1.6, 4.6.1.7, 4.7.6

RATING (1)	THRUST (Min.) (lb.)	ENGINE ROTORS (Max.) RPM(s)	SFC (Max.) (lb/Hr/Lb)	MEASURED GAS TEMP. (Max.) (°C(°F))	(4) AIRFLOW ±3.0% (Lbs/Sec)	(3) SECONDARY AIRFLOW ±3.0% (Lbs/Sec)
Maximum						
Minimum Augmented						
Intermediate						
Maximum Continuous						
90% Maximum Continuous						
75% Maximum Continuous						
Maximum Reverse (5)						
Idle	(Max.)	(Min.)	(2)			

NOTES: (1) Additional ratings and columns shall be added as required by the Using Service, e.g., rotor speeds, calculated turbine inlet temp., and airflow.
(2) Fuel consumption in Lb/Hr (Max.)
(3) In the event there is an additional requirement beyond secondary airflow, an additional column shall be added and the data included.
(4) Total engine airflow
(5) Required only when a thrust reverser is part of the engine.

TABLE II. Performance Ratings at Altitude Conditions

REF.- 3.1, 3.2.1.1, 3.2.1.3, 3.2.1.3, 4.5.1.6, 4.5.3.2, 4.6.1.7, 4.6.3.2

RATING (1)	Altitude (Feet)	Ambient Temp. (°C(°F))	Mach Number	Net Thrust (Lbs.)	Max SFC lb/hr/lb	Measured Gas Temp (°C(°F))	Total Airflow (lbs/sec.) ±3.0%	Compressor Bleed Airflow (lbs/sec)	Horse-power Extraction (hp)	(2) Secondary Airflow ±3.0% (Lbs/Sec)

NOTES:
(1) Ratings shall be as required by the Using Service to cover the operating envelope and to be compatible with mission requirements.
(2) In the event there is an additional requirement beyond secondary airflow, an additional column(s) shall be added and the data included herein.

TABLE III TURBOJET CHARACTERISTICS SUMMARY

①

REF. - 3 1.6.6

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TURBOJET

TURBOFAN

Propulsion Characteristics Summary

TURBOJET ②

③ ④

⑤

⑥

⑦ FEATURES

⑧ AVAILABILITY

Program Initiated . . . .
Development Contract Award . . . .
Engine Mock-up Inspection . . .
Experimental Engine . . . .
Mock-up for Vehicle . . . .
Installation Engine . . . .
PFRT . . . .
Qualification Test . . . .

⑨ CONTRACTUAL

⑩ STATUS

⑪ GENERAL

Compressor . . ____
LP Rotor . . . . . ____
HP Rotor . . . . . ____
Max Design Pressure Ratio/SLS
LP Rotor . . . . ____ :1
HP Rotor . . . . ____ :1
Overall . . . . ____ :1
Max Allowable Air Bleed . . . . . ____ %
Max Rated Airflow/SLS . . . . ____ lb/sec
Combustion Chamber . . . ____
____

Turbine . . . . . . ____
LP Rotor . . ____
HP Rotor . . . ____
Turbine Cooling . . ____
Max Allowable Ave Steady-State Temp (Combustor exit) ____ °C(°F)

Max Rated Turb Inlet Temp/SLS . ____ °C(°F)
Exhaust Nozzle ____
____
Regeneration . . . ____
Max Rated Exhaust Temp/SLS . . ____ °C(°F)
Electrical System ____
____
Ignition . . . . . . ____
Power Control . . . . . ____
Fuel . . . . ____
(alt) ____
Oil . . . . ____
MCP Oil Consumption . ____ gal/hr
Accessory Drive Provisions . ____
Thrust to Weight Ratio ____ 1
Max Allowable Ave Steady-State Measured Temp (Specify Measuring Station) ____ °C(°F)

⑫ SIZE & WEIGHT

Length, Overall . ____ in
Diameter, Nominal . . . . ____ in.
Max Radial Projection . . ____ in
Weight, Dry . . . . ____ lb
Weight, Wet . . ____ lb

⑬ UTILIZATION

⑭ ① ②

TABLE III. TURBOJET CHARACTERISTICS SUMMARY

(1)

REF. - 3.1.6.6

Sheet 2 of 2

(15)

Performance

RATINGS AT STATIC SEA LEVEL STANDARD CONDITIONS					
RATING	THRUST (lb)	RPM	SFC (lb/hr/lb)	MEAS GAS TEMP °C(°F)	AIRFLOW (lb/sec)

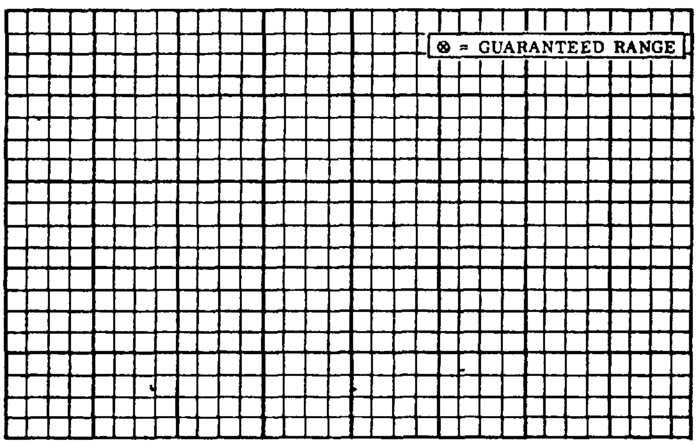
ALTITUDE RATINGS ~ US STANDARD ATMOSPHERE 1962						
RATING	ALTITUDE (ft)	MACH NR	THRUST (lb)	SFC (lb/hr/lb)	MEAS GAS TEMP °C(°F)	AIRFLOW (lb/sec)

OPERATING LIMITS	
Absolute Alt . . . . . ft	Max Starting Alt, Basic . . . . . ft
Limiting Mach Nr at sea level . . .	Max Starting Alt, Afterburner. . . . ft

(16)

US STANDARD ATMOSPHERE 1962 ~ RAM EFFICIENCY

SFC ~ (lb/hr/lb)



THRUST ~ (lb)

(17)

NOTES

(2) (1) (14)

TABLE IV TURBOFAN CHARACTERISTICS SUMMARY

1

REF - 3 1 6 6

Sheet 1 of 2

TURBOJET

TURBOFAN

Propulsion Characteristics Summary

TURBOFAN 2

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7 FEATURES

8 AVAILABILITY

Program Initiated . . .
Development Contract Award .
Engine Mock-up Inspection . . .
Experimental Engine . . .
Mock-up Vehicle . . . . .
Installation Engine . .
PFRT . .
Qualification Test . . .

9 CONTRACTUAL

10 STATUS

11 GENERAL

Compressor . . ____ ____
LP Rotor . . ____
HP Rotor ____
Max Design Pressure Ratio/SLS
Fan . . ____ 1
LP Rotor . . . . ____ 1
HP Rotor . . . ____ 1
Overall . . ____ .1
Bypass Airflow Ratio ____ 1
Max Allowable Air Bleed . ____ %
Max Rated Airflow/SLS . ____ lb/sec
Combustion Chamber ____
____
Turbine . ____
LP Rotor . . ____
HP Rotor . . . ____
Turbine Cooling ____
Max Allowable Ave Steady-State Temp (Combustor Exit) ____ °C(°F)

Max Rated Turb Inlet Temp/SLS . . ____ °F
Exhaust Nozzle . . ____
____
Regeneration . . ____
____
Max Rated Exhaust Temp/SLS . ____ °F
Electrical System . . ____
____
Ignition . . . . . ____
____
Power Control . . . ____
Fuel . . ____
(alt) ____
Oil . . ____
MCP Oil Consumption ____ gal/hr
Accessory Drive Provisions ____
Thrust to Weight Ratio . . ____ 1
Max Allowable Ave Steady-State Measured Temp (Combustor Exit) ____ °C(°F)

12 SIZE & WEIGHT

Length, Overall ____ in
Diameter, Nominal ____ in
Max Radial Projection . ____ in
Weight, Dry . . ____ lb
Weight, Wet . ____ lb

13 UTILIZATION

14 1 2

TABLE IV. TURBOFAN CHARACTERISTICS SUMMARY

①

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⑮

Performance

RATINGS AT STATIC SEA LEVEL STANDARD CONDITIONS

RATING	THRUST (lb)	RPM	SFC (lb/hr/lb)	MEAS GAS TEMP°C(°F)	AIRFLOW (lb/sec)

ALTITUDE RATINGS ~ US STANDARD ATMOSPHERE 1962 ~

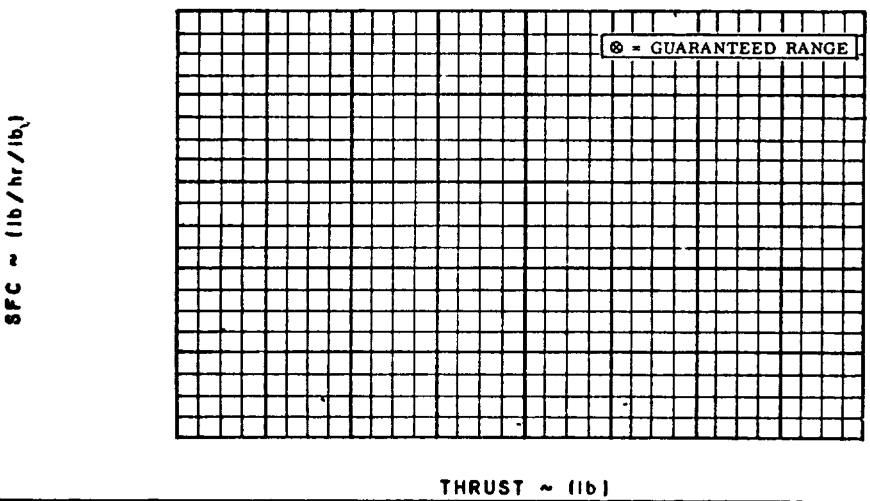
RATING	ALTITUDE (ft)	MACH NR	THRUST (lb)	SFC (lb/hr/lb)	MEAS GAS TEMP°C(°F)	AIRFLOW (lb/sec)

OPERATING LIMITS

Absolute Alt . . . . ft	Max Starting Alt, Basic . . . . ft
Limiting Mach Nr at sea level. . .	Max Starting Alt, Afterburner . . . ft

⑯

US STANDARD ATMOSPHERE 1962 ~ RAM EFFICIENCY



⑰

NOTES

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TABLE V. Gearbox Pads and Drives
REF.- 3.1.2.7, 3 7.9.4

NAME OF ACCESSORY OR COMPONENT	TYPE OF DRIVE (1)	RATIO OF PAD TO ROTOR SPEED (2)	DIRECTION OF ROTATION (FACING PAD)	TORQUE (LB. IN.)			OVERHUNG MOMENT (LB. IN.)
				MAXIMUM CONTINUOUS	OVERLOAD (3)	STATIC	

NOTES:
(1) Give the type of drive including AND or MS number and type.
(2) Ratio of speeds based on 100% engine rotor speed of _____ RPM.
(3) Specify duration and frequency of overload.

TABLE VI. Reliability Values

REF.- 3.2.3

	Hardware Reliability (MTBF in Hrs.)			Mean Time Between Power Loss (Hrs.)	Mean Time Between Shut Down (Hrs.)
	Failures Discovered Between Sched. Inspect.	Failures Discovered at Sched. Inspect.	Total		
Operational Suitability Testing					
$1\frac{1}{2}$ Years after IOC. (500,000 hrs.)					

TABLE VII. Combined Organizational and Field Level Maximum Allowable Maintainability Estimates (Mission Mix)

REF.- 3.2.4.1

Engine and Components	
Corrective * On Aircraft	________MH/FH
Corrective Off Aircraft	________MH/FH
Corrective Total	________MH/FH
Preventive	________MH/FH
NCDR On Aircraft	________hr/FH
NCDR Off Aircraft	________hr/FH

*Corrective Maintenance is Unscheduled Maintenance

MH/FH = Manhours per Engine Flight Hour

hr/FH = Hours per Engine Flight Hour

NCDR = Non-Concurrent Downtime Rate

Estimated time required for engine overhaul ___ days.

Estimated manhours required for engine overhaul ___**.

**Based on a typical Using Service overhaul facility operating at a reasonable level of efficiency.

TABLE VIII. Estimated Intermediate Organizational Maintenance for Operational Suitability Demonstration

REF.- 3.2.4.1

Elapsed Downtime (Average)	MMH/FH
Unscheduled	
Installed in Aircraft (Aircraft Downtime)	________
Off Aircraft (Engine Downtime)	________
Scheduled	
Periodic	________
Hot Section Audit	________

TABLE IX. Design Duty Cycles

REF.- 3.3.8.1, 3.3.8.3, 3.3.8.8,
3.7.6.7, 3.7.6.7.1, 4.6.6.2.1

SYSTEM CATEGORY		SERVICE LIFE (HRS)		LOW CYCLE FATIGUE REQUIREMENTS (CYCLES) (7) S-L T-O (4)	T & G (5)	THRUST REVERSE	COMBAT SUBSONIC CYCLES	COMBAT SUPERSONIC CYCLES	STRESS RUPTURE/CREEP REQUIREMENTS (6) POWER SETTING	ALTITUDE (FEET)	MACH NUMBER	TIME %
FIGHTER		COLD PARTS	4,000	3,500	2,000	--	2,200(1)	400(1)	MAX MAX (3)	(2) (2)	(2) SUPERSONIC .9	1 4
									INTERMEDIATE	10,000	.9	(8)30
FIGHTER		HOT PARTS	2,000	1,750	1,000	--	1,100(1)	200(1)	CRUISE LOITER	35,000 S.L.	.75 .3	60 5
BOMBER	GROUND ALERT	COLD PARTS	10,000	2,000	3,000	--	2,000(1)	1,000(1)	MAX MAX (3)	(2) (2)	(2) SUPERSONIC .9	4 1.0
									INTERMEDIATE	10,000	.9	(9)14.0
BOMBER	GROUND ALERT	HOT PARTS	5,000	1,000	1,500	--	1,000(1)	500(1)	CRUISE LOITER	40,000 S.L.	.8 .3	75.0 6
BOMBER	AIR ALERT	COLD PARTS	40,000	4,000	--	2,000	--	--	INTERMEDIATE	(2)	.75	5
BOMBER	AIR ALERT	HOT PARTS	10,000	1,000	--	500	--	--	CRUISE LOITER	35,000 (2)	.72 .5	45 50

NOTES:
(1) Include SLTO cycle - use as major cycle when more damaging.
(2) To be supplied by Using Service.
(3) Full afterburner.
(4) S-L T-O (Sea level takeoff).
(5) T&G (Touch and Go).
(6) Use stress rupture half life allowables for design with these charts.
(7) For design use factor of 2.00 times the cycles shown in this chart.
(8) 5% time at 80% and above P.S. has been included for ground run time.
(9) 1.5% of time at 80% and above P.S. has been included for ground run time.

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TABLE IX. Design Duty Cycles

REF.- 3.3.8.1, 3.3.8.3, 3.3.8.8,
3.7.6.7, 3.7.6.7.1, 4.6.6.2.1

SYSTEM CATEGORY	SERVICE LIFE (Hours)	LOW-CYCLE-FATIGUE RQMT (CYCLES) (6)				STRESS RUPTURE/CREEP RQMTS (5)			
		S-L T-O (2)	T&G (3)	Thrust Reverse	Subsonic Cycles	Power Setting	Altitude Feet	Mach Number	Time %
CARGO									
1. Assault									
Cold Parts	10 000								
Hot Parts	5 000								
2. Medium & Heavy									
Cold Parts	30 000	9 000	5 000	4 000	--	T.O.	S.L.	(1)	4(4)
Hot Parts	10 000	3 000	2 000	1 000	--	Cruise	30K	.7	87
						Idle	(1)	(1)	9
3. Utility									
Cold Parts	15 000								
Hot Parts	7 500								

Notes:
(1) To be supplied by Using Service.
(2) Sea-level takeoff.
(3) Touch and go.
(4) 3% time at 80% and above P.S. has been included for ground run tim.
(5) Use stress rupture half-life allowables for design with this chart.
(6) For design use factor of 2.00 times the cycles shown in this chart.

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TABLE IX. Design Duty Cycles

REF.- 3.3.8.1, 3.3.8.3, 3.3.8.8,
3.7.6.7, 3.7.6.7.1, 4.6.6.2.1

SYSTEM CATEGORY	SERVICE LIFE (HOURS)	LOW-CYCLE-FATIGUE RQMT (CYCLES) (9)				STRESS RUPTURE/CREEP RQMTS (8)			
		S-L T-O (2)	T&G (3)	THRUST REVERSE	SUBSONIC CYCLES	POWER SETTING	ALTITUDE (FEET)	MACH NUMBER	TIME %
TRAINER									
						Max. (6)	S.L.	(1)	1
						Max. (7)	(1)	(1)	3
COLD PARTS	5000	5000	7500	--	3500 (4)	INT	10K	(1)	25 (5)
HOT PARTS	2500	2500	2500	--	1750 (4)	Cruise	(1)	(1)	64
						Idle	(1)	(1)	7

NOTES:
(1) To be supplied by Using Service.
(2) Sea-level takeoff.
(3) Touch and Go.
(4) Includes SLTO cycle -- use as major cycle when more damaging.
(5) 5% time at 80% and above P.S. has been included for ground run time.
(6) T.O. A/B
(7) A/B Supersonic FLT
(8) Use stress rupture half-life allowables for design with this chart.
(9) For design use factor of 2.00 times the cycles shown in this chart.

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TABLE X. Fuel Contaminants

REF.- 3.7.3.3.2, 3.7.3.4

CONTAMINANT	PARTICLE SIZE	QUANTITY
Ferroso-Ferric Iron Oxide (Fe_3O_4, (Black color) Magnetite)	0 - 5 microns	14.5 gm/1,000 gal.
Ferric Iron Oxide (Fe_2O_3, Hematite)	0 - 5 microns	14.5 gm/1,000 gal.
Iron Oxide	5 - 10 microns	1.5 gm/1,000 gal.
Crushed Quartz	1000 - 1500 microns	.25 gm/1,000 gal.
Crushed Quartz	420 - 1000 microns	1.75 gm/1,000 gal.
Crushed Quartz	300 - 420 microns	1.0 gm/1,000 gal.
Crushed Quartz	150 - 300 microns	1.0 gm/1,000 gal.
Prepared dirt conforming to A.C. Spark Plug Co. Part No. 1543637 (coarse Arizona road dust)	Mixture as follows: 0 - 5 microns (12 percent) 5 - 10 microns (12 percent) 10 - 20 microns (14 percent) 20 - 40 microns (23 percent) 40 - 80 microns (30 percent) 80 - 200 microns (9 percent)	8.0 gm/1,000 gal.
Cotton Linters	Below 7 staple (U.S. Department of Agriculture Grading Standards SRA- AMS 180 and 251)	0.1 gm/1,000 gal.
Crude Napthenic Acid		0.03 percent by volume
Salt water prepared by dissolving salt in distilled water of other water containing not more than 200 parts per million of total solids	4 parts by weight of NaCl 96 parts by weight of H_2O	0.01 percent by volume entrained

TABLE XI. Fuel Properties for Tests
REF.- 4.3.4.6, 4.3.5.10

Fuels are to be procured to specification MIL-T-5624, except as follows:

REQUIREMENT	JP-4		JP-5	
	min	max	min	max
Distillation:				
Fuel recovered, 10 percent		210°F		400
" " 20 percent	180	230	385	415
" " 50 percent	230	290	410	440
" " 90 percent	325	400	460	500
End point		470		550
Gravity, °API	50.0			43.0
Sulfur, total, wt. percent	.004		.004	
Freezing point, °F		-67		-40
Viscosity, centistokes as -30°F			10.0	
Aromatics, volume percent	10.0		10.0	
Smoke point, mm.				21.
Flash point, °F			120	
Corrosion inhibitor				none

Where no specific limit is given above, the limits of MIL-T-5624 apply.

TABLE XII. DATA RECORDING REQUIREMENTS

REF.- 4.3.5.4, 4.3.5.5, 4.3.5.6

	DATA RECORDING FREQUENCY			TAKEN DURING TESTS	
	START	ONCE/30 MIN OR ONCE/CYCLE STEADY-STATE	CONTINUOUSLY DURING TRANSIENTS	CAL/RECAL	PFRT/QT
1. Time of day	X	X		X	X
2. Total endurance time					X
3. Power setting	X	X		X	X
4. Exhaust nozzle throat, nozzle discharge, and bypass nozzle throat areas sq. in.	X			X	X
5. Exhaust nozzle position	X	X	X	X	X
6. Engine rotor(s) speed(s) rpm	X	X	X	X	X
7. Rotor speed(s) at idle rpm	X	X			
8. Rotor speed(s) at ignition rpm	X	X			
9. Rotor speed(s) at starter cutout rpm	X	X			
10. Engine Fuel Flow lb/hr		X	X	X	X
11. Afterburner Fuel Flow lb/hr		X	X	X	X
12. Thrust, lb		X	X	X	X
13. Data for determining airflow, including W^*_{ah} and W^*_{ac} and W^*_{as} lb/sec		X		X	
14. Engine inlet total pressure average in Hg abs		X		X	X
15. Engine inlet total temperature average °C(°F)	X	X		X	X
16. Compressor discharge total pressure in Hg abs		X	X	X	X
17. Compressor air bleed total pressure (Customer) psia		X	X	X	
18. Compressor air bleed total pressure (Acceleration) psia			X		

TABLE XII. DATA RECORDING REQUIREMENTS
(Continued)

	DATA RECORDING FREQUENCY			TAKEN DURING TESTS	
	START	ONCE/30 MIN OR ONCE/CYCLE STEADY-STATE	CONTINUOUSLY DURING TRANSIENTS	CAL/RECAL	PFRT/QT
19. Compressor air bleed static pressure (Customer) psia		X		X	X
20. Compressor air bleed static pressure (Acceleration) psia			X		
21. Compressor air bleed total temperatures (all ports) °C(°F)		X		X	X
22. Compressor bleed airflow rate (all ports) lbs/sec		X		X	X
23. Turbine discharge total pressure average in Hg abs		X		X	X
24. Bypass exit total pressure in Hg abs		X		X	X
25. Bypass exit static pressure in Hg abs		X		X	X
26. Bypass exit total temperature °C(°F)		X		X	X
27. Exhaust nozzle exit total pressure in Hg abs		X		X	
28. Exhaust nozzle static pressure in Hg abs		X		X	X
29. Exhaust nozzle total temperature °C(°F)		X		X	X
30. Oil flow lb/min		X		X	X
31. Oil inlet temperature at pressure pump inlet °C(°F)	X	X		X	X
32. Oil pressure at pressure pump inlet psig	X	X		X	X
33. Oil pressure at pressure pump outlet psig	X	X		X	X
34. Oil pressure at scavenging pump outlet psig		X		X	X
35. Oil temperature at scavenging pump outlet °C(°F)		X		X	X
36. Oil temperature at outlet from fuel/oil cooler °C(°F)		X		X	X

TABLE XII. DATA RECORDING REQUIREMENTS
(Continued)

	DATA RECORDING FREQUENCY		TAKEN DURING TESTS		
	START	ONCE/30 MIN OR ONCE/CYCLE STEADY-STATE	CONTINUOUSLY DURING TRANSIENTS	CAL/RECAL	PFRT/QT
37. Oil consumption for each cycle of the PFRT and QT		X			
38. Fuel pressure at fuel system inlet psig	X	X		X	X
39. Fuel pressure at point shown on engine configuration and envelope figure psig	X	X		X	X
40. Fuel temperature at fuel system inlet °C(°F)		X		X	X
41. Fuel temperature at outlet from fuel/oil cooler °C(°F)		X		X	X
42. Measured gas temperature °C(°F)	X	X	X	X	X
43. Maximum measured gas temperature °C(°F)	X	X			
44. Liquid injection flow lb/hr (eg., water)		X		X	X
45. Engine vibration at points shown on engine configuration and envelope figure velocity-in/sec	X	X	X	X	X
46. Accessory compartment temperature(s) where applicable °C(°F)		X		X	X
47. Cooling air inlet temperature °C(°F)		X		X	X
48. Cooling air outlet temperature °C(°F)		X		X	X
49. Engine condition monitoring system data (list each parameter)		X		X	X
50. Cell static pressure in Hg abs	X	X		X	X
51. Ignition source voltage and current (when external power is being used)	X	X		X	
52. Oil leakage at accessory pads		X		X	X

TABLE XII. DATA RECORDING REQUIREMENTS (Continued)

	DATA RECORDING FREQUENCY			TAKEN DURING TESTS	
	START	ONCE/30 MIN OR ONCE/CYCLE STEADY-STATE	CONTINUOUSLY DURING TRANSIENTS	CAL/RECAL	PFRT/QT
53. Start number	X			X	
54. Time to ignition actuation	X				X
55. Time to light-off	X			X	X
56. Time to starter cutout	X			X	X
57. Time to stabilized idle RPM	X			X	X
58. Time to oil pressure indication (at point shown on engine configuration and envelope figure)	X			X	X
59. Time to stabilize to normal oil pressure (at point shown on engine configuration and envelope figure)	X			X	X
60. Additional data as required by the Using Service	X	X	X	X	X

NOTE:

Wah = hot airflow

Waf = cold airflow

Was = secondary airflow

TABLE XIII. Sea Level Anti-Icing Conditions

REF.- 4.6.4.2

	PART 1			PART 2
Engine Inlet Total Temperature	$-4^{\circ}F(-20^{\circ}C)\pm1^{\circ}$	$+15^{\circ}F(-10^{\circ}C)\pm1^{\circ}$(1)	$+23^{\circ}F(-5^{\circ}C)\pm 1^{\circ}$	$23^{\circ}F(-5^{\circ}C)\pm1^{\circ}$
Velocity	0 to 60 knots	0 to 60 knots	0 to 60 knots	0 to 60 knots
Altitude	0 to 500 ft	0 to 500 ft	0 to 500 ft	0 to 500 ft
Mean Effective Drop Diameter	20 microns	20 microns	20 microns	30 microns
Liquid Water Content (Continuous)	1 gm/m^3 ±0.25 gm/m^3	2 gm/m^3 ±0.25 gm/m^3	2 gm/m^3 ±0.25 gm/m^3	0.4 gm/m^3 ±0.1 gm/m^3

(1) This condition is deleted for non-fan engines.

TABLE XIV. Schedule of Salt Spray Injection Endurance Cycle*

REF.- 4.6.4.3

Phase (Note 3) No.	Duration of Phase Hrs.	Test Engine Operation	Salt Solution Injected Parts per Billion (PPB)	Engine Ambient Air	
				Temperature	Relative Humidity
1	3 (Notes 1 & 5)	Operating	200 (Note 4)	$10^{\circ}C$ Min.	73% Min.
2	2	Not Operating	0	Atmospheric	Atmospheric
3	7	Not Operating	200 (Notes 2 and 4)	$10^{\circ}C$ Min	73% Min.
4	12	Not Operating	0	$43 \pm 5^{\circ}C$	90% Min.
5	3 (Notes 1 & 6)	Operating	200 (Note 4)	$10^{\circ}C$ Min.	73% Min.
6	2	Not Operating	0	Atmospheric	Atmospheric
7	7	Not Operating	200 (Notes 2 and 4)	$10^{\circ}C$ Min.	73% Min.
8	12	Not Operating	0	$43 \pm 5^{\circ}C$	90% Min.

*See next page for explanation of Notes 1 through 4.

Notes: 1. During shutdown, while the engine is decelerating from idle, the salt solution shall continue to be sprayed into the engine until the rotor has come to rest.

2. The test facility blower system will provide the flow of salt-laden air through the engine gas flowpath(s) and over the external surfaces of the engine.

3. Engine inlet and exhaust openings shall remain open for all phases of the test cycle.

4. Salt solution ingested by the engine shall conform to that specified in 4.6.4.3 and shall be regulated to provide a constant concentration of 200 ppb by weight during those phases of each cycle which require salt ingestion. A salt sampling system shall be employed to determine the concentration level during each cycle of operation.

5. Phase 1 Engine Operating Cycle (Total accumulative time - 3 hours)

(1) Four 10-munutes cycles, each consisting of five minutes at maximum power followed by five minutes at idle.

(2) 110 minutes at maximum continuous power.

(3) 30 minutes at intermediate power

6. Phase 5 Engine Operating Cycle (Total accumulative time - 3 hours)

(1) 10 minutes at maximum continuous power.

(2) Six five (5) minute cycles consisting of two and one-half minutes at idle, followed by two and one-half minutes at intermediate power.

(3) 130 minutes at ninety (90) percent maximum continuous power.

(4) 10 minutes at maximum continuous power.

APPENDIX A

REQUIREMENTS FOR PFRT

Para. No.	Requirement	Analysis	Demonstration	Test	Notes
3.1.2.5	Externally Applied Forces	X			A
3.1.2.8.2	Heat Rejection and Cooling Test Report	X			A
3.2.3	Reliability	X			B
3.2.5.5	Corrosion Susceptibility	X		X	C
3.3.1.1	Materials and Processes	X			D
3.3.2	Electromagnetic Interference	X			E
3.3.5	Interchangeability	X			F
3.3.8.4	Engine Pressure Balance	X			A
3.3.8.6	Strength and Life Analysis	X			A
3.3.8.10.2	Vibration and Stress Analysis	X			A
3.7.7.4.6	Wear Rate Analysis	X			K
3.7.10.3	Infrared Radiation	X			R
3.9.1	Engineering Evaluation Tests	X			G
4.3.5.1	Pre-test Data	X			H
4.3.6.1	Test Reports	X			I
4.3.6.2	Summary Reports	X			J
4.4.1	Customer Air Bleed			X	K
4.4.2	Engine Heat Rejection and Oil Cooling			X	L
4.4.3	Oil Flow Interruption Test			X	G
4.4.4	Engine Electrical Power Failure Tests			X	G
4.4.5	Engine Vibration Survey	X			M
4.4.6	Starting Torque		X		N,S
4.4.7	Verification of Correction Factors	X		X	S
4.4.9	Materials Corrosion Test			X	C
4.5.1.1.1	Engine Dry Weight		X		O
4.5.1.1.2	Power Lever Torque		X		
4.5.1.2.1	Temperature Sensing System Calibration			X	
4.5.1.2.2	Engine Control System Calibration			X	P
4.5.1.2.3	Engine Calibration			X	
4.5.1.2.3.1	Compressor Bleed Air Analysis	X		X	Q
4.5.1.3	Endurance Test Procedure			X	
4.5.1.3.1	Starts			X	
4.5.1.4.1	Engine Recalibration			X	
4.5.1.4.2	Temperature Sensing System Recalibration			X	

Para. No.	Requirement	Analysis	Demonstration	Test	Notes
4.5.1.4.3	Engine Control System Recalibration			X	
4.5.1.5	Engine Disassembly and Inspection	X			
4.5.1.6	Endurance Test Completion	X			
4.5.2	Engine Component Tests			X	
4.5.2.2	Explosion-proof			X	
4.5.2.3	Fuel Pump Altitude-proof Test			X	
4.5.2.4	Oil Reservoir Pressure Test			X	
4.5.2.5	Fire Test			X	
4.5.3	Altitude Test (Engine)			X	
4.5.3.1	Altitude Engine Calibration			X	
4.5.3.2	Altitude Test Procedure			X	
4.5.3.3	Altitude Test Completion	X			
4.5.4	Detail Tests			X	
4.5.4.1	Engine Pressure Tests			X	
4.5.4.2	Rotor Structural Integrity			X	
4.5.4.2.1	Overspeed			X	
4.5.4.2.2	Overtemperature			X	
4.5.4.2.3	Disc Burst Test			X	
4.5.4.3	Engine Static Load Test			X	
4.5.4.4	Attitude Test			X	
4.5.4.5	EMI and Susceptibility Tests			X	

NOTES:

A. A report shall be submitted to the Using Service prior to the initiation of the PFRT.
B. An engine failure mode and effect analysis shall be performed prior to PFRT.
C. The proposed materials and coatings test plan shall be submitted to the Using Service prior to initiation of the materials test. A report of the materials testing shall be furnished to the Using Service prior to the start of the PFRT.
D. When engine manufacturer's documents are used for materials and processes, such documents shall be subject to review by the Using Service prior to the start of the PFRT.
E. An EMI control plan and an EMI/EMC test plan, as required by MIL-STD-461, shall be prepared prior to PFRT.
F. Matched or selected fit parts shall be identified and a listing shall be provided to the Using Service prior to PFRT.
G. Test reports shall be submitted prior to the completion of the PFRT.
H. Pre-test data shall be submitted to the Using Service for approval prior to the initiation of each test or demonstration required for PFRT.

NOTES (continued):

I. Test reports shall be submitted to the Using Service for approval following completion of each test or demonstration required for PFRT.
J. Summary reports shall be submitted to the Using Service following completion of PFRT.
K. A report shall be submitted prior to the start of PFRT endurance test.
L. A report verifying the analytical heat rejection and surface temperature analysis shown in the engine specification shall be submitted to the Using Service prior to the initiation of the PFRT.
M. A vibration survey report shall be submitted to the Using Service for approval prior to the initiation of the PFRT endurance test.
N. Procedure for accomplishing the starting torque demonstration shall be submitted to the Using Service for approval prior to initiation of the test.
O. Engine weight shall be measured, before the engine has been serviced with fuel or oil, prior to initiation of calibrations.
P. Shall be performed prior to the Engine Calibration of 4.5.1.2.3.
Q. The results of the bleed air analysis and the methods and test apparatus used shall be detailed in the engine test report.
R. The maximum IR levels for the specified azimuth, elevation, bandpass, altitude, and engine power settings shall be submitted to the Using Service prior to the initiation of the PFRT.
S. A test report shall be submitted to the Using Service prior to the initiation of the PFRT.

APPENDIX B

REQUIREMENTS FOR QT

Para. No.	Requirement	Analysis	Demonstration	Test	Notes
3.2.3	Reliability	X			A
3.3.2	Electromagnetic Interference	X			B
3.3.5	Interchangeability	X			C
3.3.8.6	Strength and Life Analysis	X			D
3.5.1.5	Repair Procedures and Wear Limits	X			E
3 7.6.7.1	Relative Damage Chart	X			F
3.7.7.3.1	Oil Flow and Heat Rejection	X			G
3.7.7.4.6	Wear Rate Analysis	X			P
3.9.1	Engineering Evaluation Tests	X			H
4.3.5.1	Pre-test Data	X			I
4.3.6.1	Test Reports	X			J
4.3.6.2	Summary Reports	X			K
4.4.2	Engine Heat Rejection and Oil Cooling			X	G
4.4.8	Maintainability/Maintenance Demonstration		X		
4.6.1	Endurance Test			X	
4.6.1.1.1	Engine Dry Weight		X		L
4.6.1.1.2	Electromagnetic Interference and Susceptibility Tests			X	
4.6.1.1.3	Power Lever Torque		X		
4.6.1.2.1	Temperature Sensing System Calibration			X	
4.6.1.2.2	Engine Control System Calibration			X	N
4.6.1.2.3	Engine Calibration			X	
4.6.1.2.3.1	Compressor Bleed Air Analysis	X		X	M
4.6.1.3	Endurance Test Procedure			X	
4.6.1.3.1	Starts			X	
4.6.1.4.1	Engine Recalibration			X	
4.6.1.4.2	Temperature Sensing System Recalibration			X	
4.6.1.4.3	Engine Control System Recalibration			X	
4.6.1.5	Engine Disassembly and Inspection	X			
4.6.1.6	Engine Reassembly and Retest			X	
4.6.1.7	Endurance Test Completion	X			
4.6.2	Engine Component Tests			X	

Para. No.	Requirement	Analysis	Demonstration	Test	Notes
4.6.2.2	Simulated Operational Component Tests			X	
4.6.2.2.1	Component Calibration			X	
4.6.2.2.2	Component Test Procedures			X	
4.6.2.2.3	Component Test Cycles			X	0
4.6.2.2.3.1	Fuel Pump Test Cycle			X	
4.6.2.2.3.2	Engine Control System Test Cycle			X	0
4.6.2.2.3.3	Ignition System			X	
4.6.2.2.4	Accelerated Aging			X	
4.6.2.2.5	High Temperature			X	
4.6.2.2.6	Room Temperature Endurance			X	
4.6.2.2.7	Low Temperature			X	
4.6.2.2.8	Fuel Pump Cavitation			X	
4.6.2.2.9	Recalibration			X	
4.6.2.2.10	Component Test Completion	X			
4.6.2.3	Environmental Component Test			X	
4.6.2.3.1	Component Calibration			X	
4.6.2.3.2	Component Test Procedures			X	
4.6.2.3.3	Humidity			X	
4.6.2.3.4	Fungus			X	
4.6.2.3.5	Explosion Proof			X	
4.6.2.3.6	Sand and Dust			X	
4.6.2.3.7	Sustained Acceleration			X	
4.6.2.3.8	Impact			X	
4.6.2.3.9	Vibration			X	
4.6.2.3.10	Ignition System Fouling			X	
4.6.2.3.10.1	Carbon Fouling			X	
4.6.2.3.10.2	Water Fouling			X	
4.6.2.4	Individual Component Tests			X	
4.6.2.4.1	Oil Reservoir			X	
4.6.2.4.2	Accessory Drive/Power Takeoff			X	
4.6.2.4.3	Generator/Alternator Test			X	
4.6.2.4.4	Heat Exchangers			X	
4.6.2.4.5	Fire Test			X	
4.6.2.4.6	Hydraulic System			X	
4.6.3	Altitude Test (Engine)			X	
4.6.3.1	Altitude Engine Calibration			X	
4.6.3.2	Altitude Test Procedure			X	
4.6.3.3	Altitude Test Completion	X			
4.6.4	Engine Environmental and Ingestion Test			X	

Para. No.	Requirement	Analysis	Demonstration	Test	Notes
4.6.4.1	Low and High Temperature Starting and Acceleration Test			X	
4.6.4.2	Environmental Icing Test			X	
4.6.4.3	Corrosion Susceptibility Test			X	
4.6.4.4	Bird Ingestion Test			X	
4.6.4.5	Foreign Object Damage Test			X	
4.6.4.6	Ice Ingestion Test			X	
4.6.4.7	Sand Ingestion Test			X	
4.6.4.8	Atmospheric Water Ingestion Test			X	
4.6.4.9	Armament Gas Ingestion Test			X	
4.6.4.10	Noise Survey		X		
4.6.4.11.1	Exhaust Smoke Emissions			X	
4.6.4.11.2	Invisible Exhaust Mass Emissions		X		
4.6.4.12	Nuclear Hardening Tests			X	
4.6.5	Engine Characteristics and Fuel Tests		X	X	
4.6.5.1	Starting Torque		X		
4.6.5.2	Radar Cross Section (RCS)		X		
4.6.5.3	Infrared Radiation Test		X		
4.6.5.4	Alternate Fuel Test			X	
4.6.5.5	Emergency Fuel Test			X	
4.6.6	Structural Tests			X	
4.6.6.1	Engine Pressure Tests			X	
4.6.6.2.1	Low Cycle Fatigue Component Tests			X	
4.6.6.2.2	Low Cycle Fatigue Engine Test			X	
4.6.6.3	Containment			X	
4.6.6.4.1	Overspeed			X	
4.6.6.4.2	Overtemperature			X	
4.6.6.4.3	Disc Burst Test			X	
4.6.6.5	Engine Static Load Test			X	
4.6.6.6	Vibration and Stress Test			X	
4.6.6.7	Gyroscopic Test			X	

NOTES:

A. An engine failure mode and effect analysis shall be revised as required prior to QT.

NOTES (continued):

B. An EMI control plan and an EMI/EMC test plan, as required by MIL-STD-461, shall be prepared prior to QT.
C. Matched or selected fit parts shall be identified and a listing shall be provided to the Using Service prior to QT.
D. The strength and life analysis report shall be updated prior to QT.
E. The contractor shall establish, prior to QT, after-run wear limits, standards, and parts repair procedures.
F. A relative damage chart shall be submitted prior to the initiation of the QT.
G. A report verifying the heat balance analysis shown in the engine specification shall be submitted to the Using Service prior to the initiation of the qualification endurance test.
H. A report shall be submitted prior to the completion of the QT.
I. Pre-test data shall be submitted to the Using Service for approval prior to the initiation of each test or demonstration required for QT.
J. Test reports shall be submitted to the Using Service for approval following completion of each test or demonstration required for QT.
K. Summary reports shall be submitted to the Using Service following completion of QT.
L. Engine weight shall be measured, before the engine has been serviced with fuel or oil, prior to the initiation of calibrations.
M. The results of the bleed air analysis and the methods and test apparatus shall be detailed in the engine test report.
N. Shall be performed prior to the Engine Calibration of 4.6.1.2.3.
O. The test cycle shall be defined by the contractor and submitted to the Using Service in the pre-test data.
P. A report shall be provided to the Using Service prior to the endurance portion of the QT.

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