SAE The Engineering Society For Advancing Mobility Land Sea Air and Space

400 COMMONWEALTH DRIVE, WARRENDALE, PA 15096

AEROSPACE STANDARD

AS 943A

Issued 1-31-68
Revised 12-31-86
Supersedes AS 943

Submitted for recognition as an American National Standard

ENTIRE STANDARD REVISED

STARTER, PNEUMATIC, AIRCRAFT ENGINE, GENERAL SPECIFICATION FOR

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1. SCOPE: The starters covered by this specification shall be designed to operate on compressed air from ground support equipment, engine interbleed or on board air supply for the purpose of starting aircraft jet engines.

2. APPLICABLE DOCUMENTS: The documents listed in Appendix A, unless obsoleted, shall form a part of this specification to the extent specified herein. The applicable issue of each shall be that in effect on the date of issue of this AS, unless otherwise specified. Buyer or contractor specifications may be used, provided a clear relation to existing similar military specification is available. For additional information, a listing of applicable SAE documents (ARP's, AIR's, AS) is included in Appendix A.

3. REQUIREMENTS

3.1 Qualification Testing: This specification makes provision for qualification testing.

3.2 Model Specification: When required by the purchaser, a starter model specification in accordance with the outline and instructions for preparation specified herein shall be prepared by the starter contractor and submitted to the purchaser for approval. The appropriate approval status shall be shown on page 1. After specification approval, changes shall be submitted as amendments. Each amendment shall be approved and shall include and supersede the previous amendment. A model specification may be revised only to incorporate previously approved amendments. Such a revision must be complete or alternately must include a "revision status" listing, showing the current issue of each page of the document.

3.2.1 The headings and numbering of sections and paragraphs in the model specification shall correspond to those in this specification. Data required by this specification and such other additional data as may be required to completely describe the unit, shall be included in the model specification. (Omission of reference in the model specification to a particular requirement of this specification by the starter manufacturer shall be interpreted as compliance therewith, unless otherwise noted by the detail specification.) When departures from the requirements of this specification are necessary, the details of such departures shall be stated as specific requirements bearing the same section, paragraph heading and numbering as in this specification. In the event of conflict, the model specification shall govern.

3.2.2 All applicable documents shall be listed in numerical order in section 2 of the model specification and shall include the applicable revision and date of issue.

3.2.3 The model specification shall be assigned a model number and a part number by the starter manufacturer. When a revised model specification is submitted, it shall be designated by the use of the model number and the part number with the part number followed by a dash and a number. Date of the revision shall be shown on page 1 only. The model number and the part number followed by a dash and the revision suffix number shall be shown on subsequent pages.

3.2.4 For purposes of permitting preliminary evaluation of a proposed starter design, or for release of approved starter performance characteristics in connection with a design competition, the starter manufacturer shall submit a preliminary model specification to serve until superseded by a complete coordinated model specification which will be required for a production contract.

3.2.5 All curves shall be presented on graph paper having an adequate number of subdivisions to permit easy interpolation.

3.2.6 Definitions and Symbols: Terms, their definitions and symbols used in the model specification shall be in accordance with 6.2 and 6.3 herein.

3.2.7 A cross reference of Requirements and Verification Means is included in Appendix B herein.

3.3 Mockup: When required by the customer, a full scale mockup shall be prepared for examination and approval by the customer. At completion of the qualification test, the mockup of the final configuration shall be furnished to the customer.

3.3.1 Changes: Changes to the starter features requiring changes in the vehicle or ground support equipment made after approval of the mockup shall be submitted to the purchaser for approval in accordance with DOD-STD-480. Any changes required by the purchaser shall be subject to negotiation as provided in the contract. Unless otherwise authorized, the mockup shall be kept current with approved changes.

3.4 Components: Normally, the complete starter shall consist of the following assemblies and systems:

a. Energy conversion and speed reduction assembly (3.11.1 herein)
b. Clutch and output assembly (3.11.2 herein)
c. Control System (3.11.3 herein)
d. Lubrication System (3.11.4 herein)
e. Containment Provisions (3.6.1 herein)

3.5 Materials

3.5.1 Metals: Metal parts in storage or service use as defined by the purchaser, shall be of the corrosion resistant type or suitably treated to resist corrosion due to fuels, oil, hydraulic fluid, combustion gases or residue, or atmospheric conditions likely to be met in storage or service use. Any corrosion resistant protective coating used shall have adequate resistance to cracking, chipping and scaling with age, use or extremes of atmospheric conditions.

3.5.2 Dissimilar Metals: Unless protected against electrolytic corrosion, dissimilar metals shall not be used in contact with each other. Dissimilar metals are defined in MIL-STD-889B.

3.5.3 Synthetic Rubber Parts: Age of synthetic rubber parts shall be controlled in accordance with MIL-STD-1523.

3.5.4 Castings: Castings shall be classified and inspected in accordance with MIL-C-6021.

3.5.5 Organic Materials: Materials that are nutrients for fungi shall not be used where it is practical to avoid them. If used, nutrient materials and their associated fungicidal treatment shall be identified in the model specification.

3.6 Design and Fabrication: The starter shall be designed for operational use with pneumatic energy sources. The design shall be amenable to production processing methods.

3.6.1 Overspeed Protection: When not provided as part of the aircraft system, the starter shall incorporate both the following features:

3.6.1 Continued

a. Except for particles emitted from the exhaust, which do not contain sufficient energy to cause harm to equipment, structure or personnel, the starter shall be capable of containment of all starter fragments within its envelope and remain on its mount should a failure at free run speed occur with air at the worst combination of pressure and temperature possible in the system from sea level to the maximum aircraft operational altitude. The starter shall be designed to provide containment of maximum energy hub burst (3 piece 120° segments) of the turbine wheel at a speed not less than the maximum cutout speed or the maximum free running speed as specified in the detail specification. Containment shall also be provided for a turbine blade separation or a rim separation, if the turbine rotor is fused at the separation speed. Containment demonstration of all high speed rotating components shall be required.

b. The starter shall incorporate a speed limiting feature which will safely limit the starter speed, either loaded or unloaded. The speed limiting feature(s) shall limit rotation of all high speed components to less than 100% of the minimum burst speed(s). The limiting feature shall not require manual resetting and shall function, as necessary, throughout the overhaul life of the starter without maintenance or adjustment. The speed limiting feature(s) shall be described in detail in the model specification. The containment requirement shall address nacelle structural and design considerations, such as fuel line proximity and location of other critical engine equipment, as will be made available by the airframe manufacturer.

3.6.2 External Surface Temperature: The external surface temperature of the starter shall not exceed the value specified in the detail specification during or following any operating condition, throughout the ambient temperature range specified. This temperature is exclusive of any external influences such as engine radiated heat. Provisions necessary to meet this requirement shall be integral with the starter.

3.6.3 Emergency Disengagement: When required by detail specification, an automatic emergency starter drive disengagement mechanism shall be incorporated external of the starter gear section to effect emergency disengagement of the starter from the engine in the event normal disengagement does not occur. The disengaging mechanism shall be so designed that removal of the starter from the engine pad shall be required to effect re-engagement of the starter drive. An attempted start, after an emergency disengagement has been experienced, shall not cause damage to the starter or engine. The disengagement mechanism shall be described in detail and its operating limits specified in the model specification.

3.6.4 Loads and Forces: The starter shall withstand the required number of operational cycles as specified in the detail specification, without permanent deformation or degradation of the performance, when subjected to the maximum normal forces resulting from the combination of loads and rotational accelerations specified in the detail specification. The starter shall not rupture and shall remain on its mounting pad when subjected to the design limit torque load including the torque loading resulting from turbine wheel seizure. The loading of the starter shall include that portion of the valve and duct weight supported by the starter. The external loading requirements shall be as specified in the detail specification.

3.6.4.1 External Loads - The load factors and rotational accelerations are to be considered acting separately and in combination with the design limit torque load and overhung moment.

3.6.5 Electrical Equipment: All electrical equipment shall be designed in accordance with MIL-E-25499 and MIL-C-5015. Electrical power, either generated or used, shall meet requirements of MIL-STD-704.

3.6.6 Threads

3.6.6.1 Straight Screw Threads: All conventional straight screw threads shall conform to the requirements of MIL-S-8879 except for electrical connections, thermocouple harness, fluid fittings and ground and cut threads incorporated in proprietary parts which do not have equivalent standards. All exceptions shall confirm to Fed. Std. H28.

3.6.6.2 Tapered Pipe Threads: Tapered pipe threads shall be in accordance with MIL-P-7105 and may be used only for permanently plugging drilled or cored openings. Pipe threads shall not require the use of inserts.

3.6.6.3 Threaded Inserts: All straight threaded connections in non-ferrous materials which are heavily loaded or removed frequently shall have steel inserts which are suitably protected from electrolytic corrosion. Fill and drain boss inserts shall be designed to permit the use of standard gaskets or seals and standard straight thread plugs.

3.6.7 Mounting and Drive Provisions: Unless specified otherwise in the detail specification, the starter shall incorporate a quick-attach-detach (QAD) type of mounting flange. Any adapter, required to modify the engine accessory drive in order to mount the starter or to make the starter drive compatible with the engine drive, shall be furnished with the starter. The adapter shall provide for indexing and torsional restraint of the starter. Mounting of the starter shall be accomplished without requiring any measurements or adjustments of the engine accessory drive or starter prior to installation. Operation of the QAD mounting shall be such that the starter will always be in the same position. The device for actuation of the QAD mounting shall be retained when not in use.

3.6.8 Envelope: All components of the starter shall be contained within the envelope dimensions specified in the detail specification. The required dimensions and tolerances together with clearances required for removal shall be specified on the installation drawing.

3.6.9 Weight: The weight of the starter shall be specified in the model specification and shall not exceed that specified in the detail specification. The weight should be specified as both dry weight and weight when serviced with the prescribed amount of lubricant.

3.6.10 Overhung Moment: Maximum overhung moment of the complete starter, serviced with lubricant, shall be specified in the model specification and shall not exceed that specified in the detail specification when measured from the face of the mounting flange. The location of the starter's center of gravity shall be specified on the starter vendor's outline drawing.

3.6.11 Polar Moment of Inertia: The effective mass polar moment of inertia of the starter rotating parts at the starter drive shall be specified in the model specification.

3.6.12 Inspection Seals: The model specification shall specify inspection seal locations if required.

3.6.13 Safetying: All fittings and attachments shall have approved self locking features or shall be lockwired.

3.6.14 Drainage: The starter shall incorporate provisions for drainage or be configured to prevent water from accumulating within the unit. Drainage shall be such that any condensed or accumulated water will not cause malfunction or cause delay in starting if frozen.

3.6.15 Fitting Identification: The starter shall be marked to indicate connections and ports as required by the model specification.

3.6.16 Indexing: All components of the starter, such as the pneumatic plenum and gear train housing, shall be indexed relative to each other to prevent mispositioning of the components with respect to the mounting pad during starter assembly.

3.6.17 Accessibility: Parts of the starter that require routine service checking, adjustment or replacement shall be readily accessible for servicing and replacement without disassembly of the unit or removal of any major part, component or accessory.

3.6.17.1 Lubrication Data Plate: A lubrication plate, which shall provide the following information, shall be located near the filler plug, or sight glass if provided. The plate shall specify type of oil, capacity and any fill instructions required. Check and drain periods will be specified via maintenance instructions or the model specification.

3.6.18 Disassembly: Design of the starter, if possible, shall be such that no special tools are required for disassembly or re-assembly of the unit or its components. All of the special tools required shall be defined in the model specification and the appropriate overhaul manual.

3.6.19 Handling Support: When the weight of the unit warrants, the starter shall have provisions incorporated for hoisting and resting the unit on a level area without damaging lines, cables, fittings or components attached to the surface of the unit.

3.6.20 Cover Plate: Cover plates or plugs, which shall be suitable for transient or storage conditions, shall be provided for all openings on the starter.

3.6.21 Overhaul Life: The unit shall perform in accordance with the requirements of this specification throughout the start cycles and hours of overrunning as specified in the detail specification.

3.6.22 Design and Fabrication Changes: No changes shall be made in the design of parts or materials listed in the approved starter parts list except when such changes are approved in accordance with the provisions of MIL-STDS-480 and 481.

3.6.23 Material Substitutions: Temporary material substitutions shall be made in accordance with agreed customer/supplier procedures.

3.6.24 Approval of Changes: Approval of changes does not relieve the contractor of full responsibility for the results of such changes on starter characteristics.

3.6.25 Changes in Vendors: No changes shall be made in vendors of source control items except when such changes are approved by the purchaser.

3.6.26 ø Parts List: The parts list for the starter that successfully completes the qualification test shall constitute the approved parts list for subsequent starters of the same model to be delivered to the purchaser.

3.7 Inspection Processes and Certification

3.7.1 Magnetic Particle Inspection: Magnetic particle inspection shall be in accordance with MIL-I-6866.

3.7.2 Fluorescent Penetrant Inspection: Fluorescent penetrant inspection shall be in accordance with MIL-I-6868.

3.7.3 Radiographic Inspection: Radiographic inspection shall be in accordance with MIL-STD-453.

3.7.4 Radiographic Inspection Certification: Laboratories performing radiographic inspection shall be certified in accordance with MIL-STD-453.

3.7.6 Fusion Welding Certification: All operators performing fusion welding shall be certified in accordance with MIL-STD-1595.

3.8 Reliability and Maintainability

3.8.1 Reliability: The starter shall be designed and developed to achieve the highest operational reliability commensurate with the design requirements. Unless otherwise specified, a minimum demonstrated reliability of 0.999 based on a one cycle mission with a confidence level of 90%, is required. The contractor shall define, in the model specification, how the values are to be demonstrated. Factors to be considered during the design and manufacture of the starter to assure in-service reliability are:

a. Simplicity of design
b. Selection and application of reliable components
c. Consideration of operational and environmental parameters
d. Mechanical Structures - adequate design stress margin on all parts
e. Design review by technical specialists prior to drawing release
f. Use of proven manufacturing techniques
g. Rigid quality control procedures imposed throughout procurement, manufacturing, assembly and testing to assure that maximum design reliability is built into the equipment.

3.8.2 Maintainability: The starter shall have a minimum number of parts consistent with reliability. Its design shall permit easy assembly, disassembly, location of trouble sources, routine service checking, adjustment and maintenance with tools and equipment normally available commercially, by service maintenance personnel with a minimum of training. The modular concept of assembly shall be utilized wherever possible in order to increase maintainability and reduce overhaul and maintenance costs.

3.8.2 Continued

The design goal shall be such that any subassembly of the starter can be replaced without disassembly of the complete starter or removal of other components. Maintenance between overhaul periods shall be held to an absolute minimum with only routine oil changes at not less than 500 engine hours.

3.9 Performance Characteristics: The starter shall meet the minimum performance requirements specified herein. The actual performance characteristics shall be specified in the model specification and shall be predicated on the use of production hardware with adequate allowance for tolerance variations. Performance characteristics shall be based upon the pneumatic inlet conditions as defined in the detail specification, which should also indicate whether or not control valve effects are to be included. The definition of supply conditions should also reflect effects of installation losses.

3.9.1 Starter Output Torque: The starter output steady state torque versus rpm shall be as measured at the output drive of the starter for each inlet condition defined in the detail specification. The minimum torque output when defined in the model specification shall not be less than that required in the detail specification.

3.9.2 Duty Cycle: The starter shall be capable of making the required number of consecutive start cycles when exposed to the environmental conditions specified in the detail specification with a maximum interval of 60 seconds between the completion of one cycle and the beginning of the next cycle. In addition, the starter shall be capable of motoring the engine for a minimum of 5 minutes at an output shaft speed load condition specified in the detail specification. The desired duty cycle(s), including consecutive start cycles, accessory drive, overrunning and/or motoring cycles, shall be specified in the detail specification.

3.9.3 Automatic Starting: The starter shall be so designed that a continuous main engine start cycle can be accomplished by initiation of a single switch or other device. Initiation of the automatic starting cycle shall be from the aircraft cockpit. The automatic starting provisions shall be specified in the model specification.

3.9.4 Stopping: It shall be possible to terminate the starting cycle at any time during the start cycle without damage to the starter.

3.9.5 Running Engagement: The starter shall suffer no detrimental effects when subjected to the required number of impact cycles at speeds as specified in the detail specification.

3.9.6 Performance Curves: The starter performance shall be defined by the following curves which shall be part of the model specification. The curves shall include minimum and maximum performance limits. Performance shall be defined for each pneumatic inlet condition over the complete altitude and temperature range specified in the detail specification. Minimum performance shall be guaranteed performance.

3.9.6.1 The generalized starter output steady state shaft torque vs. shaft speed shall be defined as shown in Figure 1 or as required by the detail specification.

3.9.6.2 The maximum and minimum impact torque vs. rpm up to the cutout speed shall be defined in the model specification. The impact torques shall be based on the "no load" torque resulting from the maximum normal operating condition with pressure rise rate duplicating that of the starter valve under this operating condition. The engine polar moment of inertia, torsional stiffness and range of backlash shall be as specified in the detail specification. The starter polar moment of inertia, torsional stiffness and range of backlash shall be based on all the rotating elements of the starter configuration required to meet the detail specification. All impact torque calculations shall be based on AIR 781-"Guide for determining engine starter drive torque requirements."

3.9.6.3 The starter maximum "no load" speed shall be defined for the maximum normal operating condition.

3.9.6.4 The typical starter output steady state torque shall be defined using the specified inlet conditions of the detail specification.

3.9.6.5 The generalized starter airflow consumption shall be defined at each inlet condition required by the detail specification, Ref. Figure 2.

3.9.7 Performance Deterioration: Performance after completion of 2,000 start cycles shall meet or exceed the minimum performance specified in the model specification, and shall not be more than 5% below pretest levels.

3.10 Environmental Requirements: The starter shall meet all the performance requirements of this specification and shall suffer no detrimental effects during and after being exposed to the environmental conditions specified herein. Test and service experience on similar hardware shall be described in sufficient detail to permit similarity analyses in lieu of testing.

3.10.1 Altitude: The starter shall meet the performance requirements of this specification from sea level to the maximum starter operating and maximum aircraft operational (starter overrunning condition) altitudes specified in the detail specification.

3.10.2 Temperature: The starter shall meet the performance requirements of the detail specification during or after exposure to:

a. The local installed ambient temperature conditions as defined in the detail specification during both the start and overrunning cycles.
b. Heat flux as defined in the detail specification emanating from the starter mounting pad.

3.10.3 Rain: The starter shall meet the requirements of this specification and shall suffer no detrimental effects when exposed to the rain test, method 506, of MIL-STD-810, except that Step 5 shall not be a requirement.

3.10.4 Humidity: The starter shall meet the performance requirements of this specification and shall suffer no detrimental effects during and after exposure to the humidity test, method 507, MIL-STD-810, except that concurrent operation/exposure of the unit will not be required for the test demonstration.

3.1.5 Salt Fog: The starter shall meet the requirements of this specification and shall suffer no detrimental effects during and after exposure to the salt fog test, method 509, of MIL-STD-810, except that concurrent operation/exposure of the unit will not be required for the test demonstration.

3.10.6 Sand and Dust: The starter shall meet the requirements of this specification and shall suffer no detrimental effects during and after exposure to the sand and dust test, method 510 of MIL-STD-810. Operational exposure to contaminated air supply will be as required by the detail specification.

3.10.7 Fungus: The starter shall suffer no detrimental effects from being exposed to the fungus test, method 508 of MIL-STD-810. If no fungus nutrients are used in the starter, a statement to this effect may be submitted in lieu of testing.

3.10.8 Explosive Atmosphere: Operation of the starter in accordance with method 511, explosive atmosphere of MIL-STD-810 shall not create a hazard. The details necessary to meet this requirement shall be defined in the model specification. If the starter does not include electrical components, there will be no test requirement.

3.10.9 Vibration: The starter shall meet all detail performance requirements after being subjected to vibration testing in accordance with method 514.2 category 1B per MIL-STD-810 curve D, Figure 514.2.2 and Table 514.2, or as required by the detail specification, based on expected environment.

3.11 Details of Components

The design and operating requirements for the starter and its major components will be conveyed via the detail specification. These will result from consideration of the specific requirements of the application and service experience on similar applications.

3.11.1 Energy Conversion and Speed Reduction Assembly

3.11.1.1 Turbine Characteristics

3.11.1.1.1 Operating and Free Running Speed: The maximum operating and free running speeds of the turbine wheel, at sea level and maximum operating altitude specified in the detail specification, shall be specified in the model specification.

3.11.1.1.2 Minimum Yield Speed: The minimum yield speed of the turbine shall be greater than the maximum free running speed and shall be specified in the model specification.

3.11.1.1.3 Minimum Burst Speed: The turbine minimum burst speed shall be specified in the model specification.

3.11.1.1.4 Proof Speed: The turbine proof speed shall be less than the minimum yield speed and greater than the maximum free running speed and shall be specified in the model specification. An equivalent proof test at room temperature ambient and component temperature will be allowed.

3.11.1.1.5 Turbine Identification: Each turbine wheel shall be identified by serial number. The wheel serial number and date of installation shall be recorded and retained with final acceptance test and build records.

3.11.1.2 Speed Reduction

3.11.1.2.1 Gears: The gear ratio between the energy conversion mechanism and the starter output shaft shall be specified in the model specification. The amount of gear backlash shall be the minimum consistent with the application and shall be specified in the model specification.

3.11.2 Clutch and Output Assembly

3.11.2.1 Clutches

3.11.2.1.1 Engaging Clutch: An engage-disengage clutch shall be provided which will automatically engage or disengage the starter from the engine at the completion of a successful engine start (i.e., engine acceleration to idle speed). The clutch operating limits shall be specified in the detail specification.

3.11.2.1.2 Slip Clutch: In the event a slip clutch is used, the operating limits shall be specified in the model specification.

3.11.2.1.3 Clutch Failure Mode: The starter clutch must not fail in the engaged mode. The failure mode for the starter in the event of a failed output bearing or seal should be such as to minimize load transmittal into the engine gearbox. Consideration shall be given by both the airframe/engine and starter suppliers, to the imbalance of the starter shaft system under such a failure condition, and its effect on the engine at the gearbox pad interface.

3.11.2.2 Output Shaft: The maximum starter output shaft torque and direction of rotation shall be specified in the model specification. The direction of rotation, viewed from the anti-drive end of the starter, shall be as specified in the detail specification.

3.11.2.2.1 Shear Section: The required shear section configuration shall be defined in the detail specification. The requirement for a replaceable or integral shaft shall be defined. The applied torque value (and allowable tolerance limits) at which shear will occur shall be specified in the model specification. The maximum value at which the shaft will shear shall be specified in the detail specification. If a replaceable shear section is specified, all pieces of sheared output shaft shall be capable of being removed without requiring disassembly of the starter. The drive coupling, which incorporates the shear section, shall be positively retained in the output shaft.

3.11.2.3 Mounting Flange and Drive: The starter mounting flange and drive spline shall conform to the requirements specified in the detail specification and shall mount on an engine accessory drive in conformance with the detail specification. The accessory drive type number shall be specified in the detail specification.

3.11.3 Control System

3.11.3.1 Cutout Device: If required by the detail specification, the starter shall provide a control signal to terminate starter operation within the speed limits specified in the detail specification. For starters other than those whose total rotating parts completely disengage from the engine, the cutout device shall sense the speed of a starter component that is driven by the engine accessory drive, unless otherwise specified in the model specification. The cutout device and electrical interface shall be defined in the model specification.

3.11.3.2 Starter Control Valve: The starter control valve shall not be a part of the starter and shall not be furnished with the starter unless specified by the purchaser. However, if a valve is required in the starting system, the valve requirement shall be specified in the detail specification and the starter must be compatible with the requirements specified.

3.11.4 Lubrication System: The lubricant used shall be specified in the detail specification. If the lubricating system is integral with the unit, it shall be adequate to lubricate the starter throughout its operating range. Shared or forced feed lubrication systems interface data will be defined via customer specification. The starter design shall be such that no change in lubricant shall be required for operating throughout the ambient temperature range specified in the detail specification. The starter shall be capable of completing the number of starting cycles and hours of overrunning required by the detail specification without changing or adding to the lubricant.

3.11.4.1 Oil Supply: If dedicated oil is used as a starter lubricant, the oil reservoir shall be furnished as a component part of the starter. The consumption rate shall not exceed the requirement of the detail specification. Refilling of the reservoir shall not require disassembly or removal of the starter from the engine. The lubricant used shall conform to MIL-L-23699, MIL-L-7808 or other lubricant specified in the detail specification. An overflow device shall be provided to prevent overfilling with lubricant. The minimum lubricant level shall be defined by markings adjacent to a transparent sight glass or as defined in the detail specification.

3.11.4.2 Oil Loss: All sources of oil loss shall be specified by the contractor. Rate of oil loss shall be specified in the model specification, and shall not exceed the requirements of the detail specification.

3.11.4.3 Oil Flow and Heat Rejection: In the event pressure lubrication is utilized, the oil flow and heat rejection rates shall be specified in the model specification.

3.11.4.4 Oil Filter: A suitable oil filter element, if required, shall be provided as a component of the lubrication system and shall be specified in the model specification.

3.11.4.5 Oil Fill Provisions: Suitable oil fill provisions shall be provided. The unit shall be adequately marked as to capacity and type of oil to be used.

3.11.4.6 Oil Level Measurement: The oil reservoir of the starter shall be provided with a means for either manual, visual or remote measurement of the oil level. The method of oil measurement shall be defined in the model specification and shall be readily visible/accessible with the starter installed in the aircraft.

3.11.5 Other Components: The description and performance characteristics of other starter components not specified herein shall be described in detail in the model specification.

3.12 Interchangeability: All parts having the same manufacturer's part number shall be functionally and dimensionally interchangeable. Matched parts or selective fits will be avoided wherever possible; however, where required, these parts shall be serialized.

3.13 Drawings and Diagrams: The contractor shall furnish the following drawings and diagrams to the purchaser with submission of the model specification and in addition, shall incorporate reduced sized copies of the same drawings and diagrams in the body of the model specification. The contractor shall furnish the following drawings to the purchaser:

a. Starter installation drawing, showing overall dimensions, clearances required for removal, periodic inspections, identification, weights, approximate C.G., direction of rotation, location and definition of all connecting points.
b. Electrical installation connection diagrams showing the circuits up to the connection points of the aircraft.
c. A complete cut away cross sectional or assembly drawing showing the starter's components and assembly.

3.14 Identification of Product: The starter shall be provided a nameplate that meets the requirements of MIL-P-514 and MIL-STD-130. The plates shall be attached to the starter unless otherwise stated in the detail specification. As a minimum, the following information shall be included:

Part number; Model number; Part name; Serial number; Customer; Contract number; Model data (as required).

NOTE: The arrow showing the direction of rotation may be included in a single nameplate with other specified data or, at the option of the contractor, it may be stamped on a separate plate attached immediately adjacent to the main nameplate.

3.15 Workmanship: The workmanship and finish shall be of sufficiently high grade to insure satisfactory operation, reliability and durability consistent with the application and storage life requirements of the starter.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection: Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the purchaser. The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure suppliers and services conform to prescribed requirements.

4.2 Classification of Tests: The inspection and testing of starters shall be classified as follows:

a. Acceptance Test
b. Qualification Test. Use of similarity data is acceptable in lieu of qualification testing subject to agreement between contractor and purchaser.

4.3 Test Condition: Unless otherwise specified herein, the following conditions shall apply for the starter and component tests.

4.3.1 Temperature: Unless otherwise specified, all tests shall be conducted at ambient temperature as defined in 4.3.1.1. Temperature parameters for the following test conditions shall be as specified herein or in the detail specification for the applicable starter installation.

4.3.1.1 Ambient Temperature: Ambient temperature is defined as the existing temperature within the test cell at the time of test. Starter temperatures shall be as specified for the particular test.

4.3.1.2 Low Temperature: Low temperature tests shall be conducted at -65°F +0/-10 when utilizing MIL-L-7808 and -40°F +0/-10 when utilizing MIL-L-23699.

4.3.1.3 Normal Temperature: Normal temperature tests shall be conducted at 59°F ± 30°F.

4.3.1.4 High Temperature Operating: As specified in the detail specification, except that the high limit must be consistent with temperature limits of the specified lubricants.

4.3.1.5 High Temperature Overrunning: As specified in the detail specification.

4.3.2 Pressure: Unless otherwise specified herein, all tests shall be conducted at ambient atmospheric pressure.

4.3.3 Inlet Conditions: Unless otherwise specified, all pneumatic cycling tests shall be conducted at rated inlet conditions. The pressure and temperature parameters for the following inlet conditions shall be specified in the detail specification for the applicable starter installation. Pressure and temperature limits for all acceptance and calibration cycles shall be ± 1 psia and ± 15°F.

4.3.3.1 Rated

4.3.3.2 Maximum Temperature

4.3.3.3 Minimum Temperature

4.3.3.4 Maximum Pressure

4.3.3.5 Maximum Engine Interbleed

4.3.3.6 Minimum Pressure

4.3.4 Conditioning Time: Conditioning time for the starter shall be such that all parts of the starter shall have reached a temperature within the specified temperature limits. During the conditioning time, the temperature of the conditioning chamber shall not vary more than ± 5°F from the specified temperature.

4.3.4.1 Long Term Low Temperature Soak: The starter shall be maintained at the low temperature for a period of 24 hours or until oil temperature is stabilized

4.3.5 Test Apparatus

4.3.5.1 Accuracy: For all starter and component tests, the test apparatus shall be such as to insure that reported data will have a steady state accuracy of ± 2% of the maximum rated value, except that temperature shall be accurate to ± 2°F and weight shall be accurate to ± 0.2%. All apparatus shall be calibrated often enough to insure that this degree of accuracy is maintained. Calibration records shall be retained by the testing agency for 2 years and furnished to the purchaser upon request.

4.3.5.2 Automatic Recording Equipment: Automatic recording equipment shall be used to obtain data during those parts of starter and component test requiring evaluation of time versus starter component variables.

4.3.5.3 RPM Measurement: The device used to measure starter output shaft rpm shall be specified in the model specification.

4.3.5.4 Test Flywheel: The polar moment of inertia shall be specified in both the detail and model specification. It shall equal the maximum polar moment the starter is intended to operate with or adjusted to reproduce start times by dynamometer excitation braking.

4.3.6 Starter Attitude During Testing: All starter tests shall be conducted with the starter mounted in the same orientation as the aircraft installation. As part of the overrunning tests, variations in starter attitude shall be made to simulate typical, flight operational attitudes.

4.4 Acceptance Tests: An acceptance test shall be conducted on every starter and shall consist of the individual tests under 4.4.3 as a minimum. Additional tests may be required, depending upon the particular starter design.

4.4.1 Acceptance Test Method: An acceptance test method, including performance parameters, shall be included as a part of the model specification.

4.4.2 Acceptance Test Data: Performance data shall be obtained from tests conducted on starters submitted for acceptance and shall be prepared as follows:

4.4.2.1 General

4.4.2.1.1 Dimensional Units: All dimensions shall be expressed in the English gravitational system of units.

4.4.2.1.2 Pressure Corrections: Performance characteristics shall not be corrected for ambient pressure. Pressure correction factors shall be furnished in the model specification

4.4.2.2 Acceptance Data Summary Sheet: An acceptance data summary sheet shall be prepared for each starter. The following shall be used as a guide and contains the minimum requirements for acceptance. Special features of the starter may necessitate additional data. The acceptance test data requirements shall be included in the model specification.

a. Date
b. Serial number of starter
c. Model number of starter
d. Size of flywheel used (slug ft^2)
e. Ambient temperature (°F)
f. Oil temperature (°F)
g. Barometric pressure (in Hg. abs)
h. Cutout switch actuation speed (rpm if applicable)
i. Actual weight of unit - specify dry or wet
j. Acceleration time (zero rpm to cutout) (Seconds)
k. Inlet air total pressure (psia)
l. Inlet air total temperature (°F)
m. Stall airflow (lbs/min at conditions specified)
n. Overrun test speed and time
o. Oil leakage test results (rate)

4.4.3 Individual Tests: Component acceptance tests (4.4.3.10) shall be completed prior to initiation of the following starter acceptance tests.

4.4.3.1 Examination of Product: Each starter shall be subjected to a careful inspection to insure that all dimensions are within specification and drawing limits and that all parts are correctly assembled. This shall include inspection of customer interface dimensions on the final assembled unit.

4.4.3.2 Initial Acceptance Cycling: Each starter shall be subjected to a minimum of two cycles, which shall be at rated inlet conditions. Performance must equal or exceed the minimum specified in the model specification.

4.4.3.3 Dielectric Strength Test: Each starter shall be subjected to a dielectric strength test which meets the requirements of MIL-E-25499, if electrical components are utilized.

4.4.3.4 Overrunning Test: Except when an engaging device, which completely disengages the engine accessory shaft at the completion of a start cycle is employed, the starter output shaft shall be driven by external means for 10 minutes at the overrunning speed ± 100 rpm specified in the detail specification. Failure of the starter to remain disengaged shall be cause for rejection. All starters submitted for inspection in accordance with 4.4.3.6 shall be subjected to a total of 30 minutes of overrunning before teardown.

4.4.3.5 Oil Leakage: Any leakage of oil from the starter during acceptance cycling or overrunning in excess of that allowed by the model specification shall be cause for rejection.

4.4.3.6 Teardown Inspection: After completion of the acceptance cycling and overrunning test, each starter of the first ten, every tenth of the first 100 and every fiftieth thereafter, production configuration starter shall be disassembled sufficiently to allow a detailed inspection of all working parts; the extent of the disassembly shall be at the option of the purchaser or his authorized representative. If at any time, the disassembly discloses internal deficiencies after the acceptance cycling and overrunning test which can only be detected by disassembly, the original schedule for teardown inspection shall be re-initiated.

4.4.3.7 Final Acceptance Cycling: Starters which have been subjected to the requirements of 4.4.3.6 shall be subjected to a minimum of two cycles at rated inlet conditions. Performance must be equivalent to that obtained during the initial acceptance cycling.

4.4.3.8 Rejection and Retest: If any starter fails to meet the requirements of the acceptance test, the starter shall be rejected, and may be reworked and submitted for retest.

4.4.3.9 Retest: Starters which have been rejected may be reworked to correct the defects and resubmitted for acceptance. Before submission of the reworked starter, full particulars concerning previous rejection and the action taken to correct the defects found in the original starter shall be furnished the purchaser or his authorized representative. Starters rejected after retest shall not be resubmitted without approval of the purchaser or his authorized representative.

4.4.3.10 High Speed Components Test: Prior to conducting any operational starter tests, the following shall be accomplished on all high speed components.

a. Raw material shall be subjected to penetrant or ultrasonic inspections to detect cracks or occlusions that will adversely affect starter performance or life. They shall be per MIL-I-8950 or MIL-I-6866 as applicable.
b. Proof spin each machined turbine wheel at room temperature at the proof speed.
c. Upon completion of a and b above, subject each turbine wheel to X-ray, penetrant or ultrasonic inspection to determine the extent of deformity, structural damage and growth of cracks or occlusions. Any deformity, structural damage, growth of cracks or occlusions or any new cracks shall be cause for rejection.

4.6 Qualification Tests

4.5.1 Qualification Test Method: The qualification test method shall be submitted to the purchaser and shall have been approved prior to the initiation of qualification testing. This document shall not be a part of the model specification; however, any deviation to this method or the detail specification shall be defined in the model specification.

4.5.2 Qualification Test Data

4.5.2.1 General

4.5.2.1.1 Dimensional Units: All dimensions shall be expressed in the English gravitational system of units.

4.5.2.1.2 Pressure Corrections: Performance characteristics shall not be corrected for ambient pressure. Pressure correction factors shall be furnished in the production test report.

4.5.2.2 Qualification Data Summary: A summary shall be prepared by the contractor of all qualification testing accomplished. It shall include, as a minimum, the general data required in the following paragraphs and all specific data required in the particular test paragraphs. Where the length of traces makes their inclusion difficult, only the initial and final portions and any other portions of significant interest shall be included. Component test reports covering all component tests conducted on each type of component shall also be submitted. These reports shall be prepared in accordance with MIL-STD-831.

4.5.2.3 Limits: Performance limits shall be superimposed on all curves. These limits shall be those specified in the model specification.

4.5.2.4 Cycle Data: The following minimum data for each starter cycle shall be recorded:

a. Starter model designation
b. Starter serial number
c. Date and time of cycle
d. Observed barometric pressure
e. Corrected barometric pressure
f. Size of flywheel used (if applicable) (slug ft^2)
g. Ambient temperature (°F)
h. Type of pre-test treatment or conditioning (if applicable)
i. Time in and out of conditioning
j. Pneumatic inlet conditions (specify)
k. Recorded oil temperature (°F)
l. Cutout switch actuation (rpm) (if applicable)
m. Maximum speed (rpm)
n. Maximum vibration
*o. High speed trace of impact torque vs. time with point of starter switch actuation shown.
*p. High speed trace of torque vs. speed with point of starter switch actuation shown.

*NOTE: High speed traces shall be required for each calibration cycle (performance check), first and every tenth valve compatibility cycle, first and every fiftieth endurance cycle and whenever specified for special tests.

4.5.2.5 ø Reduced Data: The following data shall be reduced for typical cycles which are recorded on traces:

a. Impact torque (lb-ft)
b. Torque at 15%, 30%, 45%, 60% and 75% cutout speed
c. Air consumption (lbs/sec.)
d. Time from cycle initiation to 60% cutout speed (seconds)
e. Cutout switch actuation (rpm) (If applicable)
f. Maximum speed (rpm)
g. Inlet air total pressure (psia)
h. Inlet air total temperature (°F)

4.5.2.6 Calibration Data: In addition to the data required in 4.5.2.5, separate curves sheets shall be prepared for each calibration run. The curve shall have torque plotted vs. speed and each sheet shall have the specification performance limits superimposed on the curve. Torque may be shown as τ/δ_1 vs. $N/\sqrt{\theta}$.

4.5.2.7 ø Disposition of Qualification Test Data: Qualification test data shall be retained by the testing agency for two years and furnished to the purchaser or authorized reprsentative upon request.

4.5.2.8 ø Qualification Test Data Analysis: An analysis of all qualification test data shall be conducted by the contractor and shall be included in the qualification test report. Any unusual condition, malfunction, failure or out of specification performance shall be explained in detail in the test report and the purchaser shall be notified in writing as soon as any of the above conditions are evident.

4.5.2.8.1 Recalibration: The point at which a significant difference occurs in any parameter shall be recorded and the starter shall be calibrated. If this point occurs prior to the last cycle of testing, the test shall be stopped until the purchaser is notified and gives approval to proceed.

4.5.3 ø Qualification Test Samples: A minimum of three starters shall be required as qualification test samples and shall be referred to hereinafter as units one, two and three. Maintenance, adjustment or replacement of components or parts shall not be permitted after initial acceptance of the starters. Disassembly of any part of the starter to any extent prior to the final teardown inspection shall not be permitted.

4.5.3.1 Lubrication: Lubrication shall be accomplished prior to the cycling and endurance testing. After initiation of the testing, addition of oil shall not be permitted. Oil may be added or changed after completion of 600 cycles and 500 hours of overrunning or as specified in the model specification. If overrunning time exceeds the cycle requirement, the oil may be changed after each 500 hours of overrunning.

4.5.4 Qualification Tests: Qualification tests as proposed by the contractor in accordance with 4.5.1, shall be designed to demonstrate complete compliance with all the requirements of section 3 herein. The following test schedule is provided as an outline for the tests to be conducted on each of the three test units. Specific tests required to demonstrate compliance with each requirement shall be integrated into the individual unit test schedule.

4.5.4.1 Test Sample Number One:

a. Acceptance test
b. Calibration
c. Endurance Cycling (at all operating and all inlet conditions, 2,000 cycles minimum)
d. Valve compatibility (at maximum pressure inlet conditions, 100 cycles minimum)
e. Free running
f. Overpressure test
g. Recalibration
h. Teardown and inspection
i. High and low temperature
j. Consecutive cycling
k. Sustained motoring tests
l. Containment demonstration (free run to destruction)

4.5.4.2 Test Sample Number Two:

a. Acceptance test
b. Calibration
c. Endurance Cycling (at all operating and all inlet conditions - 500 cycles minimum)
d. High temperature cycling overrunning test (1,000 hours minimum). Cycling shall consist of 10 hour cycles at temperatures as specified in 3.10.2 (a) and (c).
e. Running engagements (60 cycles minimum). (Engagements to be made at 3%, 15%, 45%, 60% and 75% cutout speed.)
f. Recalibration
g. Electromagnetic interference
h. Teardown and inspection
i. Containment demonstration (tri-hub disk separation)

4.5.4.3 Test Sample Number Three:

a. Acceptance test
b. Calibration
c. Environmental tests
d. Recalibration
e. Speed limiting and no load tests
f. Teardown and inspection
g. Locked clutch containment demonstration

4.5.5 Test Completion: The starter qualification test is considered complete when the starter and the components have been subjected to the required tests and inspections and the required reports have been submitted to the purchaser and approved.

5. PREPARATION FOR DELIVERY

5.1 Preservation and Packaging

5.1.1 Preservation: If oil is used as the lubricant, the following shall apply: At the discretion of the contractor, the final acceptance run may be conducted using undiluted corrosion preventive oil of the proper grade conforming to MIL-C-8188, immediately after which all excess corrosion preventive shall be allowed to drain. Otherwise, the starter shall be drained of oil and the oil reservoir filled to the appropriate level with MIL-C-8188 corrosion preventive then agitated, immediately after which all excess corrosion preventive shall be drained. The exposed mounting flange and drive shall be cleaned and coated with light film of corrosion preventive.

5.1.2 Packaging: After preservation of the starter in accordance with 5.1.1, the starter shall be packaged in accordance with Method II, submethod IIa of MIL-P-116.

5.2 Packing: Starters preserved and packaged in accordance with 5.1.1 shall be packed in accordance with the requirements of the contract. The shipment marking nomenclature shall be "Starter, Pneumatic Aircraft Engine".

5.3 Marking: In addition to any special marking required, unit packages, intermediate packages and shipping containers shall be marked in accordance with MIL-STD-129.

5.4 Packing List: The contractor shall furnish a packing list with each starter. All parts that are not installed on the starter, but are shipped with it, shall be included on the packing list.

6. NOTES

6.1 Intended Use: The starters covered by this specification are intended for use in starting gas turbine engines.

6.2 Definitions: The applicable definitions used herein and in the detail specification are as specified:

Purchaser: The purchaser is the activity which is responsible for the starter contract.

Air Turbine Starter: A prime engine starting device, incorporating a turbine wheel driven by compressed air that may be heated. The starter also generally includes an inlet scroll, reduction gears, an engaging mechanism and a switch to signal cutoff speed.

Anti-Drive End: The end of the starter or accessory opposite the end which mates with the engine, or drive device.

Auxiliary Power Unit (APU): An internal combustion (usually gas turbine) engine used as the prime mover for equipment which supplies a starter with a desired medium of energy. Also frequently used as a source of bleed air for environmental control systems.

Back Pressure: The pressure level measured in the exhaust collector of the starter.

Break-In: A procedure required to produce desired surface conditions on component parts (e.g., gears, piston and cylinder) operating relative to each other.

Clutch, Face Jaw: A type of engaging mechanism that makes use of a pair of face teeth that will transmit torque from the starter to the engine in one direction. These splines are generally moved axially into engagement with each other by the starter engaging mechanism during the start cycle; disengagement occurs when the speed of the engine driven side of the engaging device exceeds the speed of the starter driven side.

Clutch, Overrun: A type of clutch mechanism that employs sprags, rollers or pawls, etc., with appropriate driving and driven members. This clutch drives in one direction only, overrunning in the other direction. During overrunning, which occurs when the driven member's speed exceeds the driving member, the sprags, rollers and pawls, etc., (carried by the driven member) are caused to lift clear of the driving member.

Consecutive Starts: Start cycles which follow each other at close intervals. The engine may or may not have come to rest before the second or successive starts.

Containment: The ability of the starter to retain within its envelope all energy laden fragments of the turbine(s) or other rotating components if these parts are caused to fail.

Crank (verb): To rotate the main shaft of an internal combustion or gas turbine engine by means of a starter.

Cross-Bleed: Ducted air from the compressor section of an operating engine to another compartment such that this compressed air can be used for starting or other purposes.

Cross-Bleed Starting: The starting of one engine utilizing cross bleed air from another operating engine.

Cutout Switch: A speed sensing device, often incorporated in the starter used to terminate the start cycle at the predetermined cutout speed.

Cutout Speed: See "Speed, Starter Cutoff".

Disengagement: The uncoupling of the starter from the engine by means of the starter clutch, or engaging device. Normally occurs at starter cutoff speed or starter maximum speed.

Detail Specification: The detail specification referred to herein, is defined as a military or aircraft manufacturer prepared document used to define the applicable design and performance parameters required for a particular starter application.

Engagement: The automatic connecting of the starter gearing to the engine at the beginning of the start cycle.

Gear Ratio: The ratio of the revolutions per unit time of one shaft to the revolutions in the same unit time of another shaft connected to it by a gear device. Starter gear ratio usually expressed as ratio of starter turbine speed to starter output speed.

Ground Power: A power source that remains on the ground and is not airborne.

Hot Start: An engine start during which allowable engine turbine gas temperature limits are momentarily or temporarily exceeded.

Hung Start: The operation of starting a gas turbine engine wherein the combined torque output of the engine and starter are insufficient to provide positive acceleration at some speed less than idle.

Inspection Tests: Those tests performed upon a production starter to determine acceptability prior to shipment. Also referred to as Production Acceptance Tests.

Installation Drawings: Drawings which define the exterior size of the unit and include data on all connection points, ports, etc.

Light Off: The initiation of combustion in the combustor of a gas turbine.

Model Specification: A specification covering the essential detail and technical requirements of a specific unit design, including a description of the procedures by which it will be demonstrated that the requirements have been met. This may consist of a proposal document.

Moment of Inertia: A measure of the resistance offered by a body to angular acceleration. The mass moment of inertia is usually expressed in slug ft^2 or when multiplied by the gravity constant (g), lb ft^2. Its point of application must be expressed, as it varies as the square of a gear ratio.

Motor (verb): To rotate an engine with the starter, but without fuel or ignition.

Mounting Pad: The pad upon which the starter or accessory is attached. Consists of a fixed pad with studs or suitable attaching means concentrically located with respect to a shaft which has a spline or similar power transmitting means.

Output Shaft: The starter shaft which connects the starter to the engine gearing.

Overrun: Refers to the relative speeds of the engine and starter after the start cycle has been completed.

Overspeed Switch: A switch provided within a starter to stop the energy source to the starter on attainment of a predetermined speed.

Proof Pressure: The pressure above normal operating pressure which is used to non-destructively test a pressure container.

Qualification Test: Those tests which are run on one or more units that are representative of the production article, to test the performance, endurance, environmental and special features of a design to demonstrate the suitability of the unit for production and use in service.

Quick Attach-Detach (QAD) Mounting Flange: A disconnect device that can attach the starter or accessory to the engine using simple tools on a single fastener. Usually incorporates a special flange which is pre-bolted to the mounting pad.

Quick Disconnect: A disconnect that can be uncoupled or coupled without the use of tools commonly employed in hydraulic and pneumatic lines. May be self-sealing when disconnected.

Rated Conditions: The inlet and outlet conditions at which the starter is designed to operate and performance calibration is desired. Usually expressed in terms of pressure, temperature and flow rate.

Re-Engagement: The act of the starter engaging the engine while the engine is at any speed condition other than rest. This is typically limited to maximum cutout speed.

Rise Rate, Initial Instantaneous Pressure: The pressure rise rate, measured in the first 1/4 sec. of pressure rise, expressed in psi/sec., developed from the tangent to a pressure time curve.

Run-In: See “Break-In”.

Shear Section: A special section, usually in the starter or accessory output shaft, that is designed to shear or fail at or above a specified level.

Slip-Clutch: A clutch which may be incorporated into a starter to limit the maximum torque (impact and steady) that can be transmitted by the starter to the engine.

Speed:

Engine Idle: The rotor speed at which the engine will operate with the power lever in the idle position.

Engine Lite-Off: The rotor speed at which combustion is initiated.

Engine Self-Sustaining: The engine rotor speed from which the engine is capable of accelerating to idle speed within specified engine limits without the assistance of a starter.

Free Running: See “No Load”.

No Load: The peak speed which the starter will normally reach without any load connected.

Overrunning: The speed at which the starter overrunning element is driven by the engine.

Pad: Engine rotor speed at the accessory pad.

Rotor: The speed of the engine rotor.

Runaway: See “No Load”. In electrical starter-generator systems, this is the speed to which the starter-generator will go without load at maximum applied voltage.

Starter Cut-Off: The speed, up to which the starter provides starting assistance and at which its power source is switched off.

Start Switch: Any switch or other device used to initiate a start cycle.

Start Time:

Actual: The measured length of engine starting time from initiation of the start cycle to engine idle speed.

Calculated: The calculated time of engine starting time from initiation of the start to engine idle speed, analytically obtained using graphical or tabulated data, or equations describing engine and starter characteristics.

Starter Drive Coupling: The elements of the starter which engage the engine and through which torque to accelerate the engine is transmitted.

Starter Envelope: The external three-dimensional shape of the starter or space allowance for the starter.

Start Cycle: The events which take place between start initiation and the point of engine idle.

Teardown Inspection: That inspection of the unit usually imposed as part of the acceptance testing of a starter.

Tests:

Acceptance: A test program usually imposed on production articles run prior to delivery of a component or batch of components to demonstrate that the item meets specification requirements.

Qualification: A series of tests run on a newly developed component to demonstrate compliance with specification requirements.

Torque -

Accelerating: The net torque (algebraic summation of applied torque, accessory torque and engine starting torque) which produces acceleration of the combined engine, accessories and starter, as typified by the starting cycle.

Accessory: The torque attributable to the accessories driven by the engine which must be overcome during the start cycle.

Applied: Starter output torque applied to the engine.

Engine Drag: The sum total of torque loads developed by the engine that resist engine rotation, and whose absolute value is considered to be negative.

Impact: The high transient torque which may occur when the starter first engages the engine during a start, and which exceeds that torque nominally generated by the starter.

Output: See “Applied Torque”.

Rated: Starter torque developed when rated input power is applied.

Stall: That torque developed by the starter at zero output speed.

Starter: The torque produced by the starter during the start cycle. It is a function of starter, speed and starter power supply.

Steady State: That torque developed by the starter or engine while operating with its output held to a constant speed.

Transient: That torque developed by the starter or engine while operating with its drive accelerating.

6.3 Symbols

	SYMBOLS	QUANTITY	UNIT
	A	Area	in^2
ø	A_e	Effective nozzle area(s)	in^2
	g	Gravitational constant	ft/sec^2
	I_p	Polar moment of inertia	slug ft^2
	n_g	Gas generator shaft speed	rpm
	n_s	Starter output shaft speed	rpm
	n_t	Turbine Speed	rpm
	p	Pressure	psi
	P_1	Starter inlet total pressure	psia
	P_2	Starter discharge static pressure	psia
	T	Temperature	°F
	T_1	Starter inlet total temperature	°R
	τ	Starter output steady state torque	lb-ft
	τ_S	Stall torque	lb-ft
	$\tau_{max.}$	Maximum torque	lb-ft
	τ_i	Impact torque	lb-ft
	W	Starter airflow	lb/min
	W_S	Total weight of the starter	lb
PR	$= P_1/P_2$	Pressure ratio across starter	
δ_1	$= P_1/14.7$	Standard pressure ratio	
θ_1	$= T_1/518.4$	Standard temperature ratio	

FIGURES AND APPENDIX