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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 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.
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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:
- The local installed ambient temperature conditions as defined in the detail specification during both the start and overrunning cycles.
 - 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.